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J. W. POWELL, DIRECTOR

CORRELATION PAPERS

NEOCENE

BY

WILLIAM HEALEY DALL

AND

GILBERT DENNISON HARRIS

WASHINGTON

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CONTENTS.

ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF GEOLOGIC CORRELATION,
Washington, D. C., July 12, 1891.

SIR: I have the honor to transmit herewith a memoir by Messrs. William H. Dall and Gilbert D. Harris on the Neocene 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 continents; 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 examinations 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 fifth of a series, having been preceded by essays on the Carboniferous and Devonian, the Cambrian, the Cretaceous, and the Eocene, prepared severally by Messrs. Williams, Walcott, White, and Clark, and constituting Bulletins 80, 81, 82, and 83.

Besides assembling and systematically outlining the published material available for the correlation of the Neocene formations, the memoir makes important original contributions based on personal investigations by Mr. Dall in the field and in the laboratory. In respect to Florida these contributions are so important that it has seemed best to expand the chapter on that State so as to include practically all that is known of its geologic history.

While using freely the terms of the Lyellian classification of the Cenozoic, the authors are of the opinion that the correlation of individual American formations is impracticable; that all the present classifications and correlations are provisional merely; and that in the nature of the case it is not to be expected that even the major divisions of European Cenozoic classification can be paralleled with synchronous divisions in America. Their use of the terms Eocene, Miocene, and Pliocene is analogous to that defined by Huxley as homotaxial.

Very respectfully, your obedient servant,

G. K. GILBERT,
Geologist in charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey.

OUTLINE OF THIS PAPER.

This paper, after discussing general principles connected with the study and description of the Tertiary or Cenozoic rocks and fossils contained in them, takes up the Neocene deposits of the United States in particular.

A chapter is devoted to a summary of what is known in regard to the Neocene of the eastern coast of the United States, each State in geographical order being separately considered, beginning at the north. The State of Florida, in regard to which much unpublished information was available, being entirely composed of Cenozoic rocks, and therefore as a type of such structure peculiarly interesting, is treated of in greater detail and more at length than in other cases. The part of this essay relating to the State of Florida is really a preliminary geological report on that State, of which the structure has hitherto been very little known. The important fact that until the Pliocene period Florida, so far as it was elevated above the sea, was an island separated from the mainland by a wide strait, is here first demonstrated. It is also shown that the strata are probably gently folded lengthwise of the peninsula, and that in the trough now occupied by the "lake region" of Florida in Pliocene time a large lake probably existed, to which the name of De Soto has been applied. The age of the remains of fossil vertebrate animals, which in south Florida are associated with the so-called "pebble phosphates," is here definitely determined.

After discussing by States the character and distribution of the Atlantic Neocene, a chapter is devoted to the consideration of the general geological movements and fluctuations of land, sea, currents, and water temperatures which appear to have been concerned in producing the characteristics described.

In like manner the Neocene geology of the Pacific Coast has been treated, and in addition to that of California, Oregon, and Washington, a synopsis of data relating to British Columbia has been included, together with a summary of what is known in relation to Alaska during this epoch. The latter discussion contains a large amount of material extracted from unpublished notes covering some fifteen years' study and exploration by W. H. Dall in the Alaskan region, and therefore adds materially to the sum of our knowledge in regard to that part of the United States.

The Great Interior region of the West is then taken up, and a summary of our knowledge in regard to its Neocene geology is brought together for the first time. While this is necessarily far from perfect, the very fact that such gaps exist will stimulate the collection of information to supply the missing links.

The essay closes with a list of names proposed for geological beds, groups, and formations in the American Cenozoic strata and a description of the data upon which the coloration of the general map is based.

THE NEOCENE OF NORTH AMERICA.

By William H. Dall and Gilbert D. Harris.

INTRODUCTION.

This paper has been prepared at the request of the Director of the U. S. Geological Survey as one of a series of essays on American geologic systems, with the view of presenting a summary of the state of our knowledge of the Neocene of the United States. This summary being needed by a stated time, it has been necessary to attempt only what could be done in a satisfactory manner within that period, rather than what might have been practicable with unlimited time at one's disposal. It will be understood, therefore, that absolute completeness, however desirable, was neither attained nor sought. It is believed, nevertheless, that reference has been made to all facts of serious importance within the scope of the paper as planned.

It will be understood, to begin with, that the scope of this essay is not intended to include matters lying within the field of paleobotany, vertebrate paleontology, or the vulcanology of the American Neocene.

To sketch, from researches into the literature, the extent and character of the Neocene deposits on the coasts and in the interior regions ot the United States; to point out the sequence of the chief modifications, faunal and physical, of the regions concerned during the periods stated; to enumerate the names applied to geologic formations, beds, etc., included in the American Neocene; to refer to the chief sources of information bearing on the subject; and to indicate the work most urgently needed to be done in order to supply deficiencies in our knowledge;—these have been the objects kept in view.

It has been found impracticable at the present time to do more for the Interior region than to summarize the literature. Any attempt to correlate fresh-water deposits of limited extent with each other or with the marine beds laid down in the coast regions, presents such difficulties that authors differ greatly among themselves. The information, especially the knowledge of the fauna of these various beds, notwithstanding all that has been done and the extensive literature which exists, is extremely fragmentary and imperfect when the whole field is considered. It has been found impossible to map some formations of which the age is pretty well determined from the vertebrate fauna, for the reason that authors have frequently refrained from stating the exact provenance of the fossils which they have described.

The small scale of the map available for use in this connection has also tended to give this part of the present work a general rather than a detailed character. This, perhaps, would have been advisable at any rate on account of the imperfection of our present knowledge.

Time has not been available for researches into the literature of such extra-limital regions as Mexico, the Antilles, Greenland and the Dominion of Canada, which might very properly have been correlated with those relating to our own territory.

Nearly all the literature of importance in the general history of research into the geology of the Neocene of America has been referred to by footnotes in the course of this essay. This literature is hardly to be separated as a class by itself from the general literature of the American Cenozoic. The names of Say, Conrad, Lyell, Lea, and Rogers are eminent among those who have contributed most to the progress of knowledge in this direction, to say nothing of others who are still living. The same names would hold a similar preeminence in a discussion of the Eocene. To separate the history of research into the Neocene from the other geological investigations with which it was originally associated and is more or less firmly linked, has appeared a work of too little interest or importance to occupy time which could be otherwise profitably employed; and therefore it has not been attempted.

The character of the topography associated with the rocks of this series is referred to in the local discussions of particular regions. The rocks of the system, as a whole, have no such topographic distinctness from lithologically similar rocks of other epochs as would make it practicable to diagnose them without a knowledge of their fossil fauna. Indeed, one of the most necessary reforms in Cenozoic nomenclature is the elimination of such mineralogical designations as "White limestone", "Rotten limestone", "Lignitic", "Buhrstone", etc., for geological formations. However applicable they may be in describing single strata of a single section, the belief in their distinctiveness as applied to larger areas is responsible for much confusion. It has happened that strata ranging all the way from the Cretaceous to the Upper Miocene have been correlated and discussed as a single stratigraphic unit because they were all suitable for use in building chimneys. While this may be regarded as an extreme case, yet the principle is applicable to all the names above cited, and numerous others.

Publications like the present are useful much as are milestones on public roads. They show us approximately how far we have gone and suggest by implication how far we still have to go. Fully aware of the inevitable imperfections of the present summary, reflecting as it does both the imperfection of our knowledge and the limitations of those concerned in its preparation, the writers hope that its very faults may stimulate new and more thorough investigation leading to wider and more accurate knowledge of the rich and interesting system of which it treats.

From the perfection of its fossils and their close relationship to existing faunas the paleontology of the Neocene has for the biologist a unique interest. Nowhere is there a more perfect succession of fossiliferous beds of this epoch than on the Atlantic shores of the United States. We may therefore anticipate the inscription of a really epoch-making page in the history of organic evolution when the record of these faunas shall have been perfected.

As regards the division of labor between the senior and junior authors of this paper, it may be stated that the work of searching the literature and bringing together the scattered data relating to particular States or regions has been largely performed by Mr. Gilbert D. Harris. For the revision and correlation of this material and for the whole of the chapters on Florida, British Columbia and Alaska, and the general discussions embodied in the essay, Mr. Dall is responsible. The list of formations, which, short as it is, has cost much labor and correspondence with authors who have proposed the names, has been prepared by Mr. Harris, who has also prepared the chapter on the Interior region.

CHAPTER I.

GENERAL CONSIDERATIONS.

EARLY CLASSIFICATION OF AMERICAN CENOZOIC BEDS.

The original division of the Tertiary formations into Eocene, Miocene, and Pliocene by Deshayes and Lyell on the basis of the supposed percentage of living forms in their fossil contents was, early in the history of American geology, applied by Lea[1] and Conrad to the Cenozoic beds of the Atlantic coast.

The discrimination of the Chesapeake Miocene from the Eocene, as soon as the beds and fossils were studied, followed as a matter of course. The gap between them, which farther south is partly bridged by strata of the Tampa and Chattahoochee groups, sufficiently emphasized the distinction thus drawn. Lea, in the publication above cited, doubting whether any Miocene in the European sense had been observed in America, referred the Miocene of Virginia, Maryland and New Jersey to the "Older Pliocene" of Lyell, a term equivalent to Pliocene of our present notation; the "Newer Pliocene" being what we now term Pleistocene.

About the same time Conrad[2] had divided the Tertiary into Upper Marine (Miocene), Middle Tertiary (Eocene), and Lower Tertiary, following the system of Conybeare and Phillips; but in the second edition of his cited work (part 4, p. 36) he adopts the nomenclature introduced by Lea. Three years later[3] he substituted for "Older Pliocene" the term "Medial Tertiary" (p. VI) which he still regarded as the equivalent of Pliocene (cf. p. 45). The use of the term Miocene as applied to the American strata now known as such was established by Conrad in 1841, in a communication[4] to the National Institution of Washington,

[1] Contributions to Geology, by Isaac Lea, Philadelphia: Carey, Lea, and Blanchard. 1833. 8°. pp. 227, 6, pl.; cf. pp. 18–21.

[2] Fossil shells of the Tertiary formations of North America, by T. A. Conrad, Philadelphia, the author, 1832, 8°. Introduction, pp. 9–14; 2d edition. Mar., 1835.

[3] Fossils of the Tertiary formations of the United States, Philadelphia: J. Dobson. 1838. 8°.

[4] Observations on a portion of the Atlantic Tertiary region. Proc. Nat. Inst., 1841, 2d bull., p. 177; published in 1842. Isaac Lea, in his Contributions to Geology, 1833, p. 158, places the "Upper Tertiary (Conrad) of Virginia" in apposition to "the Miocene of Lyell." In the same work, however, on page 211, he refers the fossils at St. Marys, Md., to the "Older Pliocene" of Lyell.

Conrad used the term Miocene in the first edition of the introductory part to the republication of No. 3, Fossil Shells of the Tertiary Formations, 1835, p. 36, in designation of that portion of the now so-called Miocene which outcrops at Stow Creek, N. J., Charlotte Hall, and Choptank River, Maryland, and is characterized by *Perna maxillata* Lam. In the second edition of this introduction these localities are placed among those of the Older Pliocene.

W. B. Rogers used the word Miocene as now understood April 8, 1841, before a meeting of the Association of American Geologists. See Silliman's Journal, 1841, volume 41, p. 175.

in which he gives a table of the supra-Cretaceous deposits of the Atlantic coast. In this the absence of the Pliocene between the Miocene or Medial Tertiary and the Pleistocene or Upper Tertiary is duly indicated. Similar conclusions were announced by Lyell[1] in 1842, as a result of which the nomenclature of the chief divisions of the American Cenozoic series was definitely fixed: The marine strata of the Atlantic coast, which are Pliocene as now understood, were first definitely referred to that epoch by Prof. Michael Tuomey in 1846. He found the percentage of living forms in certain beds of South Carolina to be nearly 50 per cent and, on that ground, referred[2] the Carolinian fauna to the Pliocene of Lyell. This fauna was afterward beautifully illustrated in the well known publication by Prof. Tuomey and Dr. F. S. Holmes.[3] It has since proved to be, as will be shown later, a mixed assemblage, containing numerous Upper Miocene species, together with others properly referable to the Pliocene.

Realizing the impracticability of a rigid application of the system of percentages employed by Lyell, Dana proposed[4] for the American epoch referred to the Miocene by Lyell and Conrad the alternative term "Yorktown epoch," and for the American Pliocene the term "Sumter epoch." In 1884 Prof. Heilprin prepared a convenient summary[5] and discussion of the existing knowledge of the Atlantic coast Tertiaries, in which he refers Tuomey's Pliocene to the uppermost part of the Miocene, leaving the question open as to the existence of genuine Pliocene on the Atlantic border. Assuming that the mixed assemblage of Tuomey was a natural fauna, this course was justified by the presence in it of several characteristic Miocene types.

In this publication Prof. Heilprin classified the Atlantic Miocene as follows:

(1) CAROLINIAN (Upper Atlantic Miocene), comprising deposits of North and South Carolina, equivalent to the Sumter epoch of Dana.

(2) VIRGINIAN (Middle Atlantic Miocene), comprising deposits of Virginia and of the "newer" group of Maryland, equivalent to part of Dana's Yorktown epoch.

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[1] Proc. Geol. Soc. London, 1842, vol. 3, pp. 735-742; also 1845, vol. 4, pp. 547-563.

[2] Final report on the Geology of South Carolina, 1846.

[3] Pliocene fossils of South Carolina, containing descriptions and figures of the Polyparia, Echinodermata, and Mollusca. Charleston, S. C., Russell & Jones, 1857. This fine work appeared in quarto in bi-monthly numbers, as follows: Nos. 1 to 6 in 1855, Nos. 7 to 15 in 1856, the title page and index and pp. i-xvi in 1857. Each number comprised two plates and accompanying text; Nos. 3 and 4, 5 and 6, 9 and 10, 11 and 12, 13 and 14 were double numbers. The total comprised pp. i-xvi, 152, and 30 leaves unpaged explanatory of the plates. Each number had a printed title on the cover, with date.

[4] Manual of Geology, by James D. Dana, Philadelphia: Bliss & Co. 1863. 8°. pp. xvi, 798; cf. pp. 506-507. The author remarks, in relation to the Lyellian percentages, "These proportions are not capable of general application. It is possible that beds in America containing all extinct species may be synchronous with those of Europe in which there are 10 or 15 species of recent shells. Moreover, not even the subdivisions in different parts of Europe can be made to correspond to these epochs; still they are convenient terms for Lower, Middle, and Upper Tertiary, and with proper caution may be used to the vantage of the science, op. cit., p. 506.

[5] Contributions to the Tertiary Geology and Paleontology of the United States, by Angelo Heilprin; Philadelphia, the author, 1884, pp. (vi) 118, 4° and map. This work is in part an expansion and reissue of articles previously published by the author.

(3) MARYLANDIAN (Lower Atlantic Miocene), comprising deposits of the "older" group of Maryland and possibly the lower Miocene beds of Virginia, equivalent to that part of the Yorktown epoch not included in the Virginian.

Prof. Heilprin further correlates the "Virginian" with the "Second Mediterranean" of the Austrian geologists, and with the faluns of Touraine. The "Marylandian" he correlates to a greater or less extent with the "First Mediterranean" and with the faluns of Leognan and Saucats (op. cit., p. 67).

In the course of explorations in Florida, undertaken at the instance of Mr. Joseph Willcox, of Philadelphia, a fine series of Pliocene beds on the Caloosahatchie was explored in 1886-'87 and identified as true marine Pliocene by Prof. Heilprin in an extensive report[1] on the expedition. This identification completed the series of the Atlantic Tertiaries, excluding all contested deposits.

Beds of all three divisions of the Cenozoic were early recognized on the Pacific coast of the United States,[2] and the fauna has been summarized by Gabb in the Paleontology of California, volume II, 1869, and more lately by Dr. J. G. Cooper.[3]

These notes comprehend the chief points of interest in the history of the nomenclature of the marine Neocene of the United States. That of the fresh-water beds and strata containing terrestrial vertebrates of the great Interior region is still in an unsettled and more or less contested state, as will be pointed out in detail later in this essay.

BOUNDARIES OF THE SUBDIVISIONS OF THE CENOZOIC.

Preserving to some extent the Lyellian nomenclature for the chief divisions of the Neocene of America, while rejecting the method of percentages upon which it was originally based, it seems advisable to substitute provisional definitions for the chief subdivisions in place of those we have discarded.

EOCENE.

The end of the Mesozoic in America was for the most part marked by such physical changes that on the Atlantic coast at least little difficulty has been experienced in determining the fundamental boundary of the Cenozoic. The presence of sundry species of nearly world-wide distribution, like *Venericardia planicosta*, enables a certain correlation between the Eocene of Europe, of eastern and of western America to pass unchallenged. During the Eocene, or, at all events, the latter part

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[1] Trans. Wagner Free Inst. of Science, Philadelphia, vol. 1, Philadelphia, the Institute, 1887; cf. p. 31.

[2] Cf. Report on the Geology of the Coast Mountains and part of the Sierra Nevada by Dr. John B. Trask; legislative document No. 9, Assembly, session of 1854, Sacramento, B. B. Redding, 95 pp. 8°, 1854. See pp. 35, 39.

[3] Catalogue Inv. fossils of the western slope of the United States. San Francisco: Bacon & Co. 1871, vi, 39 pp. 12mo., printed on one side only, for labels. Also, continued in Seventh Ann. Rep. State Mineralogist, Cal. State Mining Bureau, Sacramento, J. D. Young, 1888; pp. 223-308.

of it, it is known that a fauna indicating warm temperate or subtropical conditions extended on the Atlantic coast nearly to the Hudson, and on the Pacific to Oregon. At the same time a more or less free communication between the Atlantic and Pacific oceans existed in the present Central American region. Toward the end of the Eocene a movement in elevation affected the equatorial and Gulf regions of the two Americas and the Antillean area between them. One result of this disturbance was the elevation of Yucatan and part of Florida above the sea and the serious diminution, though not complete closure, of the passages connecting the Atlantic and Pacific.

MIOCENE.

For present purposes, therefore, the Miocene may be defined as that period of geologic time which began with the culmination of a vertical movement which terminated the Eocene and first raised central Florida above the sea.

As might be expected from the vertical range of this movement, the greater part of the littoral invertebrate fauna perished in the change, only those forms belonging to deeper water surviving. Among the forms which seem to have suffered total wreck at this time several large foraminifers, *Orbitoides*,[1] (?) *Nummulites*, etc., are conspicuous.

A second and analogous vertical movement brought the Miocene to a close and appears to have been marked by the definite and permanent connection of the Eocene island of Florida with the mainland to the north and west, and probably by the union of North and South America.

The Miocene, as thus defined, is distinctly separable into two epochs, recognizable by their faunal facies.

The first or Older Miocene presents a warm-water fauna, the invertebrates being such as might, so far as temperature is concerned, have existed in the preceding Eocene. The warm temperate conditions exhibited by the supposed Miocene leaf beds of Greenland were perhaps synchronous with the spread of this fauna, which can be traced as far as New Jersey, the conditions there being then similar to those now exhibited in the vicinity of the Isthmus of Panama.

The second or Newer Miocene is characterized by the extension southward of a relatively cold-water fauna which took the place of the warm-water assemblage. This fauna extended to Florida and to the Appalachicola River.

The first period is typified by the Chipola beds and the second period by the Ecphora bed or the Chesapeake Miocene in general.

If the invasion of the cold-water fauna was consequent upon an elevation of the sea-bottom at the south deflecting off shore the gulf and equatorial currents and allowing a cold polar stream to find its way

[1] Mr. J. C. Purves states, on the authority of Rupert Jones, that *Orbitoides mantelli* extends "*jusq'au sommet du Miocène* de la Jamaïque."—Bull. du Musée Royal d'Histoire Naturelle de Belgique. Tome III, 1884, p. 290.

southward inshore, the changes which mark the inception of the Pliocene might equally harmonize with a subsidence such as is called for by the deposition of the Lafayette formation.

PLIOCENE.

The marine Pliocene of the eastern United States is marked by a return to the Floridian region of a warmer, chiefly Antillean, invertebrate fauna. Many of the Chesapeake species survived the change and still persist in the Gulf region, indicating that the change, though obvious and well marked, was not sudden or cataclysmal. That the subsidence which permitted this influx from the south did not separate the two Americas or Florida from the mainland, is proved by the appearance, in mid-Pliocene, of South American terrestrial vertebrates in great numbers on the shores of Florida, and also in the interior of the continent.

By common consent the Glacial Period is taken as closing the Pliocene epoch. Yet we may be confident that its end was gradually attained and there seems to be no obvious reason why the great Pliocene mammals might not long have enjoyed in Florida a peaceful existence, undisturbed by the northeastern ice sheet. The rocks show that no very great or very violent changes took place there, whatever may have happened on the borders of the Appalachian region.

The minor divisions of the Neocene of the eastern United States will be found discussed in another place.

GEOGRAPHIC PROVINCES OF THE AMERICAN NEOCENE.

The deposits of this age divide themselves naturally into three principal geographical, faunal and dynamic regions, each of which has, for physical reasons, a certain individuality.

These are the Atlantic and Pacific coast regions, offering marine fossils, and the Interior or terrestrial and fresh-water basins, offering an appropriate fauna and flora. At present we are unable to correlate the Interior with the Coast regions in any general and satisfactory way, but with the increase of our knowledge of the stratigraphy and of the vertebrate remains, it can not be doubted that this desirable result will be within our reach.

To what extent these regions, when sufficiently studied, will admit of being subdivided into more limited natural areas, is yet quite uncertain. In fact, few paleontologists of America seem to have fully grasped the principles upon which such subdivisions must be based. For this reason it is perhaps advisable briefly to consider them.

PRINCIPLES OF CLASSIFICATION.

Apart from purely petrologic characters the Cenozoic formations exhibit several dynamic types marked by special features which distinctly characterize them, but which are not to be regarded as evidence in discussing their time relations. These are:

(1) Marine sedimentary deposits, either littoral or deep water, characterized by the presence in either case of an appropriate fauna, and the greater or less amount of included terrigenous material which in deep-sea deposits may be entirely absent.

(2) Perezonal deposits; terrigenous, with a sparse fauna, if any, characteristic of the conditions of deposition, totally different from faunas of the preceding class, yet often absolutely synchronous with them.

(3) Lake beds of the interior; and, lastly,

(4) Subaerial and fluviate deposits.

All these varieties, corresponding to as many types of dynamic action, not only may have been, but must have been, in process of formation simultaneously. Every marine bed must have had its contemporary perezone, its river bottoms, its lake beds, its contemporary abyssal fauna, with all their intermediate phases or diversities.

From this it obviously follows that diversities in the fossil fauna of different beds do not, in the absence of stratigraphical evidence, necessarily indicate any want of geologic synchrony, unless the beds belong to a single dynamic type.

It is now in order to consider how far in beds of the same type faunal differences may be relied upon to indicate time relations. Where there is no aid afforded by the stratigraphy, identity of fauna may fairly be regarded as establishing a presumption of synchrony. Is the reverse true, as has generally been taken for granted?

In showing that it is only relatively true, we shall be establishing only what is admitted by all biologists. This might be thought unnecessary, but as a matter of fact paleontologists have seldom tested their conclusions by biological rules or even, if we may judge from the literature, indicated in any way their cognizance that such tests were applicable, still less that they were needed.

Taking any synchronous and continuous invertebrate fauna, such as exists on either coast of the United States, let us consider by what it is characterized, and to what influences its diversities are due.

Temperature is well known to be a potent factor in such cases. On the eastern coast of the United States we shall find that certain genera occur in cold northern waters as a characteristic feature of the fauna, and that as we trace their distribution southward they disappear from the coast absolutely, if they are littoral species, or, if they are not by their habits necessarily littoral, by following the isotherms into the cold water of the deeps. The limits of the endurance of the species are probably fixed by the capacity of the embryos. A very few degrees of cold below the normal at the time of spawning will absolutely prevent the development of embryos, and in a single generation may exterminate a whole species. A temperature inhibitory of their habitual food, whether plant or animal, may be similarly destructive. Equally tender species, which have a different spawning time, may escape if the depression of temperature is not too prolonged. Another way in which the existence of a species is affected through its embryos is connected with the specific gravity of the water. If the species like the common oyster should have embryos of less specific gravity than that of the water in which they are spawned, being free-swimming during the short embryonic period, they would float, and if unable to reach the bottom would perish for want of a place of fixation. Thus an oyster reef accustomed to slightly brackish water, by a small subsidence surrounding it constantly with pure sea water (in which the adults might flourish admirably, but through which the embryos could not sink to the bottom) might be wholly exterminated in one generation. From these illustrations the student will perceive that cataclysms are by no means necessary to exterminate or seriously modify a fauna. The tolerance in the direction of heat is apparently greater than that for cold, but this point has been less investigated.

As the sea currents greatly influence the sea temperatures, so those features of the shore which deflect or modify the course of currents indirectly affect the fauna. Cape Cod and Cape Hatteras more or less influence the direction of the polar current and Gulf Stream circulation. They are, consequently, landmarks indicating notable changes in the fauna. To Cape Hatteras, and perhaps still farther south, cold water creeps along the shore. Off shore a few miles, though the water is not deep, the influence of this current is not felt, and numerous West Indian species, unknown along the shore, flourish in abundance. In shore from them various northern species maintain a precarious foothold, so that an east and west line would cut two faunas, one of southern and the other of northern facies, yet absolutely synchronous and closely adjacent.

From the point of view of temperature, therefore, we note that a continuously distributed synchronous coast fauna of invertebrates is modified as regards its constituent organisms; (1) gradually, as the latitude; (2) suddenly, as by changes due to currents; (3) in bathymetric station, or depth inhabited, by tending to follow the isotherms into deeper water.

As we are considering only a shore fauna, or one which might exist between low-water mark and twenty fathoms, it is not necessary to consider the interesting series of influences peculiar to the station of deep-sea organisms.

In the matter of food there are modifications of distribution due to geologic structure of the bottom. On the Alaskan coast I have noted that the red seaweeds grow only where granite or syenite rocks occur. The green seaweeds occur with them and also on the sandstones. On the basaltic shores and bottoms only olive-colored algæ appear. The fauna associated with the latter is different from that which frequents the region of green and especially of red algæ. These differences appear not only among the phytophagous animals, but also among the carnivorous forms which prey upon them and those which use the beds of algæ merely as a refuge. If in the midst of basaltic areas were some small islets of granite, there inevitably, and only there, would the familiar species of the granitic or red seaweed area be found. Ordinarily abundance of food is manifested in the fine development and abundance of individuals rather than in any change in the number of species or the nature of the assemblage.

The influence of the mechanical character of the bottom has been more fully recognized by paleontologists than by others, partly because it is reflected in the fauna and partly because the matrix of the fossils itself brings the question directly under the eye even of the closet philosopher. Very much more remains to be learned in regard to the details of these influences, and this must perforce be left to the biologist who can study the matter in the field, since the conditions under which fossils are found rarely admit of the determination of all the factors in the problem.

TABLE OF ZONES, WITH CENSUS OF FAUNA.

It now becomes necessary to consider the general effect of those influences which may be summed up under the term "difference of latitude." This is best determined by an inspection of known recent faunas of which the following table will give a fair idea. The species which would be absent in a fossil state, such as Nudibranchs, naked cuttlefish, etc., have been eliminated. As mollusk faunas are the best known, and, whether recent or fossil, most characteristic, they have been chosen to illustrate the argument. The number of species contained in each fauna, the date and the authority for the enumeration, and the particular fauna referred to are stated in parallel columns. It is, of course, understood that these estimates are approximate only, some of the faunas being known less thoroughly than others, and the estimate of what constitutes a species differing with different naturalists. The estimates used here are, it is believed, rational and conservative, and, on the whole, are taken from much the same point of view, none of the absurdly exaggerated estimates which have been indulged in of late by certain amateurs having been admitted. The zones adopted in the table correspond approximately to the following ranges of the minimum temperature of the coldest winter month for the surface of the sea: boreal, to a range of from 32° to 40° F.; cool temperate, 40° to 60°; warm temperate, 60° to 70°; tropical, 70° to 80°. These figures are not exact, but our knowledge of the sea temperatures is too imperfect to justify other than round numbers. The fluctuations of the maxima at the same stations are, of course, much greater than the minima, but they do not have the same important relation to the welfare of the species.

Table showing the number of shell-bearing marine species of mollusks contained in recent faunas of different temperature zones.

Fauna.	Enumerator.	Date.[1]	Species.
1. Boreal zone.			
Greenland	O. A. L. Mörch	1875	180
Cape Cod to Cape Breton	A. E. Verrill	1879	277
Vineyard Sound (shallow)	A. E. Verrill	1871	177
New England Coast (abyssal)	A. E. Verrill	1888	296
Arctic Norway	G. O. Sars	1878	332
2. Cool temperate zone.			
Britain	J. G. Jeffreys	1870	436
France, Atlantic Coast	P. Fischer	1878	444
North and South Carolina	Kurtz and Bush	1885	305
Bermuda	Dall	1889	198
Japan	Lischke	1875	429
New Zealand	Von Martens	1885	439
Upper California	J. G. Cooper	1867	598
3. Warm temperate zone.			
Ægean sea	E. Forbes	1840	405
Adriatic	S. Brusina	1866	536
Sicily	R. A. Philippi	1830	587
Cape of Good Hope	F. Krauss	1848	383
East Florida (abyssal)	Dall	1889	260
West Florida	Dall	1889	681
Isle of Réunion	Deshayes	1863	530
4. Tropical zone.			
Mazatlan, Mexico	P. P. Carpenter	1857	654
Panama	C. B. Adams	1852	517
Guadeloupe Island, W. I	P. Fischer	1858	560
Cuba	A. d'Orbigny	1842	595
Suez	R. MacAndrew	1869	818
Average mollusk-fauna in the—			
Boreal zone			252
Cool temperate zone			407
Warm temperate zone			483
Tropical temperate zone			629

[1] Of publication of list.

Of these faunas it may be said that that of Greenland is extremely well known, but very sparse, other areas equally arctic having a much richer fauna as regards species. The other boreal faunas are also quite thoroughly known, unless we except the deep-sea fauna off the coast of New England. There is, therefore, no reason to suppose that the average for this zone is far from the truth.

Of the second, the British and French faunas are probably the best known of any in the world. The enumeration for the Carolinas is defective by underestimation to some extent. Bermuda has probably more species, but the variety of station is small and the fauna is more concentrated than any of the others cited. The others mentioned under this head, of which Upper California is the best known, may be regarded as fairly representative.

Of the warm temperate faunas that of the Adriatic is probably the most thorough; that of Sicily is old and perhaps somewhat deficient, but the lists of Mediterranean species have been of late years artificially expanded so as to have little value for scientific purposes, and it became necessary to go to the older literature to find an enumeration which should be comparable with the others used in this table. The east Florida deep-water fauna represents the number of species obtained from an examination of about a bushel of gravel from two or three casts of the dredge in about 300 fathoms off Fernandina. There were no large shells in the gravel, but it represents much such an assemblage of specimens as might be obtained from sifting an equal quantity of fine shell marl. The West Florida fauna includes some deep-water species which in that region appear in quite moderate depths, as well as the littoral species.

Of the tropical fauna cited, all probably err on the side of underestimation. That of Mazatlan is probably the best known. Doubtless there are localities in the Indo-Pacific region which would largely exceed any of the estimates above cited in a complete enumeration of their shell-bearing mollusks, but none of these seemed sufficiently authenticated to be worthy of citation, and for a discussion of the fossils of our Tertiaries they would not be especially relevant.

It will be noted that nearly all these citations are of faunas sufficiently diffused, or, rather, of areas sufficiently large to eliminate differences due to station within the 100-fathom line.

It is not probable that within the narrow limits of a single collecting spot or beach all the species of any cited fauna could be found, but in collecting fossils access to the original sea bed is so much facilitated and the possibility (as from our Neocene marls) of making a complete collection at any one spot so much more favorable, that it is quite certain that the fauna will be more adequately represented than any recent fauna could be by much more extended work. This is abundantly proved by recent collections made under the writer's direction in the southern marl beds, where the number of species collected in a single locality in each case closely approximates the average for the warm temperate zone above described. Peculiarities of station may limit a fauna to a comparatively small number of species, but in such a case the nature of the matrix and the specific assemblage will discover the reason when properly studied.

CONCLUSIONS FROM THE TABLE.

We may then conclude that that part of the average mollusk fauna which is capable of leaving traces in the shape of fossils, under conditions not greatly differing from those of the present day, if situated in the arctic or boreal region, would comprise about 250 species; in the cool temperate region about 400 species; in the warm temperate, about 500 species; and in the tropical region, not less than 600 species. In regions where the conditions have greatly changed, as for instance, in Greenland since the old Miocene, during a period corresponding by the character of its fauna and flora to a different temperature zone from that in which it is now classified, the fauna should correspond in number of species to that which would be normal to the temperature as it was, not as it is. To illustrate, if we could discover old Miocene marl beds with well preserved fossils in Greenland, they should contain a mollusk fauna of 400 species normal to the cool temperate zone, rather than of 180 species, as is normal to Greenland at present.

Allowing 150 species as equivalent to the boreal species not represented south of New York, we have on the eastern coast of North America, from the Rio Grande to the arctic regions, 1,772 recent species by actual count.[1] Summing up the averages of our table we find that for a coast extending from the boreal region to the tropics (allowing the tabular figures to be exclusive for each zone) we should have 1,771 species for the whole range. This coincidence is accidental, for the tabular figures are deficient in the enumeration of the deep-sea forms. Deducting from our actual enumeration of east North American forms those which appear to live exclusively in the deeps beyond 100 fathoms, we have left 1,364 species.

But the species credited to the zones are, as we know, not exclusive, many of them being included in more than one faunal zone. The difference between the 1,771 theoretically present along the whole line and the 1,364 actually enumerated may be approximately a measure of the overlapping. In this case we should have 1,364 species of potential fossil shells represented by the existing faunas from the Rio Grande to Greenland. If the present sea bottom were elevated the paleontologist who might examine the beds should find, according to the region which he searched, a number of species approximating to the number assigned to that region in the preceding table, provided his estimate of the differences which indicate a species did not differ essentially from ours.

As he proceeded southward he would find a change in the fauna. Species would drop out, but a large number would appear which he had not observed before. Where cold currents have crept along the shore he would find a sparser and more boreal fauna; yet traveling eastward on the continuous strata he would find the more numerous and chiefly different warm water fauna of the edge of the Gulf Stream in absolutely synchronous deposits.

An interesting confirmation of these views is found in the Ecphora marl bed of northwest Florida, a cold water fauna which was preceded and succeeded by a warm water fauna. In the same bluff collections show the much smaller number of species in the Ecphora bed.

It should be noted that in geological changes species of the warmer region are more likely to persist from one formation into another than

[1] U. S. National Museum, Bull. No. 37. A preliminary catalogue of the shell-bearing marine mollusks and brachiopods of the southeastern coast of the United States, by W. H. Dall, Washington, 1889, 221 pp., 8vo, 74 pl. Cf. p. 176.

those of colder regions. This is accounted for by the greater liability to injurious changes in regions which may be buried in or torn up by ice or visited by exceptional winters, while the conditions in the south are less uniform, and the greater area of the tropics gives more chance for widely distributed tropical species to escape destruction from local changes of level or from volcanic activity. Small species have more chances of escape than large ones, being able to hide from enemies in crannies, and, as they offer less food, they are less attractive to hungry prowlers. Species inhabiting moderate depths are safer than those whose station is between tides, from the action of sudden elevation or the visitation of frost, fresh water or water charged with noxious gases, such as break out at intervals on the Florida coast and other shores built of porous lime-rock. Thus it happens that the forms in the recent fauna which can be traced back to the Eocene are all warm-water species of small size, living seaward from low tide as a rule. We should also expect to find, as we do find, that southern beds will contain a larger percentage of still living forms than northern beds of the same age.

The lesson which is to be learned from these facts is not obscure. It is, in brief, that in correlating the fossil contents of different strata with a view of extracting the geological information they can yield, it is necessary to contemplate the growth and evolution of the continent as a whole, to recognize the interrelation of the details, and especially the fact that they can not be scientifically treated by any method which assumes their isolation and fails to take account of the factors we have indicated.

Such treatment is less easy than the old-fashioned way of basing an elaborate discussion on supposed faunas of fifty or a hundred species, but it is capable of yielding results which will stand the test of time and will express with some approximation to accuracy the truths which are the province of paleontology.

The conclusion to which present study seems to lead is that which in the main derives each successive fauna, in an area of reasonable extent, from that which preceded it, though the imperfections of the record in most cases leave this to be inferred. In those rare cases where the record is not greatly interrupted (as in part of the Floridian region) the characteristics, in a general sense, persist from one bed to another. If, owing to changes in temperature, a fauna is replaced by one not related to it, as in the case of the Chipola and Ecphora Miocene beds, with the recurrence of the original conditions the original types show themselves again, as in the Pliocene marl of the Caloosahatchie.

In the above case the Ecphora bed, or Chesapeake fauna, can be traced northward whence it came; while the Chipola types, during their temporary extinction in Florida, were preserved in some undisturbed Antillean area and reappeared by migration in Florida when conditions favored. Both groups of species are essentially American and recall recent American types, just as the Neocene of southern Europe is of a genuine European type. In the imperfect state of our knowledge it is rash to speak of species common to them, but it is certain that there are more species common to the recent fauna referred to than have been yet recognized in their fossil remains. Occasionally a type appears which seems out of place and recalls some distant region where it still lingers, as in the case of *Batissa* of the Oregonian Neozoic, which now is known only from the Indo-Pacific region. But in this case, as in general, when the history of such groups is studied, it is found that *Batissa* is merely a slight modification of *Cyrena*, which is abundant, recent and fossil, in America; such a modification as might have been expected to occur sporadically anywhere where *Cyrena* abounded during several geological periods or was represented by numerous species.

It may be as well to add, for fear of misconception, that it is true that in older geologic epochs the differentiation of faunas and of zones of temperature was certainly less marked than in Neozoic and recent time, and the methods we have recommended for the latter are less applicable to the former. Still it is possible in some cases to trace special characteristics in successive faunas for long periods; as in the faunas of the Californian coast, where, from the Cretaceous to the recent period inclusive, every marine fauna has included a large species of *Nucula* (e. g. *Acila*) with strongly marked divaricate sculpture, a certain type of *Cancellaria*, of *Turritella*, and of *Natica*. Something of the same sort will probably be found true of the successive faunas of the north shore of the Gulf of Mexico.

DIFFICULTIES IN CORRELATING FAUNAS.

In correlating contemporaneous faunas which are geographically separate, it is but seldom that one may have the aid of many identical species. This is especially the case with shallow-water or littoral species of the tropical or warm temperate regions. From the polar regions, owing to the polar circulation and uniformity of conditions, certain species are, as it were, centrifugally distributed to several adjacent faunas. On account of the long persistency of analogous conditions near the poles these species have little value as indications of minor divisions of geologic time. It is rather by the parallelism in stages of development by homologous groups in widely separated regions that a correlation of the Neozoic beds of such regions may eventually be reached, if at all. On the other hand, we do occasionally find a widely distributed yet little modified form like *Venericardia planicosta* of the Eocene; and it is not improbable that more thorough study and careful comparison of Neocene faunas of different parts of the world may reveal a larger number of such species.

CONCLUSIONS.

The conclusions to which the above considerations point at the present time may be summarized as follows:

1. The final correlation of the different beds of Atlantic Neocene will depend on a rational study of their fauna, which is now too imperfectly known to form the basis of satisfactory conclusions.

2. Correlation of these beds with those of Europe is wholly impracticable at present.

3. Faunal division of the known fossil contents of the different formations would be at present premature.

4. While paleontology holds the key to the problems of local and comparative stratigraphy, yet no study of paleontology that neglects the broad and general stratigraphic changes which accompanied the development of the continental border as a whole is calculated to afford results of permanent value.

CHAPTER II.

SUMMARY OF OUR KNOWLEDGE OF THE NEOCENE OF THE ATLANTIC AND GULF COASTS OF THE UNITED STATES, CONSIDERED BY STATES.

SUBMARINE STRATA OFF NEWFOUNDLAND, AND SOUTHWARD TO CAPE COD.

Remains that have been supposed to belong to the "Miocene or Later Tertiary" formation, have been dredged from the Grand Banks off Newfoundland (lat. 44° 30′, long. 50° 15′), at a depth of 35 fathoms. Of these, *Cyprina islandica* only has been definitely determined.[1] At Banquereau, Nova Scotia, have been found *Fusus decemcostatus*, *Latirus albus?* and a species of *Furritella*. Again, on Georges Bank, at a depth of from 35 to 70 or more fathoms, fragments of rocks were dredged up, containing, among other things, *Isocardia* resembling *Cyprina islandica*, but differing in hinge structure; *Myatruncata*, *Solen americana*, *Cyprina*, *Natica*, *Venericardia*, allied to *V. borealis*, but with smaller ribs, and *Cardium islandicum*.

From these facts Verrill is led to infer that there is an extensive bed belonging to the Tertiary formation, which extends beneath tide from Cape Cod to the Banks of Newfoundland. Mr. C. H. Hitchcock[2] had a somewhat similar idea in mind when he wrote, "Possibly Sable Island off Nova Scotia and the Great Banks off Newfoundland may indicate the position of the place of these (Tertiary and Alluvium) Cenozoic deposits at the close of the Tertiary period."

MAINE.

Both Jackson and Hitchcock have mentioned the occurrence of Tertiary deposits in this State. The former says[3] that nearly all the river valleys below 150 feet A. T. are filled with marine deposits, and abound in marine shells, some recent, some extinct. At Kittery,[4] a deposit was found containing *Saxicava rugosa*, *Mytilus edulis*, *Macoma*, and *Astarte castenea*. A similar deposit was found at Lubec. These beds, however, are now regarded as Quaternary. Hitchcock at one time held[5]

[1] A. E. Verrill: Am. Jour. Sci., October, 1878, 3d ser., vol 16, pp. 323–324.

[2] Geol. of New Hampshire, Chas. H. Hitchcock, 1877, vol. 2, p. 21.

[3] Maine State Geol. Report, No. 3, 1839, C. T. Jackson, p. xiii.

[4] New Hampshire State Geol., Final Report on Geology and Mineralogy, 1844, Chas. T. Jackson, p. 94.

[5] Prelim. Report on Nat. Hist. of the State of Maine (Geology, by C. H. Hitchcock), in "Agriculture and Geology of Maine," by the Sec. of Board of Agriculture, 1861, pp. 256–257.

that certain hematite breccias, found at Blackington Corner, belong to the Tertiary, since Miocene fossils had been found in similar material in Vermont.[1] Later, however, he asserts[2] the absence of all Cenozoic deposits northeast of Massachusetts.

NEW HAMPSHIRE.

Jackson[3] mentions the discovery of a Tertiary deposit of blue plastic clay in the southeastern part of Portsmouth, in which were found *Nucula*, *Sanguinolaria* (*Macoma*) and a few recent forms. Hitchcock, however, makes no mention of any such deposits in this State. Moreover, he implies by a statement in Vol. II of the Geology of New Hampshire that none such exist.[4] The stratum in question is doubtless of the same age as the Quaternary beds previously mentioned as occurring on the coast of Maine.

VERMONT.

In 1853 Prof. Edward Hitchcock gave[5] a description of a brown coal deposit at Brandon, Vermont, with an attempt to determine the geologic age of the principal hematite ore beds in the United States. Though figures of fossil plants are given from the above named locality, he seems to have drawn no conclusions from them as regards the age of the deposit; for he says,[6] in substance, that the Brandon deposit belongs to a Tertiary formation, for (1) it lies below the drift and is not consolidated; (2) it contains all the varieties of rocks of the Tertiary formation: white clay, variegated clay, water-worn beds of sand and gravel, carbonaceous and bituminous matter, iron, and manganese. Moreover, he states[7] that this deposit is probably Pliocene or newer Tertiary, for (1) it lies immediately beneath the drift, (2) is not consolidated, and (3) similar brown coal of Europe is of the newer Tertiary.

In Vol. I of the "Geology of Vermont"[8] the above statements are repeated together with those of other eminent specialists. J. P. Lesley[9] is quoted as opposing the idea that the deposit is of Tertiary age, maintaining that it represents simply a mass of disintegrated Paleozoic rock. J. W. Bailey,[10] after examining the fruits microscopically, concludes, or rather intimates, that one may be that of a palm. Leo Lesquereux[10] states that none of the species are living, hence it can not be

[1] Geol. of Vermont. In two vols. Published under the authority of the State legislature by Albert D. Hager, 1861. The "Scientific Geology" by Prof. Edward Hitchcock, vol. 1, pp. 226-240.

[2] Geol. of New Hampshire, 1877, vol. 2, p. 21.

[3] Final Rep. Geol. and Min., New Hampshire 1844, by C. T. Jackson, State geologist, p. 121.

[4] Geol. of New Hampshire by C. H. Hitchcock, 1877, vol. 2, p. 21.

[5] Mass. Report on Geol., 1853, by Edward Hitchcock, p. 22.

[6] Ibid., p. 31.

[7] Ibid., p. 33.

[8] Geology of Vermont. In two volumes. Published under the authority of the State legislature by Albert D. Hager, 1861, vol. 1, pp. 226-237.

[9] Ibid., p. 237-238.

[10] Ibid., p. 240.

Pliocene, and he likens the flora to that of "Oeningen, the upper lignitic bed of the Tertiary."[1]

In an abstract of an article by Mr. H. Carvill Lewis,[2] in which he treats of the iron ores of the "Brandon Period," this deposit is discussed in connection with others of a similar character in southeastern Pennsylvania. Feeling assured of the identity of the deposits in the two States, he concludes that the lignitic clays of Pennsylvania are probably Oligocene, though he suggests that they may be Wealden.

RHODE ISLAND.

Certain deposits of clay and sand in this State were once supposed by Jackson[3] to belong to the Tertiary system; but there seems to be no evidence recorded in support of his views.

The cliff of "plastic clay" on Block Island is probably composed of beds referred with some doubt to the Tertiary, by Mr. Aug. F. Foerste.[4] The beds are said to "lie at such an angle as to make their dislocation by mountain-building forces almost certain."

MASSACHUSETTS.

MAINLAND.

Various deposits of clay in this State were at one time considered by Hitchcock[5] to be of Tertiary age; but in his final report[6] on the geology of Massachusetts, he concludes that none of these clay deposits are of Tertiary age except "the plastic clay of Marthas Vineyard."

Though no undisturbed Tertiary deposits have as yet been positively identified on the mainland of this State, fossils recognized as Eocene species[7] have been found in bowlders in the drift on the east side of Cape Cod. These fossils[8] are found most abundantly about one-half mile south from Highland Light, where a bluff rises to a height of 150 feet. At this place the fossiliferous fragments are not found imbedded in the modified drift, but are scattered about on the slope of the bluff. Farther to the south, however, one mile south from the head of Pamet River, Mr. Warren Upham has observed them so imbedded; and hence he concludes that they were probably brought there by glacial action from a Tertiary deposit in the bottom of Massachusetts Bay.

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[1] For distribution of the Brandon beds, see vol. 2 of the above report, map, p. 989.

[2] H. C. Lewis: Proc. Am. Assoc. Adv. Sci., 1880, vol. 29, p. 427.

[3] Rept. Geol. Survey R. I., by Chas. T. Jackson, 1839, p. 129. For distribution of these so-called Tertiary deposits see "Geological and Agricultural Survey of Rhode Island," 1840, by Chas. T. Jackson (map at end of volume).

[4] Bull. Geol. Soc. Am., 1890, vol. 1, p. 447.

[5] Mass. Geol. Surv. Report, 1832, vol. 1: Edward Hitchcock. See map (frontispiece).

[6] Op. cit., 1841, vol. 2, p. 360.

[7] W. O. Crosby: Proc. Bost. Soc. Nat. Hist., vol. 20, pp. 136-140, 1878; and W. Upham, Am. Nat. Sept. 1879, vol. 13, p. 562.

[8] *Venericardia planicosta* Lain; *Venericardia* probably *parva* Lea; *Venericardia alticosta?* Con., Young; *Ostrea* apparently *divaricata* Lea; *Ostrea* possibly *sellæformis* Con.; *Ostrea virginiana*; *Anomia* resembling *tellinoides*; *Plicatula* near *filamentaria* Con.; *Axinea staminea, Camptonectes, Yoldia, Corbula, Cardium, Natica, Turritella?*

DEPOSITS ON THE ISLANDS OFF THE MAINLAND OF MASSACHUSETTS.

The announcement of Tertiary deposits on Georges Bank has already been referred to.

NANTUCKET.

The next area to be considered, proceeding in a general southwesterly course along the Atlantic border, is the island of Nantucket.

This island has been made the subject of a special study by Shaler,[1] and as there seems to be no good reason for believing that any of its beds[2] are of Tertiary age, it need here receive but little attention. Nevertheless, since Shaler has suggested[3] the possible identity of the clays observed by Messrs. Desor and Cabot at Sankaty Head with those which occur on the southern shore of Chilmark, and since he has recently intimated[4] that the latter may be Pliocene, it may be well briefly to review the opinions that have been expressed in regard to the age of these clays by various scientists. In 1849 Messrs. E. Desor and Edward C. Cabot published in the proceedings of the Geological Society of London a letter written to Sir Charles Lyell[5] "On the Tertiary and more recent deposits in the island of Nantucket." The bed termed by these gentlemen "Tertiary" was probably seen by Mr. S. H. Scudder in 1874,[6] and it was considered by him to be of great thickness. He observes, moreover, that it contains no fossils, and dips strongly (17°) to the southwest. On account of the present superincumbent débris, Prof. Shaler failed to find, with certainty, the beds described by the foregoing writers. The fossiliferous post-Pliocene strata conformably overlying these clays have been fully discussed by Prof. A. E. Verrill[7] in the American Journal of Science.[8]

MARTHAS VINEYARD.

From the facts thus far obtained it appears that the deposits which form this island may be classified under the following heads, viz: Cretaceous, Miocene, Pliocene, Glacial, or Recent. Of these the last mentioned has by far the greatest areal distribution. In fact, there are but two localities where any considerable outcrops of the pre-Glacial deposits appear, viz: At Gay Head[9] and at Chilmark (or Nashaquitsa) cliffs.

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[1] Bull. U. S. Geol. Survey No. 53, 1889.

[2] Ibid., p. 15.

[3] Ibid., p. 34.

[4] Bull. Geol. Soc. Am., 1890, vol. 1, p. 445–446.

[5] Quart. Jour. Geol. Soc. London, 1849, vol. 5 (proceedings), p. 340. (For this reference see Bull. U. S. Geol. Survey, No. 53, 1889, p. 31).

[6] Am. Jour. Sci., 3d ser., 1875, vol. 10, pp. 364–375.

[7] Ibid.

[8] These have been referred to the Columbia formation by McGee. See Am. Jour. Sci., 3d ser., 1888, vol. 35, p. 450.

[9] N. S. Shaler: Report on the Geology of Marthas Vineyard. Seventh Annual Rept. U. S. Geol. Survey, 1888, p. 327.

Cretaceous.—Though the gorgeous colored clays, sands, and lignites at Gay Head and Chilmark cliffs have been regarded by various writers as Cretaceous,[1] Eocene,[2] Miocene,[3] and even Alluvium,[4] it now appears that they can not all belong to one and the same system, but that at Gay Head at least two different ages are represented. Omitting, therefore, all details relating to the lower or Cretaceous[5] portions of these bluffs, suffice it to say that at Gay Head these beds[6] are more or less folded and faulted, but have a general northeasterly dip of from 15° to 50° or even[7] 90°, having the so-called Miocene superimposed conformably, whereas at Chilmark cliffs[8] an anticlinal axis causes the beds to have a northeasterly dip of from 15° to 25° east of the axis, and a southwesterly dip of from 20° to 45° west of the same, while the Miocene beds are wanting.[9]

Miocene.—Very little evidence has been brought forth to prove the existence of Miocene deposits on this island; nevertheless, that there are Tertiary deposits of a horizon "above the base of the Eocene and below the summit of the Miocene"[10] can scarcely be doubted.

Near the northern end of the section at Gay Head[11] there is a series of beds, comprising brown and greenish clays and sands, which have commonly been termed "Greensand." Beneath or to the south of these are sands, clays, and lignites of the Cretaceous,[12] as well as others of doubtful horizon, while above and to the east-northeast are the so-called Pliocene[13] sands.

This Greensand deposit has furnished the greater part of the animal remains that have been mentioned in connection with this locality.

The Testacea, sharks' teeth, etc., mentioned by Edward Hitchcock in his Final Report[14] on the Geology of Massachusetts are scarcely characteristic enough to be of any particular value in determining the age of this series.

The statements of Lyell[15] are somewhat more definite, yet by no means conclusive. The fossils he enumerates are as follows: A tooth of a seal allied to *Cystiphora proboscidea;* a skull of a walrus

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1 Wm. Stimpson: Am. Jour. Sci., 2d ser., 1860, vol. 29, p. 145.

2 Ed. Hitchcock: Reports on the Geology of Massachusets, 1832, 1833, and 1841.

3 Chas. Lyell: Am. Jour. Sci., 1st ser., 1844, vol. 46, pp. 318–320.

4 F. J. H. Merrill: Trans. N. Y. Acad. Sci., 1885, vol. 4, p. 79.

5 D. White: On Cretaceous Plants from Marthas Vineyard. Am. Jour. Sci, 3d ser., Feb. 1890, vol. 39, pp. 94–101, pl. 9.

6 N. S. Shaler: Tertiary and Cretaceous deposits of eastern Massachusetts. Bull. Geol. Soc. Am., vol. 1, pp. 443–452, pl. 9.

7 Seventh Annual Rep. U. S. Geol. Surv., 1888, p. 331.

8 Ibid., p. 327, Fig. 59.

9 Mr. D. White, of the U. S. Geol. Survey, has very recently furnished us with specimens of Greensand from this locality containing sharks' teeth, crab remains, fragments of shells, etc., similar in every respect to those of the Greensand of Gay Head.

10 See Bull. Geol. Soc. Am., vol. 1, p. 446.

11 U. S. Geol. Survey, 7th Ann. Rep., 1888, p. 329.

12 Bull. Geol. Soc. Am., 1890, vol. 1, pp, 445–446.

13 U. S. Geol. Survey, 7th Ann. Rep., 1888, pp. 329–332.

14 Vol. 2, p. 432, pl. xix, figs. 16, 17, 18, 1841. The fossil "Testacea" here figured are casts of a *Venus*, *Tellina*, and *Turbo*.

15 Lyell: Am. Jour. Sci., 1st ser., 1844, vol. 46, pp. 318–320.

somewhat different from any living species; bones of a whalebone whale and of a bottle-nosed whale (*Hyperoodon*); shark teeth, some of which were like those found in the Miocene, near Evergreen, on the right bank of the James River; two crustaceans; casts of a *Tellina*, allied to *T. biplicata*, and one allied to *T. lusoria;* casts of a *Cytherea*, resembling *Sayana;* three casts of a *Mya*, one of which bears a close resemblance to *M. truncata.*

The numerous remains of Cetacea of the genera *Balæna* and *Hyperoodon*, the author contends, are adverse to the supposition that the bed is Eocene, while such fossils abound in the Miocene of America.

In 1863, Dr. William Stimpson[1] discussed the crab remains in these beds, and found them generally referable to two types. One of these, *Archæoplax signifera*, a new genus and species, he describes and figures; but, on account of its distant relationship to other crabs, recent and fossil, it gives no clew in regard to the age of this deposit.

Other Tertiary deposits of doubtful age—later Miocene or Pliocene.—Between Gay Head and Indian Hill there is a series of deposits which resemble lithologically the various beds at Gay Head, but whose fossil contents are unknown. Shaler has estimated[2] the thickness of this series at no less than 15,000 feet. This estimate, however, was made under the supposition that between the localities mentioned above the northeasterly dip is constant and equal in amount to that at Gay Head. This supposition, it appears, must be somewhat in error, for in a later publication[3] he represents the Cretaceous and Tertiary in a section from the valley of Tisbury River to Vineyard Sound as having a northwestern dip of at least 45°.

Nothing more definite than what is implied in the preceding statements is known regarding the distribution of this series.

The series of deposits termed by Shaler[4] the Weyquosque, Nashaquitsa or Chilmark series is typically exposed at the bluffs on the southwestern coast of the island which bear these various names. Beds resembling lithologically those at Gay Head are imperfectly disclosed[5] near the base of these cliffs at certain stages of erosion. The Weyquosque series rests unconformably upon these beds[6] and is entirely different in its physical characters. Its various deposits consist of gray and blue clays and whitish sands, and in the latter are occasional hypogene pebbles. There are no traces, however, of the red and white sands and the lignites so characteristically exposed at Gay Head. The total thickness of this series has been estimated[7] at over 1,500 and possibly over 2,000 feet. On account of the absence of organic remains the geological horizon of these beds is unknown. Shaler[8] is inclined to refer

[1] On the fossil crab at Gay Head: Bost. Jour. Nat. His., 1863, vol. 7, pp. 583–589, Pl. xii.
[2] U. S. Geol. Survey, 7th Ann. Rep., 1888, p. 332.
[3] Bull. Geol. Soc. Am., 1890, vol 1, p. 451, Pl. ix, Fig. 1.
[4] N. S. Shaler: U. S. Geol. Survey, 7th Ann. Rep., 1888, p. 340.
[5] Ibid., p. 327.
[6] Ibid., p. 320.
[7] U. S. Geol. Survey, 7th Ann. Rep., 1888, p. 341.
[8] Ibid., p. 320.

them to the Tertiary system on account of their various small contortions and plications, as well as their general inclination, which often amounts to 15°. These dislocations show evidences of such mountain-building forces as have not been displayed in this region since the close of Tertiary times.

These deposits are mainly confined[1] to the limited areas to the south and east of Menemsha and Squipnocket ponds, though several small patches of apparently similar material have been noted around the northern border of the island. Moreover, there are reasons[2] for suspecting that the lower clays of Nantucket,[3] others on No Man's Land, and possibly certain others in Duxbury may belong to this series.

NAUSHON.[4]

Immediately to the northwest of Marthas Vineyard is the island of Naushon, composed for the most part of reddish and yellowish sands, with occasional water-worn pebbles. The surface of these great arenaceous deposits is worn into forms characteristic of glacial erosion and is strewn with glacial débris. The time of their deposition may, therefore, be supposed to antedate the last glacial period, though to what extent is unknown. Similar deposits, however, have been noted about the shores of Marthas Vineyard, which lie unconformably upon the upturned edges of the Weyquosque series. Shaler is inclined to believe that these sands are more nearly related to the deposits of the glacial age than to those of the preceding series.

NEW YORK.

LONG ISLAND.

Both Hitchcock[5] and McGee[6] have mapped the southern portion of this island as belonging to the Neocene or post-Eocene Tertiary. Very few facts, however, have been given in proof of this view. The island is little more than a glacial moraine, a mass of débris, both unmodified and in every stage and form of modification. Judging from the character and position of the brown and red plastic clays of Huntington and Gardiners Island, Mr. Merrill[7] has been led to surmise that they may be of Tertiary age. The paleontological evidence brought forward in support of this view consists of a shark tooth, which might indicate an Eocene or Miocene period.

If the reported find of an *Exogyra costata*[8] between Brooklyn and Flatbush be authentic, there would seem to be little doubt as to the

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[1] U. S. Geol. Survey, 7th Ann. Rep., pl. xx, opp. p. 308.
[2] Ibid., p. 341.
[3] Ibid., and Bull. 53, U. S. Geol. Survey, 1889, p. 34.
[4] U. S. Geol. Survey, 1888, 7th Ann. Rep., pp. 342-343.
[5] Geol. map of the United States, compiled by C. H. Hitchcock, 1866.
[6] Ibid., W. J. McGee, 1884.
[7] F. J. H. Merrill: Ann. N. Y. Acad. Sci., 1886, vol. 3, p. 356.
[8] Cozzen's Geol. History of L. I., 1843, p. 51.

existence of Cretaceous beds on this island. Between these bedsand the Columbia[1] and glacial deposits above, Tertiary deposits do perhaps exist.

NEW JERSEY.

Though very few localities have yielded fossils characteristic of the Miocene beds, there is good reason to suppose that such beds are extensively developed in the southeastern portion of the State.

Their northern limit can not be accurately determined,[2] on account of the superincumbent superficial deposits, but it may be supposed to extend in a general way from Asbury Park, southwest, to the mouth of Salem Creek; south of this line none but Miocene and Quaternary deposits appear.

Topography.—That portion of the State included within the limits referred to above consists, for the most part, of level, sandy plains covered with forests of pine. The streams meander through flat valleys and are usually bordered by impenetrable swamps of white cedar, often miles in extent. The sea and Delaware Bay shores are fringed by an intricate network of creeks and are broken by numerous bays.[3] In this section of the State there are but two considerable areas whose mean elevation exceeds 100 feet above tide. The more northerly of these occupies the western part of Ocean County, together with a portion of Woodland township in Burlington County. It contained two points which respectively rise to the height of 208 feet above tide, the one 4 miles northwest of Cedar Bridge, the other 3 miles southwest of Shamong Station, called Applepie Hill.[4] The more southerly elevated area occupies the southeast central portion of Camden and Gloucester counties, together with the central portion of Salem and the extreme northern part of Cumberland counties. The highest point in this area is 2 miles north of Berlin, on the line between Camden and Burlington counties, where an altitude of 214 feet A. T. is attained.

These two more elevated areas are separated by a marked depression which extends across the State in a northwesterly direction from Great Bay to Burlington. Along this line of depression the watershed between the Delaware River and ocean systems of drainage is very low,[5] reaching a minimum of 85 feet A. T.

THE MIOCENE MARLS.

In the southwestern part of the State the erosive action of Stow Creek has exposed the upper portion of a bed of gray marl containing typical Miocene fossil remains. It is from this horizon that the fossils enu-

[1] Am. Jour. Sci., 3d ser., 1888, vol., 35, pp. 383, 453, 455, et seq.

[2] Cope states (Proc. Phila. Acad. Nat. Sci., 1872, p. 14) that a thin stratum of loamy sand containing terrestrial vetebrate remains of the Miocene period overlies the Eocene marl on Shark River.

[3] Geol. Survey N. J., Ann. Rep., 1887, p. 18.

[4] Geol. Survey, N. J., 1888, vol. 1, Topog. Magnet. Clim., p. 170.

[5] Geol. Surv. N. J. (Geo. H. Cook, State Geol.), 1888, vol. 1, p. 170.

merated in various publications as "from Jericho and Shiloh, near Bridgeton, N. J.," are obtained.

The Shiloh marls.—A visit made by W. H. Dall in June, 1888, to the classic locality at Shiloh and its vicinity, afforded the following observations:

Section at Shiloh, New Jersey.

6 inches vegetable mold.
10 feet drift gravels rather fine and sandy.
2 feet yellow marl.
2 to 3 feet black marl.
8 to 10 feet shell marl.
Blackish sand not marly and of unknown depth.

Above the barren black sand which underlies the marls are three distinct successive unconformable marly strata, locally known as the "Shell marl," the "Black marl," and the "Yellow marl."

The lower stratum, or Shell marl, when moist, as it lies in the bed, is blackish, becoming grayish green when dry, with numerous rolled fragments and broken pieces of white fossil shells scattered through it. With these fragments are occasional perfect valves or complete specimens of *Turritella, Astarte, Crassatella,* and *Balanus,* with occasional sharks' teeth and other vertebrate remains.

The upper surface of this bed is very irregular, with small and large rounded hummocky hillocks separated by lower areas or channels, the whole bearing evidence of having been deposited in disturbed water subject to strong and irregular currents.

Above the Shell marl and unconformably filling its cavities is the Black marl, destitute of fossils and clayey or unctuous to the touch. The layer of this is two or three feet thick and its upper surface is worn into irregular rounded lumps, like that of the Shell marl surface below, but not conformably to the latter.

Above the Black marl is the Yellow marl, also destitute of fossils for the most part and unconformable with the surface below it. It is less unctuous than the Black marl, but rather greasy, of an orange brown color and does not average over two feet in thickness. It is sometimes absent in spots or indicated only by a narrow yellow line, and also has an irregularly worn, lumpy surface.

About 10 feet of sandy drift gravel, capped with some 6 inches of vegetable mold, overlies the marls.

The areas in which these marls occur are patches of comparatively limited extent, not indicated by any surface features, so that exploration is always required to determine whether there is any marl under a given field or not. The succession of the beds at Marlboro, Shiloh, and Jericho was essentially the same in all the pits and sections examined.

The appearance and contents of the beds strongly recall the condition of the sea bottom off Hatteras at the present day, where Miocene and

Pliocene sharks' teeth are being mixed with those of recent species and Miocene fossil shells come up in the dredge with living forms. The turbulent and irregular whirls and currents which are characteristic of the sea off Hatteras were paralleled in the waters in which these marls were laid down, and the genera represented in the latter are the same as those of the recent shells dredged off Hatteras.

It may be added that the ferruginous matter, to which the Yellow marl owes its color, sometimes settles to the bottom of the stratum and forms a thin hard layer over the upper surface of the Black marl below it. The latter is occasionally absent, so that the Yellow marl rests directly over limited areas upon the surface of the Shell marl bed.

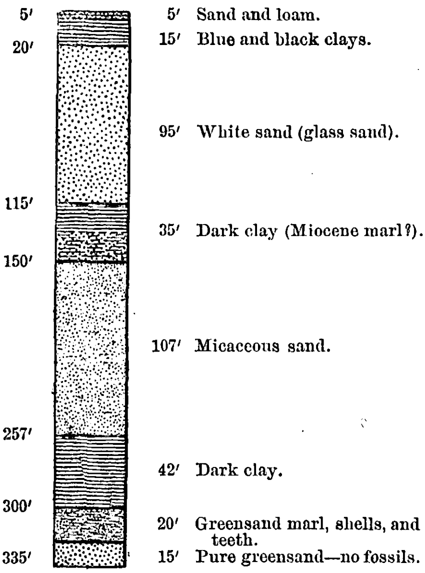

FIG. 1.—Section of artesian well at Winslow, Salem County, N. J.

The area in which these marly deposits are found is very limited. Its most northerly portion now known is about 3 miles north of Shiloh, whence it extends in a narrow belt in a southwesterly direction to a point about 1½ miles southwest of Jericho. The average thickness of the beds has been estimated[1] at from 10 to 15 feet, though, on account of the undulations of both upper and under surfaces, these figures must be understood as only approximate. The nature of the formation beneath the marl is not well exhibited in the vicinity referred to by Prof. Cook. Immediately above it, he states, there lies a bed of Black marl, varying in thickness up to 6 feet; upon this in turn rests a yellow earthy deposit of from 1 inch to 3 feet in thickness; above the latter appear the surface gravel and sand. The order of superposition, however, is not constant on account of the absence of some of the above-mentioned strata or the interpolation of others.

The stratigraphic relations of this bed to others of presumably Tertiary age can best be seen by referring to the section of the artesian well at Winslow, Salem County.[2] (See Fig. 1.)

The bed termed "Miocene marl" in this section is probably the same that appears on the branches of Stow Creek.

Its thickness is here represented as being 35 feet when taken in connection with the clays above. Beneath this there is a deposit of "micaceous sand" 107 feet thick, that appears not to have been identified at any place on the surface. Below this stratum of sand there is a

[1] George H. Cook: Geol. of N. J., 1868, p. 296.
[2] See Geol. N. J., 1868, pp. 291-292.

deposit of "dark clay," evidently identical with the "astringent clays" of later reports.[1] The "Greensand marl, with white shells and teeth," below the "dark clay," is evidently the Eocene marl bed that appears at the surface about Deal and Shark River in Monmouth County.

Above the "dark clay," that rests immediately upon the "Miocene marl" is a stratum of "Glass sand" 95 feet thick. This sand forms the surface rock of no less than one-fourth of the whole Tertiary portion of the State. South of the valley of Mullica River it is for the most part obscured by later deposits, except along the valleys of the Great Egg Harbor and Maurice rivers. North of Mullica River the strips of Glass sand alternate with those of later deposits, each extending in a general southeasterly direction from the Cretaceo-Tertiary boundary line to the low Atlantic shore.

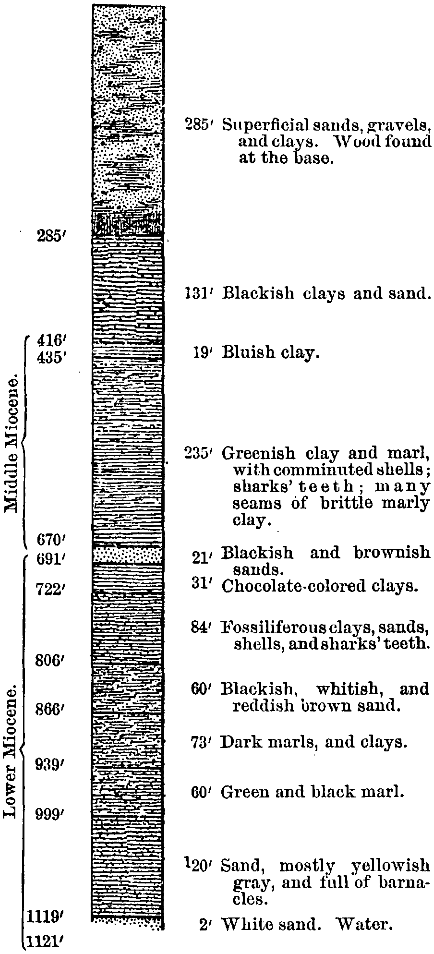

FIG. 2.—Section of well at Atlantic City, N. J.

Section of the well at Atlantic City, N. J.—In 1886-'87 a well was sunk at Atlantic City to the depth of 1,150 feet, which proved beyond all doubt the general and wide distribution of Miocene deposits in this part of the State. The section[2] here given (Fig. 2) is compiled from an article by Mr. Woolman in the Proceedings of the Philadelphia Academy of Natural Sciences. Many fossils were obtained from the borings of this well[3], but unfortunately the depths from which they respectively came were not recorded, with perhaps three exceptions, viz:

Turritella plebeia came from a depth of 450 feet.

Corbula elevata came from a depth of 730 feet.

Perna maxillata came from a depth of 800 feet.

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[1] See Rept. of 1886, Geol. Surv. N. J.

[2] Lewis Woolman: Proc. Phila. Acad. Sci. for 1887, pp. 339-341.

[3] Prof. Angelo Heilprin identifies the following species: *Anomia* (prob. *ephippium*), *Arca centenaria A. subrostrata, A.* (*idonea?*), *A.* (*lienosa?*), *Artemis* (*acetabulum*), *Astarte compsonema, A. abrupta, A. perplana, A. thomasii, Cardita granulata, C. arata, Crassatella melina, Corbula idonea, C. elevata, Cardium* (prob. *laqueatum*), *Cytherea, Discina lugubris, Donax* (*variabilis?*), *Fulgur, Lucina trisulcata, Mactra lateralis?, M. ponderosa, Mytiloconcha incurva, Mytilus incrassatus, Mysia, Natica catenoidea, Nassa trivittata, Nucula obliqua, Ostrea, Pecten madisonius, P. humphreysii, P. vicinaria, Tellina subreflexa, T. declivis, Turritella cumberlandiana, T. æquistriata, Turbinella woodii.* Also shark teeth, barnacles, etc.

The division of that portion of the section below 400 feet into "Middle" and "Lower" Miocene is said to be based upon "paleontological evidence," but the propriety of the division is certainly questionable while so little is known in regard to these deposits.

A second well was drilled in 1888, on which Mr. Woolman has given some notes[1] in regard to the diatoms and Foraminifera. These occur in a series of clay beds, separated by sand beds, the whole aggregating 250 feet in thickness and extending from a depth of 387 feet to 638 feet. The clays contain diatoms in abundance, though they are almost absent from the sand. Samples from 406 feet and 550 feet are especially rich. About 100 species have been catalogued by C. H. Kain. Nearly all the forms occurring in the diatomaceous outcrops of Maryland and Virginia have been recognized, except two or three regarded as characteristic of the outcrop near Nottingham, Maryland, on Lyons Creek. Mr. Woolman regards these diatomaceous beds as belonging collectively to the Miocene, though referable to various separate horizons, of which that at Nottingham is probably the lowest.

Five forms of Foraminifera were found at 435 feet and fifteen forms at 1,125 feet, those of the upper horizon recurring in the lower level, and all practically the same as species described by d'Orbigny in 1840 from the Miocene clays of Vienna, Austria.

A *Nonionina* is now the common recent foraminifer in the Atlantic City sands, an ounce of which has been computed to contain 18,000 specimens. This, which is almost the only form now found on the New Jersey coast, does not occur in the samples obtained from the wells.

CENOZOIC SANDS.

Above the so-called "glass sand"[2] of this State there is a deposit of coarse white sand of more than 100 feet in thickness, which forms the base of the highest hills southeast of the marl belt. It may be seen in the Hominy Hills east of Freehold, and also in Apple Pie, Bear Swamp, and Governors Hills, as well as in the high ground of the plains, and especially near Lakewood and in the Forked River Mountains. This deposit Prof. Cook[3] has classified as Tertiary, though for want of paleontological evidence its geological horizon is not known with any degree of certainty.

Above this deposit of coarse sand, a series of beds of blue or light colored clays[4] may be seen at Winslow, near Wheatlands, Mount Misery, Vineland, Millville, and elsewhere. Whether these beds are Upper Pliocene or Pleistocene is uncertain. Resting unconformably over all these beds is a deposit of "yellow gravel." This is presum-

[1] Microscopical Bulletin of Queen & Co., Phila., Dec., 1888, vol. 5, No. 6, p. 41.

[2] Geol. Surv. New Jersey, Ann. Rep. for 1886, by Geo. H. Cook, p. 133.

[3] Idem.

[4] Idem.

ably post-Pliocene[1] and will accordingly receive no further attention here.

Dip.—By calculations based upon the depths at which the various marl beds were found[2] in the "Ocean Grove" well, together with the position of their respective outcrops, it has been found that the dip of the Tertiary beds here represented is about 25 feet per mile in a southeasterly direction. From various observations and calculations Prof. Cook[3] concludes that the dip in the southern part of the State varies from 20 to 40 feet per mile in the same general direction as stated above.

PENNSYLVANIA.

In accordance with the results of the most recent and trustworthy investigations, there appear to be no deposits belonging to the Tertiary system in this State. But since certain clays, lignites, ores, gravels, and conglomerates have been supposed by various authors to belong to this system it may be worth while briefly to consider the reasons that have led to these suppositions, together with those by which they have been opposed.

Cenozoic gravels.—At an average distance of 5 miles from the Delaware River, in the vicinity of Philadelphia, roughly parallel to it, there extends a prominent gneissic elevation, termed by Lewis[4] the "upland terrace." Within this terrace, and resting upon its slopes there is a deposit of gravel, termed[5] "fossiliferous gravel" by the same author, and identified by him with the "yellow gravel" of New Jersey.[6] This he regards as "probably of newer Pliocene age,"[7] drawing his conclusion from facts substantially as follows: Unlike the Quaternary gravels and clays this deposit is not limited in extent, but occurs all along the Atlantic seaboard of the Southern States. It is therefore of oceanic origin. It is characterized by small water-worn pebbles of quartz and quartzitic rocks. There are also occasional pebbles of flint and fossiliferous hornstone and chert. It contains no bowlders, and its pebbles nearly all have a water-worn, eaten appearance. The great amount of erosion it has suffered and the decomposed state of the beds upon which it lies point to the conclusion that it is an ancient deposit of marine origin, made during a submergence in preglacial times. The glacial drift overlies and is consequently more recent than this yellow gravel. To these various arguments it is only necessary to say that they are equally applicable to the beds of the Columbia formation;

[1] Geol. Surv. N. J. Ann. Rep. for 1886, p. 133; see also McGee's article on the Columbia formation in Am. Jour. Sci., 3d ser., 1888, vol. 35, pp. 383, 452–453, etc.

[2] Geol. Surv. N. J. Ann. Rep. for 1883, p. 19.

[3] Geol. Surv. N. J. Ann. Rep. for 1886, p. 129.

[4] H. C. Lewis: Jour. Frank. Inst., 3d ser., May, 1883, vol. 85, pp. 359–372.

[5] Proc. Phila. Acad. Sci. for 1880, p. 267.

[6] Geol. Surv. N. J., Ann. Rep. for 1886. p. 127.

[7] Jour. Frankl. Inst., 3d ser., May, 1883, vol. 85, pp. 370–371.

and that, according to Lewis's own statement, this deposit is but a continuation of the "yellow gravel" of New Jersey, whose post-Tertiary age has already been proved.

Back of the upland terrace there are isolated patches of two surface deposits, which from their elevated position and peculiar lithological characters are evidently more ancient than the gravels just described. In 1878 Mr. Lewis[1] named these deposits the "Branchtown clay" and "Bryn Mawr gravel," noted the identity of their contained bowlders, and assigned them to a Tertiary period.

In subsequent discussions[2] he seems to have discarded the first-mentioned name, but discusses the "Bryn Mawr gravel" in great detail, giving its peculiar lithological characters and geographical distribution, and reiterated his views as to its Tertiary age. The antiquity of the deposit, as stated above, is proved by its elevated position and its lithological characters, entirely different from the Columbian and Glacial formations below. Nevertheless, these arguments would be equally applicable to pre-Tertiary or even pre-Cretaceous deposits; so that, with no other evidence to the contrary, there appears to be no reason for doubting McGee's identification[3] of this "gravel" with his "Potomac formation." It is, however, worth while to note that Lewis[4] finds that "a precisely similar formation caps some of the hills in New Jersey. On top of the hill at Mount Holly, N. J., is an identical conglomerate of gravel, similar in appearance and composed of the same materials as the formation in Pennsylvania. The conglomerate has the peculiar ferruginous glaze already noticed. It here overlies Cretaceous marls and sands."[5]

Iron ores and lignites, supposed to be of Cenozoic age.[6]—The stratigraphy of the various "Tertiary" lignitic and iron-ore deposits of southeastern Pennsylvania, especially of Montgomery County, has been carefully studied by Mr. Lewis, who has found them severally of the Bryn Mawr gravel horizon,[7] or stratigraphically beneath it.[8] Owing to the probable age[9] of this gravel, these lignites and ores will not be discussed here.

DELAWARE.

Geographical distribution of Cenozoic deposits.—The Cenozoic as well as the older deposits in this State are covered to such an extent by the Columbia[10] formation that their geographical distribution is as yet but

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[1] Proc. Phila. Acad. Sci. for 1880 pp. 268–272.
[2] Ibid., p. 277, 288, 289. Jour. Frankl. Inst., 3d ser., May, 1883, vol. 85, p, 371.
[3] Am. Jour. Sci., 3d ser., 1888, vol. 35, p. 130.
[4] Jour. Frankl. Inst., 3d ser., May, 1883, vol. 85, p. 372.
[5] Recent observers have informally expressed the opinion that these gravels would prove to be Lafayette.
[6] Proc. Acad. Nat. Sci. Phila. for 1880, vol. 32, pp. 281–291.
[7] Ibid., p. 288.
[8] Ibid., pp. 288–289.
[9] Upper Jurassic; Am. Jour. Sci., 3d ser. 1888, vol. 35, p. 138.
[10] The "Delaware gravels" and "Estuary sands" of Chester. See Am. Jour. Sci., 3d ser., 1885, vol. 29, p. 36. The "Lower clays" of "recent (post-Tertiary) origin.' Booth, Mem. Geol. Surv. Del., 1841, p. 94.

indefinitely known. According to the interpretation of Mr. F. D. Chester,[1] the boundary line between the Cretaceous and Cenozoic systems extends across the State in an ENE. and WSW. direction, passing in its course about 3 miles south of Middletown. From this line south as far as Murderkill Creek a belt of Miocene clays occupies the whole width of the State, just beneath the Columbia formation. Still farther to the south the pre-Columbia sands and clays are, according to the same author,[2] presumably of "later Pliocene" age.

Judging from the general trend of the Tertiary outcrops in adjacent States, it seems probable that the foregoing statements approximately represent the truth, provided only that the "glass sand" of New Jersey and this State be regarded as Pliocene, a supposition for which there appears to be no paleontological evidence.

Stratigraphy.—The uppermost layer in the Cretaceous system is, according to Booth,[3] a sandstone or conglomerate which separates the fossiliferous sands below from the Yellow clay formation of the Appoquinimink hundred above.

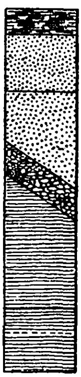

FIG. 3.—Section of well near Blackbird, New Castle County, Del.

The last-named formation consists for the most part of yellow clay,[4] though beds of coarse gravel and bluish and whitish clays are not uncommon. Not far from Blackbird, on the north bank of a creek of the same name, a well was dug to the depth of 15 feet and a boring made 7 feet deeper. A section is given in Fig. 3 of the various beds passed through, together with their respective thicknesses.[5] The Yellow sand contains numerous particles of green sand, and hence has been supposed to be derived from Cretaceous deposits. Not far from the same locality fragments of silicified wood are frequently seen, which belong, perhaps, to the genus Pinus.[6] No other fossils seem to have been noted in this "Yellow clay formation."

Just how much of the section here represented Mr. Chester would consider Miocene and how much Columbia[7] is a difficult question to settle; yet, from his brief characterization of the Miocene bed of this State, it may be presumed that at least the lowest 4 feet of the boring penetrates into Miocene clay.

Farther to the south, along the branches of Old Duck Creek[8], perhaps 4 miles below Smyrna, a stratum of blue clay appears, proved to

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[1] Proc. Phila. Acad. Nat. Sci., 1884, p. 240. Map.
[2] Ibid.
[3] James C. Booth: Memoir of the Geological Survey of Delaware, Dover, 1841, pp. 53, 88.
[4] Ibid., p. 89.
[5] Ibid., p. 90.
[6] Mem. Geol. Surv. Del., 1841, p. 89.
[7] Cf. McGee. "Delaware Gravels" of Chester's nomenclature.
[8] Mem. Geol. Surv. Del., 1841, p. 81.

be of Miocene age by the fossil shells it contains. The clay is mixed with white sand in such proportions as to crumble without difficulty, when dried, to a leaden gray, pulverulent mass. In some instances the upper layer of this stratum consists of a ferruginous sandstone, averaging a foot in thickness, and abounding in casts of shells. Among these have been noted[1] *Venus alveata*, *V. inoceroides*, *Nucula lævis*, *Myoconcha incurva?*, *Pecten madisonius*, *Mactra*, *Cardium*, and *Serpula*. The blue argillaceous layers below contain casts of apparently the same genera and species. The thickness of the whole stratum is known to be at least 12 feet; and, like the Miocene clay of New Jersey, becomes somewhat arenaceous in its lower parts. Above it reposes a bed of reddish yellow sand, passing at times into a similarly colored clay and capped by a gravelly layer cemented into a conglomerate by oxide of iron, while this in turn is covered by a light, loamy soil. The order of superposition, together with the thickness of the various strata, is represented in Fig. 4.

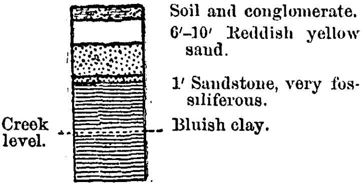

FIG. 4.—Section at Wales's mill-dam, near Smyrna, Del.

Farther to the southwest, near the headwaters of Choptank Creek, a blue clay has been observed[2] at "Smith's mill," rising a few feet above tide, differing in no respect from that on Old Duck Creek except in the absence of fossils. It is also overlain by a yellow gravel sand and loam and capped by gravel. This clay, according to Booth, appears to be continuous with Miocene clays lower down the Choptank, and it may therefore be a continuation of that at Old Duck Creek.

For several miles southward from these creeks the substratum of clay[3] observable in nearly all the streams seems to be without fossil remains. On Jones Creek, east of the Statehouse[4] the clay rises a little above water level and appears to be of a general yellowish color, though streaked with a few white seams. Upon it rests a reddish gravelly loam 8 or 10 feet thick, and upon this in turn a yellowish sandy loam 4 or 6 feet in thickness. The greatest known thickness of the Yellow clay stratum (15 feet) was obtained by a boring near the junction of Tydbury branch and Jones Creek. The yellow sand at the bottom, however, may be only a subordinate bed in the clay. The accompanying section (Fig. 5) represents graphically the sequence, character, and thickness of the above-mentioned deposits.

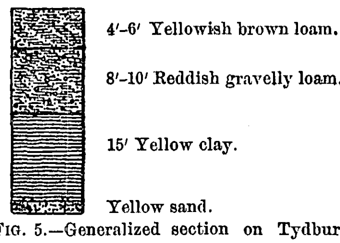

FIG. 5.—Generalized section on Tydbury branch and Jones Creek, Kent County, Del.

[1] Mem. Geol. Surv. Del., 1841, p. 81, 82. *P. madisonius* is on Dall's authority.
[2] Ibid., p. 83.
[3] Ibid., pp. 91–94.
[4] Ibid., p. 92.

It is evident from the statements of Chester[1] that he regards this stratum of clay as a continuation of the fossiliferous deposit on Old Duck Creek. Booth[2] is inclined to think it stratigraphically above this deposit, and below that of Murderkill Creek to be described hereafter.

Little is known definitely regarding the dip of the various Tertiary and Quaternary deposits of this State, but upon general principles it has been assumed that there is a general low dip toward the southeast.[3] The observations of Booth,[4] however, tend to show that the city of Dover is located in a general depression of the subjacent strata. The slight northern dip for some distance southward from Dover tends to prove that the stratum of clay under consideration merges into the blue fossiliferous clays of Murderkill Creek.

Along the confluents of this creek, in the neighborhood of Frederica, the Miocene is again fully developed, abounding in fossil remains. A typical section of the representative beds of this vicinity was obtained at "Springmills" by Booth,[5] which is here represented graphically (Fig. 6). "The uppermost stratum is loose sand, below which is a ferruginous conglomerate of sand and pebbles, 1 to 2 feet thick; next a brownish yellow sand, containing a large portion of oxide of iron, 3 feet, at the bottom of which is a thin layer of gravel; still lower a light gray, somewhat argillaceous sand, partially indurated, and abounding with casts of shells, from which the carbonate of lime has been wholly removed and sometimes replaced by a thin coating of brown oxide of iron, excepting in one instance, in which a part of a single shell remained; its thickness is from 3 to 6 feet; below it is a stratum of hard ironstone, 1 foot; and the lowest stratum visible is a blue clay similar in every respect to that of the Northern Tertiary (at Old Duck Creek), consisting of more or less white sand imbedded in a highly tenaceous blue clay and abounding in impressions of the same shells that characterize the upper white sand. The hardest shell-casts are found in the ironstone, and among these we recognize a large scallop shell, probably the *Pecten madisonius*. A boring made to the depth of 5 feet below tide-water offered no variation in the nature of the blue stratum."

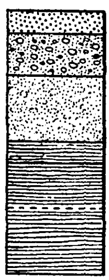

FIG. 6.—Section at "Springmills," Frederica, Kent County, Del.

The series of sands and clays termed Pliocene by Chester,[6] occupies

[1] Proc. Phil. Acad. Nat. Sci. for 1884, p. 240.
[2] Mem. Geol. Surv. Del. 1841, pp. 91, 93.
[3] Ibid., p. 93, and Proc. Acad. Nat. Sci. Phila. for 1884, p. 240.
[4] Ibid., pp. 92–93.
[5] Ibid., p. 86.
[6] Proc. Phil. Acad. Nat. Sci. for 1884, p. 240.

that portion of the State to the south of Murderkill Creek. That some of the sand beneath the Columbia formation may represent the Glass sand of New Jersey seems very probable ; but, admitting this, their Pliocene age, as before stated, is not proved for want of paleontological evidence. Booth[1] includes all these beds under "Recent Formations."

MARYLAND.

The terms Eastern Shore and Western Shore have been used to designate those portions of the State lying respectively to the east and west of Chesapeake Bay. For the sake of convenience and perspicuity, the Miocene deposits of these two divisions will here be considered separately.

EASTERN SHORE MIOCENE.

According to Mr. Uhler[2] the southeastern boundary of the Eocene in this part of the State begins "near the head of the Andover branch of Chester River, next the Delaware line,[3] and extends, in an interrupted order, west of southwest past Sudlersville, Churchill, and Centerville, and, taking in Kent Island, crosses to Chesapeake Bay."

Several characteristic Miocene fossils have been found at Easton, on Treadhaven Creek.[4] The southern limit of the Tertiary series has been defined[5] as extending from near the head of the Little Choptank eastward to the Delaware line. The evidence upon which this limitation is based is wholly lithological and very unsatisfactory.

WESTERN SHORE MIOCENE.

On this side of the Chesapeake the southeastern boundary of the Eocene is said[6] to begin at the mouth of West River ; thence it passes in a general southwesterly direction, above Lower Marlboro, to near Ludlows Ferry on the Potomac. To the south of this line the peninsula is mainly composed of Miocene beds, overlaid by the Columbia formation.[7]

The knowledge hitherto acquired in regard to the Miocene of this state has been obtained almost exclusively from examinations made along the low banks and escarpments of Chesapeake Bay and the Patuxent and Potomac rivers. In the following discussion, the formation as it appears along the above-mentioned bodies of water will be considered as constituting three sections, extending from the Eocene

[1] Mem. Geol. Surv. Del., 1841, p. 94.

[2] Trans. Md. Acad. Sci., 1888, p. 30.

[3] At "Wye," doubtless the modern Wye mills in the extreme northern part of Talbot County, Prof. J. W. Bailey found the "Infusorial Stratum" of Rogers "with all its usual characteristic species." Am. Jour. Sci., 2d ser., 1851, vol. 11, pp. 85-86.

[4] Second Bull. Proc. Nat. Institution, 1841-'42, p. 176, Proc. Acad. Nat. Sci. Phil. for 1880, p. 25.

[5] First Rept. of State Agric. Chemist, Md., 1860, p. 44, map.

[6] Trans. Md. Acad. Sci., 1888, vol. 1, p. 30.

[7] Am. Jour. Sci., 3d ser., 1888, vol. 35, p. 380, 383, 449.

on the north to the Pleistocene beds on the extreme end of the peninsula.

Section along the west shore of Chesapeake Bay—In accordance with Conrad's observations,[1] the northernmost outcrop of Miocene deposits along this section is that near Fair Haven, Anne Arundel County.[2] The bluffs in this vicinity generally rise to the height of about 50 feet above tide, while their continuity is interrupted by numerous valleys of bayward-flowing streams. The lowest stratum, level with the tide, is composed of clay, containing a layer of *Ostrea percrassa*, *Vola humphreysii*, and various other species. The top of this stratum is about 5 feet above the level of the bay. Above is a light-colored clay, containing great numbers of siliceous casts of small shells, chiefly Turritellas; to this succeeds a whitish clay without fossils.

Section at Fair Haven, Anne Arundel County, Md., after Conrad.[3]

Feet.	Character of strata.
50	Whitish clay.
	Bones of cetacea.
3	Clay, with siliceous casts of marine shells, and fragments of bones.
5	Clay, with *Ostrea percrassa* and *Vola humphreysii*.

This locality is "interesting from the occurrence of joints which traverse all the strata without interruption, and which were evidently produced by the same cause as those in Paleozoic formations.[4]"

About 20 miles south of Fair Haven ("near Col. Blake's"[5]) the escarpment is at least 150 feet high. At its base the clay stratum is replete with a species of *Tellina*, and above this, at about 6 feet elevation, there is a thin stratum of *Ostrea percrassa*. The upper portion of the cliff consists of sand and clay, apparently destitute of fossils. At a point a few miles farther to the south ("Capt. Hance"[6]) a small stream has worn a channel in the bank and exposed the beds of a mixture of sand and clay, in general very incoherent, with numerous fossil remains. Its elevation is but a few feet above the level of the bay. From it Conrad cites thirty-seven species of Mollusca.[7] Three or 4 miles farther to the

[1] Second Bulletin, 1841, Proc. Nat. Inst., p. 181.

[2] Prof. J. W. Bailey discovered (Am. Jour. Sci., 2d ser., 1849, vol. 7, p. 437) the "Infusorial stratum" of the Lower Miocene, at Herring Bay, on the west coast of Chesapeake Bay.

[3] T. A. Conrad, Second Bull. Proc. Nat. Inst., 1841–'42, p. 181.

[4] Ibid.

[5] Ibid.

[6] Ibid.

[7] Ibid.

south (Capt. Beckett's[1]) there is another vertical cliff, perhaps 35 feet in elevation, whose basal portion is formed of a brown mixture of sand and clay, and contains the same fossils as those found at "Capt. Hance's"; above, the fossils occur, but less frequently; then succeeds a 20-foot stratum of sands and clays apparently without fossils; above, and resting on this, is a stratum of quartzose sand, very incoherent and filled with shells, among which are *Dosinia acetabulum*, *Discina lugubris*, and *Pecten madisonius*.

Cliff near "Capt. Beckett's," Calvert County, Md.[2]

Feet.	Character of strata.
5	Sand, without shells.
3	Sand, with innumerable shells.
20	Mingled sand and clay, without fossils, or very rare.
3	Same as below; less numerous.
......	....
4	Sand and clay, with a group of shells like that at Hance's.

From this place to the mouth of the Patuxent, escarpments containing Miocene fossils are numerous. It is not, however, till Cove Point is rounded that they have received any scientific investigation. In the vicinity of Cove Point, both Conrad[3] and Clark[4] have noted the occurrence of cetacean bones; and between this point and the mouth of Patuxent River each has noted the occurrence of a great number of fossil mollusca. Concerning the geology of this section between the mouths of the Patuxent and Potomac no observations seem yet to have been recorded.

Section along the Patuxent River.—On the Calvert County side of the Patuxent River, about three-quarters of a mile below Lyons Creek, an abrupt bank rises to the height of 44 feet.[5] In the lower portion typical Eocene materials and fossils appear, while in the upper part there is a stratum of diatomaceous earth, or "Tripoli," about 3 feet thick. From this point to Hollands Cliffs, 2½ miles below Lower Marlboro, the upper surface of the Eocene approaches nearer and nearer the level of the river, while the stratum of Tripoli increases to a thickness of 30 feet. This in turn is here overlain by a slightly ferruginous sand, about 6

[1] T. A. Conrad, 2d Bull. Proc. Nat. Inst., 1841-'42.
[2] Ibid, p. 182.
[3] Ibid., p. 183.
[4] Johns Hopkins University, Circ. No. 65. April, 1888, p. 3.
[5] P. R. Uhler: Trans. Md. Acad. Sci., 1888, pp. 22, 23.

feet thick, holding an abundance of Miocene shells, *Perna maxillata* and *Ostrea percrassa.* At a short distance above Coles Creek, Miocene blue sandy clay appears.

Miocene beds very similar to these have been noted by Conrad at some distance away from the river, but which can be most conveniently discussed in this section. At Huntington[1] in the northern part of Calvert County, about 4 miles east of the river, he found *Perna maxillata* at the bottom of the race-way excavation, in a quartose sand, above which rests a "blue marl, with shells similar to the group at Captain Hance's. Three miles from here, at the bottom of a ravine, great numbers of *Perna maxillata* and *Discina lugubris* are imbedded in a lead-colored clay. At Charlotte Hall,[2] between the Patuxent and Potomac, Mr. Conrad found *Perna maxillata* at the bottom of a ravine, in a matrix of sand, above which rested a 30-foot bed of "diluvial."[3]

Returning again to the Patuxent river,[4] at a point not far from Benedict where the cliffs are very high, their upper portions are formed of an arenaceous fossiliferous bed some 15 or 20 feet in thickness; beneath this, as is known from observations farther down the river, are *Perna maxillata* beds. Two or three miles farther down the river the arenaceous bed becomes thinner, is filled with *Scutella alberti*, is overlain by a thin bed of *Ostrea virginica*, and beneath it, to the water's edge, is a bed replete with *Perna maxillata.* Six miles farther to the south ("at the landing of Dr. Gilliams") the *Scutella* rock reaches the water's surface. At a distance some 12 miles from Benedict a range of cliffs begins that continues to the mouths of the Cuckold and St. Leonard's creeks. Near the base of the bank, at the mouth of the last-mentioned creek, a rock appears which resembles in its lithologic character the *Scutella* rock before mentioned, and is characterized as follows: "This rock has originally been a stratum of coarse sand, full of fragments of *Balanus proteus*, mixed with many whole specimens of the same, and of *Pecten madisonius*, which abounds on the upper surface." Much of the sand has been washed out, and the remainder of the stratum has become cemented by carbonate of lime and oxide of iron. It is a very porous rock, with an exceedingly craggy or irregular surface.

Resting upon this is a stratum of fine, siliceous sand, cemented by carbonate of lime, in which are imbedded innumerable casts of *Perna maxillata*, with many *Pholas ovalis.* At the mouth of Cuckold Creek, on the opposite side of the river, these fossiliferous beds appear at the water's edge, but on account of the southeastern dip they soon disappear beneath stratigraphically higher deposits. To the northward they extend along the range of cliffs referred to above.

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[1] 2d Bull. Proc. Nat. Inst., 1841, p. 183.

[2] Jour. Acad. Nat. Sci. Phila. 1st series, 1830, vol. 6, p. 212.

[3] In Cope's article "Vertebrate Fauna of the Miocene period," etc., Proc. Acad. Nat. Sci. Phila., for 1867, pp. 138, 139, a list of about 50 species of molluscan forms is given from near J. T. Thomas's residence, not far from the Patuxent River; Charles County, Md., Conrad's identifications.

[4] 2d Bull. Proc. Nat. Inst., 1841, p. 183–184.

For some distance toward "Point Patience," from St. Leonard's Creek, the Balanus rock appears along the shore. When last seen it rises to a height of 6 feet above the water, overlain by a stratum of friable sand 4 feet thick; then follows a bed of gravel a foot thick with an occasional pebble, and the highest stratum consists of a clay without fossils 7 feet thick.

Section along the Potomac River.—A short distance above the mouth of Port Tobacco Creek the Eocene deposits grade upward into drab clayey sands. Near Ludlows Ferry this sand is overlaid by diatomaceous earth as on the Patuxent. That the Miocene series extends along the banks of the Potomac from this point to St. Marys river can not well be doubted, but unfortunately this region has never been examined by a geologist.

In the right bank of St. Marys River, near the water's edge, innumerable fossils are exposed. Here it is that Conrad and others have made extensive collections. According to Conrad the stratigraphy of this bank near the mouth of the river is as follows:[1]

Section on St. Mary's River, Maryland.

Feet.	Character of strata.
10	Mixed sand clay, without fossils.
2	Sand and clay, with the same shells as below.
5	Lead-colored clay with, 3, group of shells as given in the lists, 2, veins of *Turritella plebeia*, 1, *Panopæa*.

From the fragmentary, comminuted state of the shells and from the occurrence of separated valves, Mr. Conrad concludes that this deposition was made near enough to the sea beach "to be influenced by the currents along the shore, or perhaps by the undercurrent of the surf, during the prevalence of violent tempests."[2] Some of the large univalves are most common in the arenaceous stratum, but none are limited to it. The eastern bank of the river presents a cliff of nearly the same elevation, 15 or 20 feet. The clay rises about 3 feet above tide, containing the same group of shells which prevails on the opposite shore. Near the southern end of the cliff the fossils disappear, having been converted into masses of selenite, many of which are 12 inches in diameter, and which are profusely imbedded in the clay near the level of the beach.

The predicament in which Conrad leaves the stratigraphy of the Miocene beds of this state is very remarkable. From his study of the Chesapeake section he is led to conclude[3] that the beds in the northern

[1] 2d Bull. Proc. Nat. Inst., 1841, p. 185.
[2] Ibid., p. 186.
[3] Ibid., p. 176.

part of the section are contemporaneous with those of the southern, that, in fact, they extend horizontally along the coast line. Strongly contrasted with these statements are those referring to the stratigraphy of the Patuxent River section. In several places he refers to the dip along this river carrying beds beneath those of higher formations to the south and causing them to rise toward the north.[1] The following diagram is a graphical representation of the ideas conveyed in his text.

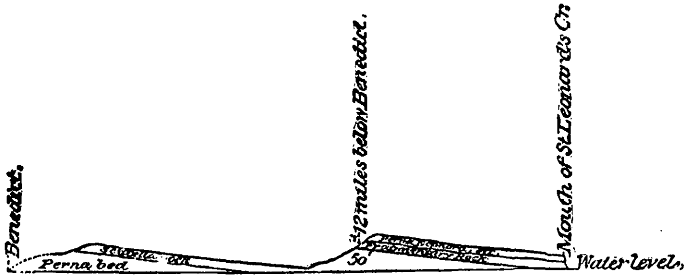

FIG. 7.—Section along the Patuxent, after Conrad.

Chesapeake group.—Heilprin has endeavored to show, chiefly by paleontological evidence, that there are two well defined divisions in the Miocene formation of this state, as well as in others to the south.

That the fossiliferous beds exposed in the northern part of the Miocene area of the peninsula are stratigraphically lower, and hence older than those of the southern part, is probably true. One would accordingly expect to find a larger number of recent species in the southern beds than in the northern ones; this Heilprin has shown to be the case. But there is no evidence characterizing two or any other particular number of subdivisions. It is for the present better to regard them as a continuous series of beds, in which some species keep dropping out and new ones appearing, instead of two distinct groups of deposits. The finding at St. Leonards Creek in the same bed of what have been regarded as fossils typical of the lower and upper beds respectively[2] goes far toward proving a continuity of deposition in the Miocene as represented in this state from the base to the uppermost deposits. For this series of beds the name of Chesapeake formation has been proposed by Darton.[3]

[1] 2d Bull. Proc. Inst., 1841, p. 184.

[2] W. B. Clark: The Johns Hopkins Univ. Circ. No. 65, 1888, p. 3; and T. A. Conrad: 2d Bull. Proc. Nat. Inst., 1841, p. 184. Recent collectors have found *Perna maxillata* and some other species to be by no means confined to or characteristic solely of the older beds. See also discussion of the Chesapeake group under "Florida" of this essay. Darton is of the same opinion.

[3] For a discussion of the nomenclature of this series see under "Chesapeake group" in the section devoted to Florida.

Cf. Darton, Bull. Geol. Soc. Am., vol. 2, pp. 431-450. This publication was issued after the present work was practically complete. Mr. Darton has found the Chesapeake formation to be much more extensively developed in some parts of Maryland than earlier writers had supposed.

POST-MIOCENE DEPOSITS.[1]

From observations made on the Chesapeake and Potomac, Conrad concludes that the upper Tertiary borders the lower part of the peninsula from near the mouth of Town Creek, on the Patuxent, to a point on the Potomac about half way between St. Marys River and Brittains Bay.

The most common fossils of this formation[2] are *Ostrea virginica, Mytilus hamatus, Pholas costata,* and *Arca transversa.* Some of the species retain their colors and nearly all are known to exist in a living state. Heilprin does not state his reasons for regarding this formation as belonging to the Pliocene epoch, but he probably relies on the presence of a few supposed extinct species.[3] McGee seems to regard it as synchronous with the beds of Delaware, containing several recent species, which Chester, tracing them inland, found to be continuous with the Delaware gravel.

VIRGINIA.

For our knowledge of the Neocene beds of this State we are mainly indebted to the labors of W. B. Rogers and T. A. Conrad. The latter described or identified molluscan forms from nearly all the more important exposures, while the former by a series of investigations, extending from 1834 to 1841, examined and described in detail the stratigraphy and lithology of this as well as other formations in the State. The work of Rogers[4] will therefore form the basis of this brief discussion, though the material has been rearranged and, in some instances, slightly modified for the sake of clearness, and to bring it into harmony with the results and methods of more recent investigations.

The final disappearance of the Eocene formation with its gentle dip eastward may be roughly defined as on a line extending in a southerly direction from Mathias Point on the Potomac, past City Point on the James, to the North Carolina line. To the east, the state is traversed by numerous large rivers, from whose banks our knowledge of the Tertiary deposits has been chiefly derived. Of these, the four most important are the Potomac, Rappahannock, York, and James. Sections along each of these will now be considered, beginning with the most northern.

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[1] Upper Tertiary formation, Post-Pliocene period, Conrad, 2d Bull. Proc. Nat. Inst., 1842, pp. 187–188. Post-Pliocéne (Pliocene?), Pleiocene, Heilprin, Proc. Phil. Acad. Nat. Sci. for 1880, pp. 21–23.

Columbia formation, McGee, Am. Jour. Sci., 3d Ser., 1888, vol. 35, p. 449.

[2] Jour. Acad. Nat. Sci. Phila., 1st ser., 1830, vol 6, pp. 205 et seq.; also 2d Bull. Proc. Nat. Inst., 1841, pp. 187–188.

[3] This fauna should be reexamined. The congregation of species as identified by Conrad is in general of a type resembling the present or a slightly colder water fauna, but it is remarkable for the presence of *Gnathodon* or *Rangia cuneata* Gray, which is now confined to the brackish estuaries of the Gulf of Mexico.

[4] Most conveniently consulted in the octavo reprint of [his] papers on the Geology of the Virginias, New York, Appleton, 1884, pp. xvi, 832, with many maps and illustrations.

RIVER SECTIONS.

Section along the southern bank of the Potomac.—As before stated, the Eocene beds disappear beneath the waters of this river not far from Mathias Point, but their contact with the beds known to be of Miocene age is nowhere shown. The reddish and yellowish clays incumbent on the Eocene just above the point disappear just below it, and the "shore becomes low and retiring."

We are left, by the statement of Rogers,[1] somewhat in doubt as to the exact distance down the river from Mathias Point to the first appearance of the Miocene, but it is certain that beds of this age do appear four miles above the mouth of Chantilly Creek, Westmoreland County.[2]

A bluish sandy stratum 5 feet in thickness here appears in the face of Stratford cliff at an elevation of about 50 or 60 feet above tide. This is filled with numerous and well preserved specimens of *Perna maxillata* (small size), *Turritella plebeia*, *Mactra modicella*, *Arca idonea*, and other large shells. This bed dips gradually to the east and at a distance of a mile and a half below its first appearance it is but 15 feet above the river. Nearer the mouth of Chantilly Creek[3] the fossils exist only as impressions in a blue sandy clay matrix that occupies the base of the bluff to a height of from 50 to 70 feet. The species here noted were *Pecten madisonius*, *Venus mercenaria*, *V. cortinaria*, and *Mactra modicella.*

Chantilly cliffs, situated below the mouth of the creek of the same name, form, according to Rogers,[4] a continuation of the Stratford cliffs just described. The fossiliferous stratum rises from the water's edge to a height of 25 feet. It contains few Pernas, but Mactras and Pectens are abundant.

Still farther down the river, at Cole's Point, on the south side of the mouth of the Lower Machodoc, a low bluff appears "which is prolonged for about 1½ miles down the river at a pretty uniform elevation of 14 feet. A few paces below the point the following strata occur:

1. A layer 2 feet thick, consisting of a bright yellow mixture of sand and clay, abounding in shells of various kinds, among which are *Perna maxillata*, *Ostrea compressirostra* [as identified by Rogers], *Venus mercenaria*, *V. Cortinaria*, *V. paphia*, *Isocardia fraterna*, *Pecten madisonius*, *P. jeffersonius*, *Pectunculus pulvinatus*, *Corbula inequale*, and *Turritella variabilis*.

2. Next a layer 6 feet thick, composed of mottled ferruginous sand with a small admixture of clay, containing no shells, but abundant markings, as if shells had once been present in great numbers.

3. A band of iron sandstone 3 inches thick, and

4. A dark mold, extending to the top.

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[1] Geology of the Virginias, p. 422, 1884.

[2] Ibid., p. 428.

[3] Dr. Leidy mentions the occurrence of *Balæna prisca* and *Crocodilus antiquus* with *Pecten jeffersonius* in Westmoreland County, Virginia, Proc. Acad. Nat. Sci. Phila., vol. 5, p. 308.

[4] Geology of the Virginias, 1884, p. 429.

In proceeding down the Potomac the yellow marl is seen gradually rising higher in the bank. A stratum of blue marl lying beneath it next comes in view, and this continues along the base of the bank extending some distance out upon the beach, until the shore sinks into a low sandy flat at Ragged Point.[1]

By this it would seem that the general southeasterly dip is here reversed, at least for a short distance. Similar reversions will be frequently referred to in connection with the sections along the rivers farther to the south.

Farther to the southeast, in Northumberland County, Miocene fossils occur in the banks of Hull Creek about 2 miles above its mouth. The lowest stratum here exposed consists of a ledge of ferruginous rock, containing immense numbers of *Perna maxillata*, with *Venus* and *Pecten*, firmly cemented together. The bed is 2 feet thick. Above it rises a stratum of yellowish sandy clay of the same thickness, abounding in *Perna maxillata* in a very friable condition. Incumbent on this is a 10-foot bed of light blue marbled clay, capped by course diluvium.

From the foregoing detailed description of what is recorded of the various Miocene exposures along or near the southern bank of the Potomac it may be seen that the stratigraphy of the section is as yet almost wholly unknown.

Section along the Rappahannock River.—The Eocene strata finally disappear beneath the level of this river[2] not far from the mouth of Chincoteague Creek. The bluffs, such as border the river in this vicinity, give place to low sandy shores farther down the river, as did those on the Potomac at Mathias Point. No Miocene outcrop has been definitely mentioned above Belmont, Lancaster County. Here the cliffs are made up of heavy beds of clay and sand, overlain by the ordinary diluvium and resting upon a stratum of soft ferruginous sandstone. No fossils are mentioned up to a distance of 1½ miles below this place. Here a rocky layer is met consisting entirely of shells, converted into brown oxide of iron, situated at the base of the cliff. This continues in the same direction for a distance of 1¼ miles. The following is the order of the strata composing the bank at a point near its eastern termination:

1. Six feet of diluvium.
2. Five feet of sand.
3. Ferruginated shelly rock, 4 feet thick, with the same shells as in No. 4.
4. Blue marl, containing numerous *Venus*, *Natica*, and *Oliva*, extending beneath the base of the bluff into the water.

Below this, and within a short distance of Curratoman River, marl beds occur below the level of the flats, consisting chiefly of a peculiar elongated variety of *Ostrea virginica*.

Below the mouth of the above-mentioned river may be seen, extending from half a mile to 1 mile above Cherry Point, a cliff which consists of the following strata:

1. Ten feet of diluvium.
2. Ferruginous sandstone.

[1] Geology of the Virginias, p. 430.
[2] Rogers: Geology of the Virginias, p. 422.

3. A bed of partially decomposed *Serpula*, containing few other fossils, 1 foot thick.
4. Chocolate colored clay, with vast numbers of the *O. virginica* referred to above, 3 feet thick.
5. Blue clay marl, extending from beneath water level to a height of 3 feet.

Miocene marl, clay, and shelly rock continue at intervals from here to Mosquito Point, below which the shores become flat and sandy. Here, as well as on the Potomac, there is a slight syncline, causing a reversal of the direction of the dip near the most eastern exposures of the two sections. The finding of marl with characteristic Miocene fossils near Kilmarnock indicates[1] "the prolongation of the Miocene strata to the very extremity of the peninsula." Finally, it must be admitted here, as in the case of the section along the Potomac, that the stratigraphic relations of the various beds exposed are as yet wholly unknown.

Section along the York River and its tributaries.—Though there may be a few Miocene outcrops along the Mattapony, the northern fork of the York River, none seem to have been recorded by Rogers in any of his various publications. But on the Pamunkey, the southern fork of the York River, numerous sections have been made in the vicinity of and above Piping Tree[2] that show the Eocene beds overlaid by those of Miocene.

At the place just referred to the strata taken in a descending order as follows:

		Ft.	In.
Miocene.—	1. White friable sandy clay, containing fossil impressions	10	0
	2. White sandy marl with broken shells		6
	3. Ferruginous stratum, abounding in casts, and occasionally containing the shells themselves		6
	4. Thin band of black pebbles		
Eocene. —	5. Dark greensand stratum, no shells	4	0
	6. Rocky shell of cemented shells of *Ostrea sellæformis*		6
	7. Dark greensand stratum, with small shells	2	0
Total		17	6

The precise point at which the Eocene finally disappears "occurs at Northbury,[3] and directly opposite at the plantation of Dr. Charles Baxton."

From this point bayward no references of any importance are made to Miocene beds until a point is reached about 6 miles above Yorktown, termed by Rogers[4] "Jones's Plantation." At this place the shelly stratum similar to those nearer Yorktown is overlain by a thin and interrupted layer of a siliceous rocky mass, "approaching in its porous character and harsh, gritty texture to the nature of the buhrstone of France. Associated with this is a more compact rock, containing some carbonate of lime, with much silex, and exhibiting very perfect casts

[1] Rogers: Geol. of the Virginias, p. 433.
[2] Geol. of the Virginias, p. 53.
[3] Ibid., p. 51.
[4] Geology of the Virginias, p. 38.

and impressions of *Pecten*, *Cardium*, etc. Over these strata is the usual layer of ironstone, and the general aspect of the upper bed is somewhat ferruginous."

From Kings Creek to Wormleys, numerous Miocene beds are exposed in the banks of the river. These were examined in a cursory manner by Rogers and described in his first annual report of 1835.[2] More recent investigations by G. D. Harris, of the U. S. Geological Survey, have shown that the stratigraphy is by no means so simple as Rogers's description would imply, but that there are numerous local anticlines and synclines together with lines of uncomformability. Following, then, our more recent investigations, these various beds may be described as follows: Between Kings and Filgates creeks a bluff rising to the height of from 15 to 30 feet may be seen extending along near the margin of the river. The lower portion, to an altitude of from 10 to 20 feet, is composed of a grayish sandy marl, literally packed with large bivalve shells, of which those in the lower part are mostly *Pecten jeffersonius*, while above, *Venus tridacnoides*, *Venus rileyi*, *Ostrea disparilis*, *Pectunculus subovatus*, and *Dosinia acetabulum* prevail. Here, too, various forms of *Crepidula* as well as *Fissurella* are abundant; *Striarca centenaria* is occasionally met with. Below Filgates Creek, and extending over a mile toward Yorktown, is the famous Bellefield Cliff, from which great numbers of fossils have been obtained. Its lower portion is mainly composed of gray fossiliferous marl, save in one instance where a local syncline carries the marly portion beneath tide level, and the incumbent (Columbia?) clay bed alone forms the bluff. The other irregularities of the upper surface of the Miocene seem to be due to two causes, viz, erosion and disintegration. The effect of the first is plainly seen at the southern extremity of the bluff, near the mouth of Indianfield Creek. Here the marl bed slants abruptly beneath tide level, and is overlain by loamy sand. Nothing in the lamination of the marl indicates that this incline of the marl bed is due to dip; and, from the wholly different character of the incumbent material, it is evident that the marl suffered extensive erosion before the latter was deposited upon it. The effects of the second cause of irregularity, i. e., disintegration, are plainly marked by sinks wherever the marl owes its rigidity to calcium carbonate, and is overlain by no impervious layers. They are formed in somewhat the following manner: Surface water that possesses slightly acid properties percolates through the overlying sand till it reaches the bed of marl. Its calcium carbonate is attacked and dissolved. The water thus charged passes into subterranean veins and is at length discharged into the river. The rigidity and part of the component material of the marl being removed, it gradually sinks down in the particular locality thus acted upon till finally great holes or channels are formed in the marl, filled, of course, with the residuum of disintegration and the overlying sands.

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[1] Geology of the Virginias, p. 37, 38.

The sides of the cavities are often very irregular, sometimes perpendicular, and sometimes even overhanging.

The diagram below (Fig. 8) shows the general features here mentioned. That these cavities were not produced by the denuding action of water upon the surface of the marl before the overlying sands were deposited (as suggested by Rogers)[1] is proved beyond all doubt, considering the comparative softness of the marl; by (1) the perpendicularity or even overhang of the walls; (2) their great depth (being in some instances at least 10 feet); and (3) the material with which they are filled. This is evidently a marly product, from its color and ingredients,[2] though the fossils it once contained are wholly obliterated.

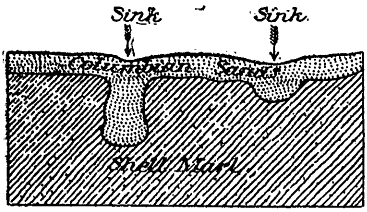

Fig. 8.—Diagram showing cavities in Shell marl filled with sand, near Yorktown, Va.

Marked examples of irregularities thus formed can be seen in the Bellefield cliff west of the bed of blue clay, as well as in the bluff already described that extends from Filgates to Kings Creek.

At the western extremity of the Bellefield cliff "the marl" rises to a height of at least 17 feet, and forms nearly the whole perpendicular height of the bluff. It is here a gray sand full of fairly well preserved fossils. These are essentially the same as those mentioned above, with a greater abundance of *Dentalium*, *Murex*, *Natica*, and numerous smaller forms. The great abundance of huge *Pectens*, extending along the base of the cliff for perhaps one-eighth of a mile, is one of its most pronounced features. Just west of the local syncline before mentioned a marked change takes place in the appearance of the marl. The shells are often finely comminuted and cemented together by calcium carbonate. Though large *Pectens* are very abundant at the base of the cliff, they do not occupy it to the exclusion of all other forms as they do farther west. In this cemented fragmentary rock, a few specimens of *Perna maxillata* were found.

All along in this portion of the Bellefield cliff the lamination of the marl is very oblique. To this structure Rogers refers in his report for 1835,[3] likening it to "appearances described by Lyell and others as existing in the Crag of England." The angle of lamination varies, sometimes amounting to 30° but generally not over 20°, and sometimes closely approaching zero; the direction is approximately east.

The Miocene, as exposed in this cliff to the east of the local syncline, contains fewer fossils than do the more western beds just described; it consists of a yellowish sandy marl, without the peculiar, regular, and well defined oblique lamination. It contains numerous remains of Cetaceans.

[1] Geology of the Virginias, 1884, p. 32.
[2] Ibid., p. 31.
[3] Ibid., p. 35, 39.

The same marly bed appears in the right-hand bank of Indianfield Creek at its mouth, though it is here but 5 feet above the water level and soon passes entirely below it. It reappears in low cliffs toward Berrys Landing, but contains few well preserved fossils.

Judging from the steep westerly dip in the strata well exposed in a bluff about 200 yards below Berrys Landing, it is probable that the marl we have been describing is at this place wholly or mostly absent, and that the strata exposed here represent a lower horizon. The fauna is widely different, though containing many of the larger forms already mentioned; the abundance of *Astarte symmetrica*, *A. concentrica*, *A. abbreviata? Lucina crenulata*, *Gouldia lunulata*, etc., is here quite noticeable. *Diplodonta acclinis*, too, puts in an appearance at this place. In a second bluff, about one-half mile below Berrys Landing, the same beds are exposed, though higher up in the bluff, owing to the western dip. They are at least 15 feet thick, and as they appear in cliffs nearer Yorktown they rise higher and higher and become fragmentary and consolidated into a rock of considerable hardness.

In the extensive cliff that stretches along the shore from about a mile above Yorktown, the beds just mentioned can be seen for but a short distance at the western extremity. The fossils soon disappear and the sands become mingled with those of the Columbia formation above. Below it, at this place, however, there is a bed of gray marly matter 14 feet thick, containing few fossils. Still below this, and reaching to the water's edge, is a stratum of blue marl whose upper portion is often stained brownish by iron oxide. In its upper portions *Dosinia acetabulum* and *Panopæa reflexa* are fairly abundant, but are very tender and fragile; below, in the more purely blue portions, *Yoldia limatula*, *Cytherea sayana*, *Pandora crassidens*, *Mactra delumbis Solen*, *Tellina*, *Scaphilla*, *Dentalium*, *Cadulus*, etc., are very common, but owing to the softness of the shelly material, a perfect specimen can rarely be found. Near the Yorktown end of this cliff these fossils are replaced by *Crepidula*, *Pecten*, *Venus*, etc., and the marl becomes more arenaceous and of a yellowish gray color. Beneath it, at the eastern extremity, about half a mile above Yorktown, another fragmentary bed appears containing *Pecten jeffersonius* and other large bivalves. This is the top of a series of fragmentary rocks which appear in bluffs to a point at least 1 mile below Yorktown. The fragmentary structure is a more or less variable and local feature, being developed, as a rule, more commonly near the lower portion of the cliffs. The fossils in this series include nearly all that have been mentioned as occurring in the beds between Yorktown and Kings Creek, except, perhaps, those characteristic of the blue clay or *Yoldia limatula* bed. About one-half mile above Temple Place this fragmentary series is underlain by a stratum of blue clay marl, very similar in character to the *Yoldia limatula* bed. Its thickness is not far from 5 feet on an average; its color becomes brownish upon long exposure. Just above Temple Place the base of this bed may be seen, appearing in detached patches along the top of the marl and just beneath the Columbia sands. It is here about 25 feet above tide, thus giving a westerly dip of about 25 feet in one-half mile. The fragmentary series in the meantime disappears, its various members, having been brought up to a height of 25 or 30 feet by this westerly dip, have all been planed down to this height by pre-Columbia erosion. Immediately under the 5-foot stratum of blue clay appears a stratum 10 to 15 feet thick, literally packed with *Crepidula.* Inasmuch as this genus is so abundantly represented throughout the whole of the upper portion of the Miocene, this bed is most easily identified by *Striarca centenaria,* which it contains in great abundance. The usual representatives of *Ostrœ*, *Venus*, *Pectunculus*, *Pecten*, *Fulgur*, etc., are fairly abundant. Owing to the westerly dip its lowest layers are brought up to the Columbia sand a short distance below Temple Place. The superior hardness of this rock to the one below is very manifest just above Temple Place, where it protrudes beyond or overhangs the underlying bed. This last, though mostly hidden, appears to extend perhaps a quarter of a mile below Temple Place, is probably 12 feet thick, and contains few well preserved shells. The bed just beneath this is slightly more argillaceous and contains *Turritella alticosta* in great abundance. When the Miocene finally disappears, about half a mile below Temple Place, it presents the section described by Rogers[1] as at Wormleys Creek, though its component parts are by no means so separate and distinct as one might imagine from his description. The marl bank is here only about 8 feet high. Farther to the east it is absent, the bluffs being formed wholly of Columbia sands.

Section along the James River.—The Eocene finally disappears beneath stratigraphically higher formations three-quarters of a mile below the mouth of Powells Creek, but the Miocene extends back, in detached areas, over the Eocene for some distance west of this point, and even appears in and about Richmond. Near that city Rogers first discovered the existence of an "infusorial stratum" in Virginia.[2] Its relations to the adjoining Eocene and Miocene beds are typically presented in the principal ravine on the west side of the valley of Shockoe Creek.[3]

	Feet.
1. Sandy stratum of mottled gray and yellowish brown clay, vegetable impressions and prints of *Pecten.s* .... MIOCENE..	14
2. Greenish brown and lead colored less sandy clays, with vegetable impressions .... MIOCENE..	6
3. INFUSORIAL STRATUM	20
4. Lead colored heavy clay of a greenish tinge	3
5. Brownish black, containing a few prints of fossils and a large amount of carbonized vegetable matter, to which the color of the stratum is owing	5

[1] Geolo gy of the Virginias, 1884, p. 37.

[2] *Procamelus virginiensis* Leidy, was found in this vicinity. It is described by Leidy, vol. 1, U. S. Geol. Survey Terr., 1873, p. 259, Am. Nat., 1886, vol. 20, p. 621.

Regarding this species Dr. Leidy informs us that he has modified his original opinion that it belongs to *Procamelus* and now thinks it "more nearly related to the living *Auchenia*" (Nov., 1890). Its stratigraphic position can hardly be regarded as definitely ascertained.

[3] Geology of the Virginias, 1884, p. 453.

		Feet.
6. Lighter colored bed, with yellowish blotches, and streaks, very friable even when moist, being more sandy than the succeeding. A few impressions	EOCENE..	8
7. Dark olive and bluish stratum, tenacious while moist but becoming mealy and of a grayish tint when dry, and in that condition showing an efflorescence of gypsum upon the surface. Impressions of *Cardita*, etc	EOCENE..	4
8. Felspathic sandstone, Upper Cretaceous		4

Rogers includes the infusorial deposit in the Miocene Tertiary. It rests either upon or but little above the top of the Eocene, [1] is composed largely of diatoms, and contains occasional casts of Miocene shells.

From Richmond down the James River for some distance Miocene beds are occasionally seen lying upon the Eocene. After the latter dips beneath tide level, the banks of the river present no point of particular interest until the vicinity of Williamsburg is reached. The cliff at Kings Mills is abrupt and has a height varying from 20 to 45 feet above the water. The strata of shells extend along the river with slight interruptions, when the cliff sinks nearly to the level of the water for a distance of between 2 and 3 miles, and they are found in a somewhat similar order of superposition for some distance inland. Their general direction is horizontal, but the outline of any one is frequently very irregular. This irregular outline is particularly remarkable with the beds of *Chama* which are very thick at some points, and then thin out rapidly and again thicken. A detailed account of the Miocene and Quaternary beds at King's Mills will be found on p. 36 of the Geology of the Virginias.

At Days Point, the most eastern exposure of marl immediately on the southern bank of the James River, at a short distance above the mouth of Pagan Creek, the shelly stratum that first emerges from the beach, consisting of the overlying bed of ferruginous marl, is seen gradually rising to a higher level as we ascend the river. A quarter of a mile above, and in a direction northwest from the point at which the marl first came in view, we see the blue stratum beginning to show itself beneath the other, and soon, with a gentle slope rising to the height of several feet above the base of the river bank.[2]

Here, as in the various exposures on Pagan and Nansemond rivers, the yellow ferruginous upper marl layer is often fragmentary and cemented together at the top.

The only remaining point of interest to be considered in connection with this section is one on the north bank at the mouth of the river, namely, Fortress Monroe. Here an artesian well was sunk to the depth of 907 feet, penetrating Miocene, Eocene, and Cretaceous strata. The infusorial stratum was encountered at a depth of 558 feet below the parade ground, and the base of the Miocene Rogers considered to be between the depths 577 and 583 feet. The importance of these determinations will be discussed elsewhere.

Cenozoic district south of James River.—But little detailed descrip-

[1] Notes from Macfarlane's Geological Railway Guide, 1879. Reprint in Geology of the Virginias, 1884, p. 725.

[2] Geology of the Virginias, 1884, p. 258.

tion is given by Rogers of this district. The line of contact between the Tertiary and older rocks passes in a general way, meridionally south from Richmond. But in its course it presents most complex sinuosities.

Indeed, islands and peninsulas of the sandstone (secondary) are met with some distance eastward of the general boundary, while inlets of the Tertiary strata are seen penetrating beyond it to the west. Thus on a branch of the Appomattox just above the fork near Broadway, on a meridian several miles to the east of that of Petersburg these layers of coarse and fine sandstones and conglomerates are seen lying horizontally, one upon the other, forming a cliff about 50 feet in height, while in the vicinity of Petersburg the greenish sandy strata of the Eocene are found.[1]

South of this place "no unequivocal indications of the continuation of this lower member of the Tertiary series can be found."[2] The Miocene and later formations therefore abut directly upon the primary rocks to the west.

High up along the Nansemond River, and along the Blackwater, Nottoway, and Meherrin, as well as their branches, a striking constancy is remarked in the position of that portion of the series of marl deposits called the blue marl, the lowest of the series as exposed in this and other parts of the area occupied by the Miocene Tertiary of the State. * * * This stratum may be seen skirting the water line in a slightly undulating band and rarely rising to the height of many feet above the stream. In the southern portion of the tract this feature is most uniformly displayed, while near the James River a decided rise of the strata may be seen as we trace them westward. * * * The general parallelism thus maintained between the plane of the marl and that of the rivers throughout most parts of the southern tract distinctly indicates a gentle declination of the marl in a southerly direction or that in which the Blackwater, Nottoway, and Meherrin flow, and indeed it might with some reason be maintained that the sloping of these beds in that direction, as well as the comparatively unyielding nature of the tenacious clays of which they are principally made up, have exerted an important agency in determining the drainage in that direction, as well as preventing the streams from forming a deeper channel than is furnished a few feet below the upper surface of these beds.[3]

In Norfolk and Princess Anne counties diligent inquiry, aided by shallow borings at several places, has been made along the canal and feeder and at other points within the Dismal Swamp, but no unequivocal deposit of marl has yet been found excepting in the vicinity of the Great Bridge in Norfolk County and 4½ miles northeast of Suffolk near the western margin of the swamp. Of these the latter consists of blue marl, identical in character with the upper portion of that formation west. The former was of more ambiguous character, and owing to the small number ot species obtained, its exact horizon in the Miocene could not be determined.[4] However, in 1889, Prof. Shaler obtained a small collection of fossils in the northern part of the Dismal Swamp, immediately below the vegetable soil, containing 29 species of which 24 are known in the recent state and, of the others, one is known only from the Caloosa-

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[1] Geol. of the Virginias, 1884, p. 261.
[2] Ibid., p. 262.
[3] Ibid., p. 256.
[4] Ibid., p. 257.

hatchie Pliocene and the 4 remaining extinct forms are common to the Miocene of Maryland and Virginia, and the Pliocene of Florida. This would indicate a position, if not Pliocene, at least very high up in the Miocene system.

GENERAL CONSIDERATIONS.

Rogers's generalized section[1] along the James River, from Primary to Quaternary rocks, is as follows:

A-B. Represents the beds of sand and gravel, usually lying immediately below the soil, which from their oblique position and the general coarseness of the materials, indicate a deposition under the influence of strong currents. This overspreading the region extensively, and evidently due to some general cause, is properly to be regarded as *Diluvium*.

B-C. Horizontal beds of sand and clay, prior to the diluvium and partially and sometimes entirely removed at the time of its deposition.

C-D. Upper portion of the yellow marl—a conglomerate of fragments containing in its lower parts nearly entire but water-worn shells.

D-E. Lower portion of the yellow marl—shells contained in a friable sand, and near the bottom is a tenacious clay; numerous species above, *Mactra modicella* almost exclusively beneath.

E-F. Upper blue marl—a blue clay of fine texture; rich in *Mactra modicella;* shells becoming more varied as we descend.

F-G. Lower blue marl—a more sandy material, abounding both in number and variety of its shells.

G. Thin band of pebbles, separating the Miocene from the Eocene Tertiary.

G-H. Eocene on the James River—clays and sands usually of a grayish tinge, containing shells and their impressions, often presenting a considerable proportion of green sand and some gypsum.

H-I. Sandstone formation—deeply channeled above, before the deposition of the Eocene.

I-K. Granite and other Primary rocks, upon which the sandstone rests.

There seem to be two discrepancies in Rogers's views of the stratigraphy of the Miocene: first, the supposition that these strata everywhere preserve such horizontality as is stated by this author is opposed by the finding of the infusorial stratum which crops out at the surface near Richmond, at a depth of 558 feet below the surface at Fortress Monroe; second, not all the blue marl exposed at the base of the bluffs along the principal rivers can be considered as belonging to a lower bed in the Miocene formation. These beds of a bluish clayey marl are frequently interpolated in grayish and yellowish marl beds, as has recently been proved in the case of those exposed about Yorktown. Again, the borings from the Fortress Monroe well do not show the Upper Miocene as consisting of yellow marl and the lower of blue marl.

That the blue marl nearly always appears at the base of the bluffs instead of higher up is due to the fact that when the dip brings the stratum up from the lower part of the bluff it is so weathered and oxidized that it loses its characteristic blue tinge and is not readily dis-

[1] Geology of the Virginias, 1884, p. 264.

tinguished from the ordinary yellow marls, except by careful examination of its dips and fossils.

It is probable that nearly the whole of the Miocene of the state when better known will prove to belong to the beds of the Chesapeake group.

PLIOCENE ROCKS.

The uppermost Miocene or lower Pliocene fossils found by Shaler in the marl of the great Dismal Swamp have been already referred to, (p. 64), and, if Pliocene, appear to form the first recognized fauna of that age in the state. But if the conclusions of McGee be correct, this horizon is well represented by a perezonal formation, that first makes its appearance on Potomac Creek and expands rapidly toward the south. Its distinctive characteristics, geographical distribution, and probable age will appear from the appended quotations, from the description given by McGee,[1] who applied to it the name (since replaced by the term Lafayette) of the Appomattox formation.

THE LAFAYETTE FORMATION.

Character and distribution.—Near the summits of the bluffs overlooking the Rappahannock River from the southward a mile or two west of Fredericksburg, a distinctive, stratified, orange-colored, sandy clay is found reposing upon Potomac sandstone, from which it is readily distinguishable by its greater homogeneity, the more complete intermingling of its arenaceous and argillaceous materials, its more regular stratification, and its more uniform and predominantly orange color. It is as readily distinguishable from the Columbia deposits, on the other hand, by its vertical homogeneity, its comparatively regular stratification, its distinctive color, and its greater range of altitude, extending, as it does, from tide-level to the highest eminences of the Piedmont escarpment between the Rappahannock and Roanoke. At Fredericksburg the deposit is commonly thin and confined to limited isolated areas, especially at the higher levels, and it appears at but a single locality (Potomac Creek) north of the immediate valley of the Rappahannock; but it rapidly increases in thickness and continuity to the southward. About the confluence of the Ny, Po, and Ta Rivers it forms the surface over a meridional zone fully 10 miles wide. It is well exposed in the bluffs of the Tapony, along which it reposes on the fossiliferous Eocene, and in the bluffs of the Mattapony and the Anna rivers, as well as over the intervening divide, it is the prevalent surface formation, maintaining the characteristics exhibited at Fredericksburg, save that it is frequently gravelly. In the vicinity of Richmond it is occasionally exposed toward the summits of the river bluffs, but is there less conspicuous than the subjacent Miocene, Eocene, and Potomac deposits, while still farther southward it continues to thicken and expand.

The distinctive orange-colored sand and clays of the formation are typically exposed on and near the Appomattox River from its mouth to some miles west of Petersburg. A mile below Petersburg they are found at tide-level in the river banks. In the eastern part of the city they appear overlying the fossiliferous Miocene beds midheight of the bluff; and at the "Crater," a mile and a half east, in the railway cuttings in the southwestern part, and on the upland, 2 miles west of the city, they occupy the highest eminences. The zone of outcrop here is at least 30 or 40 miles wide. As at Fredericksburg, the deposit is a regularly but obscurely stratified orange-colored clay or sand, sometimes interbedded with gravel or interspersed with pebbles. Perhaps the best exposure is at the "Crater" (a pit formed by the explo-

[1] Am. Jour. Sci., 3d ser., 1888, vol. 35, p. 328.

sion of 8,000 pounds of powder in a mine carried by Federal engineers beneath a Confederate fort July 13, 1864). Here the principal material is a dense, tenaceous clay, orange, gray, pink, reddish, and mottled in color, plastic yet firm when wet, and so hard and tough when dry that medallions stamped from it as souvenirs are as durable as rock; indeed, the well known strategic measure to which the "Crater" is due was rendered successful by the firmness and tenacity of the clay through which the entire mine was excavated save where it barely touched the subjacent fossiliferous glauconitic sands of the Miocene. At Butterfield's bridge, in the southwestern part of Petersburg, the railway cutting exposes some 20 feet of plastic clay (like that found at the "Crater"), pebbly and sandy clay, and cross-laminated clayey sand, all predominantly orange-colored, in alternating beds, and it is noteworthy that here, as at some other points, flakes and lines of white, plastic clay, similar to those of the Potomac arkose, are occasionally included in the formation.

The formation continues to thicken and expand south of the Appomattox River, until it forms the surface everywhere in the vicinity of the fall line, save where it is cut away by erosion or concealed beneath the Columbia deposits. * * *

In the brief inland margin of the Appomattox formation, as exposed north of Roanoke river, is a moderately regularly stratified sand or clay, with occasional intercalations of fine gravel, generally of pronounced orange hue and without fossils; it reaches a thickness of probably 50 to 100 feet and forms the predominant surface formation over a zone 40 or 50 miles wide on the Roanoke, but attenuates and narrows northward, finally disappearing at Potomac Creek, 4 or 5 miles north of Fredericksburg; and although it appears to thicken seaward it soon disappears beneath tide level and newer deposits.

Stratigraphic relations.—At Fredericksburg the formation reposes, sometimes unconformably and again without visible unconformity, upon the lower member of the Potomac, and like relations are frequently exhibited in the vicinity of Richmond and Petersburg; in the bluffs of the Tapony generally, and of the Pamunkey, 2 or 3 miles north of Hanover court-house, it rests unconformably upon fossiliferous Eocene beds; at the "Crater" and at a number of other localities in the vicinity of Petersburg it rests without visible unconformity upon fossiliferous Miocene beds; in the western part of Petersburg it lies directly upon the Piedmont crystallines; 2 miles northeast of Bellefield it can not be clearly demarked from the fossiliferous Miocene. * * *

The formation is overlain only by the alluvium of small streams, æolian sands, etc., on the broad plain between Petersburg and Weldon, by occasional accumulations of wave-washed débris derived from its own mass in the extensive Quaternary terraces prevailing in its area, and by the characteristic clays, sands, and gravels of the Columbia formation in the vicinity of the larger streams.

Taxonomy.[1]—No fossils have thus far been found in the Appomattox formation, except at Meridian [Mississippi], where Johnson has found it to contain well preserved magnolia leaves apparently identical with those of trees now growing in the same vicinity. Its stratigraphic position, unconformably below the Pleistocene and unconformably above the (probably) Miocene Grand Gulf formation, indicates an age corresponding at least roughly with the Pliocene.

The formation represents a considerable part of a more or less vaguely defined series of deposits variously called "Orange sand," "Drift" or "Quaternary," "Southern drift," etc., by many geologists; but since this vaguely defined series included not only the Appomattox, but also the basal gravel beds of the Pleistocene loess, parts at least of the Cretaceous or Jurassic Potomac (Tuscaloosa) formation, and other deposits of various ages, none of the old designations can be retained without material modification in definition. It therefore seems wise to extend the term applied to the formation in the region in which it was first studied and clearly defined.[2]

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[1] Am. Jour. Sci., 3d ser., 1890, vol. 40, p. 33.

[2] See discussion of the nomenclature farther on and also in the list of formations.

NORTH CAROLINA.

In this state, as in Virginia, two entirely distinct classes of deposits have been included in the Tertiary system, viz, the marine and the perezonal. Those of the first class include both Eocene and Miocene beds, and are exposed along river bluffs, in ditches, wells, etc., for a distance sometimes not less than 75 miles inland from the ocean.

MIOCENE ROCKS.

Chesapeake formation.—The Miocene has a much greater horizontal extent than the Eocene, and is thicker, reaching sometimes as much as 20 feet or more and averaging about 5 to 8 feet in thickness. It is less continuous than the Eocene according to Kerr, and often exposed in small and disconnected patches. Yet it is probable that its continuity has really been underestimated, since Clark regards it as forming a tolerably continuous sheet over Eocene and Cretaceous alike. Its distribution is perhaps best ascertained by consulting Kerr's map, prepared to illustrate his report for 1875.

FIG. 9.—Section on Roanoke River, North Carolina.

The Miocene strata, consisting mainly of various colored marls, are generally exposed on the south side of the large rivers and on the north slopes of the divides or swells of land between the rivers. This formation thickens, deepens toward the northern border of the State, the beds being much thicker on the Tar and Roanoke than on the rivers farther south. They are in fact of such thickness here as to conceal both the Eocene, if it exists, and the Cretaceous, with a few local exceptions. The shell beds are rich in fossils, which are often in very perfect preservation.[1]

The principal exposures along a few of the more important rivers will now be considered, beginning with the most northerly.

Chowan River and its tributaries.—At Murfreesboro, on the south side of the Meherrin, there are numerous small gorges, excavated by streams in beds of sand, at whose base a stratum of Miocene marl is distinctly exposed. From these, fossils shells, especially *Ostrea* and *Pecten*, have been washed out in great profusion.[2] Other limited exposures have been noted farther down the same river.[3]

Roanoke River.—A section given by Emmons in his report for 1852,[4]

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[1] Rep. Geol. Survey N. C., by W. C. Kerr, 1875, vol. 1, pp. 149-151.
[2] J. T. Hodge: Am. Jour. Sci., 1st ser., 1841, vol. 41, p. 333.
[3] W. C. Kerr: Rep. Geol. Survey N. C., 1875, vol. 1, frontispiece.
[4] Op. cit., p. 67.

probably from the vicinity of Halifax, is here represented diagrammatically (Fig. 9). The marl beds are probably of Miocene age. Another limited exposure of beds of this age is represented near Palmyra on the map accompanying Kerr's report of 1875.

Tar River.—Beginning in Nash County, 5 or 6 miles above Rocky Mount, we find the shelly marl at intervals as far down as Washington.[1] The marl from a locality 4 or 5 miles above Rocky Mount is more or less consolidated and breaks up into masses. Both the brown or red and blue varieties are here noted, the former of which is a little stronger in calcium carbonate than the latter. "The appearance of granite and syenite at Rocky Mount has produced a series of falls in the Tar River; and sometimes the marl is found resting immediately upon those pyrocrystalline rocks." It is more or less sandy, with its upper portion filled with small shells, while below are large scallops and clams (*Venus tridacnoides*). Upon this rests a stratum of sand and rounded pebbles, which is 10 feet thick.

Marl appears at Tarboro at many points, sometimes on the river banks and sometimes in the banks of creeks. Sections of the marl and its accompanying strata, shown in Figs. 10 and 11, have been compiled by Prof. Emmons.

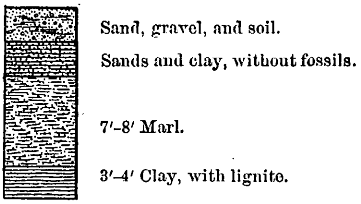

FIG. 10.—Section on Tar River, North Carolina.

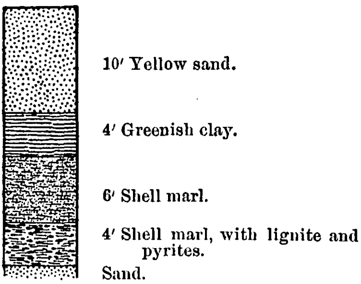

FIG. 11.—Section on Tar River, North Carolina.

The marl is intermixed with coprolites, a few bones, and water-worn pebbles, mostly at the bottom of the bed.[2] There is the same tendency to consolidation as at Rocky Mount, and at other places on the Neuse and Cape Fear rivers. The same shells are found in it comprising large Pectens (*Pecten madisonius*), *Venus tridacnoides*, and two or three species of *Pectunculus*. Marl beds appear in numerous places along the river as far down as Washington, notably at Sparta and in the vicinity of Greenville. In each bluff there is usually but one bed, and it varies somewhat in thickness, though apparently averaging from 7 to 8 feet.[3]

Neuse River.—The principal localities on this river where the Miocene marl is well exposed are about Goldsboro and Newbern; at the former place the bed is from 12 to 15 feet thick, and consists of shells imbedded in a green marly clay. At the latter, beds have frequently been brought

[1] Emmons's Rep. Geol. Survey, N. C., 1852, p. 51.
[2] Ibid., p. 55.
[3] Emmons, Geol. Surv. N. C., 1852, pp. 62–64.

to light by accident in various favorable spots, thus proving a fairly general distribution of the Miocene in this vicinity. In 1858, Emmons[1] published the following diagram (Fig. 12) to show the relations of the shell marl to the white Eocene beds of the Neuse.

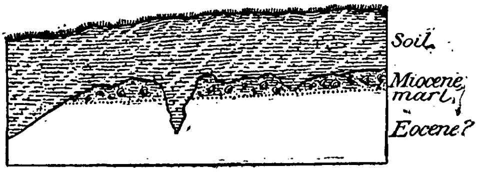

FIG. 12.—Section on Neuse River, North Carolina.

Cape Fear River.—The recent investigations of Prof. W. B. Clark[2] along this stream have thrown some light on the way in which the Neozoic beds of this state have been laid down. The Eocene, according to this author, "occupies wide basins or hollows within the Cretaceous."

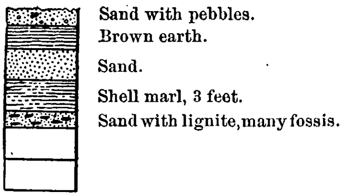

FIG. 13.—Section on Cape Fear River, North Carolina.

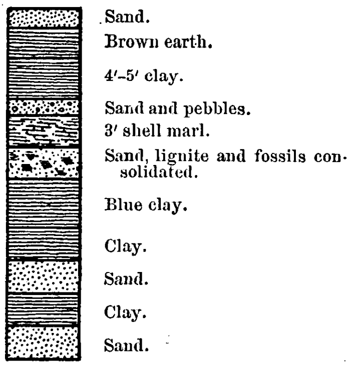

FIG. 15.—Section at Brown's Landing, Cape Fear River, North Carolina.

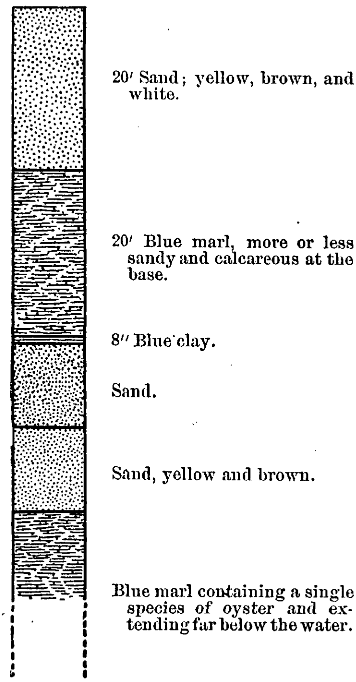

FIG. 14.—Section above Brown's Landing, Cape Fear River, North Carolina.

"Widely extended over Eocene and Cretaceous alike is an incoherent shell marl that may be referred to the Miocene." The rise and decline of the shore line, of a character and extent sufficient to produce this arrangement of deposits, is briefly discussed. He dwells also at some

[1] Rep. Geol. Surv., p. 87.
[2] Bull. Geol. Soc. Am., vol. 1, 1890, p. 537-540.

length on the commingling of the Cretaceous and Eocene faunas near Wilmington, and the occurrence of *Exogyra costata* in Miocene beds, observed by Emmons in 1858,[1] and since confirmed and explained by Stanton in 1891.

Kerr represents,[2] on the geological map accompanying his report for 1875, the Miocene formation as extending along the right flank of this river valley at least 20 miles above Elizabethtown. According to Emmons,[3] "The first [marl] beds which appear upon the river are about 10 miles above Elizabethtown in Bladen County." It here presents three varieties: viz, sandy, argillaceous, and cemented. Just below Elizabethtown, perhaps half a mile, a marl stratum from 2 to 3 feet thick is exposed in the bank on the south side of the river. Fish teeth, coprolites, bones, and rounded pebbles are frequently found at the base of the stratum.[4] The marl with its associated strata are shown in Fig. 13.[5]

"Below Elizabethtown, in Bladen County, the marls continue to be exposed at intervals. One exposure is at Walkers Bluff, 9 miles below Elizabethtown. It is the highest upon the river. It presents a steep escarpment, which consists of different colored sands, with a thick layer of shelly marl."[6] One mile above Browns Landing, or 11 miles above Black Rock, the following beds may be seen:

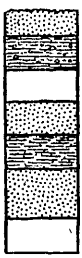

FIG. 16.—Section at Black Rock, Cape Fear River, North Carolina.

"At Brown's Landing, 10 miles above Black Rock, there are numerous distinct beds. In arrangement they belong to two distinct dates: First, the upper, which is Miocene, and the lower, which is probably Eocene."[7] The beds here exhibited are shown in Fig. 15.

Below the shell marl horizon there are at least 60 feet of sand and clay beds considered by Emmons[8] to be of Eocene age, though they may prove to belong to the Miocene.

The shell bed itself contains *Exogyra*, *Belemnites*, and coprolites which were derived from the Cretaceous formation. At Black Rock[9] the beds shown in Fig. 16 occur.

The bed of shell marl represented is, according to Emmons, identical with that at Browns Landing, and here it rests directly upon the Greensand, while there at least 60 feet of sand and clay intervene.

[1] Geol. Surv. N. C., 1858, p. 85. His locality was Browns Landing, Cape Fear River. The mixture is entirely mechanical.

[2] W. C. Kerr: Rep. Geol. Surv. N. C., 1875, frontispiece.

[3] Rep Geol. Surv. N. C., 1852, p. 44.

[4] Ibid, p. 46.

[5] Emmons: Rep. Geol. Surv. N. C., 1858, p. 86.

[6] Emmons: Rep. Geol. Surv. N. C., 1852, p. 47.

[7] Emmons: Rep. 1858, p. 84.

[8] Rep. Geol. Surv. N. C., 1858, p. 85.

[9] Ibid., pp. 81-85.

In the vicinity of Wilmington, Mr. J. T. Hodge made a collection of Miocene fossils, which were identified and published by T. A. Conrad in 1841.[1] Kerr maps a limited Miocene area in this district, but makes no reference to it in his text.

Lyell, in writing of the Eocene limestone, states[2] that "on the shore at the town of Wilmington it is 12 feet thick, covered with a shelly Miocene deposit 6 feet thick."

Mr. Stanton, of the U. S. Geological Survey, also found Miocene beds at this place during a visit made in 1891. They contain the ordinary fossils of the Chesapeake group, like the Yorktown beds of Virginia.

Natural Well, Duplin County.—There is one more Miocene locality in this state that deserves special mention on account of the extensive collection made at that place by Mr. Hodge. This he designates[3] as the "Natural Well," of Duplin County, North Carolina. The sink, so called, is a circular basin, partly filled with water, with steep banks presenting the following section:

Section at Natural Well, Duplin County (after Hodge).

Feet.	Character of strata.
3-4	Soil, loam.
4	Shell marl.
6-8	Tough blue clay.
	Blue sandstone.

The marl consists entirely of shells and fragments of shells, with a small proportion of fine white siliceous sand, more or less discolored by peroxide of iron. The shells are mixed together in great profusion, are soft and friable, and show signs of having been massed together by strong currents. Conrad enumerates about 80 species from this locality.

This locality has recently been visited by Mr. Frank Burns, of the U. S. Geological Survey, who reports the "well" or sink to be situated in the midst of a hard-wood "hammock" covering a few acres. The surrounding country is low and level. The whole seems to be underlain by the shell bed, the commoner Miocene fossils fairly paving the bottom of the small rivulets, ditches, and streams over a radius of several miles. The section at the sink shows 10 feet of reddish sandy clay covering the marl bed, which on the west side of the sink is about 5 feet thick. The sink known as the "Natural Well" is one of several

[1] Am. Jour. Sci., 1st ser., 1841, vol. 41, p. 344.
[2] Geol. Journ., 1845, vol. 1, p. 431.
[3] Am. Jour. Sci., 1st ser., 1841, vol. 41, pp. 335-343.

which are grouped in this vicinity. It appeared to Mr. Burns to be about 200 feet in diameter, circular, and with perpendicular sides rising about 30 feet above the water, which is popularly supposed to be bottomless. On the west side part of the bank has caved in so that, on the bank thus formed, the water can be reached. On the south and east sides of the well the superficial loam diminishes to some 4 or 5 feet in thickness and the marl bed to about the same number of inches. Below them on all sides is a tenacious bluish clay mixed with sand, which at the time of Mr. Burns's visit extended under water to a depth of 4 feet, where it rests upon the sandstone of Hodge's section. Much of the marl has been removed for use as a fertilizer and good specimens of fossils are now rare. But better exposures of the marl can be found in the immediate neighborhood of Magnolia, a village about 2 miles northeast from the well. On the farm of Mr. Strickland, 1½ miles northwest from Magnolia, the same bed afforded better preserved fossils than at the well, while on the farm of Mr. Hollingsworth, 2 miles northeast of Magnolia, the marl is cemented into a comparatively solid rock, hard enough to burn for lime.

Mr. Burns obtained a very large collection from the vicinity of Magnolia and the well, but the fauna appears to be remarkably similar to that of the beds at Yorktown, Virginia.

Vertebrate remains.—Bones of six cetaceans, one Sirenian, and *Mastodon obscurus* Leidy, beside a large number of fishes, have been enumerated by Prof. Cope[1] from the Miocene of North Carolina.

Submarine beds.—Among the dredgings made on the coast of the Carolinas in 1885 by the U. S. Fish Commission, were hauls at the following stations:

No.	Latitude.		Longitude.		Fathoms.	General location.
	°	′	°	′		
2595	35	8	75	5	63	22 miles ESE. from Cape Hatteras.
2596	35	8	75	10	49	17 miles ESE. from Cape Hatteras.
2615	33	45	77	25	18	27 miles ESE. from Cape Fear.
2616	33	43	77	31	17	25 miles ESE. from Cape Fear.
2617	33	37	77	36	14	25 miles SE. from Cape Fear.
2619	33	38	77	36	15	Do.

In the gravel brought up at these stations were numerous Miocene fossils, mostly in a worn condition, including about twenty species of shells and nearly as many fishes, among which Prof. Cope recognized *Galeocerdo egertoni* Ag., *Nemipristis serra* Ag., and a *Lamna* known to be Miocene. The indications are that a considerable part of the submarine plateau extending eastward from the shores of the Carolinas is composed of rock of Miocene age.

[1] Rep. Geol. Surv. N. Carolina, vol. 1, 1875. Appendix B, by E. D. Cope, pp. 29-52, pls. 5-8.

PLIOCENE ROCKS.

Lafayette formation.—This formation belongs to the second class of deposits into which the Tertiary system of this state is divided—i. e., the perezonal.

In the eastern central part of North Carolina the formation[1] is notably variable and heterogeneous over the thinly covered eastern extension of the Piedmont crystallines now culminating in the continental projection of Cape Hatteras (which has been during past ages an even more conspicuous geographic feature than to-day), and its features are evidently connected with the proximity of the crystalline strata. Thus, at Wilson there is the usual partition into several regular and rather heavy (2 to 5 feet) strata, the usual orange hue, and the usual distribution of quartzite and quartz pebbles either throughout the several strata or in bands or pockets; but the lowermost stratum exposed in the northern part of the town is largely composed of arkose, slightly rearranged and sparsely intermixed with fine quartz pebbles, and there is some admixture of arkose in the superior layers. Then, half a mile south of Wilson a 9-foot railway cutting displays the usual heavy and moderately regular bedding, and the usual hues both in weathered and unweathered strata, while the lowest exposed bed (4 or 5 feet thick) is made up of interlaminated gray or white clay and orange or reddish loam, the clay being fine and plastic, the loam rather sandy and massive within each lamina, and the laminæ sensibly horizontal and ranging from an eighth of an inch to half an inch thick for the clay, and quarter of an inch to an inch or more for the loam. Both of these exceptional aspects of the formation are exhibited in various exposures in this region; both resemble in some measure characteristic aspects of the Potomac formation seen in eastern Virginia, and it is significant that the Potomac is not found here (probably by reason of removal through degradation), that crystalline rocks approach and in the immediate vicinity reach the surface, and so that the Appomattox probably rests immediately upon the eastward extension of the ancient Piedmont crystallines.

Nearer the coast the formation is frequently exposed in railway cuttings and displays the features characteristic of the contemporaneous deposits north of the Roanoke, save that the orange tints are less pronounced and mixed with browns and grays in some strata, that the bedding is thinner and more pronounced, and that the pebbles are small and rare. It is significant that the aspect of the formation here approaches that displayed by the phosphate-bearing Pliocene beds of the South Carolina coast.

The latter, it may be added, are also of a perezonal nature.

Marine Pliocene.—While it is highly probable that marine Pliocene strata were deposited along the shores of this state at the same epoch as those known to exist farther south, yet their presence in that part of the state now above the sea has never been demonstrated. A very considerable addition to our knowledge will be required before it can be definitely stated that such beds are totally absent from the Atlantic border of the state, where it is by no means unlikely that they may have been confounded with beds of the Chesapeake group, as in South Carolina, and for the same reason.

SOUTH CAROLINA.

At present the literature on the geology of South Carolina indicates that there are two classes of deposits or formations which, though

[1] McGee: Am. Jour. Sci., 3d ser., vol. 40, pp. 19–20. Appomattox is the name used by McGee in this article.

widely differing from each other in all paleontological, lithological, and structural features, are, nevertheless, both regarded as having been laid down in Neocene time. The one consists of "a series of predominantly orange-colored, nonfossiliferous sands and clays, resting unconformably upon Miocene and older formations, and unconformably overlain by the Columbia formation."[1] This McGee regards as a southern extension of his Appomattox (=Lafayette) formation, and assigns to it "an age corresponding at least roughly with the Pliocene."[2] It will be described hereafter.

NEOCENE MARLS.

The other consists of isolated patches of marl,[3] filling depressions in the underlying Eocene or Cretaceous strata.

Mineralogically this marl[4] differs from that of the Miocene beds in Virginia in that it contains a much greater percentage of calcium carbonate. Paleontologically the difference is equally marked; for both Tuomey[5] and Heilprin[6] maintain that the proportion of recent to extinct species is more than double that in the Miocene of the Old Dominion. These facts led Tuomey, in 1846, to refer[7] the beds in question to the Pliocene rather than the Miocene, a view which was reasserted in Tuomey and Holmes' "Pliocene Fossils of South Carolina,"[8] though Holmes,[9] Ruffin,[10] Lyell,[11] and Conrad[12] had previously regarded them as Miocene. More recently Dana[13] has seemingly followed Tuomey's interpretation, though he substitutes the name Sumter for that of Pliocene. Heilprin[14] correlates these with the North Caroliana Miocene beds, and styles them "Carolinian" or "Upper Atlantic Miocene." Since the discovery[15] of undoubted Pliocene deposits in Florida with their abundant and characteristic fauna it has become possible to state with certainty that some of the South Carolina forms are typical Pliocene species. Dall concludes that these marly patches probably consist for the most part of Miocene material that has, in some places, a certain mechanical admixture of true Pliocene forms incorporated subsequently to their original deposition.

In South Carolina, as in North Carolina, paleontologists have been

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[1] Am. Jour. Sci., 3d ser., 1890, vol. 40, p. 15; ibid., 1888, vol. 35, p. 328.

[2] Ibid, p. 33.

[3] M. Tuomey: Geol. S. C., 1848, p. 171; Agric. Surv. S. C., by E. Ruffin, 1843, pp. 27–28; Contr. Tert. Geol. and Paleont. U. S., by A. Heilprin, 1884, p. 21.

[4] M. Tuomey: Geol. S. C., 1848, p. 171; E. Ruffin, Agric. Surv. S. C., 1843, p. 29.

[5] Geol. S. C., 1848, p. 183.

[6] Contr. Tert. Geol. and Paleont. U. S., 1884, pp. 51–53 and 60–61.

[7] Geol. of S. C., p. 171.

[8] Op. cit., 1857, p. 9.

[9] Notes on the Geol. of Charleston, S. C., Am. Jour. Sci., 3d ser., 1849, vol. 7, p. 191.

[10] Agric. Surv. S. C., 1843, p. 27.

[11] Quart. Jour. Geol. Soc. Lond., 1845, vol. 1, p. 413.

[12] Medial Tert. Intr., 1843, p. 5.

[13] Dana: Man. Geol., 1863, p. 506.

[14] Contr. Tert. Geol. and Paleont. U. S., 1884, p. 66.

[15] Trans. Wagner Free Inst. Sci. Philadelphia, 1887, 1890, vols. 1, 3.

confronted with a difficulty arising from the alleged coexistence in the same beds of fossils mollusks elsewhere characteristic of different formations. In the fine work on the Pliocene of South Carolina by Messrs. Tuomey and Holmes, both Miocene and Pliocene species are included, with the result that, by some authors, the whole fauna has been regarded as Miocene, and by others, including the writers of the work in question, as Pliocene. Both conclusions rest on the assumption that all the species referred to have been derived from the undisturbed matrix of a single horizon, although collected at a number of different localities. This assumption appears insufficiently supported by the facts, since no critical stratigraphic investigation of the beds in question has ever been made, and especially no researches directed to the solution of this particular series of discrepancies. It may, however, be assumed that no very obvious, if any, stratigraphical differences exist, since otherwise it would seem as if they must have compelled recognition before now. The shell marl, from which the fossils in question have been derived, in part, at least, exists as patches of relatively small extent occupying shallow depressions in older deposits, which, as well as the marl and the superincumbent sands, are unconsolidated, loose, and liable to more or less shifting. The action of the torrential rains which annually visit this region, the influences at work in subaerial denudation, freshets, and floods, as well as the earthquakes which occasionally disturb the soil, offer means not at all inadequate to the confusion of thin, superficial, incoherent strata of similar constitution already in contact with one another; at least to an extent which would make it extremely difficult to recognize any distinction of age or stratification on a casual examination. There is, of course, no reason why in this state, as elsewhere, some species originating in the Miocene should not persist to the Pliocene, or even to the present fauna, essentially unchanged, as they are known to do in Florida, for instance. If this were all, no question need be raised as to the synchronous existence of species which have been collected from these beds. But this is not the real question; on the contrary, it is entirely beside the point. What we find in the supposed fauna of Messrs. Tuomey and Holmes is an aggregation of species of which some have (both north and south of the state) a definite stratigraphical position in certain Miocene beds, where they have never been found associated with certain others as in the South Carolina deposits. These others, again, are known to be mutually associated in beds of Pliocene age, from which the above-mentioned Miocene types have never been collected. Lastly, the known order of development, deduced from the succession of these forms in regions where, as in Florida, the stratigraphical succession is unquestioned, complete, and distinct, is violated by their alleged contemporaneous existence in a locality so nearly adjacent. The annexed tables illustrate the kind of discrepancies alluded to.

I. South Carolina species exclusively belonging to the Miocene (Ecphora zone) in Florida, North Carolina, Virginia, and Maryland.

Scaphella trenholmii, Fla., N. C., Md.
Mitra carolinensis, Fla., N. C.
Fasciolaria rhomboidea, Fla., N. C., Va.
Fasciolaria sparrowi, Fla., N. C.
Fulgur incile, Fla., N. C., Va., Md.
Ecphora 4-costata, Fla., N. C., Va., Md.
Cypræa carolinensis, N. C.
Arca centennaria, Fla., N. C., Va., Md.

II. South Carolina species exclusively belonging to the Pliocene or later in Florida:

Mitra lineolata.
Fasciolaria gigantea.
Fasciolaria distans.
Pisania auritula.
Astyris lunata.
Arca rustica.
Janira hemicylica.
Ostrea raveneliana.

These tables are given as illustrations merely, and comprise conspicuous and characteristic members of the particular faunæ. With a single exception they are of large size and distinctive appearance. With a better knowledge of the Tertiary fauna a complete list of such species would probably be a long one, but we have taken only those which happened to be conspicuous and thoroughly investigated. Now, it seems to the writer[1] that the supposition that the so-called Pliocene of South Carolina represents a mechanical mixture of species of two horizons, is more in harmony with what is known and with paleontological experience than the view that these species, elsewhere diversely distinctive, are, in this locality and for this occasion only, biosynchronous. At least it would seem as if the onus probandi lies with those who would claim a nominally transitorial character for these beds.

The Great Carolinian ridge.—Another fact bearing directly on this question is the lesser Pliocene and Pleistocene change of level in South Carolina. The level of the Columbian (Quaternary) perezone above the sea is here less elevated than it is either north or south of South Carolina. The off-shore deep sea soundings show that the sea bottom rises in an east-west general direction off that state, so that the Gulf stream flows up and over a hill or ridge transverse to its course. This indicates a relatively stationary axis or wide fold here (for which in this essay the term Great Carolinian ridge has been used), over which the Miocene beds are thin because it was not greatly depressed, and the following Pliocene beds also may be supposed to have been extremely thin, a state of affairs, considering the incoherence of the beds, which would greatly have facilitated subsequent confusion of the fossils and mixture of the material beds.

Stratigraphy.—These fossiliferous deposits are mainly confined to the northeastern part of the State. In Horry district slight exposures were noted by Tuomey on Little River; better ones were seen along the

[1] W. H. Dall.

Waccamaw, for some distance from Conway borough. At Potters Landing and at Harpers the strata appear as follows:

Feet.	Character of strata.
30-40	Yellow sand.
8-12	Yellow fossiliferous marl.
8	Cretaceous beds.

On the right bank of the river, not far from Nixonville, the beds as exposed stand thus:[1]

Feet.	Character of strata.
30	Loose sand and clay.
10	Marl.
2	Cretaceous. *Exogyra costata.*

From these and other less important exposures on the Waccamaw Tuomey enumerates 47 molluscan species, 21 of which he regards as recent.

In the southeastern part of Marion County several marl beds have been noted in the banks of or near the various rivers by which this district is crossed. The most easterly of these[2] is exposed on the Marion road, 2 or 3 miles from Galovants Ferry on Little Peedee River. It is 6 feet in thickness, is laid bare for a distance of 100 yards, and contains *Pecten eboreus*, *Ostrea virginica*, and *O. disparilis*. On the Great Peedee three localities are worthy of special mention, viz, Witherspoons Bluff, Giles Bluff, and Godfreys Ferry. At the first of these marl is seen rising from the water's edge, in a bed 10 feet thick, the upper portion of which is more siliceous than the rest. *Modiola ducateli* and *Panopœa reflexa* have here been identified. At Giles Bluff[3] the marl bed is from 8 to 10 feet thick, and is underlain by Cretaceous deposits at least 20 feet thick. The lower part of the marl is soft and of a light ash color, and contains fine specimens of *Pecten mortoni*. Above the structure is coarser, of a ferruginous color, and made up principally of casts of shells, among which *Chama congregata* predominates. The

[1] M. Tuomey, Geol. S. C., 1848, p. 173.

[2] Ibid., p. 175.

[3] E. Ruffin gives the thickness of the Miocene at this place as 12 feet and the underlying Cretaceous bed 14 feet.—Agric. Surv. S. C., 1843, p. 24.

upper, firmer portion of the marl is again seen at Godfreys Ferry,[1] which is its southern limit on the Peedee.

Leaving the river and proceeding toward Darlington Court-House, marl occurs at wide intervals and is rarely exposed except in artificial excavations. Immediately about the village localities are quite numerous. The marl is usually found in the beds of creeks and their branches, though sometimes met in digging wells. Above it are superficial incoherent beds of sand, clay, and the accumulating organic matter of swamps. The most important exposure in this vicinity is that at "Col. Ervin's," on a small stream one mile east of the court-house. The marl is here 10 feet in thickness. The fossils are in a fine state of preservation, and, owing to extensive excavations that were being made at the time of Tuomey's visit to this locality, he was able to make an excellent collection. This assisted him materially in his conclusions in regard to the age of these marl deposits. In a southwesterly direction from Darlington, as far as the Black River, in Sumter County, numerous exposures of marl may be seen; one of these has yielded[2] fragments of deer horns, together with *Gnathodon* and *Cyrena;* from another a tusk of *Mastodon* has been reported.[3] Below Eutaw, in St. John Berkeley, marl[4] is dug from pits for agricultural purposes, though there are no natural exposures. From these, Tuomey has obtained *Ostrea disparilis*, *Pecten septenarius*, *Venus rileyi*, and *Ecphora quadricostata.* Again, at Grove,[5] on the left bank of Cooper River, the Miocene marl has been cut into during the construction of a canal. This marl is lithologically like the Eocene, and can be distinguished only by its fossil remains. Very similar to this marl bed is one on Goose Creek;[6] the latter, however, is somewhat more ferruginous and harder.

On the Edisto,[7] below Givham's Ferry, *Ostrea disparilis* and other fossils of this formation have been detected.

In the vicinity of Oakley Inlet, Georgetown District, Ruffin[8] collected "*Venus rileyi*, *V. alveata*, *Corbula inequale*, *Arca limosa*, a variety of *Ostrea virginiana*," and others, all in an excellent state of preservation. They were evidently thrown up by the waves and "must have formed part of a submarine bed of Miocene marl, which still exists and perhaps has always remained under the sea." Moreover, a shark's tooth "precisely similar to those of large size found in the Miocene of Virginia" was "drawn up by an anchor from the bottom of Charleston harbor, in water 45 feet deep, off Fort Sumter."

[1] Ruffin states that the Miocene marl has a visible thickness of over 25 feet above water the and on Cretaceous marl was seen beneath it.—Agric. Surv. S. C., 1843, p. 24.

[2] Geol. S. Car., M. Tuomey, 1848, p. 177.

[3] Ibid p. 178. These remains are hardly Miocene in character.

[4] Ibid p. 178. This deposit, on the other hand, is characteristically Miocene.

[5] Ibid p. 179. Lyell mistook this for Eocene: Quart. Jour. Geol. Soc., 1845, vol. 1, p. 432.

[6] For the history of the discovery of this deposit, see Ruffin's Agric. Surv. S. C., 1843, p. 28.

[7] Geol. S. C., M. Tuomey, 1848, p. 179.

[8] Agric. Surv. S. C., 1843, p. 34.

PLIOCENE ROCKS.

Lafayette formation.—This formation, as has already been stated, consists of a perezonal series of predominantly orange-colored, nonfossiliferous sands and clays, resting unconformably upon Miocene and older formations, and unconformably overlain by the Columbia.

Unfortunately, little has as yet been published concerning the geographical distribution, thickness, lithological features, etc., of this formation in South Carolina. McGee says in substance that it forms a terrane 40 or 50 miles wide on the Roanoke, thence extends southward in a broad zone at first widening but afterward narrowing with the encroachment of the overlapping coast sands upon its area, quite across the Carolinas.[1] Hypsographically it extends from an elevation of from 25 feet to 650 feet above tide[2] level. South of the Roanoke[3] it is subject to local variations in its lithological and stratigraphical features. In some instances it approaches in appearance the phosphate-bearing Pliocene beds[4] of the South Carolina coast, into which it perhaps merges.[5] He says:[6]

Another distinctive but hardly distinct aspect of the formation is extensively displayed in central South Carolina, notably about Columbia. Here the usual moderately regular and rather heavy but always inconspicuous bedding of the formation is displayed; but the prevailing colors are richer and darker than in other parts of the terrane, commonly ranging from orange red to chocolate brown. Moreover, certain of the strata exhibit a peculiar mottling (which is better displayed farther southward); certain other strata exhibit a distinctive cross-stratification defined by gray or white plastic clay in laminæ, irregular sheets, and lines of pellets; the various strata are more uniform in composition than in the north, consisting rather of loam than of sand and clay in alternating beds, and the deposit as a whole takes on a solid, massive, and rock-like appearance, and gives origin to a distinctive topography. So conspicuously diverse in color, texture, and habit of erosion are the prevailing formations of central South Carolina that over thousands of square miles the surface is popularly divided into "red hills" and "sand hills"—the former representing the Appomattox, the latter the southern interfluvial phase of the Columbia formation.[7] The distribution of pebbles in this vicinity is especially interesting; northeast of the Congaree River, on the line of the Richmond and Danville Railway, pebbles are rare to within 2 miles of the present water way; there they suddenly increase in abundance, and in some sections within a mile from the river form a considerable and sometimes the principal part of the deposit; while south of the river they quickly become rare, being abundant only within a mile or less of the river bluffs. The pebbles are predominantly of quartz, though partly of quartzite, and comprise a few gneissoid fragments. They range in size from two and a half

[1] Am. Jour. Sci., 3d ser., 1890, vol. 40, p. 28.
[2] Ibid., p. 30.
[3] Ibid., p. 19.
[4] Ibid., p. 20.
[5] Ibid., p. 33.
[6] Ibid., p. 20.
[7] This expression needs modification to avoid misconception. The "red hills," as above used, means merely the superficial debris rearranged from the subjacent formations; the same is true of the "sand hills." The "red hills" and "sand hills" formations of South Carolina local usage are the red Buhrstone (or Claiborne Eocene) beds of Tuomey and the white siliceous Buhrstone which lies below it. The material derived from them and used in the Lafayette and Columbia perezones is that to which the words of McGee relate.

inches downward. Commonly they are accumulated in lines or pockets, sometimes at the base of the formation; but a few also occur disseminated throughout the ill defined strata.

About the fall line on the Santee River system the Appomattox (Lafayette) loam is in part overlain unconformably by the Columbia formation, though it has been severely degraded; and in an admirable section on the Richmond and Danville Railway immediately east of the state house, where both upper and lower contacts are displayed, the Appomattox rests unconformably on the Potomac. Farther up river the Appomattox rests directly upon the Piedmont crystallines, which here give origin to residuary products of dark red and brown color, and so the origin of the exceptionally rich hues of the formation in this region are not difficult to trace.

As our note (p. 80) shows, there is a liability to misconception in the language of McGee's account of the deposits included in the Lafayette formation. He seemingly includes in it beds of much greater age than that to which the Lafayette can be referred. But we understand that his intention was to indicate, as part of his Lafayette, only that superficial portion of these older beds which has been rémanié by the perezonal forces at a later time.

GEORGIA.

The distribution of the Tertiary deposits of this state is still but imperfectly understood, and the information brought together here, though fuller than elsewhere published, is still only roughly approximate.

MIOCENE.

Altamaha grit.—Descending the Ocmulgee River from Hawkinsville, Pulaski County, the main body of the country rock composing the bluffs along the river is the Orbitoides or Vicksburg limestone, often silicified and occasionally surmounted by a still more cherty layer, corresponding to the foraminiferal beds which form the culmination of the Eocene in Florida. These rocks rise to some 80 feet above the river, and at House Creek, Willcox County, are covered by a thin sandy bed containing the same silicified oyster shells, and presenting much such a petrologic character as the Hawthorne beds of Florida. Below this point the bluffs recede from the river but near the middle line of Coffee County appear again, exhibiting at Rocky hammock the first example on the river of a formation to which the name of Altamaha grit may be applied. The preceding notes are from observations by Mr. Frank Burns, of the U. S. Geological Survey, but the first reference we have found to this formation is by Loughridge[1] who describes it as follows:

Included between the Savannah River and the Atlantic and Gulf water divide, there seems to have been once formed a large shallow basin, which is now filled with a sandstone composed for the most part of coarse angular grit and clay partly cemented with silica, and resembling in character the Grand Gulf sandstone of the Gulf states. The area is marked on the map by the deep green color of the pine barren region, whose soil overlies the formation. The rocks have a slight dip to the southeast, have been traced by Capt. M. T. Singleton for 60 miles along Oconee River, and he estimates the thickness to be 200 feet.

[1] Dr. R. H. Loughridge: The Cotton Product of Georgia, in Tenth Census, vol. 6, part II, pp. 15, 16.

Outcrops have been observed in Irwin, Dodge, Ware, and other counties. Paramore hill, in the western part of Screven County, is of this sandstone, which has a thickness of 50 feet or more. Its grains of quartz are partly clear and translucent and partly white and opaque, and the rock is highly aluminous.

The southern limit of the sandstone is apparently at the edge of the second terrace, near the coast and along the Satilla River north of Okefinokee swamp, but the formation (represented by blue clays underlying the sandy land) extends probably still farther southward, including in its area the country near the Florida line, between Allapaha River on the west and the ridge on the eastern side of the swamp, a part of the main Atlantic and Gulf water divide of the state.

In order to define more closely the limits of this formation and determine, if possible, its age, Mr. Frank Burns, of the U. S. Geological Survey, was requested to follow the river from Hawkinsville to the point where it emerges from the highlands upon the flats of the Coastal plain. This point is approximately marked by the Atlantic Coast Railroad, as the last bluff of the grit is only a few rods above the bridge across the Altamaha River at Doctor Town, the piers of the bridge resting upon a newer formation.[1] Between Rocky hammock and Doctor Town all the bluffs (which are mostly on the right bank of the river) are composed of the grit, somtimes extremely hard and flinty and at others more disposed to crumble, but always composed of angular grains of slightly worn quartz mixed with more or less clay as a matrix and with waterworn quartz pebbles. The Altamaha grit is well exposed in these bluffs, which sometimes, as at Tillmans Ferry, Tatnall County, reach an elevation of 70 feet above the river, the beds being nearly horizontal or dipping slightly to the south and east.

The soil above them is sour and sterile, the decomposed quartz grains allowing the finer vegetable mold or any applied fertilizer to leach away rapidly. The district under which they occur has the local name of the "wire-grass section," and from an agricultural standpoint has only its healthfulness to recommend it. It is but sparsely settled and has few attractions.

These grits are obviously of a perezonal nature and represent, for the Georgian embayment, the operation through the agency of the southeastern drainage of Georgia of the same forces and analogous circumstances, to those which on the borders of the Mississippi embayment produced the Grand Gulf perezone. Though the contact with the oyster-bearing Hawthorne beds of House Creek was not observed by Mr. Burns, there can be little doubt that the latter are overlain by the grit where they join, and that the grits which contain no fossils except a little silicified wood are consequently of Miocene age. Seaward from them marine Miocene beds of the Chesapeake series were doubtless laid down, since Conrad records the washing up on St. Simons Island of a specimen of *Ecphora*.[2]

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[1] Mr. Burns learned that in digging for the foundations of these piers a bed of marine shells was cut through about 20 feet below the surface. At Jesup, not far west on the railroad, at 20 to 23 feet, an artesian well passed through a bed of oyster shells, below which was only yellow sand, and the well after being driven 500 feet without reaching water was abandoned. These shell beds are probably Pliocene or Pleistocene, but without much labor could not be reached at the present time.

[2] Proc. Acad. Nat Sci., Phila., 1852, vol. 6, p. 199.

Chattahoochee group.—Rocks of this age are known to occupy at least a narrow strip along the southern border of the southwestern tier of counties, being probably more or less continuous with the belt of Hawthorne beds observed by Burns on the Ocmulgee River and regarded by him as extending over a considerable area to the southwest. A large silicified coral, similar to those found in the clay of the Hawthorne beds in Alachua County, Florida, was, according to L. C. Johnson (letter of May 11, 1885) obtained by State Geologist Little at Thomasville, Georgia. Very recently from Barrows and Campbell Hill, Decatur County, Georgia, in the vicinity of Bainbridge, Prof. R. Pumpelly has forwarded specimens of silicified corals belonging to the same species as those found in the Hawthorne beds of Florida, together with fragments of rock containing fossils of the Chipola marl.

The latter, according to Prof. Pumpelly, come "from broken-up siliceous beds in the great mass of clays which are the residuum of the shrinkage by dissolution of, I think, a great thickness of strata." "Underneath them is limestone" belonging to the Vicksburg group, containing *Orbitoides mantelli* and *Pecten poulsoni*, in place at Russells Spring on the Flint River.

This evidence confirms the former existence of Miocene sediments, forming the link between Altamaha grits and the Miocene of the Chattahoochee River in Florida, which bordered on the north the Miocene strait connecting the Georgia embayment with the Gulf of Mexico. These sediments have here, as in many other places, disappeared under the solvent influence of percolating waters; leaving only the harder fragments, silicified fossils, and insoluble clays to indicate their presence. Subsequently, probably in early Pliocene time, the processes which formed the La Fayette perezone have rearranged to some extent the residual materials of the older Miocene rocks without, apparently, transporting them from their original site.

Jacksonboro limestone.—A locality near the northeastern border of the state has recently afforded evidences of Miocene strata apparently belonging to a horizon near that of the Chipola series. Near the confluence of Brier Creek and Beaver Dam Creek, which together form a tributary of the Savannah River, and 3 miles below Jacksonboro, Scriven County, Georgia, is a stratum of limestone containing very numerous casts of shells and occasionally a silicified specimen, on the whole not unlike the Tampa limestone. This stone was formerly burned for lime. It was visited by Lyell,[1] who referred to it on several occasions and supposed it to be of Eocene age. This locality was recently visited by Prof. W. B. Clark, who found the quarry and ruins of the kiln spoken of by Lyell. An examination of the material collected there showed the presence of *Strombus chipolanus; Fissurella* like *Marylandica; Infundibulum perarmatum* Con?; *Xenophora humilis;* a *Cerith-*

[1] See Lyell, Proc. Geol. Soc., vol. 3, pp. 735, 742; vol. 4, pp. 547, 563, and reprints of the same papers in Quart. Jour. Geol. Soc., 1845, vol. 1, pp. 413 and 429.

ium, much like *C. hillsboroensis;* a species of *Vertagus*, recalling one from the Caloosahatchie Pliocene; *Capulus*, like one in the Tampa silex beds; *Bulla petrosa? Pecten septenarius*, a small *Macoma* like one from the Tampa silex beds; a *Cardium* and an *Ampullina*, resembling the Chipola species, besides a number of forms which might be Eocene or later, but had a Miocene aspect. There were, as in the Chipola beds, several forms known from the Upper Eocene, such as *Eburna sp.*, *Serpula sp.* The section here showed 5 feet of ferruginous sand and over 12 feet of compact marly rock with fossils. Until a more thorough examination and study of the species has been made the matter can not be said to be finally settled, but at present the presumption is obviously in favor of the early Miocene age of this deposit, from which Lonsdale has described[1] several corals collected by Lyell. The uppermost fossiliferous layer at Shell Bluff, while probably Eocene, presents indications of a modification of the fauna in the direction of that following it in the Miocene epoch. *Cerithium*, *Cardium*, and *Yoldia* closely resembling *Y. limatula*, were found by Prof. Clark in Richmond County west of Augusta, in a pit at McBean, on the land of R. W. Knight. A similar silicified layer was observed by Frank Burns capping the softer Vicksburg along the Ockmulgee River between Hawkinsville and House Creek.

PLIOCENE ROCKS.

Marl beds.—Two very different deposits in this state have been referred to the Pliocene age. The one is described by Loughridge as follows:

> The Savannah region along the coast, which occupies the first terrace at an elevation of from 10 to 15 feet above tide-water, is assigned to the Pliocene formation. Marls or shell beds of this age are found on the Savannah River near the Effingham and Chatham County lines. On Satilla River a white marl bed outcrops at Burnt Fort, the head of tidewater, which is mostly devoid of fossils. In the sand and clay beds of the coast region in Glynn, Chatham, and other counties have been dug up the remains of gigantic quadrupeds, such as the mastodon, and along its borders are buried stumps of cypress and other trees still standing upright.

The Lafayette formation.—This, according to McGee, forms "the most conspicuous terrane of central Georgia, where it stretches from the fall-line to the inland margin of the coast sands all the way from the Savannah to the Chattahoochee.[2] It is in this state that the formation appears best developed. "At many points it overlaps far upon the Piedmont crystallines. On the seaward side of the fall-line it is unquestionably overlapped in turn by the pine-clad sands of the Columbia formation over many thousand square miles. It evidently reaches a considerable thickness, perhaps 100 feet or more." Good exposures may be seen at Augusta, Green's Cut, Munnerlyn, Sun Hill, and especially at Macon, where it is typically developed. "Above the

[1] Quart. Jour. Geol. Soc., 1845, vol. 1.
[2] Am. Jour. Sci., 3d ser., 1890, vol. 40, p. 23.

reach of modern alluvium, and above the vaguely defined and poorly exposed 'second bottoms' it forms the prevailing surface;[1] and in every street and suburban road, in every storm-carved runnel and road-side gulley, and in every cutting of the seven railways radiating from the city its materials are exposed." Here it displays its usual orange-yellow and orange-red tints, its cross-bedded structure, and its indefinite and irregular stratification. Here, too, near the fall-line the formation abounds in small pebbles, arranged in lines, accumulated in pockets or disseminated throughout the deposit. At Macon, as at Columbia, the Appomattox (Lafayette) is intercalated between the Columbia and Potomac formations. It is noteworthy that although the Appomattox (Lafayette) and the Potomac are here, as elsewhere, strikingly unconformable, they sometimes merge so completely that no line of demarcation can be drawn with precision. Of these three formations, the finest southern exposures may be seen just below the falls of the Chattahoochee in the villages of Girard and Lively, Alabama, opposite Columbus.

Vertebrate remains.—In the American Naturalist, 1878 (vol. 12, p. 129), it is stated that Prof. Little, director of the geological survey of Georgia, has accumulated a valuable collection of the vertebrate fossils of the state, of Cretaceous and Tertiary age. Among these there have been identified the dinosaurian *Hadrosaurus tripos*, and the turtles, *Taphrasphys strenuus* and *Amphiemys oxysternum*, a new genus and species related to *Adocus*. Mr. Loughridge, of the Survey, also discovered a very fine specimen of that rare propilurid, *Peritresius ornatus.*

FLORIDA.

INTRODUCTORY.

The state of Florida presents the most complete succession of Tertiary and post-Tertiary fossil-bearing strata of any part of the United States. These have been but little disturbed by orogenic movements, exhibit but trifling uncomformities, and present numerous interesting cases of the survival of forms from one horizon to another, thus illustrating in the most forcible manner to the biologist the uniformity of conditions under which the beds have been laid down.

Perhaps no other region on our coast presents so many instances of Miocene species still existing in the deeper waters off its own shores. Nowhere else can the problems of descent with modification during Cenozoic and later time be so well studied in the fossil and recent faunas.

For these reasons, since Florida offers a sort of standard, with which it may be convenient to compare the Cenozoic beds of other parts of the coast, and also because much unpublished material pertinent to the occasion is in the writer's[2] possession, the description of Floridian geol-

[1] Am. Jour. Sci., 3d ser., 1890, vol. 40, p. 22.

[2] For the portion of this essay relating to the state of Florida W. H. Dall is solely responsible.

ogy has been more fully detailed than in the case of either of the other states referred to in connection with this essay. The peculiarity of certain processes, such as erosion by solution and deposition by chemical rather than by gravitative energy, which have played such an important part in the geology of the peninsula, the simplicity of its petrographic character, originating almost solely from oceanic, chiefly organic sediments; and the total absence of certain forms of action, conspicuous, if not overshadowing all others, in most other parts of the continent; all these things render the geology of Florida especially interesting.

In offering here and there a working hypothesis in explanation of sundry problems, the writer would explain, once for all, that these hypotheses are provisional, that he fully appreciates the defectiveness of our knowledge and anticipates the necessity, with further knowledge, of much revision and correction. Nevertheless, he believes that facts, like beads, can be better appreciated strung on the thread of even a working hypothesis than when merely incoherently aggregated.

All the facts at present gathered tend toward the conclusion that the Floridian peninsula is a region where geological action has been gentle, slow, and very uniform; where elevations and depressions, if sudden, have been slight in vertical range and symmetrical over considerable areas; where the total elevation has probably not been very much greater than at present, in post-Cretaceous time; and where organic sediments in the main, have been the building material. The changes in the rocks have been almost exclusively due to chemical rather than mountain-building forces, and have repeated themselves in rocks of each successive epoch by methods which can be studied in actual operation at the present moment.

TOPOGRAPHY OF THE FLORIDA PENINSULA.

Foundation of the peninsula.—The shore lines of the peninsula of Florida very imperfectly indicate its fundamental topographic relations. To understand those it is necessary to study a chart, such as that accompanying this volume, or a model which exhibits the submarine topography of the adjacent seabottom as well as the subærial modeling of the land surface. On grounds which are more fully discussed in another section of this essay, I am disposed to believe that the present peninsula rests on a much more extensive foundation of Eocene limestone, mostly of Vicksburg age, forming a plateau which formerly extended from the southeastern margin of the continent to the Cuban and Bahaman region and possibly to Yucatan. The deeper channels which now separate the Floridian part of this plateau from the Antillean and Yucatan areas are probably, as Agassiz has suggested, due to scour exerted by the Gulf stream as its flow became restricted by the gradual elevation of the land, though there is some evidence in favor of faulting in this connection. The material, as originally deposited, consisted almost wholly of siliceous and calcareous remains of marine invertebrates, which at the period when the scour was initiated may well have been in a comparatively soft or incoherent condition, as much of the Vicksburg limestone still remains. The attrition of the siliceous particles and harder calcareous fragments, contained in the uppermost layers and transported by the tremendous energy of the current, would have formed a sand blast capable of almost any amount of cutting, and more than equal to the task which has been performed in the Florida strait and its northern extension under the Gulf stream.

Folds of the strata.—In considering the topography of Florida it has been customary among geologists and others to speak of the "central ridge," "elevated axis," and in the latest contribution to the subject[1] Prof. Shaler regards Florida as "formed of lowlands rising as a broad fold from the deep water on either side to a vast ridge, the top of which is relatively very flat, there being no indication of true mountain folding in any part of the area." In an extremely wide and general sense it is of course true that the peninsula forms a great fold, but in the ordinary and literal meaning of the words this description conveys an inaccurate idea of the structure of the region.

ORIGIN, CHARACTER, AND DECAY OF ROCKS.

Before endeavoring to give an idea of the topographic structure, as observed by the writer, it will be well to consider the material of which the peninsula is composed and its behavior under the conditions to which it has been almost invariably subjected.

The materials hitherto observed in the peninsula of Florida, and of which the rocks are for practical purposes exclusively made up, are lime, clay, and silex, with occasionally a little oxide of iron, all materials which at the present moment are being copiously deposited in the bed of the ocean.[2] In Florida, for the most part, they may be assumed to have been derived from organisms or sediments transported to the spot by the sea. From organic agencies, operating since part of the peninsula has been raised above the sea, have been received sulphuretted hydrogen, carbon dioxide, and phosphoric acid, which, in a state of solution or chemical combination with rainwater, have energetically acted upon the rocks.

The Eocene lime rocks were deposited over a vast area of the sea

[1] The Topography of Florida, Bull. Mus. Comp. Zool., 1890, vol. 16, No. 7.

[2] At a depth of 600 feet, in boring the artesian wells for the Sub-Tropical Exposition at Jacksonville, Florida, two years ago, a thin stratum of greenish clay was struck which contains numerous extremely fine particles of mica. These particles were, of course, derived from the continent to the northward, the rocks with which the clay was associated in the wells, being of the Chesapeake group or newer, cold water, Miocene. This clay much recalls the clay associated in many places farther north with the fossils of this age. The bed which contains it is the only stratum reported from the peninsula part of Florida, and yet brought to the writer's notice, which might not have been derived from the material of which the peninsula has been built up. Pebbles of crystalline rock from the St. Augustine well and the small particles of volcanic rock of Antillean origin, in the marls of Southern Florida may be considered as exceptional exotics. Most of the latter probably reached Florida attached to drifting seaweed or the spongy floats of *Lepas fascicularis.*

bottom, instead of a narrow strip, as in the case of sediments directly derived from antecedent dry land. To the broad and even manner in which they were spread out and the fact that subaerial erosion has on the dry land of Florida proceeded rather by processes of solution than by comminution and transportation of the material comminuted, we may ascribe the feebleness of those evidences of lateral thrust and vertical flexure which on most coast regions are so forcibly exhibited. Nevertheless, flexures are not entirely absent, as was pointed out by the writer on another occasion,[1] even in the later deposits of the southern part of the peninsula, where, in the section exposed on the banks of the Caloosahatchie River, gentle folds with their axes generally parallel with the trend of the peninsula, continually succeed one another between Lake Okeechobee and the Gulf of Mexico.

Effects of solution on the topography.—From Eocene times until the present day the modification of the rocks has proceeded through a series of constantly recurring similar changes. The silica derived from organic remains has been taken up by percolating waters and redeposited in the form of sheets, strings, and nodules of flint, chalcedony, or chert, or as a cement holding together with extreme tenacity the other minerals of the particular stratum concerned. The "gravels" referred to in the description of peninsular Florida rocks are the waste of these siliceous products comminuted by wave action or left loose by the solution of their associated carbonate of lime and rounded by attrition on each other. Much of the sand of Florida is derived from the same source, excluding the shore sands of the eastern coast. Occasional minute particles may be found which seem to have had a volcanic origin, and which are doubtless derived from the volcanic region of the Antilles. The decay of organic, largely vegetable, matter carried by rain into the interstices and subterranean passages of the porous lime rock produces the sulphuretted waters, which are found all over the peninsula. These sometimes find an exit on the seashore and are often so strongly charged as to destroy life in all organisms with which they come in contact over hundreds of square miles of coast. To these or to analogous forces acting on the lime rocks may be ascribed the formation (as at Dunellon on the Withlacoochee) of extensive beds of gypsum or sulphate of lime. In a similar way the action of rain water on beds of guano or the daily ejections of great rookeries of birds in some cases, or on other decaying animal matter in other cases, has carried phosphoric acid into the subjacent porous lime rock in such a way as to result in the modification of numerous extensive beds of ordinary limestone or marl into more or less phosphatized lime rock, much of which is available for fertilizers. The presence of the organic material and the porosity of the rock beneath it have alone been in question here, as rock of all ages, from the Eocene up, has been subjected to similar influences in Florida with analogous results.

It is probable that the beds commercially most valuable are comprised

[1] Geology of Florida: Am. Jour. Sci., 3rd ser., 1887, vol. 34, p. 168.

within more limited geological confines, but essentially the same agencies have been at work up to the present moment, though with varying degrees of energy and very different quantitative sources of supply.

By the constant slow circulation of the fresh water derived from the atmosphere and contained in the porous rock, like water passing through a stone filter, a circulation incited by gravity and relieved by the outflow of myriads of springs, the salt which might have been entangled in the original sediments appears to have been almost wholly removed from the Florida rocks.

Most of the limestones contain more or less clayey matter, but occasional beds of clay occur of such magnitude as to suggest a different origin, perhaps from river sediments transported from a distance, or other sources which can not with our present knowledge be satisfactorily determined.

The general structure of the peninsula seems to indicate a succession of moderate longitudinal folds which are more accentuated in the north, and which, like those mentioned as observed on the Caloosahatchie, trend with the general trend of the peninsula. The evidence points quite strongly to the existence of two principal anticlinal folds, of but very moderate height, it is true, but high compared with the average level of the peninsula and to which its most remarkable topographic features are due. The highest and oldest of these folds is also the most western and consists chiefly of Eocene limestone. The eastern fold is somewhat narrower and lower and formed of Miocene rocks. The features of the latter are obscured by superficial sand deposits.

The peculiar solutionary method by which erosion is chiefly carried on in Florida results in unfamiliar topographic minor details. The broader features often recall that peculiar facies of the English "downs," which is due to analogous causes. The "lumpy" rounded character of the superficial sandhills is very confusing to the eye and effectively masks the long and gentle curves of the strata. Only when a water level, as along a stream, offers a direct means of comparison does one recognize the fact that these apparently horizontal rocks are really bent.

Good exposures of this sort are, unhappily, rare in Florida, and but little of the country is visible under its carpet of semitropical vegetation or even more delusive blanket of sand. For proof of the existence of the greater flexures recourse must be had to another method. It is obvious, if the strata look horizontal wherever we are and if one finds by a series of levels that the supposed level surface really describes a series of ridges, that at least a probability is established for the proposition that the strata are also flexed.

PROFILES FROM LINES OF RAILWAY LEVELS.

From series of levelings executed for railway surveys in Florida I have prepared the following profiles. It may be stated in advance that the leveling is probably of a rough and ready character, not to be depended upon for the registration of minute differences and in some cases having rather uncertain connection with the level of mean tide, here taken as zero. Yet for considerable differences of level and for general relations of altitudes to each other it may be presumed to be accurate enough for our purposes, even if the absolute altitudes are not determined with great exactitude.

These represent, respectively:

I. Profile from the ocean at San Pablo Beach east of Jacksonville westward 110 miles to the Suwanee River, reduced to the parallel of north latitude 30° 15′. (Fig. 17.)

This shows the Atlantic drainage, part of the gulf drainage, and

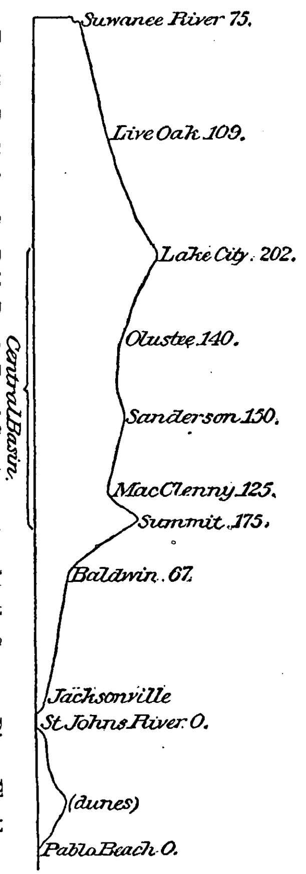

Fig. 17.—Profile from San Pablo Beach, Duval County, westward to the Suwanee River, Florida.

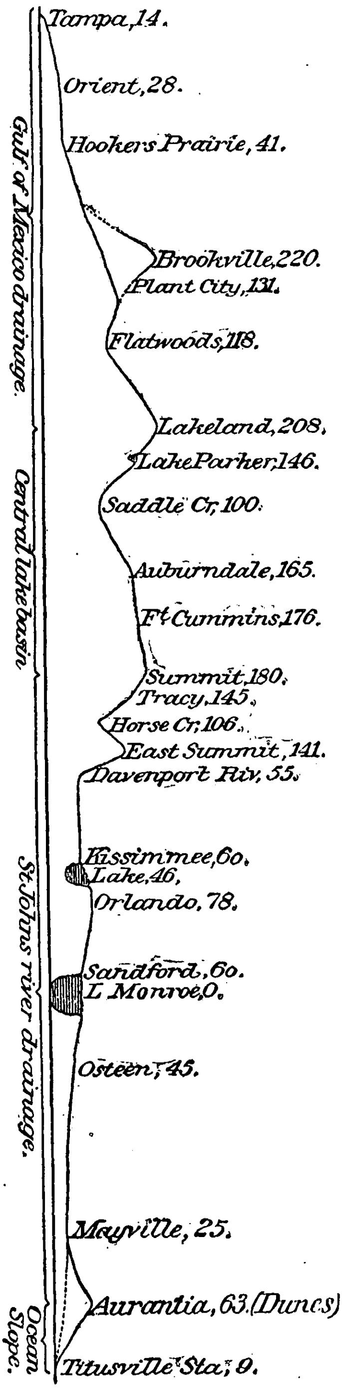

Fig. 18.—Profile across Florida from Indian River, Brevard County, to Tampa Bay.

what I have termed the Central Lake basin between the two principal anticlines, cut nearly at right angles, not far from its northern extreme. The levels were furnished by the officers of the Florida Railway and Navigation Company to the geographer of the U. S. Geological Survey.

II. A similar east and west profile reduced to the parallel 28° 30′, from the sea level at the inlet called Indian River west to the Gulf at Tampa Bay, from levels of the South Florida Railway Company. (Fig.18.)

This profile cuts the "central basin" near its southern third, and the third anticline west from it is clearly brought out. This profile is less right-angled to the anticline axes than the northern one (I), because the peninsula trends more easterly as we go south, but it is reduced from a profile almost exactly right-angled to these axes, and the difference on the scale used is unimportant. Southward from this region the general surface of the peninsula becomes lower and the elevation of the anticlines less and less marked.

III. A northeast and southwest profile from Fernandina on the Atlantic coast to the Gulf near Cedar Keys, 110 miles, from the Savannah, Florida and Western Railway leveling. (Fig. 19.)

This profile shows the Atlantic and Gulf slopes, the Central basin, and the third anticline near Archer, cutting the region traversed at an angle of 45° with the two previous lines.

IV. A north-south profile reduced by rectangular coordinates to the meridian of 82° west Green-

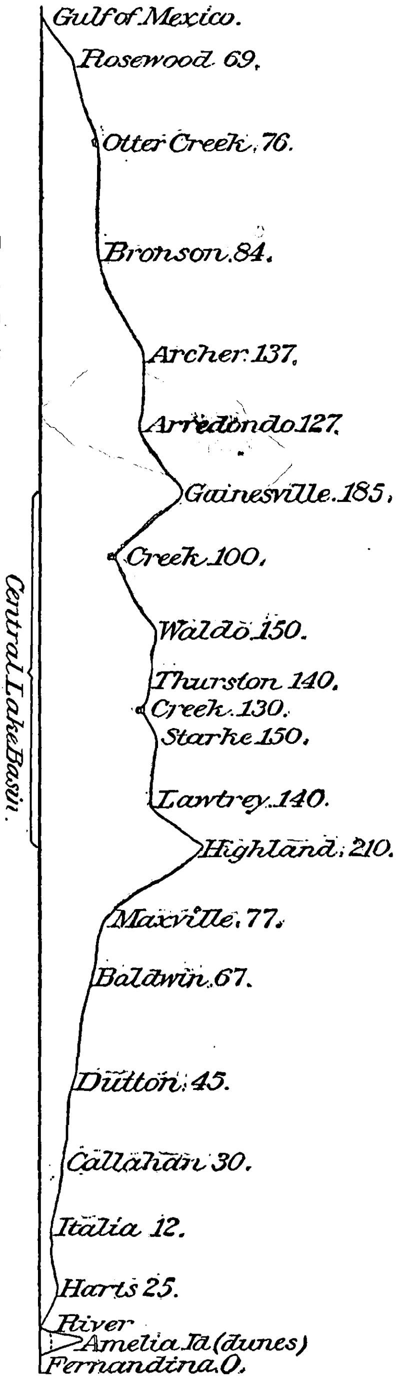

Fig. 19.—Profile across Florida from Fernandina, Nassau County, to a point near Cedar Keys, Levy County.

wich, from Callahan near the northern boundary of the State 180 miles south to Plant City, on the southern division of the Florida Railway and Navigation Company's road. (Fig. 20.)

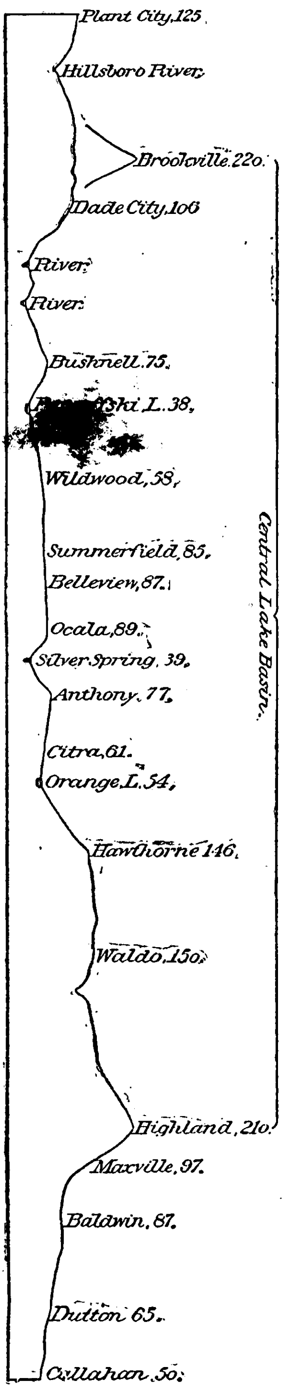

FIG. 20.—Profile from Callahan, Nassau County, to Plant City, Hillsboro County, Fla.

This profile cuts the region at an angle of 90° with sections I and II, but is somewhat oblique to the geologic axis. It leaves Callahan on the Atlantic slope, crosses the eastern anticline obliquely from Highland to Hawthorne, thence traverses the Central basin for 80 miles, rising on to the western anticline at Dade City. Between Dade City and Plant City, which last place is supposed to be on the second western anticline, there is an apparent dip into a shallow synclinal trough, but the data for this part of the road represent only the height at stations, and not the continuous profile, and its features can not be given with precision. Brookville, which is apparently on the third anticline, is indicated, but is outside the profile.

It will be admitted that these profiles unitedly testify to the existence of a ridge or height of land between the St. John's drainage area and that of the central lakes, and of another between the central area and the Gulf drainage, while there are indications of a third ridge, near to and parallel with the last, which for a certain distance shortens up the Gulf drainage streams, confining them to a narrow belt, though cut itself by the few larger rivers. An inspection of a properly constructed map, showing the railroads, will show how little modification has been needed in coordinating the railway lines with the straight lines of the sections. The sections cut the region in three different and opposed directions, yet all the profiles tell the same story. I shall therefore consider myself justified in assuming that the peninsula does exhibit a folded structure, and that there are two chief lines of elevation, and probably others, besides the minor flexures which have been observed farther south. The distribution of the lakes and rivers of the peninsula confirms this view, if confirmation is needed.

CENTRAL LAKE REGION.

It would perhaps be more strictly accurate to denominate the great syncline of the peninsula as a central trough rather than a central lake basin. The elevation which separates the central lake region from its natural continuation, the Kissimmee drainage area, Lake Okeechobee, and the Everglades, is probably not very great. Nevertheless, there are geological reasons for supposing that the northern area now dotted with innumerable lakes, marshes and sinks was at one time occupied by one or more large bodies of water, of which the existing lakes are mere remnants.

Lake De Soto: sand knolls.—This lake or lakes, which for convenience of reference may be called Lake De Soto, would then have occupied a relation to the existing land much like that which Lake Okeechobee holds to the southern part of the peninsula at present. The peculiar sculpture of the small sandy knolls or elevations occupying much of the central region, and which Shaler has compared to kames, might have been more or less due to the movement of the waters consequent on changes which finally resulted in the drainage of the area in question.

These knolls or hillocks appear to be more characteristic of the central basin. On the highlands they are absent or merged into the irregularities which appear on the surface of the country rock as the result of solution and decay. They are chiefly composed of the yellow sand, and as a rule the irregularities of their profiles do not reflect any elevations or depressions of the rocks below them. The sand hills, however elevated or irregular, rest on a relatively level surface of limestone, a fact confirmed by the experience of well-drivers all over southern Florida, as well as by the reports of the prospectors who bore for phosphates. More investigation is necessary before the idea that the form of these knolls is due to the action of currents of water can be regarded as established.

Over a large part of northern Florida a striking characteristic of the country arises from the singularly porous and incoherent character of the limestones (especially of the Vicksburg and early Miocene age) which form the country rock. When this rock is Eocene it is usually of a creamy white color, containing molluscan fossils, sometimes as complete shells, but more frequently as impressions in the saccharoidal carbonate of lime. Mingled with them, and sometimes forming almost the whole body of the rock, are enormous numbers of *Orbitoides mantelli*, heaped loosely upon each other.

If the rock is post-Eocene it is generally of less purity, containing more aluminous matter, but still whitish and porous, though without the discoid Orbitoides fossils. In either case it is easily cut when fresh, hardens when exposed to the air, and is pervious to water. In regions where it comes to the surface there are no small brooks and few streams. Rain sinks into it as into dry sand; the solution of the softer portions results in "sinks" or natural wells, sometimes of large size and often with perpendicular walls. These constitute a real danger to a wanderer who goès aside from the beaten tracks, as their apertures, from the size of a post hole to that of an amphitheater, are unmarked by anything which would serve as a warning; they are often of great depth and almost always contain water. The water sinks until it comes to a more dense stratum or the sediment it carries clogs the pores of the limestone beneath it. Then it flows in the direction of least resistance, forming underground brooks or tolerable streams whose course may be marked by a long line of sinks. If sawdust be thrown into one of these it presently appears on the water in the next below, and so on. The sinks above the stream gradually enlarge in the direction of its flow, the intervening portions remaining as "natural bridges," the number of which is extraordinary. In other places the drainage of a limited area runs toward a central point, where it is lost in the bowels of the earth. When the rainfall at some seasons of the year exceeds the capacity of this passage to carry away, a shallow lake appears, of a temporary nature, which is gradually drained off at drier seasons. Sometimes the funnel becomes permanently obstructed, and the lake remains and spreads until some new outlet appears. I have seen lands formerly used for growing cotton, and covering hundreds of acres, which had become permanently flooded in this way.[1] Fish abound in the sinks, and subterranean passages for their use evidently exist in profusion.

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[1] In illustration of these remarks the following quotations about one of the largest of the temporary lakes have an interest. The first is from the Providence Journal, September 14, 1891.

"A LOST LAKE.

"A curious spectacle was to be seen on the outskirts of Gainesville, Florida, recently. Alachua Lake, from 10 to 15 miles in length and covering some 40.000 acres of land, is no more. On its banks were lying thousands of dead fish, dead alligators floated ghastly in pools of black water, and the atmosphere was heavy with noxious gases. Men and boys were there in throngs with hoes and rakes, dragging to shore hundreds of fish which had sought the pools for refuge. The waters were fairly alive with their struggles for existence. Except for a small stream known as Payne's Creek, flowing from Newman's Lake into the Sink, the two main basins of the Sink, and a few stagnant pools, no water is now to be seen where a few years ago steamers were plowing their way. This is the second time since 1823 that a similar occurrence has taken place. At that time the bed of the lake was a large prairie—Payne's prairie—having in it a body of water called the Sink and a small creek. In 1868 heavy rains filled up the prairie, but the water disappeared after a short time and the prairie was again dry land. In 1873, after a series of heavy rains, the Sink overflowed and the creek swelled to the dimensions of a lake. During several years the waters increased till a larger lake was formed, and for fully fifteen years sufficient depth of water stood over the prairie to allow of small steamers. Dur-

When the porous lime rocks are covered with the clayey layers of the later Tertiary or the more coherent and impervious limestones of the early Miocene, or when the process of silicification has been carried on to such an extent as to render the upper layers of the porous lime rock impervious, a wholly different surface topography results. Instead of circular marshes and rows of "sinks" in which all the surface water is lost, one sees brooks and rivulets with their accompanying effects upon the landscape. It also seemed to the writer that the difference was to some extent reflected in the appearance of the vegetation.

NORTHWESTERN FLORIDA.

At the northern part of the peninsula the topography merges into that of the foothills of western Georgia and Alabama, or borders on the great cypress swamps of eastern Georgia.

At the west, in the vicinity of the Appalachicola River, Mr. Burns, of the U. S. Geological Survey, reports finding the Miocene hills, at a point 8½ miles below Bristol, terminating in a sharp cliff or bluff over 60 feet high, from the foot of which a flat plain extended seaward without interruption. An examination of the river banks to a locality known as Riccos bluff showed unfossiliferous horizontal beds of bright-colored sandy clays, everywhere covered with a thin layer of white sand. This break in the topography is a marked feature of this part of the State and is said to extend for many miles, preserving a general parallelism with the shores of the Gulf, and doubtless marking an ancient shore-line.

SOUTHWESTERN FLORIDA.

The shores of the Gulf of Mexico in the state of Florida north of Punta Rasa are chiefly sandy, or, near the rivers, sometimes formed of a chalky mud. But as far as known this stratum is usually of no great depth, being chiefly a superficial covering to beds of the country rock.

ing the last two years, however, the waters have been gradually lowering, and about four weeks ago they commenced going down with surprising rapidity, the lake falling about 8 feet in ten days, until now nothing is left of Alachua Lake but the memory of it. The Sink is considered the cause of this change. There is evidently an underground passage connected, and for some reason not understood this underground passage has been acting as a drain until all the water in the lake has been drawn off."

The second is taken from the Washington Evening Star of September 19, 1891:

"The Star recently printed an account of the disappearance of Alachua Lake in Florida, a lake that was so well established that a steamboat line was maintained on it. A U. S. Geological Survey party has been engaged at work in that region. A member of this party, Mr. Hersey Munroe, who is now in the city, gave an interesting account of the lake, or rather the ex-lake, to a Star reporter. 'Alachua Lake,' said Mr. Munroe, 'is situated in north latitude 29° 35′ and west longitude 82° 20′ in Alachua County, Fla., and 2 miles south of Gainesville, the county seat. The lake was formerly a prairie, known as Alachua prairie before the Seminole war during 1835-'37. It has since been named Paynes prairie, after King Payne, an old Seminole chief of an early day. The prairie was a great grazing spot for the Indians' cattle and later was used for a like purpose and for tillage by the whites, some fine crops of corn and cotton being grown. The prairie lands are immense meadows, covered by the finest grass, interspersed with clumps of beautiful oak trees and palmettoes. These lands are subject to inundation during the summer season. Hatchet Creek rises 3 miles north of Gainesville and flows in every direction of the compass for a distance of 10 miles, emptying into Newmans Lake, a beautiful sheet of water covering 10 square miles.

The latter extend seaward, sometimes forming extensive oyster banks near the shore through which navigation can be carried on only in small boats and by troublesome and intricate channels, when away from the main navigable outlet of each particular stream.

The sands are derived from the siliceous contents of the country rock and are frequently more or less bound together by the deposition of lime held in solution, forming a sort of coquina. Much of the shore, especially to the south and the extreme west, is defended by sandy keys formed at the neutral line of tide and land drainage, and offering much-needed facilities for coast navigation in small craft suited to these shallow waters. The sea-bottom, level as a floor to all appearances, inclines gently to the west and south, and for miles from the beach attains only a very moderate depth.

It might have been anticipated that the detritus, especially the fine sediment brought down by the Mississippi, would be conspicuous in the bottom deposits of the gulf in the direction of the prevailing currents. The soundings and samples of bottom obtained by the U. S. Coast Survey and the Fish Commission show that this is not the case. The terrigenous sediments (except at the immediate shore) extend eastward but a little way off the Floridian coast. The line indicating the change in the bottom from mud to organic limy sediments approaches the shore to the westward of Appalachicola, in the vicinity of St. Andrews Bay.[2] That this limitation of the fresh-water deposits is not a modern thing is shown by the almost identical range of the Grand Gulf beds of Hilgard on the ancient shores of the Gulf of Mexico. A reason for it may perhaps be found in the tendency, so well known, of a saline solution to precipitate the sediment contained in fresh water when the two liquids are mixed. The mixture of the two fluids in the gulf may

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'HOW THE LAKE WAS FORMED.

'The overflow from Newmans Lake forms a large creek named Prairie Creek, which wended its way through Paynes prairie to Alachua Sink, one of the curiosities of the State. There the waters found their way into a subterranean passage. Visitors, to have their curiosity gratified by seeing what the effect would be to have logs thrown into the sink, were the probable cause of the overflow of Paynes prairie. The logs would float out to the center of the sink, whirl around in a circle and suddenly disappear. This choking of the outlet to the waters of Prairie Creek caused the overflow and made a sheet of water sufficient to float small steamers and other craft.

'One steamer in particular had a splendid freight traffic, during the vegetable season carrying shipments of vegetables from its wharf on Chacala pond across Alcahua Lake to the mouth of Sweetwater branch, the nearest point to Gainesville, the principal place for shipment north. After the overflow and the forming of a lake it was christened Alachua Lake. This name has been decided upon by the United States Board on Geographic Names. Alachua Lake is 8 miles long, east and west, and in one place 4 miles in width, north and south, covers 16,000 acres, and the average depth is from 2 to 14 feet deep.

'LOWERING FOR SEVERAL YEARS.

'For several years the lake has been gradually lowering. The elevation of the water above sea level as given by the Savannah, Florida and Western Railroad some years ago is 64 feet. By accurate levels run by one of the topographical parties of the Geological Survey working in this section during the winter of 1890–'91 the elevation of the water was found to be 58 feet, thus showing that the lake had been changing elevation; and about two weeks ago I was informed that Alachua Lake had disappeared entirely, that only small pools remained and the usual amount immediately around the sink.'"

[2] Three cruises of the Blake, vol. 1. p. 286, Fig. 191.

then be supposed to be complete at any point where all the mud has been precipitated.

EASTERN COAST OF FLORIDA.

On the eastern coast of Florida toward the north we find a narrow margin composed of the coast sands, between the abrupt margin of the country rocks and the sea, and extending under the sea eastward for a distance from the shore in north latitude 30° of more than 50 miles The source of these sands is thus explained by Shaler:[1]

> During the glacial period a very large amount of arenaceous material was contributed to the sea in the region north of Cape Hatteras. The general trend of the shore of this part of the continent is from the northeast to the southwest, while the prevailing direction of the wind is from the east. The result is that, so far as impelled by the waves, this sand works down along the coast shelf to the southward. Whenever it comes upon the beach and remains within control of the waves the southward movement is quite rapid. A very large amount of this sand is continually pouring round Cape Florida.

Undoubtedly this view of Prof. Shaler is quite correct, except that the operation of the forces mentioned is not necessarily postglacial. No doubt at various times more or less of the sand has been derived from the siliceous rocks, like the Altamaha grits or the buhrstone, of the Atlantic slope, all the way along its border. Artesian borings show that the formation of the sand, its position along the coast, and its general character have been pretty uniformly maintained throughout the whole of Cenozoic time; and while, no doubt, a large addition was made to the common stock of Atlantic sands during the glacial epoch, yet this was merely an incident in the history of operations which had been going on ever since the Cretaceous period, or at least ever since the Atlantic border assumed approximately its present form and trend.

On the northern part of the east coast of Florida the dry sandy border is quite narrow and largely consists of narrow, long islands where the sand has been elevated into dunes which reach a height in some cases of more than 50 feet, but which, owing to the torrential summer rains and rapid growth of vegetation in this semitropical clime, have generally lost the sharp wind-carved sculpture of dunes formed in a drier climate and have become more or less covered with vegetation. Inland the surface sands, whatever their origin, are usually much thinner, often only a few feet, and I have seen records of no boring which revealed the existence of over 20 feet of sea or white sand, while this I suspect to be very exceptional. References have been made to much greater depths away from the coast, but I have not seen any satisfactory proof of the correctness of such estimates. The average depth in sandy places in Alachua County seems to be between 6 and 20 feet. These figures refer solely to the superficial siliceous sea sands and not to the yellow sand proper or to the interbedded calcareous sands of Tertiary age.

[1] Shaler, Topography of Florida, p. 149.

PEREZONAL FORMATIONS.

There seems to be an absence, in geological nomenclature, of a term to indicate the region between the neutral zone where sediments are dropped in the sea near the beach and the point where subaerial erosion terminates. If we regard the land above the base level of erosion in the light of an earth-glacier, more or less liquefied by the action of water and discharging into the sea, the region I refer to constitutes the terminal moraine.

The "coastal plain," or coast peneplain, in so far as it has reached the base level, forms part of it; the beaches another part; the region between the beach and the neutral zone (generally marked by a bar or shoal) a third part. Yet the whole has a certain unity. It is subject to the operation of special forces which are forever at work. In the absence of great changes of level it might happen that the same region or area might remain, so to speak, ground as between upper and nether millstones by the erosive and marine forces for a period covering several geologic epochs. Such instances can be cited. The grist of this great mill is ground over and over, its waste is constantly supplied; it may contain the relics of several periods of geologic time. The greater portion of it will be unfossiliferous, the fossils preserved will be terrestrial or brackish water rather than marine. It will border on the sea, but its marine fossils where action is energetic will be rolled, worn, and triturated, out of recognition for the most part. Here and there a limited fauna will be preserved in lagoons or on oyster banks. It will happen that the material concerned in such areas may abut on synchronous beds containing an abundant fauna, but, owing to the lines on which the forces work, the synchrony will often be very difficult to prove.

Yet such deposits may extend about a whole continent with recognizable features derived from the forces which have been concerned in its formation. Almost everywhere it will be composed of the débris of other formations often lying directly upon them and containing some of their fossils in the rehandled material. When a special area has been subject for a short time to the forces exerted and by a change of level has been removed from the zone referred to, a mixture of the fossil fauna of subjacent beds will be almost certain to be included in the resulting formation. I believe that we have on our Atlantic border several formations widely extended and of this nature and the relations of which, owing to the reasons above indicated, are and are likely long to be in dispute. For the specific belt or margin, in which the abovementioned forces are active, and in whose characteristics the results of such forces are individualized I would propose the name of perozone.[1] I believe that the clearer recognition of special dynamic genesis as well as of the continuity inherent in the process, apart from important changes of level, which is implied in the adoption of a special term for the result

[1] From *peresus*, worn or wasted, and *zona*.

will be useful in our geological discussions. The thing itself has always been known, and its genesis more or less clearly understood, but its individuality at any stated epoch has, in the absence of a special name, not always been clearly exhibited or appreciated. The perezone will be for the seacoast analogous to, though not identical with, the peneplain of interior basins. The perezone of east Florida, so far as it is above water, is very narrow and becomes still narrower as we go southward. We are indebted to Prof. Shaler[1] for information which shows that a living coral reef borders the shore of the peninsula as far north as Gilbert's bar, 12 miles above Jupiter Inlet; that a former reef probably extended as far north as Mosquito Inlet, above Cape Canaveral, and that from Titusville on Indian River south to the head of Biscayne Bay an elevated beach of coquina defends the lowlands behind it. This beach is elevated some 20 feet above its original position. It presents a steep escarpment with indications that part of the cutting which formed it took place during the process of elevation, sea caves and other reentrants existing in the cliffs at a considerable height above the present plane of the sea and separated from the latter by a barrier of drifting sands. Southward from the head of Biscayne Bay as far as the parallel of Old Rhodes Key this reef of coquina is continued as an elevated coral reef with a height at Cocoanut Grove of 22 feet and a width of about 2 miles. To the whole barrier Prof. Shaler gives the name of the Miami Reef. It has suffered considerable loss by corrosive action and is honeycombed by subterranean water passages. He says:

The effect of this reef on the drainage of Florida is very great. Although the rivers at many points have found their way across the elevation, either by subterranean streams or through the low points of the barrier, it serves to retain the land waters, and to bring into the condition of swamp a large part of the peninsula. The St. Johns River and the extensive swamps in which it heads are in good part determined by the existence of this barrier.

In a less complete way the waters of Lake Okeechobee and of the Everglades to the south of it are prevented from finding a path to the sea by this natural wall. Thus, at Cocoanut Grove, Biscayne Bay, the waters of the Everglades at a distance of only 3 miles from the shore in their time of lowest level lie 16 feet above high tide. In the rainy season they often rise to such an altitude that they pour over the reef where it is less than 20 feet in height. * * * The rivers which flow over this part of the reef come down to the sea level over a series of rapids formed upon the harder layers of the reef, and thus the full escape of the Everglade's waters is prevented. In the region more to the north, the entanglement of the vegetation about the head waters of the streams likewise hinders the escape of the marsh waters.[2]

THE EVERGLADES.

The region of the Everglades has received but little examination in recent years. Prof. Shaler examined the southeastern margin as above cited. Mr. Joseph Willcox in the winter of 1887-'88 made a determined effort to penetrate into the region with a view of determining the char-

[1] Topography of Florida, pp. 148-150 and map.
[2] Ibid., pp. 143-144.

acter of the rocks. Whitewater Bay lies a few miles north of Cape Sable, and Mr. Willcox with his party, on a small craft drawing less than 2 feet of water, made many attempts to enter it without success, spending six days in the endeavor to find a navigable channel. They entered several passes between the islands and penetrated 10 or 12 miles east of the latter in several places, but found the water too shallow to proceed. Except sand bars thrown up by the waves no land was seen in this vicinity which was not covered at high tide. All the land consisted of muddy mangrove islands, the trees being much larger than any seen farther north. Where the tide runs rapidly between the islands it scours out channels 8 to 12 feet deep with a floor of hard rock, of which it was found impossible to get specimens. Except in these channels the bay is quite shoal, and covered with calcareous mud.

At the north end of Lostmans Key they entered the river of the same name and succeeded in penetrating 12 or 15 miles inland. No hard ground was seen except near the mouth of the river, and the highest land at the latter place was not over 3 feet above high tide. Wide, shallow bays, with muddy bottom interspersed with low, muddy mangrove islets comprised the whole scenery. The boat frequently grounded and was obliged to wait for the rise of the tide. A small fresh-water stream was finally reached, the current of which had scoured a channel 4 to 6 feet deep, with a rough, hard rock bottom, fragments or which were broken off. It consisted of large masses of Polyzoa more or less completely changed into crystalline limestone, the cavities filled with crystals of calc-spar. The rock is very hard and compact. The only mollusk or other organic matter, except the Polyzoans, which was discoverable in it was a single valve of the *Chione cancellata*, which is still found living in those waters and has existed there without perceptible variation since the early Miocene. Four or five miles within the margin of the Everglades no dry land was seen; only soft, wet soil, none of it a foot above the level of the water. From the top of a tree nothing could be seen to the east but a vast extent of such marsh land, which is said to be covered with water during the rainy season of summer and early autumn. Lostmans River is sometimes mapped as the Chittahatchee, and it enters the sea behind the Ten Thousand Islands in north latitude about 25° 30′.

Allens Creek, emptying into Walaka Inlet, an arm of Chukoliska Bay, was also visited. At a point 8 or 10 miles east from the Gulf of Mexico the party were able to land on soft, wet soil a little higher and drier than that at the head of Lostmans River. A third of a mile eastward from the head of the creek specimens were obtained of a few rocks which project above the soil. They presented molds of recent shells with the interior filled with calc-spar, and an occasional *Pecten dislocatus* or *Ostrea virginica* still retaining its shell structure. The cavities between the shells were filled with hard, coarsely crystalline limestone. The rock was not coquina modified, but looked more like a fossilized oyster reef. It contained no corals, and was obviously Pleistocene. The rock formed the base of small islets of drier soil amid the marsh, on which islets grew pine trees. The marsh, apart from these islets, is probably entirely submerged in the rainy season.

Another attempt was made to reach the interior by Corkscrew Creek, about 15 miles southeast from Punta Rasa. About 8 to 10 miles from the gulf was attained. The banks of this creek are dry pine land, rising 8 or 10 feet above the sea. The rocks here are the hard, ringing Eolian limestone, with recent land shells, perhaps a local equivalent of the yellow sand, such rocks as are found on both sides of the peninsula in many places and are of extremely recent origin.

The observations of Mr. Willcox thus appear to indicate, which indeed the known circumstances would have led us to expect, that no coral reefs have occupied this region. The outpouring of fresh water and mud must have rendered the region unsuitable for such animals, probably for a very long period, perhaps since the Gulf stream has occupied its present channel.

The deposit upon which the Everglades immediately rest, in this part at all events, is a recent organic limestone probably based on the Tertiary rocks which, farther north, are elevated above the sea. For it we may provisionally adopt the name of the Everglades limestone.

THE KEYS.

Of the structure of the keys, which has been exhaustively treated by Agassiz, it does not seem necessary to speak in this place. It may, however, be pointed out that much of the limy deposit of the area behind the reefs and defended by them is probably the result of the deposition of lime originally held in solution and precipitated by chemical action rather than of mechanically transported sediment.

It may be added that the large rivers represented on most maps as flowing out of the Everglades to the southwest have no existence in fact, as such. The streams in the dry season are all small, and most ot the outflow seems to be over the whole surface, which, during the rainy season, near the sea is totally submerged.

STRATIGRAPHY OF FLORIDA.

EOCENE ROCKS.

Vicksburg group: The Orbitoides limestone.—It has already been explained that the foundation of the peninsula, as far as known, is laid in a limestone belonging to the Vicksburg epoch, which, for uniformity and brevity, will be referred to here as the Orbitoides limestone, from the characteristic *Orbitoides mantelli*, which is found throughout the formation, associated with a variety of other foraminifera, *Pecten perplanus* Morton and *P. poulsoni*, as the most obvious and abundant fossils. The older name, Orbitolite limestone, by changes in nomenclature of the foraminifera has now become misleading.

Over a large part of the northern central portion of Florida the Orbitoides limestone forms the country rock, often rising to the surface or lightly covered with a thin coating of wind-blown sand or sandy soil. Its exact extent is not determinable at present, owing to the fact that it has been more or less confounded with later rocks of similar appearance and lithologic character but containing a different fauna. It varies in character, much of it as previously described, being loose and friable in texture when first excavated, porous and pervious to water. Other portions are much infiltrated with silex, which is deposited in smaller or larger masses or which is calculated to render a considerable portion of the rock cherty and extremely hard; others again contain a certain proportion of clay, as the Lake Worth borings show, the rock then being compact and impervious. As early as 1849 this rock was observed by Prof. J. W. Bailey, U. S. Army, who noted its character in several publications.[1] He found it in diggings from a well at Piles, a settlement 40 miles west of Palatka, on the road to Tampa, and noticed it at several points intervening between Palatka and Tampa. It has been noted by Prof. Eugene A. Smith[2] in Jackson County, in the northwest; also farther east, under a thin coating of Miocene deposits, at Live Oak (109 feet above tide), and possibly at Lake City (202 feet) the highest elevation on this line in northern Florida, whence it is believed to extend southward in the interior of the State to a point near the Hillsboro river not far from Richland, Pasco County.

The opinion of the older geologists that the country rock of the peninsula of Florida is essentially a southward prolongation of the Eocene limestone of Georgia was for a time obscured by the theories of coralligenous growth suggested by the observations of Agassiz and Le Conte on the keys and the extreme southeastern margin of the peninsula. To Smith in the paper above cited we are indebted for a substantial rehabilitation of the older theory, with modifications due to greater knowledge. But later observations again oblige us to modify to some extent the range assigned by Smith to this limestone, as it has become evident from the observations of Langdon, Heilprin, Willcox, Dall, Aldrich, Neal, Stanton, and others that beds of several distinct ages have been confounded in the general estimate. It is impracticable with the data yet printed to determine exactly at how many of Smith's localities the country rock belongs to the Orbitoides horizon. Some of them, doubtless, will eventually be shown to be of later age, as will be indicated later in this summary. Only those where no doubt seems to exist will be specified here. In Alachua County it is widespread, having been observed by Smith and Dall at Gainesville and westward to and about Archer, though in many places overlain by solutionary residuum, remnants or even beds of later age but moderate thickness. It

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[1] Smithsonian Contr. Knowl., 1850, vol. 2, No. 8, p. 19; Am. Jour. Sci., 2d ser., 1851, vol. 2, p. 86. He speaks of it as the "white Orbitulite limestone."

[2] Am. Jour. Sci., 3d ser., 1881, vol. 21, pp. 299, 300.

had been identified at Silver Spring, 6 miles east from Ocala, by Le Conte, as early as 1861,[1] and subsequently the observation has been confirmed by Smith. Specimens of this rock have been collected by Willcox at Martin station, Marion County, about 8 miles north of Ocala, where the rock is very cherty; and at Jarves's Spring, on the southern border of Pasco County; at Fort Foster, on the North fork of the Hillsboro River, where, as in many other places, relics of the old Miocene beds overlie it. Several of the localities referred to by Heilprin must remain for the present on the doubtful list, but among them should hardly be counted the islet at the mouth of the Homosassa River, from which Mr. Willcox obtained the *Pygorhynchus* (*Ravenelia*) *gouldii* Bouvé, a small echinoderm originally described from the buhrstone (ante-Claibornian) of Georgia. If the identification be correct, which I do not doubt, one would hardly expect this species to appear in the so-called "Oligocene."

The thickness of this formation is very considerable in Florida. At Salt Mountain, in Alabama, excluding the still doubtful "coral-limestone" of Smith and Johnson and the "Jackson" beds below the Orbitoides limestone, the latter has a thickness of only 140 feet. But in northern Florida, west of Gainesville, according to reports from L. C. Johnson, artesian borings have started at the surface in the "Vicksburg," and have been drilled over 350 feet without finding any other rock or reaching the clayey layer of the Orbitoides rock (which is impervious) so as to obtain any water. On the eastern side of the peninsula, much farther south, at Lake Worth, an artesian well, after passing through a mass of talus in which the recent coquina was sometimes overlain by Miocene rubbish, etc., finally reached the solid Orbitoides rock at a depth of 1,000 feet, and penetrated it without finding any change for 212 feet, when, abundance of water having been obtained, the drilling was pushed no farther. In the Jacksonville well, though carried to a depth of 900 feet, the Eocene rocks were not recognized and perhaps not reached, offering a strong contrast to the well at Charleston, where they were encountered at a depth of 60 feet and penetrated for a depth of 330 feet before the Mesozoic strata were attained. At St. Augustine, south-southeast from Jacksonville, the Vicksburg limestone was encountered at a depth of 212 feet, and the boring was still in them when it ceased at about 1,278 feet.

Nummulitic beds, Ocala limestone (*Oligocene of Heilprin*).—Among the rocks which until recently were not discriminated from the Orbitoides limestone, and which appear in central Florida directly and conformably to overlie the latter, though no one has described their contact, is a yellowish friable rock containing many foraminifera, conspicuous among which are two species of Numulites, *N. willcoxii* and *N. floridana* Hp. This rock was first brought to notice by Mr. Joseph Willcox, and to Prof. Heilprin we owe a description of it which discriminates

[1] Am. Jour. Sci., 2d ser., 1861, vol. 21, pp. 1-12.

between it and the Vicksburg or Orbitoides rock. The rock was early recognized as Eocene, though not discriminated from the earlier beds. It is best displayed at Ocala, Florida, where it forms the country rock, and has been quarried to a depth of 20 feet without coming to the bottom of the beds.

Dr. John Le Conte, in 1861,[1] speaking of the portion of the peninsula about Ocala, says that it is "composed of a mixture of sand and shell limestone, probably of Eocene age." Four years later Conrad[2] refers to some fossils from the Ocala limestone received by Prof. Cook of New Jersey. He specifies *Globulus* (*Natica*) *alveatus*, *Venericardia prima* and *Dosiniopsis alta* as belonging to the Eocene of California, Maryland, and New Jersey, and refers the formation to the epoch of the New Jersey Shark River Eocene marls. Mr. Willcox has since visited the quarry at Ocala and rediscovered some of these species, as well as *Aturia alabamensis* and a number of other Eocene species, most of which are common to the Vicksburg limestone as far as identified, and others to Lower Miocene rocks, such as those of Tampa and the Chipola beds.

The original discovery of the Nummulitic stratum, by means of which it was discriminated from adjacent beds, was made by Mr. Willcox at a clearing known as Loenecker's, on the Cheehowiska or Chassahowitska River, where it occurs in fragments more or less enveloped in a Pleistocene sand rock containing recent land and fresh water shells. Since then Mr. Willcox has obtained the rock in place 15 miles northeast of the original locality, from the shore of Waccassee Bay, near Cedar Key, and also from the banks of the Wacassassa River, Levy County; from a "sinkhole" at Pemberton's Ferry on the Withlacoochee River, about 10 miles eastward from Brookville, and also at Bayport, Hernando County, and at various places about Ocala. Prof. Wetherby has also sent specimens from a well 5 miles southwest of Gainesville, Alachua County, and Mr. L. C. Johnson reports it from an old Confederate iron furnace 3 miles northwest of Levyville, Levy County[3], where it is only 20 feet thick, and is covered with a bed of bog-iron ore formerly worked. Pemberton's Ferry is the most southern point at which it has been recognized at the surface, but at Bartow, Polk County, it occurs covered by about 6 feet of later strata.

Miliolite limestone.—A rock observed on the Homosassa River by Prof. Heilprin is practically horizontal and rises 2 or 3 feet above the water at low stages of the water, on the left bank of the Homosassa at "Wheelers" about 1 mile above the river mouth. It has also been collected by Neal 6 miles southwest from Lake City. It is a tough limestone, full of foraminifera, mostly belonging to the *Miliolidæ*, for which Prof. Heilprin proposes the name of Miliolite limestone. Its distinctness from the other foraminiferal limestones of this region is hardly established as yet.

[1] Am. Jour. Sci., 2nd ser., vol. 31, p. 11.
[2] Proc. Acad. Nat. Sci. Phila. for 1865, p. 184.
[3] SE. ¼ Sec. 28, T. 11 S., R. 15 E.

From what precedes it will be noted that the Nummulitic beds occupy, as far as known, a very limited area from the vicinity of Gainesville on the north to Pemberton's Ferry on the south, extending from Ocala westward nearly but not quite to tide water. These rocks, Nummulitic, Miliolite, etc., as regards most of their fossil contents are hardly to be separated from the Orbitoides limestone and must certainly be regarded as forming part of the Vicksburg group.

The layer of siliceous foraminiferal Eocene, overlying the typical Orbitoides limestone, which has been recognized by Burns in Pulaski County, Georgia, at Hawkinsville, and southeastward across the remainder of the local Eocene belt; and by Dr. Neal in a similar situation at White Springs, on the Suwanee, in Hamilton County, Florida, is with little doubt the analogue and representative in these localities of the Nummulitic and Miliolitic areas of central Florida.

It may be added that vertebrate remains belonging to the cetacean genus *Zeuglodon*, or, possibly, to *Squalodon*, were discovered by Mr. Willcox in the Nummulitic rock of the Ocala quarry, thus adding another indication of the close faunal relations of the Nummulitic with the preceding post-Claiborne beds.

There is little doubt of the correctness of Prof. Heilprin's contention that these rocks are the analogue of the so-called Oligocene of the West Indies and of northern Europe. But, while this may be admitted, the propriety of regarding the group or series as constituting a distinct epoch, equivalent to or analogous in value to the Eocene, Miocene, or Pliocene epochs, which would be inferentially granted by adopting for them the term Oligocene, is a very different matter, and in Florida receives no justification from the paleontological evidence.

From Dr. J. C. Neal, of Lake City, Florida, we have specimens of the uppermost rock stratum at Branford, on the Suwanee. It is interesting as being of a character not common in Florida, namely, an extremely fine grained, pulverulent sandstone, apparently chiefly composed of particles of organic silica in a state of very feeble cohesion. It contains impressions of very numerous foraminifera and of a small *Pecten*, perhaps *P. perplanus* Morton, and should probably be referred to the horizon of the Ocala limestone or Nummulitic beds, though of a different lithological character from the beds of that age hitherto known.

In the foregoing brief account of the Floridian Eocene the writer may, perhaps, somewhat have overstepped the limits assigned to him. But, for a clear understanding of the Neocene series in this region it seemed necessary to do this, and the recapitulation of matters elsewhere treated of by Prof. Clark, will have done no harm, while its presentation in this connection seemed indispensable.

MIOCENE ROCKS.

Chattahoochee group: Ocheesee beds.—The Miocene rocks of Florida present, lithologically and petrographically, a series entirely analogous to the calcareous, siliceous, ferruginous, phosphatic, and clayey beds of the Eocene, but with a greater variety of strata in the same thickness. This indicates less uniform conditions and probably more numerous changes of level. In this respect the Miocene of Florida presents a contrast to that of the Antilles, where, according to Cleve,[1] the Miocene was a period of calm, regular deposition, without notable orographic disturbances, though such disturbances have left distinct traces in the Eocene strata and were again experienced in post-Miocene time.

Another feature which is noteworthy, even with our present imperfect knowledge, is the restricted area of many particular beds, which in some sections attain a considerable thickness, while other sections, without indicating uncomformities, show no traces of these special strata.

In 1887 Langdon[2] observed a group of beds on the Chattahoochee River overlying the Orbitoides limestone at a point 9 miles above River Junction, or Chattahoochee, and traced it southward by the river to Ocheesee and Rock Bluff, 17 miles below the railroad bridge at River Junction, where it dips below the Miocene beds, which are exposed at Alum Bluff, 8 miles farther down the river. At Ocheesee there were visible above the water 5 feet of creamy white granular limestone with obscure fossil corals, surmounted by 10 feet of greenish yellow unfossiliferous argillaceous limestone. At Rock Bluff 30 feet of limestone, in strata of varying purity, are exposed. These limestones are slightly phosphatic, and by disintegration afford a rich black loam characterized by the growth of *Torregia taxifolia*, the so-called "stinking cedar." The beds as a whole are more siliceous and argillaceous than those of the Orbitoides limestone, and were estimated by Langdon to have a total thickness of 250 feet, who referred them to the newest member of the Eocene or the oldest of the Miocene, under the name of the "Chattahoochee group." The same rocks were observed by Mr. Burns, of the U. S. Geological Survey, in the adjacent portion of Decatur County, Georgia; at a locality on the railroad 3 miles east of the bridge over the Chattahoochee River, Florida;[3] and below the Chipola marl, near Baileys Ferry, Chipola River, westward from Alum Bluff, Langdon obtained from these beds a large *Pecten* and an oyster resembling the recent *Ostrea virginica*. Burns, at the locality mentioned, obtained a small number of fossils, among which were 22 species identifiable with those of the Tampa Miocene, including *Pyrazisinus cornutus*, *Cerithium hillsboroensis*, *Potamides transecta*, *Conus planiceps*, *Natica amphora*, *Lucina hillsboroensis*, *Cardita serricosta*, *Venus staminea*, *V. cancellata*, *V. penita*, *Cytherea nuciformis*, *Cyrena vesica*, and *Orbitolites floridanus*. Three or four other species were identical, or probably so, with Chipola species and two were not known, a *Tagelus* and *Solen*.

There were also obscure corals and one *Echinus*. The condition of

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[1] Agassiz, Three Cruises of the Blake, vol. 1, p. 109; and Kong. Svenska Vetensk. Akad. Handl., 1871, Bd. ix, No. 12.

[2] Am. Jour. Sci., 3d ser., 1889, vol. 38, p. 324.

[3] Here his collection was made.

these fossils is poor, but they are sufficiently identifiable in all the cases above specified to speak with confidence, and in most of them with certainty.

From the general trend of this limestone, its considerable thickness on the Chattahoochee and Appalachicola rivers, and its numerous sink-holes, ponds, and natural bridges about the Chipola River, it (and not the Orbitoides limestone, as was supposed by Smith and others) is doubtless the country rock over a considerable part of northwestern Florida.

In the vicinity of Tampa, especially in the rock forming "the bed of the Hillsboro River," Heilprin, in 1886, discovered *Cerithium hillsboroensis* in large numbers.[1] This rock is variable in character, but all the specimens I have seen of it are friable and of a creamy yellow, or even somewhat ferruginous tint. The mass originally collected by Heilprin, which I have examined, is chiefly filled with the molds of this *Cerithium*. Specimens subsequently obtained from Magbeys Springs and submitted to me by Mr. Willcox, and others personally collected, undeniably belong to the Tampa limestone, though most of its fossils are identical with some of those above cited as collected by Burns from the Chattahoochee limestone. Although no one has yet established the existence of a Miocene rock under the Tampa silex beds or described their contact, yet there can be little doubt that such a rock should underlie the Orthaulax bed (by which name, for clearness, I shall hereafter denominate the Ballast Point silex bed proper) at Tampa, just as the Chattahoochee limestones underlie the Chipola marl at Alum Bluff. In other words, the equivalence of such a rock, if it exists, with the fossiliferous stratum of the Chattahoochee group from which Burns obtained his fossils must be conceded, as well as the reference of both to an older horizon than the Orthaulax bed, which is thereby implied. Thus the truly Miocene character of the Chattahoochee group is established.

But these beds do not everywhere represent the lowest member of the Miocene system. Of the artesian boring at Tampa, which would have given us the succession and thickness of the rock, unfortunately no data are preserved.

Hawthorne beds.—From the unpublished reports of L. C. Johnson, of the U. S. Geological Survey, it is gathered that in the interior a different or rather a more comprehensive succession of beds is the rule. In 1885 the writer was able to confirm by personal observation in Alachua

[1] The account given by Heilprin is extremely obscure. He speaks of the "hard siliceous blue rock, charged with Cerithium," which appears at Ballast Point and along the banks of the river. But the hard blue rock of the silex beds does not contain *C. hillsboroensis;* the species with which it is charged is Prof. Heilprin's *Pyrazisinus campanulatus*. and the rock from which he described and figured his *C. hillsboroensis* (as is evident on an examination of the specimen) is neither "hard" nor "blue," though in places the bed is, like nearly all the Floridian limestones, more or less permeated with silex. In Heilprin's Cerithium rock, which is probably a phase of the Tampa limestone, the shells are represented by molds. In the silex bed proper they are represented by siliceous pseudomorphs, among which five years' work of a half a dozen good collectors has so far revealed not a single specimen of *C. hillsboroensis*.

County the presence of beds of phosphatic rock, more or less broken up and inclosed in a younger matrix overlying the Vicksburg limestone at the "Devil's Millhopper," near Gainesville, and afterward to observe remnants of the rock in place on the hilltops near Archer and Arredondo, as well as the presence on top of the Orbitoides limestone, where the latter formed the surface of numerous silicified pseudomorphs and fragments of fossils belonging to the phosphatic rock above mentioned.

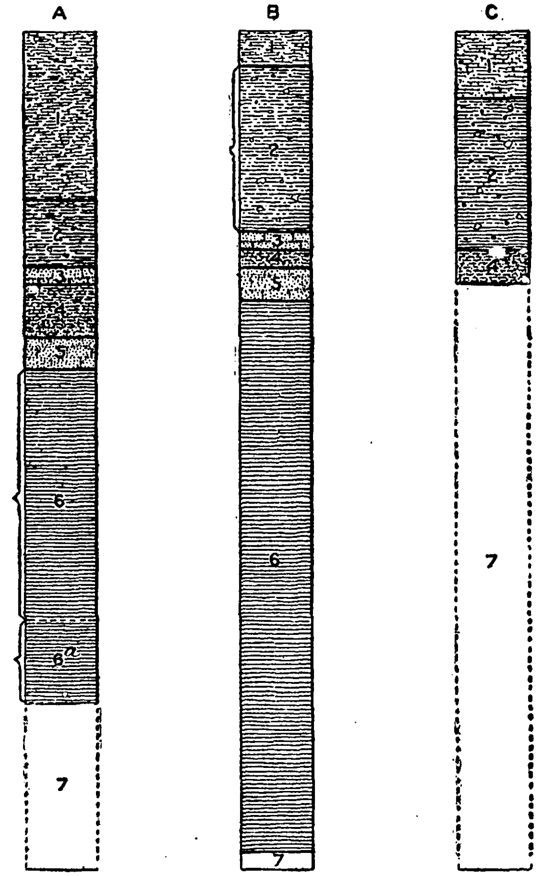

FIG. 21.—Sections in Central Florida, illustrative of Hawthorne beds. A, Nigger Sink; B, Newnansville well; C, Sullivan's hammock. 1, surface sand and loam; 2, phosphate rock; 3, soft sandstone; 4, ferruginous gravel; 5, sand or sandstone; 6, greenish yellow clay; 6a unexposed; 7, Vicksburg rock.

The latter at the time of my visit was being quarried and ground up as a fertilizer at Hawthorne, where the beds have a considerable thickness. For this reason I referred to these beds in my unpublished report as the "Hawthorne beds," and to the chief facts of their occurrence in a paper read before the National Academy of Sciences in 1887.[1] This name will therefore be adopted here for convenience in reference to the beds about to be described. Johnson has obtained several clear sections illustrating these beds, which are here graphically reproduced.

[1] Am. Jour. Sci., 3d ser., 1887, vol. 34, p. 164.

Mr. Johnson finds that the greater part of the phosphatic deposit at the Devil's Millhopper and to some extent at Hawthorne has been washed away and the rest more or less broken up. A natural sink in the midst of the phosphatic area, Downing's field, near the Natural Bridge of the Santa Fe River, Alachua County (Sec. 18, T. 7 S., R. 18 E.), affords a good section (A). This place is locally known as "Nigger sink," and the Vicksburg limestone has been reached by a well hole in the center of it. Above the well the lower 10 feet of the wall of the sink is hidden by talus, but is believed to be clay of a greenish yellow color, 30 feet of which rises above the talus, covered by a four-foot layer of firm, hard sand, almost a sandstone, and this by a sandy ferruginous layer of clay and gravel containing an oyster, like *O. virginica*, reproduced in chalcedony. This ferruginous layer, which will be referred to here under the term ferruginous gravel, seems to appear in many different sections, with its oyster and silicified corals. It also occurs in Georgia. Above it is a layer 2 feet thick of soft sandstone resembling the phosphatic rock in appearance. Covering this is a bed of sand and clay 8 feet thick containing fragments of all sizes, from a few pounds to a ton in weight, of the phosphatic rock and its large, silicified coral heads. These last, when they appear on the surface as around Archer, from the solution of the phosphatic matrix are popularly known as "fossil stumps" or "nigger heads." They are large masses of chert or chalcedony, often hollow, retaining on the surface more or less obscure indications of the original coral structure. Above this stratum come the surface sand and loam, here about 20 feet thick.

At a well near Newnansville (section B) another section was obtained by Mr. Johnson. Here 70 feet of the greenish clay overlies the Vicksburg rock, but otherwise this resembles section A, except in the following particulars: The ferruginous bed is only 2 feet thick, and 3 feet above it comes a bed 8 to 20 feet thick of solid phosphatic rock in place, with but little alluvium over it. For some distance north and east of the well this rock forms the surface of the hill. At Sullivan's hammock (Section C), 5 miles east of Mixons, in the same region, the cherty Vicksburg rock mixed with clay seems to begin immediately under the ferruginous stratum, which is surmounted by the phosphatic rock covered under a moderate depth of loam. Near Archer the phosbatic rock remains here and there on the hilltops as remnants, directly on the Orbitoides limestone, the greater portion having been dissolved away by rain and percolating water, as is also the case in Decatur County, Georgia. A similar rock with the characteristic coral heads occurs near Pasco County near the point where the South Florida Railway crosses the the North fork of the Hillsboro River, and also 1½ miles northeast from Jarve's Spring, in the same vicinity. At De Leon Springs, on the St. Johns River near Lake Helen, Volusia County, Mr. T. H. Aldrich reports a bed of well preserved Chipola fossils overlying phosphatic rock doubtless of this same horizon. The water table reached by the artesian borings near Lake Worth at a depth of about 900 feet—which 100 feet below gives place to the Orbitoides limestone—is probably formed by the impervious clays, gravel, and phosphatic rock of this group of beds, which here and in other places is covered by beds of pervious sand.

A ferruginous bed, with oysters, directly overlies the Nummulitic bed near Levyville, Levy County. At Magnesia Springs, near Hawthorne, the water comes out from under the phosphatic rock and brings with it numerous specimens of the silicified oysters which lie in the mud at the bottom of the springs. Specimens have also been received by the U. S. Geological Survey from Live Oak, Suwanee County, and Lake City, Columbia County, in the northern part of the state, where, according to Johnson, the same phosphatic rock occurs. This information has been confirmed by specimens subsequently forwarded by Mr. Stanton and Dr. J. C. Neal, of the Florida experiment station at Lake City. We are indebted to Dr. Neal, for data showing the character of the Miocene deposits in that vicinity, and along the Suwanee River between Hamilton and Columbia counties.

At White Springs on the Suwanee the following section was obtained:

		Feet.
I.	Gray soil, sand, and humus	2
II.	White sand	4
III.	Clay with silicified corals and oyster (Hawthorne beds)	6–8
IV.	Indurated clayey rock (Hawthorne beds?)	2
V.	Clayey sand-rock, rather fine grained and soft	4
VI.	The same, somewhat coarser and harder	8–10
VII.	Sand rock of coarser sharp grains, coated and cemented together with white limy matter	4–6
VIII.	Foraminiferal Eocene top-rock (Vicksburg) indefinitely below.	

The silicified corals of bed III are sometimes 20–60 pounds in weight and along the river when dislodged from the clay often wear immense pot holes in the softer lime rocks. Miocene sharks' teeth and fragments of bone also occur in the clay. Under bed VIII, when it is tilted up, as occurs in various places along the river, is found the older Orbitoides limestone of the Vicksburg group.

In a sink 4 miles north of Lake City the following section was observed:

		Feet.
I, II.	Sand and sandy soil	5
IV.	Indurated clayey rock	2
VII.	Lime cemented sand-rock	8
VIII.	Foraminiferal Eocene (indefinitely down).	

Two miles south of Lake City:

		Feet.
I.	Sandy soil	2
III.	Clay, with corals and oysters	20
VII.	Lime cemented sand-rock	3
VIII.	Foraminiferal Eocene (indefinitely below).	

Near the southern boundary of Columbia County, at Fort White, the rocks are gently folded and the surface has been more or less worn into basins containing phosphatic breccia of the older lime rocks, which are themselves under these basins of phosphate slightly phosphatized in their upper portions. Here, owing to the fact that the Miocene and Foraminiferal Eocene (Miliolite) beds have been more or less broken up by the action of water dissolving or wearing away the softer parts, the Orbitoides limestone sometimes immediately underlies the breccia in the basins and in other places the basins are composed of the Miliolite limestone. Beds VI, VII, and VIII, of the above series are more or less silicified, or when broken up the resulting breccia contains numerous angular fragments of chert.

The Suwanee strait.—The argillaceous deposits which are comprised in the Hawthorne beds appear to have been laid down toward the southern margin or the Suwanee strait, which separated the continental border from the Eocene and Miocene islands representing Florida at that epoch. Farther to the north and west the rocks indicate deeper water, contain less clay, and have a much more abundant and characteristic Old Miocene fauna. The data which have conclusively shown this were obtained by Mr. T. W. Stanton, of the U. S. Geological Survey, since much of this paper was in manuscript, and are detailed at another place. The northern border of the strait appears to have been the site of deposition of a different, more siliceous material, which resulted in the formation of the beds elsewhere referred to as the Altamaha grits of Georgia.

Old Miocene phosphatic deposits.—These rocks were among those referred by Johnson to his Waldo formation,[1] though the typical exposure at Waldo belongs to the newer or Chesapeake Miocene.

There is no doubt that the sources of phosphoric acid, through the existence of which the phosphatic rocks of Florida were made possible, were not confined to any one epoch. Rocks of unmistakably recent (Pleistocene) origin, containing sometimes remains of man, often reveal perceptible quantities of phosphoric acid on analysis. On the other hand, the leaching process to which the rocks are subjected from the semitropical rainfall has carried the precious substance into the Eocene limestones when they were adjacent and of a nature to absorb and retain it. Mr. Darton has collected unmistakable Orbitoides rock, which is mined for fertilizer and presents a large percentage of phosphoric acid, while much of the richest phosphate rock is of Pliocene age.

But when all these allowances are made the fact remains that certain lower Miocene strata below the Chipola beds, though not the richest in phosphoric acid, yet, as far as known, are more generally phosphatic than any other single group of rocks in the state, and that this condition is to some extent characteristic of them.[2] The following table will

[1] Am. Jour. Sci., 3d series, 1888, vol. 36, p. 234.

[2] Cf. George W. Hawes on a phosphatic sandstone from Hawthorn, in Florida. Proc. U. S. Nat. Mus. for 1882, pp. 46–48.

exhibit our understanding of the relations of the different beds considered as a whole, up to the base of the Chipola beds.

Miocene, Chattahoochee group	Ocheesee beds	Cerithium rock (Tampa)?.
		Chattahoochee limestone.
		Water-bearing sands.
	Hawthorne beds	Phosphatic oolite.
		Ferruginous gravel.
		Greenish clays.
Eocene, Vicksburg group	Nummulitic beds	Miliolite limestone.
		Ocala limestone.
	Vicksburg beds	Coral limestone (Salt hill)?.
		Orbitoides limestone (Vicksburg).
		White limestone (Jackson).

It is of course understood that these beds are never all present in any one section, and when their respective faunas become known parts of some of them will perhaps be found to overlap. While much of the fauna of the upper beds of the Chattahoochee group survives into later strata, and no marked unconformity has been shown to exist at the base of the Chipola, yet the lithologic and faunal differences appear sufficiently well marked to retain, at least for the present, the Chipola beds in a group by themselves.

Tampa group: Tampa, Chipola, and Alum Bluff beds.—Tampa Bay was the theater of the earliest identification of Miocene rocks in Florida, those of Conrad [1] in 1846. In the same year and journal in which Conrad's account was made public Prof. John H. Allen [2] briefly but accurately characterizes the rocks of the region about Tampa City, discriminating the siliceous rock (Orthaulax bed) and the Tampa limestone, and assigning them to their true relative situation, stratigraphically. His account in this particular is better than Conrad's and more clear and correct than anything since published, previous to the investigations of the U. S. Geological Survey in 1887. But, like others who have made brief explorations in Florida up to a recent period, he did not discriminate between the lithologically similar surface limestones of Florida elsewhere, and his observations are accurate only for the region above mentioned.

The Miocene rocks of Florida above those forming the Chattahoochee group and below the upper fossiliferous bed at Alum Bluff, I include in the group, which from their oldest known typical exposure, I name the Tampa group. This may be divided into three sets of beds, the Chipola beds (including the Sopchoppy limestone, the Orthaulax bed, Bailey's "infusorial earth," the White Beach sand rock, and the Chipola marl or lower bed at Alum Bluff); the Tampa beds (including the Tampa limestone) and the Alum Bluff beds, or unfossiliferous sand and clay strata intervening between the Chipola marl and the upper fossiliferous bed at Alum Bluff. The latter belongs to the Upper Miocene, or Chesapeake group, similar to that of South Carolina, and the later beds of North Carolina, Virginia, and Maryland.

[1] Am. Jour. Sci., 2d ser., 1846, vol. 2, pp. 36-48; 399-400.
[2] Ibid., vol. 1, pp. 38-42.

The following sections will illustrate the succession as observed at different localities:

Alum Bluff.	*Tampa.*	*Manatee River.*
Yellow unfoss. sand, 70 feet.	White sand, 6 to 24 inches.	White sand, (?)
	Yellow sand, 6 to 36 inches.	Yellow sand, (?)
Lignitic sand, 10 feet.	Pliocene breccia, traces.	
Ecphora bed, 30 feet.		Ecphora bed, 24 to 36 inches.
Alum Bluff beds, 15 feet.	Tampa limestone, 10 to 15 feet.	
Marl (Chipola), 5 feet.	Orthaulax bed, 6 to 10 feet.	Orthaulax bed, (?)
Chattahoochee limestone(?)		

At Ballast Point, Tampa, while repeating the researches of Conrad and others, the following notes were taken by the writer in the winter of 1886–1887: [1]

The Orthaulax bed.—The rock rises but a few feet above the beach. Two layers may be distinguished, especially by their fossils, for the rocks are so broken up that the superposition of the newer layer here is less clear than I found it farther inland. The older rock is composed of a limestone, which in some places is so impregnated with silex as to form an almost pure flint; and at other spots retains its limy character, or is decomposed into a marl of peculiar tenacity. In many places the marl occurs in pockets surrounded by or covered with chert. In other spots it forms the greater part of the bank, and in this condition was termed by Bailey "infusorial earth;" but, however different in character, the chert and marl are merely parts of one stratum which has been subjected to different chemical processes in its different parts, and not to two strata or beds. In the chert the fossils, of which the rock is full, have disappeared, leaving cavities from which their forms may be reproduced by molding in gutta-percha. In the marl they have also disappeared, but in favorable spots the smaller ones are represented by more or less perfect pseudomorphs of subtranslucent silex, reproducing every detail of the original shell. The larger ones, such as heads of coral, retain their outward form, but are usually mere shells with an interior of botryoidal chalcedony, often of great beauty. The fauna of this bed has been elucidated by Heilprin and to some extent by the writer. It is characterized especially among other things by the presence of the singular Stromboid genus *Orthaulax*, for which reason I have called it the Orthaulax bed. The more usual expression "Tampa silex bed," owing to the presence of silex in other beds of different age near Tampa, is less explicit and desirable.

This stratum was also recognized by Conrad[2] in the bed of a rivulet a few miles up the Manatee River, "near the shore of a creek having a very narrow entrance, but which widens above, and about 1½ miles up contracts again, then expands into a beautiful basin with tables of rock bordering the shore. * * * Above this is a buff-colored lime-

[1] Am. Jour. Sci., 3d ser., 1887, vol. 34, pp. 165, 166.

[2] Ibid., 2d. ser., 1846, vol. 2, p. 45.

stone without organic remains, about 1 foot thick. This spot is the limit of tide water." He also traced the same rock to the rapids or falls of the Hillsboro River about 9 miles above its mouth, as Allen also did, as well as later explorers. This locality is 14 miles or so northward and eastward from Ballast Point and Mr. Burns has collected the silicified fossils at various intermediate points along the bay shore. I found the same rock and fossils on Six Mile Creek at the head of navigation, near Orient station, about 6 miles to the eastward of Tampa, on the South Florida Railway. At Ballast Point the fossils are chiefly marine, but there is a certain admixture of land shells which becomes more pronounced toward the top of the bed, indicating a gradual increase of the adjacent land area during the deposition of the bed. Finally, in some places on the upper surface, nothing but land shells are found, showing that, at last, it became dry land, at least in certain spots.

These land shells are all of extinct species, allied more nearly to those of the West Indies than to the present fauna of the Southern States. A small bulimoid shell has been, I think incorrectly, referred to the Pacific genus *Partula*, which it somewhat resembles, as observed by Conrad forty years ago. But it is probably more nearly related to certain recent bulimuli of the North American, Antillean and South American recent faunas. The same rock, beside extending northward to the head of Hillsboro Bay, crops out on the other side of the peninsula which separates the latter from Old Tampa Bay. Specimens of the fossils were collected here by Mr. Burns. It extends up the Hillsboro River at least as far as the rapids, while silicified corals are reported from a point 25 miles above the mouth of the river at the crossing of the Florida Central Railway, in Pasco County, which may be of the same age. Siliceous fossils of the same character are reported to have been collected at Clearwater on the Gulf coast of Hillsboro County, west of Old Tampa Bay, and it is not improbable that the same rock occurs at the mouth of the Pithlachascootee River, Pasco County, somewhat farther north, a specimen of *Pyrazisinus* having been collected there by Heilprin. A specimen of the *Orthaulax* has been collected by Matthew Hooper on the shore of Sarasota Bay, showing that the same bed exists there.

White Beach sand rock.—A little farther south, again, in the northern and western extreme of the Little Sarasota Bay is a locality known by the name of White Beach, which was visited by Messrs. Willcox and Heilprin in 1886 and by Mr. Willcox and the writer the following year. It consists of an outcrop of rock which rises two or three feet above high water. It is a yellowish limestone, much waterworn and covered in places with a thin layer of recent sand rock. It contains distorted molds of many species which can not be recognized, but in some places these molds have become filled with a pseudomorph in lime of the original shell. These pseudomorphs are gradually exposed by the action of the sea on the rock, and afforded about forty species of molluscan fossils, besides several corals and corallines. The rock did not show any foraminifera, though several of the species of shells are identical with those of the orbitolite stratum of Tampa.[1]

While all the species collected here have not yet been determined, about half of them have been studied sufficiently to show their near equivalence to the *Orthaulax* bed of Tampa and the Chipola marl bed of Alum Bluff. Several peculiar species are common to them and several others to the Antillean Miocene. On the whole, while the White Beach fauna is too imperfectly known for dogmatism, it would seem probable that it does not greatly differ from that of the *Orthaulax* bed, is certainly to be included in the Tampa group, and may possibly be a little younger than either of the beds above mentioned. More thorough study has shown that the first impression, that this horizon is not far removed from the Caloosahatchie Pliocene, is untenable, since we now know that the whole of the Chesapeake group, at least, must intervene between the two horizons.

The White Beach bed is covered with a thin coat of Quaternary indurated sand containing recent land shells, and extremely hard.

This is the most southern point, so far, at which Miocene strata have been observed to crop out in Florida; but on Shell Creek, a tributary of Peace Creek, in about latitude 27° north, draining into Charlotte Harbor, Mr. Willcox found a specimen of *Vasum haitensis* Sby., which is a shell described from the Antillean Miocene, and probably, if correctly identified, indicates the presence of beds of the Tampa group in this vicinity.

I have referred to the presence of *Orbitolites floridanus* Conrad in rocks of the Chattahoochee group. It is also found silicified, though not abundant, in the *Orthaulax* bed from which Prof. Heilprin supposed it to be absent.

Bailey's infusorial earth.—To return to the Tampa section: it is to be noted that at one point on the bay shore between Ballast Point or Newman's Landing and the mouth of the Hillsboro River the marl associated with the siliceous fossils, forming a phase of the *Orthaulax* bed, rises above the beach to an estimated height of 10 feet. Here Mr. Burns, of the U. S. Geological Survey, Col. Bartholomew, of Tampa, and others have collected fine series of silicified fossils. At this point Prof. J. W. Bailey, U. S. A., discovered what he regarded as a bed of infusorial earth resembling that of Virginia in its lithologic character. Of this he says:[2] "Directly on the shore of the bay I detected a highly interesting stratum of fossil marine Diatomacea or Infusoria. It is exposed for at least a quarter of a mile, and from 5 to 10 feet of its thickness may be seen. In its external characteristics (whiteness, lightness, fissility, etc.) it has some resemblance to the infusorial

[1] Dall, Am. Jour. Sci., 3d ser., vol. 34, p. 167.
[2] Microscop. Obs. Smithsonian Contr. Knowl., 1850, vol. 2, No. 8, p. 10.

strata of Virginia, but is much more indurated, so that although it is easy to show that it is made up of the remains of Diatomacea, spicules of sponges, etc., it is difficult to isolate and determine the individual specimens. This infusorial earth, like that at Petersburg, Va., changes in a singular manner to a salmon color when exposed to the vapor of turpentine or Canada balsam." This bed has not, as far as we know, been examined since Prof. Bailey's visit, and in order to determine its position, stratigraphical and lithological, it was visited by the writer in January, 1891.

The most marked exposure is locally known as Conklin's Bluff, and is situated on the western shore of Hillsboro Bay, about a quarter of a mile above a long wooden pier belonging to a Mrs. Chapin, and a mile and a half north of Ballast Point. It is a steep bank 6 or 8 feet above high-water mark, and is the only place on this shore between Ballast Point and Tampa which at all corresponds to Bailey's description. The land along this shore is mostly low and the beach soft and muddy or sandy, but there are a few places where the *Orthaulax* bed rises above high-water mark. The rock is like that at Ballast Point. The shells are often represented by molds in the chert, but there are pockets of putty-like marl which contain the siliceous pseudomorphs and small nodules of chalcedony.

Bailey's white bed consists of a deposit of this marl, which elsewhere occurs in pockets in the harder rock, but here for a few hundred feet appears in sufficient quantity, by itself, to be regarded as a bed. Some of the material is pretty hard, but all of it is fissured vertically and horizontally into a profusion of angular fragments. The lower layers are the hardest and rest on siliceous rock of the *Orthaulax* bed, of which this must be regarded as merely a very local phase. At this place the marl is nearly destitute of fossils. The few which occur are nearly all small branches of coral; much of it has no fossils. The lower part is of a gray or pale green hue, bleaching when dry, as in the upper layers, to white. It also becomes softer and more fragmentary. It is penetrated by roots to a depth of 2 feet, and a piece large enough to form a good specimen can be found only low down in the bed, and then in drying will break into numerous fragments. The average thickness of the bed may be 3 feet, the maximum 6 to 8 feet. In one place it is covered by a thin layer of æolian sand rock discolored by iron oxide. The strata along this beach are gently waved; the places where rock appears above high-water mark are the summits of these waves, which seem to trend in a northwest and southeast general direction. This marl is one of the highest of the waves, and farther back from the shore is covered by the Tampa limestone, according to reports of residents. There seemed to be no recognizable dip.

It will be noticed in Bailey's list of species collected that he mentions only three or four from this deposit, all of which are also found living over a great part of the Atlantic coast, and especially in Florida, around the roots of plants growing in wet places. The deposit does not seem to be properly infusorial in character, though doubtless containing, like other marl, a few such organisms. It is really a siliceous marl formed by a decomposition of part of the rock which originally constituted the *Orthaulax* bed. An analysis, according to Prof. F. W. Clarke, shows the following composition:

Silica	70·78
Alumina and iron	11·33
Lime	2·18
Water and loss	15·71
	100·00

This indicates the material to be little different from the yellow sand, which, like it, is probably a residual product of the disintegration of indigenous lime rock of organic origin which has lost most of its lime by solution.

An examination of some of this marl by Mr. Lewis Woolman, the well known student of microscopic organisms, did not reveal a single diatom, though specimens doubtless occur in certain portions of the deposit as observed by Bailey.

The Tampa limestone.—A second stratum, which appears obscurely at Ballast Point and with clearness at other localities, overlying the *Orthaulax* bed, was first clearly described by Allen in 1846. He observes:

The first layer of solid rock beneath the soil is a stratum of limestone; it is hard and white, has an earthy texture, and appears to have resulted from comminuted and decomposed shells. The surface of this rock is exposed in several places in the vicinity of Fort Brooke; about 2 miles north, near the Hillsboro River; 4 miles west, on the shore of the bay; and 6 or 7 miles east, in the banks of a small stream.[1]

This rock I have named the Tampa limestone. It was observed by Heilprin,[2] who noted in it the great abundance of the Orbitolite described (under the name of *Nummulites*) by Conrad in 1846. But in Heilprin's text it is more or less confused with a supposedly different rock which he regarded as underlying the *Orthaulax* bed. An examination of the rock in the Hillsboro River from Tampa to the falls shows that what he mistook for the *Orthaulax* bed was merely a cherty layer of the Tampa limestone, that rock being characterized by an abundance of *Cerithium hillsboroensis* in this vicinity, and everywhere overlying the *Orthaulax* bed. The following notes on this rock were made by the writer in 1887.[3]

Above the stratum above described [*Orthaulax* bed] is a layer from 1½ to 10 feet thick, of a limestone free from silex and pretty uniform in character. The fossils are mostly represented by external molds; but a few, and particularly an orbitolite described by Conrad, and probably identical with one now living at moderate depths on the Floridian coast, retain their shell structure.

This rock underlies the town of Tampa, where wells are dug through it, and water obtained at a depth of 10 feet or less. It is probable that the more compact cherty

[1] Am. Jour. Sci., 2d ser., 1846, vol. 1, p. 38.
[2] Trans. Wagner Inst., 1887, vol. 1, p. 61, ¶ 2.
[3] Am. Jour. Sci., 3d ser., 1887, vol. 34, pp. 166-167.

stratum underlies it here and forms a water table. The same rock occurs 7 miles northeast of Tampa in wells, and also on land belonging to Mr. Lapenotiére, of Tampa (SE. ¼, Sec. 14, T. 29, R. 19), near Orient Station. Its upper surface is about 14 feet above Six-Mile Creek, near by, and about 25 feet above the water in the harbor of Tampa, at the railroad wharf, according to recent surveys. Its exact thickness here I was not able to determine. I was informed that the same rock occurred on the Manateé River above Braidentown. Still farther to the south and west I observed it about 1 mile from Sarasota village, on the road from Braidentown, in the gulley of a small rivulet about a half mile from the shore of the bay.

There is an outcrop of rock at Bowleys Creek, emptying into Sarasota Bay, about 8 or 9 miles northwest of Sarasota and about 2 miles from its mouth. This can be reached only by boat at high water, and is then a foot or two below the surface. I visited it and succeeded in getting some fragments with prints of two species of *Pecten* and one of *Ostrea*, with traces of a *Spondylus*, all of which are represented in other Miocene localities. The rock was covered with Quaternary beds of indurated sand containing recent shells in a semifossil condition.

The same rock appears to crop out at Belleview, Marion County, and Bayview, on Old Tampa Bay, where specimens were collected by Willcox.

The known area of the Tampa limestone, and that which is probably to be assigned to it, from the information in our possession, is nearly the same as that of the *Orthaulax* bed; but as yet we know very little about the geographical extent of either. These rocks are usually much corroded on their upper surface, through the action of carbon dioxide and rainwater, and are covered with from a few inches to several feet of sand, loam, and humus.

A section on the bank of the Hillsboro, near Lapenotiére's Spring, generalized from variations observed in the near vicinity, gives the following succession:

Thickness.	Character of strata.
6 to 36 inches	Humus, yellow sand, etc.
10 to 15 feet	Tampa limestone.
7 inches to 10 feet	Orthaulax bed.

Total elevation above the level of mean tide at Tampa, about 25 feet.

The Cerithium rock of Heilprin.—In January, 1891, the writer visited Tampa for the purpose of settling some lurking doubts excited by discrepancies in previous accounts of the stratigraphy of the "Cerithium rock" and Tampa limestone. The writer has never seen the so-called Cerithium rock underlying the *Orthaulax* bed, though analogy with the Alum Bluff section would seem to call for it. Heilprin distinctly affirms its existence in such a position, but his language would seem to indicate a confusion in his mind of the rock holding *Pyrazisinus* with that containing *Cerithium hillsboroensis*. His description of the rock would seem to apply to the former, but his reference to the species particularizes the latter.

A trip up the Hillsboro River about 12 miles, in a skiff, examining every outcrop of rock in the banks from Tampa to the rapids, resulted as follows: The *Orthaulax* bed is clearly and unmistakably below the Tampa limestone, but nowhere could any rock below the *Orthaulax* bed be observed; the stratum itself rarely rises more than 2 or 3 feet above the water. The Tampa limestone everywhere covers the *Orthaulax* bed, and reaches a maximum thickness of 25 to 30 feet. The two strata appear to be gently waved in a northwest and southeast direction, the Hillsboro River cutting these waves transversely, as a rule. There appear to be about half a dozen such waves between Tampa and the rapids, where the *Orthaulax* bed rises about 6 feet above the river and forms its bed for a short distance. In the *Orthaulax* bed there are many species which have not been found in the Tampa limestone, but I have found comparatively few, mostly minute, species in the Tampa limestone, except *Cerithium hillsboroensis*, which are not represented in the *Orthaulax* bed.

Along the river the summits of the anticlines bring up the Tampa limestone and less commonly the *Orthaulax* bed above the water at the shore. Between the anticlines the Tampa limestone sinks out of sight and is covered by swamp. In intermediate places it forms the bed of the river, and perhaps from some such place Prof. Heilprin's *Cerithium* was collected. The lower layers of the Tampa limestone are silicified or cherty in many places, but still remain yellowish. This part of that bed can be distinguished from the *Orthaulax* bed chiefly by color and by the absence of the characteristic *Orthaulax*, *Pyrazisinus*, and other fossils of the older stratum.

In the city of Tampa good exposures of the limestone were obtainable at the city waterworks (with which Magbey's Spring is now incorporated) and at a quarry where the rock is excavated for road metal. Here the rock is at least 20 feet thick. The lower part has few fossils. Those of the upper part are in the form of molds. *Natica amphora* and *Venus penita* are particularly abundant; *Cerithium hillsboroensis* not rare in the upper part. The upper surface of the beds, which is covered by a yellowish loamy sand, is wave-worn with Lithodomus borings, lumpy and irregular. The outer crust is harder than the rock below. The yellow sand contains occasional phosphatic nodules and fragments of bone. It descends into the fissures and depressions of the limestone and averages 2 or 3 feet in thickness, covered by the usual layer, 3 to 6 feet thick, of white siliceous sea sand.

From these observations it appears that, while the existence of a *Cerithium* rock under the *Orthaulax* bed is a priori probable, sufficient evidence of its existence is still to be collected, and the rock identified as such by Heilprin may very possibly have been a portion of the Tampa limestone.

The Sopchoppy limestone.—Specimens of a very soft limestone containing numerous imprints of shells and many fragments of vertebrate ribs and other bones were exhibited in 1890 at the Subtropical Exposition at Jacksonville. These were stated to be from Sopchoppy, Wakulla County, near the Okloconee River. This locality is not easily accessible, but through the kindness of Mr. J. C. Hodge some of the rock was obtained for examination. It proved to contain Conrad's orbitolite and about thirty species of shells, most of which are common to the Chipola marl or the *Orthaulax* bed. No sign of *Orthaulax* or *Pyrazisinus* was noticed, but the horizon is probably not far from that of the Chipola marl.

Mr. Burns was informed that a mass of limestone of this character extends from the river near Sopchoppy to the Gulf coast eastward of the mouth of the river, and this may belong to the Chipola beds, like the specimens examined. This, however, remains to be definitely determined.

Other localities of limestone belonging to the Tampa group, but of which the fauna is too little known to determine the exact horizon, are Sulphur Spring Ferry, Suwannee County (L. C. Johnson); Johnson's Limesink, Levy County, and a 50-foot well near the capitol building in the city of Tallahassee. These are represented by specimens in the National Museum collection.

In the endeavor to determine the extent of Miocene deposits in the line of the Suwanee Strait between the Miocene Florida islands and the continental border of the same epoch, an examination of the rocks along the line of the railroad from Tallahassee to Lake City was kindly undertaken, in the intervals of other work, by Mr. T. W. Stanton, of the U. S. Geological Survey.

Mr. Stanton notes that the country around Tallahassee is hilly and rolling and the surface covered with red sandy clay (referred to the Appomatox by McGee), which forms the soil and is the only material to be seen in the cuts on the railroads and wagon roads.

In a ravine 2 miles west of the town were found a large number of masses, 2 feet thick, of hard, white siliceous limestone, which do not form a continuous bed, but occur in soft gray argillaceous sand 8 feet thick, unconformably overlain by the red sandy clay referred to, which here, together with the surface soil, forms a layer 3 to 10 feet thick. This rock recalls that observed by the writer at Bowleys Creek, Sarasota Bay, and like it contains *Pecten* and *Ostrea* and other old Miocene fossils.

One mile west of this place, on the farm of G. H. Meginnis, Mr. John E. Davids has dug a shaft 60 feet deep in search of phosphate rock. This well is said by Mr. Davids to pass through—

	Feet.
1. Surface soil and red clay	10–12
2. Light green clay	14
3. Green clay, with fragments of shell	2
4. Fine white sand, with a little clay and some fragments of hard sandstone	16
5. "Soft phosphate"	9
6. "Hard phosphate"	10

Nos. 5 and 6 contained irregular fragments of rock, said to be phosphatic and apparently an altered Miocene limestone; some fossiliferous fragments of that age in the field near by were said to have come from an old well.

At Lloyd, a station 18 miles east from Tallahassee, all the streams of the neighborhood flow northward and disappear in sinks. At the station a rock said to be phosphatic was struck at the depth of 20 to 25 feet in digging a well. This is overlain by clay, in which, at the depth of 8 feet, was a bed of large oyster shells.

Two and a half miles east of Lloyd a large creek called the Miccosukee Drain flows from a lake of the same name and sinks into the limestone. The latter appears to be Tampa limestone, with abundance of *Orbitolites floridanus* Con., and other fossils; it is about 10 feet thick, and contains more or less cherty matter. Similar rock was exposed at a sink 1½ miles south of Lloyd, resting on greenish clay. Five miles southwest of Lloyd the country becomes less flat and the red clay again appears on the higher ground. It also is seen near Monticello.

South of the railway, at Weelaunee, Jefferson County, on Bailey's plantation, a Miocene limestone with the characteristic fossils occurs in a bed about 3 feet thick, which has been quarried for lime. It is covered by about 2 feet of surface soil, and the upper part is fragmental. At the farmhouse, which is on a hill a mile away, a well 100 feet deep has recently been dug, from the lower third of which much rock of the same sort has been taken. Phosphatic rock, probably of the same age, has been found at a third point, in low ground, on the same estate.

The Suwanee River is crossed by the railroad just east of Ellaville, and a light yellowish limestone is exposed here in the banks of the river. Mr. Stanton was unable to stop at this point, but specimens collected there by L. C. Johnson, and now in the National Museum, show that the rock is probably Tampa limestone.

Nine miles east from Ellaville on the railroad is a "rock cut," where 4 feet of Miocene limestone and calcareous clay is unconformably overlain by 4 feet of red and yellow clay. The limestone is of the Tampa beds, and contains the usual molluscan fossils, represented by rather imperfect casts, which have been more or less filled with crystals of calc-spar. The ground is comparatively high at this point, though the surface is more level and the hills lower than at Tallahassee or Monticello.

These observations and collections of Mr. Stanton are of much importance, since they confirm, by unimpeachable evidence, the Miocene insulation of central Florida, which had been regarded as probable by the writer previously, chiefly on theoretical grounds.

Taken in connection with the observations of Mr. Burns on the Altamaha grits of Georgia, they show that the passage between Florida and the mainland, here termed Suwanee Strait, and now occupied by the Okefinokee and Suwanee swamps and the trough of the Suwanee River, was a wide, and even in Miocene times a moderately deep, body of water, the general trend of which did not differ much from that of a line drawn from Savannah to Tallahassee, and which had a probable width of more than 50 miles.

Chipola marl.—This bed contains the lower marl bed of Langdon's section. Owing to a lower stage of the water at the time of his visit, and more detailed study of Alum Bluff by Mr. Burns, he was better enabled to determine its thickness and discover a considerable westward extension of its area.

At Alum Bluff the Chipola marl bed is about 5 feet thick and well characterized by a species of *Orthaulax* (*O. gabbi* Dall), different from *O. pugnax* of the bed at Tampa, and also from that originally described by Gabb from the Miocene of Santo Domingo.

At Baileys Ferry, on the Chipola River, an affluent of the Appalachicola from the west, the Chattahoochee beds are overlain by a stratum of yellowish calcareous sand containing well preserved fossils, identical with those at Alum Bluff, but in much better condition. The same bed is reported by Aldrich over phosphatic rock at De Leon Springs. It, or its analogue, exists in the Miocene rocks of Santo Domingo, from which Sowerby and Gabb have described so many species. Similar beds exist in Venezuela, Curaçoa, Trinidad, Barbuda, Anguilla, Haiti, Jamaica, and probably in Cuba. They have numerous species in common with the Chipola marl and the Orthaulax bed of Tampa, the differences not being greater than the faunal differences between the cited localities at the present day. Some of the interesting forms first described from this rich fauna, like *Bothrocorbula*, are absent from the immediate vicinity of the present coast, but still exist, living, in the greater depths off shore.

The White Beach bed has afforded 40 species of molluscan fossils; the Tampa Orthaulax bed about 165; the Chipola marl about 400 species, part of which have been determined. Sixty species have been enumerated from the Tampa limestone, of which more than one-half are known to be common to the Orthaulax bed. It should be added that, as one might expect from its position in the column and relations to the subjacent Eocene, these rocks contain a certain number of Eocene species which afterward die out. A few small specimens of *Ostrea sellaformis* (*O. divaricata* Lea) appear in the beds, as well as a certain number of Vicksburg fossils, and nearly the whole Chattahoochee fauna, as far as yet known, reappears in the Chipola beds.

Alum Bluff beds.—Over the richly calcareous rather ferruginous, Chipola marl at Alum Bluff we find a total change of material and a total disappearance of the fauna. There are from 5 to 15 feet of gray siliceous sand and a little clay, without fossils, while above that a radical change of fauna is revealed by the fossils of the Ecphora bed.

To these transition strata I would apply the provisional name of the Alum Bluff beds, until such time as fuller information shall be available. That they represent in the series at Alum Bluff a period of important changes of level and probably of sea temperatures, and no inconsiderable portion of geologic time, is hardly open to dispute.

Chesapeake group.—For the Miocene strata extending from Delaware to Florida, but best developed in Maryland, Virginia, and the Carolinas during the Yorktown epoch of Dana, including a large part of Heilprin's Marylandian, Virginian, and Carolinian, I propose the name of the Chesapeake group. On this noble bay and its estuaries, forming the greater part of the Patuxent, York, and James rivers, these beds are displayed in all their breadth, and the Chesapeake waters may almost be said to be inclosed in rocks of this group. I have been unable to use Heilprin's names, as they have never been recognizably defined so that one might say, from a knowledge of the fossil fauna, such and such a bed is "Virginian" or "Carolinian;" neither am I convinced that these names correspond with precision to any definite geologic facts.

That there is a gradual change in the fauna from the older beds to the newer ones may very probably be the case; but no careful stratigraphical evidence has yet been combined with such a statement of the fossil fauna of each stratum as to put the matter in a sufficiently clear light for intelligent discussion, still less for geographical apportionment. That the lowest beds of Shiloh, New Jersey, and perhaps some of those elsewhere, correspond to the Tampa group there is some reason to su spect; but even here revision and comparison of the species comprising the fossil fauna is necessary before positive conclusions can be safely drawn.

For the strata bordering on the Chesapeake in Maryland and Virginia which belong to the Miocene, Darton has proposed[1] the name of the Chesapeake formation. This term as used by him is equivalent to "Miocene" as heretofore understood in these states, and is the stratigraphic homonym of the chronologic "Yorktown epoch" of Dana.

The term *Chesapeake group*, as independently suggested, here includes as typical Darton's Chesapeake formation and also all other beds belonging to the same horizon and containing the same general fauna on the Atlantic and Gulf coasts of the United States.

The Carolinian Miocene is presumably closely analogous to the Ecphora bed at Alum Bluff, and represents the later beds of that epoch, but the terms Carolinian and Sumter, as heretofore used by most authors, involve assumptions which seem dubiously true, and for that reason I am unwilling to adopt either term. As originally used by Dana they were chronologic, and not stratigraphic terms.

It is obvious from what has preceded that the term Middle Miocene is inappropriate if used to denote what seems to be the culminating series of Miocene deposits on our Atlantic coast, as is done by Heilprin under the assumption that what I regard as the mixed Neocene of

[1] Mesozoic and Cenozoic formations of eastern Virginia and Maryland, by N. H. Darton, Bull. Geol. Soc. Am., May, 1891, vol. 2, p. 443. This use of the name was not known to the writers of this essay until the essay had been practically finished.

South Carolina is a homogenetic deposit. Consequently I am obliged to bring in a new term, which shall have no ambiguity in its meaning, and in which I intend to include all the marine Miocene of eastern America possessing a fauna newer than that of the Tampa group, and of which such species as *Ecphora quadricostata*, *Fusus equalis*, *Perna maxillata*, *Mactra congesta*, and the great Miocene Pectens are illustrative members. It is quite possible, when this group of beds has been properly investigated, that an opportunity may arise for subdividing it. At present, however, no satisfactory data exist warranting such subdivision; even the upper limits of the oldest Virginian fauna, in terms of stratigraphy, are entirely unknown.

The Chesapeake group is represented over a very wide area in Florida, if the scattered observations already made can be regarded as indicative of its extension. Borings on the eastern coast of Florida and in the St. Johns valley indicate that there the beds of this group in some places attain a thickness of at least 500 feet.

The Ecphora bed.—At Alum Bluff the group is represented by what I have termed the Ecphora bed, of gray marl, with over 100 species of fossils many of which are common to North Carolina, Virginia, and Maryland. It has a thickness here of 30 feet or more. One mile west of Baileys Ferry, on the Chipola River, the same bed appears with the same fossils and probably a somewhat greater thickness. Mr. Burns also traced it along the hills east of the Appalachicola River from about 5 miles above Bristol to a point 8 miles below that place, thus giving the outcrop a breadth of at least 13 miles, while along the Chipola he believes it may attain fully 20 miles. L. C. Johnson, of the U. S. Geological Survey, has made a small collection from what is probably the western extension of the same bed, 5 miles east of De Funiak Springs, in Walton County; and on the branches of Shoal River above Crestview, in the same general direction, he reports marl with abundance of fossils, which are likely to prove of the same age.

To the eastward of the Appalachicola River for some distance no observations are on record.

At 15 miles west from Tallahassee Mr. Joseph Willcox recently found a bed of white marl containing *Mactra congesta*, *Lucina crenulata*, *Corbula dietziana*, and *Dentalium attenuatum*, which clearly belongs to the same group. Johnson reports an extensive deposit of marl in the vicinity of Tallahassee.

Jacksonville limestone.—At Jacksonville, Florida, in Duval County, in the excavation made for the city waterworks, a porous, slightly phosphatic, yellowish rock, derived from indurated calcareous sand, was discovered.[1] It contains numerous molds of fossil shells belonging to the newer Miocene fauna. The same was apparently exposed on Black River, Clay County, and Preston sink, 3 miles north of Waldo, Alachua County, where *Pecten jeffersonius*, *Carditamera arata*, etc., were obtained.

[1] E. A. Smith, Min. Res. U. S. for 1885, p. 251.

West of Jacksonville, at Live Oak, Suwanee County, and Lake City, Columbia County, specimens of fossils were obtained which may prove to belong rather to this than to the Chattahoochee group of beds.

The borings at Jacksonville passed through what appears to have been this rock for nearly 300 feet. East of Jacksonville, at St. Augustine, similar borings were prosecuted when *Venus rileyi*, *V. permagna*, and *Arca limula* were obtained at a depth of 208 feet, while at 224 feet the characteristic fossils of the Vicksburg appeared.

Farther southward, at Rock Springs, near Zellwood, Orange County, Smith[1] obtained from a limestone bluff at least 10 feet high *Pecten madisonius*, *Venus alveata*, *Venericardia granulata*, *Carditamera arata*, *Mytiloconcha incurva*, *Cardium sublineatum?* and *Oliva literata?* which indicated decisively the Upper Miocene age of the outcrop. About 150 miles farther south an artesian boring near Lake Worth reached the Vicksburg rocks at a depth of 1,000 feet. This well was evidently bored through deposits, in part at least, of the nature of talus, since if the depths at which the specimens were obtained above the Vicksburg were correctly stated (which is open to grave doubt), several very remarkable inversions of Tertiary rock and recent coquina occurred. However, at an indeterminate point between the surface and 1,000 feet below it a few Upper Miocene fossils were obtained, including a *Corbula* and *Dentalium attenuatum*, so abundant in the Ecphora bed. This is valuable chiefly as indicating the southernmost point where beds of the Chesapeake group are known to occur on the Atlantic shore.

Manatee River marl.—In the western portion of the peninsula a few localities are known for beds of this age. At Rocky Bluff, on the right bank of the Manatee River, a few miles above Braidentown, Heilprin[2] found *Pecten madisonius*, *P. jeffersonius*, *Venus alveata*, *Perna maxillata*, *Arca incongrua*, and other Upper Miocene species. The so-called "bluff" is a ledge of rock, 2 or 3 feet above the water level at the time of his visit, which consisted of a basal white marl and yellowish sandstone and an overlying siliceous conglomerate. The latter, which is probably Quaternary, is almost entirely deficient in organic remains. The marl is "densely charged with them." It is probably from more westerly submarine strata belonging to this series of beds that was derived the *Ecphora* collected by Dr. Stearns in 1868–'69 on the beach of Long Key. At one time I was inclined to refer this specimen to the silex beds,[3] but subsequent study of the stratigraphy has led me to renounce that idea, since the *Ecphora* belongs to a later horizon, similar to that of the Manatee River stratum. Further search showed, according to Prof. Heilprin, that the marl at the Manatee River locality "thinned out and disappeared after a short distance, but the yellow sand rock, largely honeycombed and containing much fewer fossils, many of them identical with the forms of the marl, continued up the

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[1] Am. Jour. Sci., 3d ser., 1881, vol. 21, p. 302.
[2] Trans. Wagner Inst., 1887, vol. 1, p. 13.
[3] Trans. Wagner Inst., vol. 3, p. 125.

river to the farthest point reached by us." (Op. cit., p. 13.) Prof. Heilprin does not state whether the marl was above the yellow stone or sand rock or below it, or whether he regards the latter as simply another aspect of the bed elsewhere preserved in the shape of marl. But if the yellowish rock was below the other, as the context seems to indicate, it might be identical with the Tampa limestone found both north and south of this locality at no great distance. However, this supposition is rendered doubtful by the fact that in a similar rock which occurred in the banks of Phillips Creek, flowing into Sarasota Bay, Prof. Heilprin found casts of *Pecten madisonius*, *P. jeffersonius*, and *Arca idonea?* beside others which appeared identical with fossils of the Manatee River rock. The bed on this creek rises at intervals to 2 or 3 feet above the water. The fossils are in the form of molds or impressions and poorly preserved. At one or two points near the mouth of Phillips Creek this rock is seen to be overlain by 2 or 3 feet of compact coquina composed of triturated fragments of the recent shells of the coast. At Whittakers, a point a few miles south of Hunters Point, in the northern part of the bay, a similar rock was noted, but without recognizable fossils. These imperfect data indicate the most southern extension of the Chesapeake group which has yet been determined on the western edge of the Floridian peninsula.

GENERAL DISTRIBUTION OF THE FLORIDIAN MIOCENE.

The notes herewith given indicate that the older Miocene rocks surround more or less completely the original Eocene island or nucleus of the peninsula on the northwest, southwest, south, east, and northeast. On the north and northwest they exist over a large area only in patches indicative of greater original extension, the connecting deposits having been removed by solution or erosion over much of this area. On the west they are for the most part submerged, the Eocene, except in the river valleys, reaching to the Gulf coast.

In the De Soto basin they are overlain by Pliocene and Pleistocene beds, but appear again in the eastern anticline, the mass of which, if our information may be relied upon, is probably mainly composed of Miocene rocks, of which the older series east of the ridge dips rapidly under the newer rocks, reaching a depth of probably more than 600 feet at the present eastern margin of the peninsula.

In the western part of the State, near the Appalachicola River, the formations succeed each other regularly; the Eocene, old Miocene, Newer Miocene, Pliocene, and Pleistocene appearing one after another as one passes from the State boundary south to the Gulf. The near approximation of the depressions occupied by the great Suwannee and the Okeefinokee swamps, and the beds of Miocene known to exist on the highest part of the watershed between them, point toward a submersion in Miocene time of much of this region and the insularity of the area above the sea to the southward.

During the Chesapeake epoch northeastern Florida must have been deeply submerged and over five hundred feet of rocks belonging to the Chesapeake group were laid down in this embayment. A deposition of strata of this age went on along the whole Atlantic border at least as far south as Lake Worth, though at present buried over much of this coast by Pleistocene deposits. Newer Micocene in the northern half of the peninsula appears on both sides of the older Miocene ridge. In the central basin and to the south it is buried under Pliocene or later beds; in the southwest a single small patch is known; in the west it must necessarily exist, if at all, underneath the waters of the Gulf outside of the older Miocene, a supposition to which the washing up of *Ecphora* on Long Key lends a certain plausibility. The preservation of its shell structure indicates that the bed from which it came was under the sea, since no beds of Miocene rocks are known in this part of Florida, where rainwater has access to them, which retain the natural structure of their shell-fossils. On the other hand salt water does not erode or dissolve the fossils in the same way, because at moderate depths it does not contain carbon dioxide in sufficient quantity.

The Grand Gulf beds enter the State only in its northwestern extreme as far as known, and more information is urgently needed.

The appearance of mammalian bones in the Sopchoppy limestone indicates the preservation of remains of warm-blooded vertebrates considerably older than those of the Alachua clays on the Peace Creek Pliocene bed. It is likely that these bones are sirenian or cetacean, but too little is yet known to hazard any conclusions upon them. It is probable that the bones from the clays near Wakulla, which have achieved popular notoriety, are of later origin, perhaps Pliocene; but here, again, our information is deficient.

PLIOCENE DEPOSITS.

Terrestrial fauna, the Alachua clays.—Later in this essay I shall endeavor to indicate all that is known to date of writing of the marine Pliocene beds of Florida, but there is another formation to be spoken of which has been referred by some authorities to the Upper Miocene, though regarded by others as late Pliocene or even Pleistocene. This comprises the deposits of clay containing bones of extinct mammalia which, in my report to the Director of the U. S. Geological Survey in 1885, I termed the Alachua clays.

These clays occur in sinks, gullies, and other depressions in the Miocene, Upper Eocene, and later rocks of Florida, especially on the western anticline in the higher portions of Alachua County, and along the banks of many of the rivers and streams. They appear in Alachua County to have been subjected to denudation after deposition, so that only those portions protected by their depressed position in cavities or gullies of harder rocks remain undisturbed. The clay is of a bluish or grayish color and extremely tenacious, so that it is most difficult to discover remains imbedded in it. Dr. J. C. Neal was among the first to notice these remains and brought them to the attention of geologists in 1883. To his exertions and those of later collectors is due most of our knowledge of the mammalian fauna contained in them. The clays occur in patches, usually in depressions, but occasionally in short ridges whose lateral buttresses of limerock have disappeared through the dissolving agency of rainwater and carbon dioxide. These deposits are believed by Dr. Neal to have a definite relation to the margins of the ancient De Soto Lake which occupied more or less the synclinal trough eastward from the westward anticline. The rather limited opportunities for observation which the writer enjoyed in 1885, while examining these clays, did not show anything to antagonize this view of Dr. Neal, which, however, requires more evidence to receive definite acceptance.

The appearance of the bones suggests that the animals were mired and then torn to pieces by predatory carnivora. Ashes and burnt clay were found under some of the bones at Hallowell's ranch, but there is no evidence of any human agency in this. The fire was probably due to lightning, an every-day occurrence in Florida at the present time. The longitudinal splitting of the long bones sometimes observed may often be the result of the penetration and growth in the hollow of the bone of roots which might afterwards decay and leave no sign. I have observed roots penetrating the bones on several occasions.[1]

Among the localities to be noted are: In Alachua County, Mixon's farm, 10 miles south and 1½ miles east of the railway station at Archer; Hallowell's place, 10 miles north and 2 miles west of the station; a pond about one-fourth of a mile from the station; another in the vicinity of Mixon's, 2 miles northwest of the first; a ditch about 2½ miles west of Gainesville; a spot where the railway crosses the Santa Fe River, near Gainesville; 1 mile north of Gainesville, on the Newnansville road, in a ditch dug for a mill race; and Owen's, nearer the town. Other localities are: Clay Landing, on the Suwanee River, near Fort Griffin, Levy County; Rocky Creek (old Tampa Bay), Hillsboro County (*Bison latifrons*); Philipps' quarry, Ocala, Marion County.

At Arcadia, on Peace Creek, Manatee County, and some points on the upper Caloosahatchie River, Monroe County, and also in Wakulla County, similar remains have been found, associated with phosphatic gravel or nodules in the beds of streams, which has been segregated from the material of the banks by the action of the water much as in the South Carolina Pliocene or Pleistocene, where vertebrate remains are associated with nodules of phosphate of lime sufficiently rich to have resulted commercially in an important and well known industry.

In the case of the South Carolina remains, as it appeared to have been of late conceded that they are derived to a greater or less extent from geological horizons outside the limits set for this essay, though at one time supposed to be of Pliocene age, we have not attempted to consider them. But, in the case of the Floridian vertebrate fossils, more doubt has been raised by the fact that one, at least, of our most

[1] Dall, Am. Jour. Sci., 3d ser., 1887, vol. 34, p. 165.

distinguished vertebrate paleontologists has repeatedly asserted his belief in their Miocene or Pliocene age, though they have by others been referred to the Pleistocene, like most of those from South Carolina.

For this reason it has seemed desirable to state the facts upon which these different opinions are based, as understood by experts in vertebrate paleontology.

The specimens from the Alachua clays identified by Dr. Leidy are of the following species:

Species	Locality
Rhinoceros proterus *Mastodon floridanus* *Megatherium* sp. *Auchenia major* *Auchenia minor* *Auchenia minima* *Cervus (virginianus?)* *Hippotherium ingenuum*	From Archer.
Rhinoceros proterus *Mastodon floridanus* *Hippotherium ingenuum* *Hippotherium plicatile* *Auchenia major*	From Mixon's, 10 miles east from Archer.
Elephas columbi *Equus fraternus* *Auchenia minima* *Machairodus floridanus*	From Ocala, Marion County.

The following specimens have been obtained from a bed which extends for miles along the banks of Peace Creek, Manatee County, near Arcadia.

Tapirus americanus.
Elephas columbi.
Mastodon sp. (not *M. floridanus*).
Hippotherium ingenuum.
Equus fraternus.
Bison americanus.
Cervus virginianus.
Megalonyx jeffersonii.
Chlamydotherium Humboldtii.
Glyptodon sp.
Hoplophorus euphractus.
Manatus antiquus.
Priscodelphinus sp.
Emys euglypha.
Trionyx sp.
Eupachemys sp.
Testudo crassiscutata.
Alligator mississippiensis, and a variety of fish remains, including teeth of *Carcharodon*, *Galeocerdo*, *Myliobatis*, etc.

From the Pliocene beds of the Caloosahatchie were obtained:

Bison latifrons.
Elephas columbi.
Equus fraternus.

In regard to the equivalence of this fauna, assuming it to be all of one epoch, which is still to be determined, Dr. Leidy writes that he has not yet come to any final conclusion, but thinks there are no species identical with those of the Loup Fork horizon. The three forms of

Auchenia according to him "seem to belong to *Palæolama*, founded by Gervais on remains from the Pampean formation of Buenos Ayres." A specimen once obtained from Virginia, and at that time referred to *Procamelus*, Dr. Leidy now thinks "more nearly related to the living *Auchenia*." In regard to the latter Prof. Cope states that its stratigraphical provenance is doubtful, and it can not be positively stated that it came from the Miocene of Virginia, as was once supposed.

In regard to the remains from the Alachua clays, Prof. Cope furnishes the following note:

The vertebrate fauna [referred to] presents a mixture of species and genera which are found in the West in two different horizons, viz, the Loup Fork and Equus beds. This may be seen by the following table of comparisons:

Loup Fork.	*Florida.*	*Equus Beds.*
	Glyptodon petaliferus Cope.	*Glyptodon petaliferus* Cope,
	Chlamydotherium humboldtii Lund.	*C. humboldtii* Lund.
Machairodus catocopis Cope.	*Machairodus floridanus* Leidy.	
*Rhinoceros (Aphelops) fossiger** Cope.	*Rhinoceros (Aphelops) proterus** Leidy.	
Rhinoceros (Aphelops) malacorhinus Cope.	*Rhinoceros (Aphelops) longipes* Leidy.	
Hippotherium occidentale Leidy.	*Hippotherium princeps* Leidy.	
	Equus major De Kay.	*Equus major* De Kay.
	*Mastodon floridanus** Leidy.	*Mastodon serridens** Cope.
*Pliauchenia vulcanorum** Cope.	*Pliauchenia major** Leidy.	
	Pliauchenia media Leidy.	
*Pliauchenia humphreysiana** Cope.	*Pliauchenia minor** Leidy.	

A few of the other described species do not throw any light on the question of age. Those marked with an asterisk are not yet shown to be distinct from the corresponding species of the other horizons. It thus appears that six species are allied to or identical with as many of the Loup Fork horizon of the West, while four are characteristic of the Equus beds of the East, of Texas and of South America. The epoch they represent is then probably between the two.

It would be presumptuous to attempt to decide so recondite a matter in the presence of two such experts as Drs. Leidy and Cope, but it will not be amiss to point out that both their conclusions, though differing somewhat, agree in referring the epoch of the Floridian mammals to a period related to the Equus beds or Pampean formation, and perhaps somewhat earlier.

The relations of the clays to the Pliocene Lake De Soto, if Dr. Neal's hypothesis be confirmed, and the presence of some of the species in the undoubted Pliocene of the Caloosahatchie and the Pliocene age of the Peace Creek beds, all point in the same direction, and, while the determination of the precise epoch of the deposition of these remains in the clays may be regarded as still a desideratum, we may be permitted to conclude with some confidence that at least they are not Miocene.

Peace Creek bone bed.—In view of the differences of opinion in regard to the age of the mammalian remains of Florida, the writer, in January, 1891, decided to visit the Peace Creek region, believing that there an opportunity might be found for observing an interstratification of the marine beds with those containing the mammalian remains, and that thus the age of the latter, relatively to the marine beds, might be positively settled, at least as far as the Peace Creek bed is concerned. This anticipation proved to be well founded, and the visit was completely successful in its object.[1]

Some account of the condition and relations of the earlier Pliocene strata and their geographical distribution in Florida will follow under the head of Marine Pliocene beds. For the present it is only necessary to state that the "pebble phosphates" of Peace Creek are derived from the reduction into gravel of (1) a phosphatized and altered lime rock, and (2) of fragments of bones, teeth, and other vertebrate remains, which generally, in addition to the phosphate of lime they naturally contain, have been subjected to the same conditions as the lime rock above referred to, on which they originally lay or in which they were more or less imbedded.

Arcadia marl.—In the case of the Peace Creek bed the phosphatized rock in or over which the bones are situated is exposed in the bank of the river, in situ, near the mouth of a brook known as "Mare Branch," which enters Peace Creek from the east, about 6 miles north of Arcadia. The same rock is also visible along the branch, at several points, but there it is generally at or below the surface of the water in the branch and less easily inspected.

At the edge of Peace Creek the section exposed was as follows:

		Feet.
1. Humus and white sand		1½- 6
2. Yellow sand		6 -10
3. Peace Creek bone bed, phosphatized rock with bones (about)		1
4. Arcadia Marl	Yellowish sandy marl, to water's edge	3
	The same, under water (about)	3 - 6

The sandy strata above are the two beds of siliceous and argillaceous sand common to a great part of the peninsula. Varying in thickness along the creek the two, combined, will average about 12 feet in thickness.

The phosphatized rock is a calcareous sand rock, originally light colored, but here blackened, or of various shades of gray or dark brown; it contains numerous imprints of shells in rather poor preservation, but which exhibit several distinctively Pliocene species, such as *Arca rustica*, *Turritella apicalis*, *T. perattenuata*, and *Cardium floridanum*, besides a large number of forms which are to be found over a wider range. No trace of any characteristic Miocene species was to be found, though several species appeared which are common to both Miocene and Plio-

[1] For facilities extended, information furnished, and various other courtesies, the writer is indebted to numerous gentlemen, resident or interested in the region, and especially to Maj. M. T. Singleton and President M. F. Knudsen, of the Peace River Phosphate Company, of Arcadia; Mr. G. W. Land and Mr. J. H. Tatum, of Bartow; Mr. F. J. La Penotière, of Tampa, and Mr. James Willcox and Supt. I. T. Beeks, of Orlando.

cene, as well as the recent fauna of the region. I have no doubt that this is the same rock which was obtained by Mr. Alonzo Cordery, with the shell impressions much better preserved, a little farther north from the Charlie Apopka River (secs. 2 and 3, T. 36 S., R. 25 E.), where, however, it is not phosphatized.

I do not hesitate to refer this rock to the older Pliocene, a horizon somewhat lower than that of most of the Caloosahatchie beds, but containing a nearly identical fauna as far as it goes.

The mammalian bones at this point appear to lie on this stratum, and where it is broken up, as is most commonly the case, are mingled with its fragments and blackened in the same way. The fish remains are found lower down as well, but I found no evidence of any mammalian bones in the marl below the phosphatic rock. On a low point of beach where the bank showed the best exposure of the rock, the shore was blackened with fragments of the rock, mixed with an astonishing number of pieces of bone, largely fragments of ribs. Nothing could more clearly indicate the great number of the animals which found a final resting place here.

The marl which underlies the thin bed of phosphatic rock comprises a putty-like mixture of lime and sand, with minute phosphatic pebbles, a few small shark's teeth, and obscure prints of *Ostrea*, *Spondylus*, and other bivalves.

This marl, when exposed to the air, away from the water, rapidly hardens, sometimes forming a very hard and brittle rock, which splinters and rings almost like chert under the hammer. Nothing was observed in it to cause a doubt of its belonging to the Pliocene series.

The pebble phosphates of Peace Creek are derived almost exclusively from the worn fragments of this dark-colored rock and its associated bones.

Oyster marl.—At a point on the west bank of Peace Creek, 3 miles below Mare Branch, and about the same distance north from the bridge at Arcadia is an old landing, generally known as Singleton's Landing, just below which is a low flattened point of the bank called by Maj. Singleton Shell Point. This point would be covered at the stage of high water, but at the time of my visit presented the following section:

	Feet.
1. Humus and white sand	3–5
2. Yellow sand (indurated)	3
3. Oyster marl (in part subaqueous)	2–4

This oyster marl is the remnant of an old oyster bed containing the same oysters, barnacles, and Pectens, which abound in the Caloosahatchie beds. It is unmistakably later Pliocene and occurs with the same stratigraphical relations over a wide area of the Peace Creek drainage. Near Zolfo Springs it overlies the phosphatic stratum, but everywhere contains material, such as bones, phosphatic pebbles, casts of older Pliocene shell fossils, etc., derived from the beds below it.

In this way we have finally fixed the position of the Peace Creek bone bed, between an older Pliocene rock below and a newer Pliocene bed above, thus settling its Pliocene character beyond question. The Pliocene age of other beds containing similar fossils, such as the Alachua clays and the river phosphate deposits of other parts of Florida, as well as Georgia, South Carolina, etc., may reasonably be inferred from the preceding conclusion, though it must not be forgotten that in the solution or denudation of beds of different horizons their harder contents, such as bones and teeth, would remain associated in a heterogeneous assemblage, offering in some cases problems which greater knowledge than we have at present is required to solve.

Pliocene lake beds: Lake De Soto.—The whole question of the existence of a Pliocene lake or series of lakes, is obviously at present in a hypothetic stage, yet such evidence as there is points strongly in this direction.

The trough-like form of the peninsula, the present existence of at least two principal aggregations of small lakes in the axis of this trough, and of the analogic Lake Okeechobee, illustrating the same geologic processes in action on the same line farther south; the kame like mounds and ridges of the yellow sand, erected on the relatively level floor of this trough and molded as if by aqueous action, the existence of what appear like marginal beds of clay, as suggested by Dr. Neal—all these facts seem very suggestive.

The northern focus of this supposed ancient lake area would seem to have been in the vicinity of Orange and Santa Fe lakes; the southern focus somewhere near lakes Harris and Apopka; the area thus roughly indicated being now drained by the Withlacoochee, Oklahwaka and Santa Fe rivers. A watershed divides this area from the Kissimmee basin to the south. In harmony with Dr. Neal's theory of the marginal clays, we find this watershed marked in many places by a stiff, red clay, which is cut through by the railroad at Bartow Junction and at many points along the line between Bartow Junction, Lake Haines, Haines City (one of the highest points), and Kissimmee.

The Kissimmee basin, centering about Lake Hamilton and now connected by canal with the Okeechobee system, illustrates a second stage or duplication of the features we have referred to in connection with the more northern area. It is now drained to the south and west, and would seem, from its lesser elevation, never to have attained the solidarity and importance as a fresh-water area which we are inclined to claim for the De Soto basin.

In Lake Okeechobee and its surroundings, with the clayey deposit which is so characteristic of the fields of "sawgrass" by which it is encircled, we seem to have an exponent of the processes which, at an earlier period, characterized geologic action in the more northern basins.

Sand mounds of the Lake Region.—It must especially be noted in considering these supposed lake basins that the mounds and ridges, chiefly of yellow sand, which diversify the present land surface, do not reflect, as a rule, any similar irregularities of the rocks beneath. One of the geologic features most strongly insisted on by the well drivers and prospectors for phosphate, of whom the writer interviewed so many, is that the rocks below these bodies of sand are practically horizontal. In order to reach the rock on one of these sand hills, one must bore through practically the entire height of the hill, while near one of the depressed lakelets at a short distance away the rock will be found correspondingly close to the surface. This, of course, does not refer to the more general changes of level offered by the gently rising main anticlines of the peninsula and their intermediate synclinal depressions.

The form of the mounds of yellow sand, if referable to current action, would seem to indicate that the main lowering of the water in these ancient basins, though brought about, in all probability, by slow and gentle changes of level in the land, finally took place with some suddenness, as by the removal of some barrier of sand or clay which up to that time had held the waters in confinement at a higher level. Here again our information is too scanty to justify dogmatism.

PHOSPHATIC DEPOSITS.

General features of the beds.—Although the presence or absence of phosphoric acid in combination with the lime rocks of Florida is a chemical and accidental rather than stratigraphical phenomenon it would seem, in view of recent economical developments, advisable to include some notice of the manner in which this combination presents itself. The remarks here offered must be regarded as merely provisional and preliminary, as a thorough investigation of these deposits by the U. S. Geological Survey has already been organized, but from which we can hardly expect results in time to be utilized for the purposes of this essay.

Notes on the phosphatic beds would seem perhaps to be as properly in place here as anywhere in this paper, since, though the process of phosphatization has doubtless been more or less active since the first elevation as an Eocene island of any part of Florida above the sea, yet those deposits which are of most commercial importance seem to have been formed in Pliocene time, or at all events, subsequent to the deposition of the older Miocene and Pliocene rocks, and are certainly anterior to the later marine Pliocene beds.

While the association of Pliocene bones and teeth with the phosphatic lime rock either bedded or in pebbles is very general, it is merely accidental. The bones occur in many localities where the rocks are not phosphatic, and phosphatic rocks are by no means invariably bone-bearing. The natural phosphate of lime included in the fossil bones has no necessary connection with the phosphoric acid combined with the associated lime rock. In some cases, as on Peace Creek, it is obvious that a bed of rock over which bones were more or less scattered has been subjected to influences which have added phosphoric acid and a little iron to both bones and rock simultaneously.

In all cases it seems reasonable to conclude that the extraordinary supply of phosphoric acid which appears in certain localities, and makes the beds commercially valuable, has been derived entirely from organic sources, probably in the shape of rookeries of birds or seals or other gregarious animals, whose dung afforded the acid in question. This material was very probably carried into the subjacent porous lime rock nearly as fast as it was deposited, since there is no reason for doubting that Florida has always been a rainy region during certain portions of the year.

The local character of such rookeries would determine the local occurrence of phosphate rock, whose irregularities in this respect are notorious. The different forms under which the phosphates now present themselves would result from the different constitution of the rocks upon which the rookeries were originally situated; the difference in elevation and dryness or accessibility to occasional incursions of brackish or salt water; the existence or nonexistence of some subterranean water table in the particular localities; and subsequent solutionary or erosive action upon the rocks thus modified. The material of such rocks rearranged into later strata would preserve a certain proportion of phosphoric acid, even though no subsequent additions of that substance were received by the new beds. A tendency under certain circumstances for the phosphatized lime to concentrate in nodules, or as shells over harder nuclei, is very marked. In this process it would seem as if the traces of iron in the rocks followed and joined with the phosphoric acid, since these nodular concretions are almost invariably darker colored than the rest of the rock, and, when subjected to river action, frequently become blackened by the resulting chemical action on the contained iron.

As argillaceous veins or sheets in the lime rock would check the percolation of the rain-water bearing phosphoric acid and give it more time to act on the lime about it, it occurs that the accumulation of phosphatic matter is apt to be larger in the vicinity of such clayey material.

To their generally rather impervious and argillaceous character is probably due the generally phosphatic character of the Hawthorne beds, which has been previously referred to.

The phosphate-bearing rocks of Florida may, without reference to their chemical constitution, be provisionally classified by their outward appearance under several heads. It may be premised that the phosphatization of a rock seems to tend to obliterate the fossils in it, especially when the latter are in the form of casts. Rock well known to contain usually abundant fossil impressions, in places where it is thoroughly phosphatized will hardly present any trace of organic remains, other than bones, if the latter are present at all. Phosphatization increases the hardness and insolubility of lime rock; the most phosphatic portions are the hardest, other things being equal. Therefore, in the natural attrition of river gravels, originally derived from phosphatic rock, the mechanical action of the current on the gravel segregrates the more valuable (harder) portions, wearing away the less phosphatic and softer parts, and thus naturally accomplishes a result for which no suitable machinery is likely to be devised. To this is due the uniformity in quality and high average of the "river" or "pebble phosphates," now extensively mined in south Florida river beds by a process of dredging and screening.

Floridite and phosphorite.—There are two main varieties of phosphatic rock in Florida. One, which so far seems to be exclusively confined to the area of the old Eocene island on the western anticline, has been produced by the modification of rocks belonging chiefly to the Vicksburg or nummulitic group. The phosphatic rock of Florida is chemically an impure massive apatite which has been called phosphorite and the Dunellon variety floridite.[1] The latter is generally soft, pale yellow or white in color, light in proportion to its bulk, amorphous in fracture, uniform in texture, and presents no traces of organic remains, even when the nummulitic rock of which it is a modification was originally little more than a mass of foraminifera. The segregation of this mineral in masses by itself seems quite as likely to be the result of chemical as of any other circumstances, and specimens in which the original organic character of the rock has not been entirely obliterated are sufficiently common. It would be unreasonable to suppose that large masses of guano could accumulate under the circumstances which are known to have existed in Florida. Neither the dry climate nor the impervious substratum, one or the other of which would have been necessary to the preservation of guano as such, were present in the locality where the floridite occurs. It seems likely, however, from the geologic and geographic distribution of this mineral, that its genesis was not entirely unconnected with the elevated site, free drainage, and notably absorbent rock which the old Eocene island afforded. This area must have been dry land most of the time since the older Miocene epoch, since no deposits of later date occur upon it except in connection with the supposed Pliocene lakes, or along the channels of the rivers.

Other phosphates.—The other forms of phosphatic rock, which may be grouped under the general term phosphorite, are usually modifications of the Miocene or older Pliocene limestones. They comprise:

1. *Lime rock phosphatized in place*, a variety that is not abundant and often seems rather barren in phosphate of lime. (Ex.: Hawthorne beds, bed of Peace Creek.)

2. *Fragments of phosphatic rock united in a softer, geologically later, limy matrix, itself not phosphatic.*—This variety is hardly more valuable

[1] E. T. Cox, in Am. Naturalist, Dec., 1890, vol. 24, pp. 1185-1186.

though more common than the preceding, and is apt to be uneven in character. (Ex.: Devil's Millhopper at Gainesville.)

3. *Segregated gravel or pebbles of phosphatic rock united as above by a softer matrix.*—This having been subjected to a natural process of selection by mechanical forces is of a better quality than the unworn conglomerate (No. 2) and therefore more valuable. The same hard pebbles have been in many cases repeatedly consolidated in a matrix of softer lime, released from it by the action of water and reconsolidated into a later bed, a process which it would seem will only cease with the complete destruction of the pebbles by wear. (Ex.: Yellow marl of Peace Creek and the Alefia River.)

4. *Nodular phosphate rock*, produced by the alteration and rearrangement of the lime rock particles into concretionary phosphatic nodules, united by a softer matrix of less phosphatic lime. This variety occurs in masses or bunches of great irregularity, though often individually rich. This is the "rock phosphate" of many of the prospectors. The lime is often deposited over cavities in the rock in a drusy layer. The nodules are so poorly united by the softer matrix that a large mass can often be rubbed into a sort of gravel between the hands. A machine has been invented for doing this and segregating the nodules. Owing to a want of uniformity in percentages of phosphoric acid and the very irregular distribution of the larger masses in the soil, the prospects for the utilization of this variety of phosphates seem somewhat less promising than for the floridite or the "pebble phosphate" deposits. This variety appears to be more widespread in Florida than any other and occurs in rock of every age from the Eocene up. The nodules or pebbles which it contains, though similar in shape, are not the same as the phosphate pebbles obtained from the river beds of the Alefia and Peace Creek and are very much less uniform in quality. (Ex.: Some Bartow rock phosphates.)

5. *Gravel or sand, itself not phosphatic, but coated with and united by a phosphatic matrix.*—This variety is not uncommon, and is said occasionally to have a local value as a fertilizer. The matrix appears to be derived from the disintegration of antecedently phosphatic rock. These oolitic, sometimes pisolitic, rocks are usually of very recent formation, often Pleistocene. (Ex.: Rock Island, Lake Monroe.)

6. *Pebble phosphate.*—This results from the action of rivers upon the other varieties of rock, reducing them, as well as any bones or teeth they may contain, to gravel. The hardness and value of contained phosphate, being relatively proportional in a general way, the older gravels will contain, on the whole, the best material, which is usually derived from varieties 1 and 2 and their associated vertebrate remains. The pebbles are screened and dried, after being dredged from the river bottom by a centrifugal pump. They are then exported for conversion into soluble phosphates for fertilizers. Examples of this variety may be found in the river deposits of almost any part of Florida, but especi-

ally, as far as we know at present, such rivers as the Alefia and Peace Creek. Rivers in which the banks are composed of material geologically later than the older Pliocene do not afford the pebble phosphates, and the richness of others in this variety of the mineral will doubtless be found to be measurably connected with the development of old Pliocene strata along their banks.

River phosphates.—In an article on the "Phosphate Beds of Florida" Prof. Albert R. Ledoux[1] speaks of the phosphatic nodules with which the Peace Creek remains have been stated to be associated, and states that "in appearance and composition this phosphate differs very little from the South Carolina material. They are identical" (op. cit., p. 176). He also notes that "the Florida deposits may be divided into two distinct classes, one, 'the river deposits,' almost resembling in quality and manner of occurrence the South Carolina beds, and the other [floridite] totally different." The deposits of the first class, beside those above mentioned on Peace Creek, include others in Wakulla County, in the north, several points on Tampa Bay, the basin of the Alefia River, and even in the vicinity of Fernandina. Many years ago the officers of the U. S. Coast Survey called attention to the occurrence of such phosphatic nodules and vertebrate remains in the outlets of several of the western creeks and rivers of the State, but they attracted little attention except as curiosities. Experts representing the Charleston phosphate interests are said to have reported that, owing to the difficulty of access and expenses attending the collection of the material from these deposits, the South Carolina article need not fear any very immediate competition from this direction.

At present, however, the Charleston interests are investing largely in this region, and numerous other companies have secured territory which they are either working or about to develop. At one place, Zolfo Springs, the principal corporation concerned in the business not only gets out the "pebble phosphate" and prepares it for exportation, but manufactures soluble phosphates for local use as fertilizers.

It forms no part of the writer's plan to detail the commercial development of these interests, which, moreover, is so rapid in its progress that any account in this place would become obsolete before it could be made public. At the time of writing, however, it may be desirable to state that the production of dry phosphatic gravel from Peace Creek, dredgings is estimated to be about two hundred and fifty tons a day A rather full account of the business in Florida, from its economic side, by Dr. J. Shrader, has recently been issued by the Courier-Informant newspaper office at Bartow, Florida.[2]

As we ascend the Peace Creek drainage system toward its head the pebble phosphate, in the beds of streams comprising the system, naturally becomes less abundant in proportion to the smaller size and

[1] Eng. and Mining Jour., Feb. 8, 1890, vol. 49, page 175.

[2] Florida. The Underground Wealth and Prehistoric Wonders of Polk and De Soto counties. Bartow. 1890. 34 pp. 8°.

inferior mechanical efficiency of these streams. Hence, in the peripheral portions of the basin attention has been chiefly directed to the varieties of phosphatic rock which, lower down, have been subjected to the segregative action of wear by the current. On the other hand, on the Alefia River it would seem from the few data accessible that the lower part of the basin cuts through old Miocene rocks, while the upper part is situated in a newer Miocene or older Pliocene area. Consequently the deposits of pebble phosphate in this basin are richer at some distance above the mouth of the river than they are in its lower reaches.

Floridite deposits.—These deposits are described by Prof. Ledoux as follows:

At present, for a description of the new discovery, we can confine ourselves to the Gulf counties south of Wakulla and north of Tampa. There seems to be also a gradual concentration towards a center well defined and whose area at this writing may be defined by a circle whose diameter is 30 miles and whose center is near Hernando, in Citrus County. This includes Dunnellon on the north and Floral City on the south and is roughly bisected by the Withlacoochee River from southeast to northwest. * * * In this area it seems that almost anywhere a pit or auger will reveal phosphate. In no pit or opening that I visited in that section did I find it entirely absent. * * * The phosphate is found at varying depths below the surface, sometimes within 2 feet and sometimes 10 or 12 feet down. In sinking a pit it is sometimes difficult to tell where the clay ends and the phosphate begins; they shade into each other, at times gradually, at other times the clay is entirely absent, the sand being the only thing between the surface and the valuable mineral. When wet they are dark or light yellow, but usually a dazzling white when dry. The thickness of the beds is very variable. There is nothing to indicate it on the surface; it may be a few inches, or 10, 12, or 16 feet of solid mineral. * * * Prof. W. P. Frost states in a description of the Dunnellon field that "I myself saw an auger bored 16 feet into this stuff without going through it; it remained of the same consistency throughout, perfectly smooth and free from grit. * * * The natives, who are ignorant men, not knowing the value of the material, testified that they had seen wells dug 60 feet through this material to reach water-bearing strata." He estimates for the Dunnellon field that 3,000 acres (out of 13,000) are underlaid by the mineral, which occurs in ridges and pockets, running by his analyses 50 to 65 per cent and averaging between 55 and 60 per cent.

Prof. Ledoux personally observed material of a somewhat different sort occurring in Citrus County, a mile southeast of Rutland post-office, where, by sinking pits, phosphate in numerous nodules or masses, not in place, was discovered in the sand, making up fully one-third of the material excavated below a depth of 3 or 4 feet from the surface. These masses were of a yellow color and quite hard. These would seem to resemble the material at the Devil's Millhopper, elsewhere referred to as composed of fragmentary masses of the phosphatic Miocene rocks of the Hawthorne beds.

It is impossible for the most experienced person, according to Prof. Ledoux, to tell by the eye alone the difference between the white carbonate of the lime or phosphate, or between the calcareous clay and cream-colored phosphate.

He calls attention to the necessity of discriminating, in analyses, between the sand and clay mechanically mixed with the phosphate of lime and the chemical silicates and phosphates of alumina, which are commercially worthless.

A surface indication, which is considered of value by some experts as pointing to the presence of phosphates below the soil, are masses of flint or siliceous rock protruding from the surface. "The area of the beds is sometimes defined from curious bowlders and masses of a hard phosphate rock, white or yellowish white, which has stood weathering remarkably, and which is quite rich in phosphate."[1]

It may be premature to venture on an opinion of the age at which the phosphoric acid so marvellously preserved in these beds was deposited on the soft calcareous rocks which have furnished the lime. It may not be amiss, however, to point out certain facts which apparently have a bearing on this question. The phosphatic character of the Hawthorne beds would indicate that the source from which this phosphoric acid came was later than the deposition as lime rock. The rocks of the Chattahoochee group afford very nearly the soft and absorbent surface which would best appropriate the valuable element from fresh or rain-washed excreta, such as we may imagine were the source of the Florida phosphates.

At the upper part of the Orthaulax bed, which overlies the Chattahoochee group at the southern edge of the phosphate area, the presence of a large land-shell fauna (initiated in the last days of the Eocene Ocala beds) shows that a considerable area had by that time become dry land with fresh-water ponds and knolls elevated above any tide. This land must largely have presented a surface of the Eocene nummulitic or Miocene Chattahoochee group rocks, and would afford an admirable locality for rookeries of birds or other guano-producing creatures. The character of the land fauna of the Orthaulax bed shows that it was derived from the south and not from the north, and the dry land of Florida may have borne to the Miocene continent much such a relation as the Bahamas islands and lagoons do to the present peninsula of Florida.

It seems, then, as if the facts pointed toward a more or less continuous deposition of phosphoric material between the older Miocene and newer Pliocene epochs, which was absorbed by the subjacent rocks, and which, preserved there in large masses, has furnished to later, even to actually forming, rocks in Florida the more or less evident traces of phosphoric acid which many of them present and which can hardly have been wholly derived from more recent sources of supply.

MARINE PLIOCENE BEDS.

The discovery of genuine Pliocene fossiliferous beds in south Florida is of comparatively recent date. It may be said, indeed, to date from the time when the Okeechobee Canal Company endeavored to extend the area of the rich hammock land about the lake by reducing its area.

[1] Ledoux, op. cit., pp. 176, 177.

The latter was to be brought about by cutting drainage canals, and the explorations of the upper Caloosahatchie necessary to this end brought some intelligent people to a point where they could not avoid seeing the remarkable fossil shells of which the banks are so full. Some reference to this had appeared in a popular article[1] in one of the magazines, and among the earliest modern explorations recorded was that of Engineer J. L. Meigs in 1879. But the scientific exposition of these beds begins with the report by Prof. Heilprin of the results of the party led by Mr. Joseph Willcox and fitted out with the cooperation of the Academy of Natural Sciences and the trustees of the Wagner Free Institute of Science, of Philadelphia, in 1886. This report was printed in the first volume of the Transactions of the Institute, published in 1887. In the winter of 1886 and 1887 Mr. Willcox revisited the locality in company with the writer, and a third time subsequently. A description of the fauna of these beds has been begun in the third volume of the Wagner Institute's Transactions.[2]

Older marine Pliocene beds.—More recent observations by the writer and others have resulted in showing that between the epoch when these beds were deposited and a subsequent similar, vastly more extended, but probably not vertically great depression, there was a time when a moderate elevation brought large areas above the sea, when the thin sheet of newer or Chesapeake group Miocene, which had been laid down about the island of Eocene rocks formed by the western anticline of the peninsula, was more or less eroded, when the northern part of the median syncline was perhaps occupied by the Pliocene lakes, or Lake De Soto, and when the innumerable Pliocene vertebrates wandered over the hummocks or left their bones in the tenacious mud of bogs or on the marshy borders of lagoons.

The marine beds of the Pilocene, which were laid down before this time of elevation, in the main, as far as examined, do not show any marked difference in the invertebrate fauna when compared with the newer or Caloosahatchie beds. This similarity of fauna is in itself strong evidence in favor of the moderate character, both in duration and vertical range, of the changes of level referred to. A very large area in central and southern Florida was probably covered by this older marine Pliocene. There appear to be traces of it at Clay Landing and other points on the lower Suwanee River, and it is not unlikely that the whole great Suwanee swamp region may be underlaid by it, as well as the De Soto lake area. There are traces of it in the rocks of the upper Alefia, but farther to the west and north, on the Hillsboro, so far as known, if any of this rock was deposited it has since been removed. I incline to the belief, however, that the Hillsboro region, from its relation to the great western anticline, was not depressed below

[1] Which the writer of this essay read at the time and remembers, but has since been unable to trace.

[2] Contributions to the Tertiary fauna of Florida by W. H. Dall. Part I, Pulmonate, Opisthobranchiate and Orthodont Gastropods. Aug., 1890. 4°, 200 pp., 12 pl.

the sea during this part of the Pliocene. The "pebble phosphates" of the upper Alefia, like those of the Peace Creek basin, are, as far as yet observed, entirely of this rock, and on the Alefia researches hitherto made have failed to find the subsequent marine Caloosahatchie Pliocene represented. The writer has traced the older rocks in question up the Peace Creek basin to Bartow, where in one place it lies in a stratum only 3 or 4 feet thick over a knoll of Eocene nummulitic rock, but in general is of much greater, yet undetermined, depth; the phosphate rocks of the vicinity of Lakeland appear to be of this age. That it underlies the lake beds of the De Soto basin is probable from indications afforded by borings for phosphate near Tavares, in the very focus of that basin. The last traces on the northeast disappear at Orlando, just beyond which the Miocene makes its appearance on the rise of the eastern anticline.

To the south, along Peace Creek, this series of beds is covered by the newer marine Pliocene, at least as far as Zolfo Springs, but at Fort Meade the later beds would seem from report to be absent. The northern margin of the Caloosahatchie beds would therefore seem to lie somewhere between these two points. On the Charlie Apopka River (Secs. 2 and 3, T. 36 S., R. 25 E.) the older rock is abundantly represented. It has not been phosphatized, and, therefore, presents its fossil impressions in much sharper and better state than along Peace Creek; whether it is overlain by newer Pliocene on the Charlie Apopka is not yet known. On the Caloosahatchie and all the great southern region, owing to the very small elevation of the land, it is not known to crop out anywhere, the base of the Caloosahatchie beds themselves being below the level of the sea as far as yet known. It has, however, been dredged up from the channel of Tampa Bay at a depth of some 40 feet, while harbor improvements were in progress.

Caloosahatchie beds (Floridian of Heilprin).—As the Caloosahatchie beds are the original and typical exposure of the newer Floridian Pliocene, our description of that formation will best be opened by an account of the beds observed by the writer on that river in February, 1887, when accompanying Mr. Joseph Willcox.

Prof. Heilprin[1] has informed us that the level of the bottom of lake Okeechobee will average about 10 feet above the sea level, or is composed of a plain having 7–15 feet of elevation, with a depth in the greatest observed depression of 22 feet, but an average of less than half as much water over it in a dry season. Lake Hickpochee, between Okeechobee and the head of the Caloosahatchie River, now connected with both by canal, is supposed by Prof. Heilprin to have practically the same level as Okeechobee. The canal, where it leaves Lake Hickpochee to the west, on its way to connect with the Caloosahatchie, is stated by Prof. Heilprin to be 20–22 feet above the sea level. He states that this is "about 11 feet above the base of operations near

[1] Trans. Wagner Inst., Vol. I, p. 41.

Fort Thompson." If this is intended for the water level, as the context indicates, it is probable that Prof. Heilprin was misinformed, as the depth of the river, considering the character of its bed and the volume of water, by no means corresponds to a fall of nearly a foot to the mile. It is not improbable that there has been some confusion between the height of the land, which varies considerably, and the level of the stream.

The Caloosahatchie River, in the proper sense of the word, begins at the northeastern extreme of the long estuary which bears the name, some distance above the town of Myers.

The banks at first are extremely low and screened by thickets of mangroves, which only disappear when the water becomes perfectly fresh. The land appears nearly level. As the river is ascended a close scrutiny shows that it cuts through a succession of gentle waves, gradually increasing in height, inland, whose crests would show a general parallelism with the direction of the peninsula of Florida, or transverse to the average course of the river. Near the headwaters of the river these waves of elevation rise above the level of the river at low water, to a height of perhaps 12 feet at most, and their individual length from one trough to another may average about one-quarter of a mile. Though insignificant as flexures, they are interesting as showing that a lateral as well as a vertical thrust has attended the movements of the rocks in this part of the State, a fact which has been questioned. The greatest elevation studied by us extends for several miles between the sites of the old forts Thompson and Denaud. At the former point the canal from Lake Okeechobee enters the river, its bed being a compact silicified rock, which had to be blasted out. The succession of the strata is perfectly uniform, though the amount of their fossilferous contents varies.[1]

Just below the rapids at Fort Thompson the following section was obtained:

	Inches.
1. Vegetable mold and sand	18
2. Indurated sand with fresh-water shells, post-Pliocene	8
3. Mixed marine and fresh-water shells, post-Pliocene	6
4. Pliocene Planorbis rock, to the water's edge	15

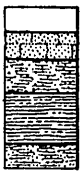
The Planorbis rock which forms the lowest member of this section is the hard rock which was blasted in making the canal; it reaches a thickness of 3 feet or more and overlies the so-called "*Venus cancellata* bed," or upper stratum of the Caloosahatchie marls. In previous reports no strict discrimination has been made beween the Quaternary fresh-water indurated sand rock (No. 1 of the preceding section), which is the youngest of all and found widely spread over the peninsula, and the Pliocene Planorbis rock, which contains only extinct species or recent species also common to the Pliocene marl. I suppose that the "fresh-water limestone" which Heilprin refers to (op. cit., p. 33) as forming the bed rock of the canal is practically the Planorbis rock (more or less inclusive of the later rocks lying upon it as above), and this, according to Captain Menge, has been traced eastward a considerable distance; disappearing about 3 miles west of Lake Hickpochee at a depth of 5 feet 2 inches below the level of the surface of the water in the canal. It probably extends much farther eastward, and has

[1] Dall, in Am. Jour. Sci., 3d ser., vol. 34, p. 168.

been found by one of Mr. Eldridge's associates near the eastern coast of Florida, in about the latitude of the southern end of Lake Okeechobee.

The same compact limestone, with the same species of *Planorbis*, etc., occurs near Hillsboro Bay, Tampa, and has been dredged in large masses from the channel by which the harbor of Tampa is entered. This shows a very wide extension of this deposit, the two localities being some 90 miles apart in a direct line.

Two miles below the point where the last section was taken, the following section (Fig. 22) was measured on the south bank of the Caloosahatchie:



1 18″. Sand and humus.
2 18″. Indurated yellow sand; no fossils.
3 2′. Sandy marl; *Venus cancellata* bed, with *Bulla*, etc.
4 3′. Compact marl.
5 18″. Sand and marl.

FIG. 22.—Section on the south bank of the Caloosahatchie River, Florida.

Nos. 3, 4, and 5 are Pliocene, the upper layers probably Quaternary.

A third measurement of the south bank, about 4 miles above Daniel's place, afforded the following section:

	Inches.
1. Fine white siliceous sand	18
2. Vegetable soil, with some sand; shows black	12
3. Sandy marl, with *Venus cancellata;* shows gray.	
4. Hard, eroded rock, with the same fossils; shows grayish.	
5. Soft yellowish marl, with the same fossils as No. 3, but more lime and less sand and many worn siliceous nodules. Total (3, 4, and 5)	66

The three lower layers grade into each other petrographically and have the same fossils, without exception. They belong to the Pliocene series.

Practically the same set of beds, measured about two miles and a half below the western end of the canal, gave 18 inches humus and sand over the same depth of indurated yellow sand without fossils, below which are 2 feet of sandy marl with *Bulla striata*, *Venus cancellata*, and a multitude of *Planorbis* and *Physa;* then 3 feet of compacter marl, with a great many marine fossils and comparatively few fresh-water shells, the deposit containing irregular nodules, lumps, and strings of silicified material, often extremely hard, and in which the fossils are often represented by mere molds. Below this, which is the chief fossiliferous stratum, lies a foot and a half of sand and marl, with few fossils and many fragments and worn siliceous fragments against which the water dashes. This stratum in other places is consolidated to a tolerably compact rock, and the fossil bed above it to a flinty chert. The chert shows manifest indications of having been worn by the action of the waves, and one of my specimens shows a boring bivalve still intact in its burrow in one of the protuberances of this layer. In other places fossil oyster-banks, corresponding to the oyster marl of Peace Creek, could be clearly seen, but nowhere any coral reef, though small isolated heads of coral were not uncommon. The intermixture of fresh-water and marine shells is characteristic of the whole deposit, though the upper stratum contains proportionally many more fresh-water individuals.

The upper siliceous Planorbis rock was by the writer,[1] as well as by Prof. Heilprin, supposed to be Quaternary until the fossils were studied.

[1] Am. Jour. Sci., 3d ser., vol. 34, p. 169.

But careful study made on the spot showed that the supposed post-Pliocene age of the so-called "Venus cancellata bed" was an error, due to the fact that layers of *Venus* (*Chione*) *cancellata* Linné, of Quaternary age, are very common in Florida, and sometimes in the Caloosahatchie region overlie the Planorbis rock.

In this connection it may be stated that *Chione cancellata* is known from the Chipola Old Miocene marls, in no respect differing from recent specimens, and that it has continued as a conspicuous member of the Florida fauna (except during the epoch when the Ecphora beds were being deposited) up to the present day. It is a warm-water shell and extended in abundance farther north during Chipola times and the newer Pliocene than during the period when the beds of the Chesapeake group were being deposited or at present. The last-mentioned periods were and are relatively cooler and the two former relatively warmer, judging by the fauna. The species has never been entirely absent and at the present day reaches as far north as Hatteras, in the warm-water area. It is also a shallow-water shell, living chiefly between tides when the climate is mild enough, and its abundant presence with *Bulla* is indicative of a formation laid down in quite shallow water. The *Bulla* has in recent times also receded southward, probably for similar reasons.

The marls of the Caloosahatchie contain a large number of species, of which a fair proportion, perhaps 15 per cent, are supposed to be extinct; many of the others are known only from deep water. How many of the so-called extinct ones, like *Amusium mortoni*, will turn out to be still living when the deeper waters of the Floridian coast are thoroughly dredged remains to be seen. A number of the species appear to be more nearly related to shells known from the Asiatic or Californian coasts of the Pacific than to the shells of adjacent waters. But these apparent relations depend a good deal on our ignorance of what the deep waters of the Gulf really contain. In their curious partial silicification these beds afford an interesting parallel to those of Ballast Point, and show that similar action has been going on since Miocene times on this coast.

The age of the Caloosahatchie beds is more clearly Pliocene than that of any others which have been so called on our eastern coast. The time has not yet arrived, nor is our knowledge sufficient to enable us to decide finally as to the chronologic relation of all of these terrestrial and marine Pliocene beds to each other. But without reference to their minor chronology the geological history of the Caloosahatchie marls is clearly stated in their structure.

The assemblage of species on the whole, in the principal stratum, is such as one might expect to find in water from 20 to 50 feet in depth, judging by what we know of living mollusks. Mixed with these are a certain number of shallow-water forms which may be supposed to have flourished as the water became shoal by elevation of the sea bottom. There were lagoons of fresh water and probably short streams emptying into the sea, and in time of flood sweeping their fresh-water population out on to the shoals, where it perished. Part of the bottom became elevated nearly to the surface, oyster banks were formed on it, and the compacter parts became water-worn. The absence of shells, like *Litorina* and *Nerita*, seems to indicate that the dry beaches were muddy or sandy rather than rocky. In the course of time elevation so shoaled the water that only species like *Venus cancellata* and others able to live between tide marks could remain. This portion of the formation constitutes the so-called *Venus cancellata* bed, though neither of its component species is peculiar to it. Finally, the area became cut off almost entirely from the sea and occupied more or less by fresh-water ponds in which the pond snails multiplied in myriads. Drifting sea sand has buried these and in its turn has been covered with a thin coat of humus in which the pine, palmetto, and a host of scrubby plants make a fairly successful fight against the invasion of civilization.

The history of Ballast Point seems to have been much the same in Miocene times, except that there the land seems to have risen sufficiently to enable true air-breathing land snails to become abundant. On the Caloosahatchie they are extremely rare, only one or two specimens having turned up among the thousands of fresh-water snails. On the other hand, if Ballast Point rose higher, it was afterward depressed lower, so that several feet of marine orbitolite rock could be formed over it. On the Caloosahatchie the thickness of the marine strata over layers of the Planorbis rock did not exceed 6 inches.

As it may be supposed that the admixture of fresh-water forms with the marine forms has been due to mechanical mixture after fossilization, which in certain places, where the marl is penetrated by roots from above, might have occurred, I will add in concluding that the same mixture occurs in the interior of the most flinty chert bowlders. It is curiously paralleled by the mixture found in material collected by the U. S. Fish Commission, in some of the inner lagoons of the Bahamas, where a similar series of geological changes may be supposed to be at this moment in progress. Among the fresh-water species is a large *Cyrenella*, a genus recently found by Hemphill living in a South Florida marsh. It has not been before known from the United States, was originally described from Senegal, and subsequently from Porto Rico.

No coral rock or coral reef formation was anywhere observed, though isolated small heads of coral are moderately common in some parts of the Caloosahatchie marl.

The uppermost strata of the Pliocene beds begin to appear above the level of the river at low water (during the dry season) about 24 miles due east from the shore of Charlotte harbor, and they dip to the eastward out of reach about 30 miles farther east. Their total measured breadth here is thus at least 30 miles and includes the whole of the elevated land between Lake Hickpochee and the point on the river above mentioned. In this distance there are not less than twenty visible but very gentle folds of the strata in the direction of the trend of the peninsula.

That these beds extend much farther north and south there can be very little doubt, though our information so far is fragmentary. The most northern point at which they have been actually observed is in the banks of a small stream crossed by the railroad a short distance north of the depot at Zolfo Springs.

On the Caloosahatchie the strata may be divided into oyster-reef marl beds, conchiferous or Turritella marl, and layers of sand; which intergrade without distinction and have no invariable succession, but always grade into the shallow-water fauna at the top,[1] which is overlain by the Planorbis rock, and this in turn by post-Pliocene deposits which are seldom of great thickness.

Near the north end of Charlotte harbor a small creek comes in from the east called Alligator Creek. Here Mr. Willcox found an extension of the Caloosahatchie beds. The banks are about 12 feet high, the upper half being pure sand; the lower half contains fossils of Pliocene age, mollusks, barnacles, and flat Echinidæ. They differ from the Caloosahatchie deposits in being in pure sand instead of marl as a matrix. The upper half of the fossiliferous stratum shows the shallow-water fauna, with its usual partial admixture of strictly Pliocene extinct species. Some parts of the bed are united by siliceous cementation into a hard rock.

A little farther north Peace Creek enters Charlotte harbor above Punta Gorda. The banks of this creek are low for some distance, but Prairie Creek, which enters the estuary from the east, has a south fork, known as Shell Creek, a short but navigable stream which heads among Pliocene beds. The banks are higher here than on the Caloosahatchie, being 25 feet at the highest point, but the difference is chiefly of unfossiliferous marine sand 12 feet deep. Then comes about 2 feet of shallow water fauna with some Pliocene species, below which is a hard limestone stratum 2 or 3 feet thick, beneath which is a bed of conchiferous marl, like that of the Caloosahatchie. There are slight differences in the fauna, such as might be expected at points 20 miles apart.

The Myakka or Miacca River comes into the Charlotte harbor from the northwest parallel with the Gulf coast, and its estuary is nearly at right angles to that of Peace Creek.

Here Mr. Willcox found a bed of lime rock at the sea level with uncharacteristic species poorly preserved. Above the lime rock are beds of shell marl considerably mixed with sand. In this deposit was collected about forty species of shells, of which about 10 per cent were

[1] There are Pliocene beds of *Venus cancellata* and *Bulla striata*, and post-Pliocene beds chiefly composed of the same two species. For this reason the name "Venus cancellata bed" for the shallow water part of the marine Pliocene is unfortunate, though very natural to anyone who has seen it. It will always require careful examination to determine to which series a bed of *Venus cancellata* should be referred, and some confusion has already occurred from taking the Pliocene age of such a bed for granted. To distinguish the Pliocene and Pleistocene beds of this kind the latter might be called, from their most abundant fossil, the *Bulla striata* marls.

extinct Pliocene species. This bed seems to have fewer extinct species than the Caloosahatchie marls and may be regarded as a little younger, perhaps corresponding to the Planorbis rock, which seems to be absent on the Myakka.

Along Rocky Creek, which falls into Lemon Bay near Stump Pass, in about latitude 26° 55′ west from the Myakka, a bed of *Venus cancellata* rises to about a foot above the water, or in many places forms the bed of the stream. It is probably the upper shallow-water layer of the Pliocene, as *Cerithidea scalata* Heilprin, a Pliocene species, has been found near by on the beach of the bay.

On Peace Creek there are no banks high enough to afford a section, and no trace of Pliocene yet observed up to 3 miles above Fort Ogden.

Farther north, on Peace Creek, the Caloosahatchie beds appear at Shell Point, 3 miles above Arcadia, as previously described;[1] and I was informed that the same bed occurs on Joshua Creek, near Nocatee, and at a point on Peace Creek 6 miles below the works at Arcadia, between that place and Fort Ogden. The same oyster bed is conspicuous in the banks of a small stream just north of the railroad station of Zolfo Springs. This stream, a feeder of Peace Creek from the east, has cut quite a deep gully, and the oyster bed occurs in the vertical sides about 2 feet, or possibly less, above the water when the latter is low, as in January, when I observed it. Above the oyster bed the elevation cut by the stream is composed of some 20 or 25 feet of yellow sand, with a foot or two of the white sand covering it. Some portions of the yellow sand here, as at Shell Point, are quite indurated and stand vertically like rock. The section can be well observed from the railway culvert.

Considerably east of Peace Creek beds of marl containing "large clams" have been reported to Mr. Willcox as occurring on the banks of Arbuckle Creek. Something of the same sort on the Kissimmee River, near Fort Kissimmee, was mentioned to me by prospectors at Bartow who had visited that locality. Both these marl beds are likely to prove to be Pliocene.

The slight tilting of the plane of the peninsula caused by the rise of the eastern border and a presumed equivalent depression of the Gulf coast opposite is indicated by the manner in which the Pliocene beds disappear west of the Tampa Old Miocene. The washing and dredging up of newer Miocene and Pliocene fossils along this shore may indicate the continued existence of beds of both ages under the adjacent waters of the Gulf rather than wash from the existing shores.

Cerithidea scalata has been found on the shore of the Gulf near Casey's Pass, 17 miles northwest of Stump Pass, and near the entrance to Little Sarasota Bay, 6 or 7 miles farther in the same direction, which would indicate the presence somewhere in that vicinity of the Pliocene marl.

Finally, the presence of large fragments of older marine Pliocene and

[1] See under the head of "Oyster marl," p. 132.

of the Planorbis rock in the channel at Port Tampa, Hillsboro Bay, before referred to, carries the Pliocene nearly 50 miles farther to the northwest.

These data would indicate the original presence of the Caloosahatchie beds over a distance on the western part of the peninsula, roughly speaking, of 100 miles northwest by 50 miles southeast. On the eastern coast of Florida no marine Pliocene has yet been identified, and the first point where the characteristic species have since been recognized is in South Carolina, where a number of them are found and have not been discriminated from the Miocene of the Chesapeake group. Still farther north one of the species appears, with a few other extinct forms, in the marl which has been found underlying a part of the Great Dismal Swamp, in southeastern Virginia.

Recent observations by Heilprin [1] seem to indicate the presence of late Pliocene rock over a considerable area in Yucatan. A few, four or five, Caloosahatchie species are, according to Prof. Heilprin, recognizable in the limestone of the Yucatan plains, but, judging from the list given, the fauna must have been at the very top of the Pliocene series, and none of the most characteristic Pliocene species occur in it.

PLEISTOCENE AND RECENT DEPOSITS.

While it does not strictly enter into the scope of this essay to discuss the Pleistocene series, for the sake of completeness in connection with the description of the Florida region a few notes on the later strata of the peninsula are appended.

The beginning of Pleistocene time is generally taken as marked by the Glacial Epoch. Recently Spencer,[2] Upham,[3] and others have postulated an elevation of the land north of the Gulf of Mexico "for a short time" to a height of "not less than 3,000 feet," in the endeavor to account for the Glacial Epoch.

Without expressing any opinion as to the possibility of such an uplift farther north, the writer desires to put on record here the reasons why such an uplift in Florida seems to him incompatible with the observed facts:

1. It is inconceivable that such an uplift and downthrow should have taken place at the end of the Pliocene without some dislocation and disturbance of the rocks, which would be conspicuously shown in the geology. But the most conspicuous feature of Florida geology is admitted to be the absence of any such dislocations.

2. It is inconceivable that rocks of the incoherent character which make up the peninsula of Florida, subjected to the torrential rains of their semitropical rainy season, should have been elevated to 3,000 feet above the sea without the carving out of canyons and the sculpturing of the topography in an unmistakable manner. The river beds would

[1] Proc. Acad. Nat. Sci. Phila. for 1891, pp. 141-143.
[2] Bull. Geol. Soc. Am., vol. 1.
[3] Am. Geologist, vol. 6, No. 6, Dec., 1890, p. 329.

have been worn to great depth, and, if subsequently filled, the filling would be heterogeneous.

But the absence of any such cutting is self-evident, the rivers often flow over undisturbed Pliocene beds of shell marl and are mostly too shallow for anything but small boats.

The larger part of the St. Johns River, which might appear to form an exception, is simply an elevated perezonal lagoon. This has become the channel of a drainage which is in no way related to the deposit of talus over which it now flows. In the so-called Indian River we see such a lagoon which has not yet been so elevated.

3. The scouring of the surface due to the steeper gradient would have left undisturbed, under the summer rains, no totally incoherent beds. They would have been carried off and redeposited at the perezone everywhere.

But it is well known that such incoherent beds exist undisturbed in every part of Florida, and represent, as a whole, rocks of every series from the Eocene up.

4. The carving referred to would have made canyons in the gulf plateau (now submarine, then dry) west of Florida indicative of the course of each of the Florida rivers which would be more or less evident in the present submarine contours.

Nothing of the kind is visible in the contours, though soundings in the gulf by the Coast Survey and Fish Commission vessels have been remarkably numerous and made with the greatest care and the best modern methods and instruments.

5. The elevation of the coast suddenly and for "a short time" to such a height would obviously have exterminated the whole marine shallow water and shore fauna, except such as lived elsewhere at a great distance, and, after the succeeding subsidence, might have immigrated to Florida. But there are a number of local species originating in the Miocene, peculiar to Florida, which live in shallow water and have preserved their continuity intact to the present moment, and there is no such preponderance of Antillean types in the present fauna as would have resulted from an immigration, possible (in the assumed circumstances) only from this direction.

Lastly, it may be pointed out that the hypothesis, so far as it relates to the Florida region, mainly rests on two unproved assumptions, either of which being shaken, will let the whole structure fall. The first of these is that submarine valleys must have been cut when the bottom was dry land. The second is, that the submarine valleys which are actually known to exist, and which have been miscalled "canyons," were necessarily cut at the end of Tertiary time.

That the first assumption is untrue every hydrographer knows, and everyone who has studied the Gulf Stream knows what a scour it exerts on its present bed at a depth of 3,000 feet.

The second assumption may or may not be true, but there is no evident reason why the valleys in question may not date from the Cretaceous quite as reasonably as from a later date. The slope, with reentrants, which the contours exhibit off the mouth of the Mississippi, the whole of which must be taken into account in any fairly constructed hypothesis, is visible in the contours at a depth of at least 9,000 feet, a height to which no one has yet ventured to elevate the Gulf of Mexico.

The collateral arguments by which this hypothesis has been supported (I speak with regard to the Florida and Gulf region) are in several instances based on error. For instance, Mr. Upham states[1] that "several low passes from ocean to ocean are found in the Lake Nicaragua region, on the isthmus (of Darien) and in the Atrato River district to the south, at heights from 133 to 300 feet above the sea level." These figures will bear a good deal of revision with the data at present available. Again, Dr. Maack is quoted in behalf of the Pleistocene age of fossils collected by him on the Atrato divide, "the lowest elevation of which was found to be 763 feet." (Op. cit., p. 396). The Doctor, in his report,[2] calls these beds "later" or "latest Tertiary," and speaks of the species as being "all living up to the present time." Unfortunately for the value of this report, Dr. Maack was a vertebrate paleontologist, unacquainted with invertebrate fossils or recent shells in the American fauna, and incompetent (even if he had been in a normal mental condition) to give any valid judgment on such a question. The unfortunate state in which his explorations left him is well known, and would render it necesssary to reexamine any conclusions which might be based on his opinions. On the other hand, we have the judgment of a good geologist and active paleontologist, the late W. M. Gabb, who examined Dr. Maack's fossils and regarded them as Miocene[3] and as including many species in common with the Miocene of Santo Domingo, which belongs to the lower Miocene, analagous to the Tampa Orthalaux bed. The Pleistocene fossils collected by Dr. Maack were obtained from an elevation of only 150 feet, 10 miles inland from Panama. I am able to state from an examination of the specimens at the Museum of Comparative Zoology, that all the fossils from the higher elevations on the Panama section are Miocene or Eocene. The explorations for the canal have shown that the ridge of greatest elevation is composed of azoic rocks, of which the age is uncertain, but probably not later than the end of the Eocene.

In this connection may be cited the observations of Everman and Jenkins,[4] who discuss at length the opinoins which have been held in regard to the mutual relations of the fish faunas of the east and west

[1] Am. Geol., vol. 6, No. 6, p. 339.

[2] Reports of Expl. for a ship canal, Isthmus of Darien, Washington, Navy Dept., pp. 155-175, 1874, fide Upham, Am. Geol., vol. 6, No. 6, p. 396.

[3] Proc. Am. Philos. Soc., 1872, vol. 12, p. 572.

[4] Proc. U. S. Nat. Mus., 1891, vol. 14, No. 846, p. 126

coasts of Central America and Mexico, especially bearing on the hypotheses of a recent water way connecting them. They show how the original view that the two faunas contain a large percentage of identical species has faded away with a more thorough knowledge of the facts, so that at present only 5½ per cent of the species are regarded as common to the two coasts, excluding species of general distribution in the tropics.

These authors then announce as their conclusion in regard to the question at issue:

> Our present knowledge, therefore, of the fishes of tropical America justifies us in regarding the fish faunæ of the two coasts as being essentially distinct, and that there has not been, at any comparatively recent [geological] time, any water way through the Isthmus of Panama.

The contact of the marine Pleistocene with the Planorbis Rock has already been described in connection with the section (p. 143) taken nearest to the end of the canal on the Caloosahatchie.

There are multitudes of localities where such beds are visible, mostly at elevations not far from the present water level, and indicating a small elevation, with possibly a smaller subsequent depression since they were deposited on the western side of the peninsula, while on the east there has been a slow, somewhat intermittent elevation, which has amounted in the total to not less than 20 feet above the present sea level in the cases where it is lowest, and possibly nearly as much more in some localities. Without definite proof of the fact, it looks as if there had been in Pleistocene time a tilting of the peninsula on its north and south axis, attended with some gentle folding of the strata, as seen on the Caloosahatchie; the eastern coast with its reef, as described by Shaler, having been tilted up, the western coast having sunk a little less; the difference having been taken up in the crumpling of the strata.

Among the localities where the marine Pleistocene is best developed on the western coast may be mentioned: Rocky creek near Stump Pass, Lemon Bay, (Willcox) overlaying the Pliocene; Phillip's Creek at the head of Little Sarasota Bay; North Creek emptying from the east into the same bay; these beds contain a large number of species, all known to be living on the coast. It is also found on top of the Miocene at Rocky Point, Old Tampa Bay, and in considerable masses near the mouth of the Manatee River.

RECENT ROCK FORMATION.

The process of rock formation is going on in a more obvious manner than would be expected along the Gulf shores of western Florida. There is a general opinion frequently expressed by Floridians, in conversation, to the effect that between Tampa and the Keys coquina rock is to be found at only one place, the mouth of the Little Sarasota Pass. But this idea is certainly erroneous, as at every projecting point of the Keys along the Gulf shore which we visited we found traces of this rock, though often not visible above the water, and frequently composed more of sand grains than of shell, so that it looks much like wet loaf sugar. It is doubtless being formed at many points along the Gulf shore, though in small quantities in each place, and not at all in the lagoons and harbors.

Another species of rock which strikes an observer as curious is in process of formation by immense compact colonies of *Vermetus* (*Petaloconchus*) *nigricans*, which raise the orifices of their minute blackish tubes to several inches above low-water mark, and in some of the larger bays have formed extensive reefs. The animal has been supposed to be a worm, belonging among the *Serpulæ*, but the writer was able to determine its proper place by an examination of the soft parts. This rock rarely occurs in a strictly fossil state, though the species is found in the Caloosahatchie Pliocene. It is locally known as "worm-rock," and many of the "rocks" described by the natives of this region as cropping out along the seashore turn out on examination to be of this kind.

There are three other sorts of rock of which the formation appears to be still going on. One is more or less indurated sand, which was observed at Myers; also near St. James city on Pine Key; on South Creek, where it was found in the banks under the usual layer of sand, and close to the landing wharf at Sarasota, on Big Sarasota Bay. It is very widely spread over the state near the sea, its absence being rather the exception. It sometimes contains the fragments of other older rocks, as in a matrix, an example of which was noted by Prof. Heilprin on St. John Island, at the mouth of the Cheeshowiska River. This rock is usually rather soft and contains recent land and a few recent marine shells. In other places, as at St. James City, it becomes extremely hard and compact, ringing under the hammer and almost destitute of fossils. A thin layer of it, from a mere film to 3 inches thick, marks the upper surface of the much older outcrop at White Beach, Little Sarasota Bay. This may prove to be identical with what I have called the Yellow sand.

A second variety of rock is formed by springs containing iron in solution, which are numerous along the main shore, as in both Sarasota bays. This water consolidates the gravel, sand, shells, etc., over which it passes, into something resembling coquina, but in which the fragments of shell, etc., are united together by a cement of limonite. A spring near the estate of Judge Webb, at Osprey, has thus affected a considerable part of what appears to be an Indian shell-heap; and among the shells, etc., in the rock may be detected fragments of pottery. Specimens showing this were brought home, and it is probable that the human remains discovered by Judge Webb near Osprey and by Prof. Heilprin in Sarasota Bay,[1] which are replaced by a pseudomorph of limonite, though older, are of a similar origin.

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[1] Leidy, in Trans. Wagner Inst., 1889, vol. 2, pp. 10-11.

In a softer stratum overlying that rock and apparently nearly of the same period of deposition were found *Venus mortoni*, *Pecten dislocatus*, *Strombus pugilis*, *Fasciolaria tulipa*, *Fulgur perversus*, and *Melongena corona*, all recent species in the same region. Some specimens forwarded by Mr. Willcox, who obtained them with some additional human remains from the same locality, appeared to be indurated sand rock of the variety first described. It contained a mixture of recent marine and land shells all common in the vicinity to-day.[1]

Other human remains in which the bones have been solidly silicified have been forwarded from the vicinity of Little Sarasota Bay to the Smithsonian Institution by Judge John G. Webb, of Osprey. They are doubtless Pleistocene and are contained in an indurated sand rock, tinged with iron oxide, and existing several feet below the surface at a considerable distance from the bay. These remains, though Pleistocene, are doubtless very ancient. It is probable no part of the world has afforded so many specimens of human remains in a truly fossil state as the peninsula of Florida.

The third variety of rock referred to occurs along the upper St. John River and about Lake Monroe. This is a sand rock in which each grain is coated with a pellicle of lime, giving the mass an oolitic appearance. In this rock, on Rock Island in Lake Monroe, Pourtalès and Wyman found the fossil remains of man which created so much excitement some years ago. The rock also contains recent land shells, but no marine fossils were observed. Rock of this character has been formed in Florida from the Miocene up. Some of the phosphatic rock of northern Florida is a variety of it, in which the limy envelope of the grains contains a certain amount of phosphoric acid.

The deposits lately formed and apparently now forming in the region of the Everglades have been already described (p. 100) in the remarks on the topography of the peninsula. They are partly organic and partly chemical in their origin. To the latter fact may perhaps be ascribed the exceptionally crystalline character which some of the Everglades limestone exhibits and which, so far, has not been duplicated elsewhere in the state.

The Yellow sand.—Very little observation is necessary to recognize over the greater part of the peninsula of Florida, away from the seacoast, two well marked varieties of sand. These differ in color, in texture, in mineral constituents, in the thickness of their beds, and in geological significance. The lower of the two beds or deposits is moreover, as a rule, where undisturbed, sharply discriminated from that above, and they are practically unconformable.

The Yellow sand, as the lower deposit may be called, forms the main mass of the sand hills and ridges of the central and southern part of Florida. These ridges and hillocks stand on the Neocene rocks below like hay ricks on a field, not reflecting the character of the surface

[1] See Leidy, Trans. Wagner Inst., Dec., 1889, vol. 2, pp. 9-12.

beneath them. They are rounded above, seldom show much, if any, evidence of stratification, and their upper surfaces are often slightly indurated or formed of a thin crust stained with peroxide of iron. The mass of the sand, like the rocks from which it was derived, is of a yellowish color, varying from pale straw color to yellow brown. It is sometimes 50 feet thick and seems to be perfectly uniform. A good example is afforded by the well near the schoolhouse at Lakeland, which after reaching this sand, which is covered by about 3 feet of white sand, continues in the former for many feet, until water is reached, the sand seeming perfectly homogeneous and uniform. This sand when closely examined seems largely crystalline and looks gritty, yet when rubbed between finger and thumb wastes away to an impalpable powder without any gritty feeling. When wet it has a loamy appearance and when dry runs with less facility than sea sand. It is chiefly composed of organic silica in an extremely fine state of subdivision and of fine residual clay, such as might result from the leaching away of the lime from almost any of the organic lime rocks of Florida. The sand is frequently indurated, as at Rock Lake, a mile and a half from Orlando, where the shores show what looks like a vertical border of waterworn rock. This can, however, be scratched with the finger nail, though hard enough to retain vertical faces of several feet in height. When subjected to the action of water it becomes brown, or even dark brown, probably from the small percentage of iron contained in it.

As a rule the sand hills are without fossils, but the upper layers may contain recent land shells or fragments of lime rock from older formations. The æolian sand rock or indurated sand, previously referred to as common near the sea coast, and containing recent shells in a more or less fossilized state, may very likely prove to be only a phase of the Yellow sand, but the best typical exposures of the latter are somewhat removed from the sea.

The Yellow sand appears to be indigenous and may date from the Lake period. At all events it is such a material as might result from the action of fresh water on the indigenous lime rocks. If the original sand is as old as the Pliocene, the portions of it now containing recent marine shells have, of course, been rearranged. For that part containing land shells the fossils offer no criterion of age. The whole question of its age and origin can be answered only by means of further study and investigation.

The analysis of some of this sand from a depth of about 40 feet in the Lakeland well, according to Prof. F. W. Clarke, afforded the following result:

Silica	80·39
Alumina and iron	15·03
Lime	1·22
Water (about)	3·36
	100·00

The absence of grittiness is probably due in part to the presence of so much clay and in part to the minuteness of the particles of silica. We may imagine that if one of the ordinary soft limestones of Florida was deprived of its lime and the organic silica which it contains remained in its original state of division, the residue would, in general, much resemble the clayey sand above described.

The White sand.—Above the Yellow sand almost everywhere on the peninsula of Florida may be observed an unconformable layer of snow-white sand. This is often grayish from a mixture of vegetable matter, but where the beds are thick or the sand has been washed by rain it is of a brilliant white, and often gives to large areas the aspect of being covered by a heavy fall of snow.

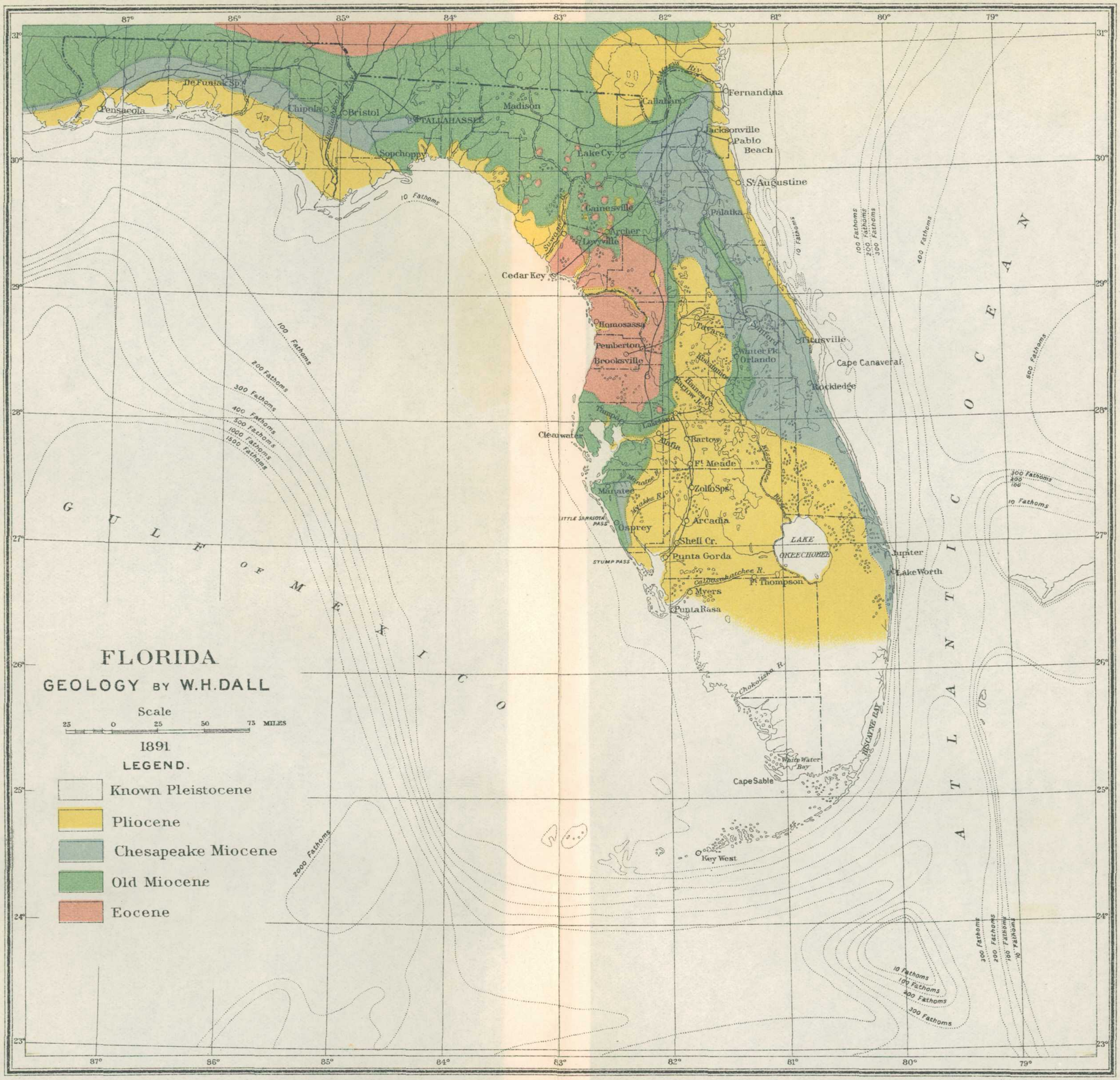
Unlike the Yellow sand, this stratum is seldom of great thickness. Leaving occasional dunes along the Atlantic border out of account, it is seldom seen more than 6 feet in thickness on level ground, and the hillocks formed by it rarely exceed 20 feet in height. Indeed, this height is extremely rare in the writer's experience. Nearly all the knolls, when cut by the railroads, show that their mass is composed of the Yellow sand and is only coated by the White sand.

This sand is mainly siliceous, sharp, and gritty, with a small admixture of lime particles. On the sea coast it is sometimes indurated or cemented into a rock which looks like wet loaf sugar. As the main superficial stratum of the peninsula, it contains vegetable matter, recent land or marine shells, pieces of coquina, etc., in many places; but in its nature is essentially a sea sand. It has been largely distributed by the wind, which never ceases in Florida, and to whose steady alternation of sea and land breezes is probably due the uniformity with which the White sand has been scattered.

In the transportation of glacial sands from the north, the silica, being the hardest component, would survive longest; hence the almost purely siliceous character of these sands from the southern extreme of the coast down which they travel. The indigenous silica is usually discolored. The glassy character of these White sands indicates a more northern origin.

The White sand is often absent from elevated surfaces exposed to the wind, but a close scrutiny of adjacent hollows will almost invariably disclose traces of it.

It has been suggested that the White sand, as here described, is merely the upper portion of the Yellow sand, from which the clay and iron have been leached out by the action of the weather. But, while the upper surface of the Yellow sand may in some places have been bleached in this way, the White sand here described appears to be distinctly unconformable to the underlying Yellow Sand and entirely independent in its distribution and bedding.



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SCHEME OF THE FLORIDIAN CENOZOIC ROCKS, APPROXIMATELY IN THE ORDER OF THEIR DEPOSITION.

EOCENE.

Group	Beds	Strata
Vicksburg group	Vicksburg beds[1]	White limestone (Jackson).*
		Orbitoides limestone (Vicksburg).
		? Coral limestone (Salt Hill).*
	Nummulitic beds	Ocala limestone (Nummulitic).
		Miliolite limestone?
		Floridite phosphatic rock.

NEOCENE.

Warm-water fauna; older Miocene.

Group	Beds	Strata
Chattahoochee group	Hawthorne beds	Greenish clays.
		Ferruginous gravels.
		Phosphatic oolite.
	Ocheesee beds	Water-bearing sands.
		Chattahoochee limestone.
		? Cerithium rock (Tampa).
Tampa group	Chipola beds	Orthaulax bed ?=Shiloh, N. J., marls.
		Chipola marl.
		Sopchoppy limestone.
		White Beach sand rock.
		? "Infusorial earth."
	Tampa beds	Tampa limestone.
		Chert of Hillsboro River.
	Alum Bluff beds	Sands and clays.

Cold-water fauna; newer Miocene.

Group	Beds	Strata
Chesapeake group	? Patuxent beds	Ecphora beds.
	? St. Marys beds	Jacksonville limestone.
Grand Gulf group	Fayette beds*	Mississippi clays.
		Lignitic sandstone and sands.
		Gnathodon beds.
		Altamaha grit.

Pliocene.

Group	Beds	Strata
Lafayette group*	Lagrange beds	Orange sand.
Floridian group	De Soto beds	Arcadia marl.
		Peace Creek bone bed.
		Alachua clays.
	Caloosahatchie beds	Oyster marl (Peace Creek).
		Turritella marl.
		Venus cancellata bed.
		Planorbis rock.

PLEISTOCENE.

Yellow sand.
Bulla striata marls.
Æolian sand rock (with *Homo*).
Coquina.
Vermetus rock.
Everglades limestone.
White sand.

[1] Some strata, here marked with an asterisk, are inserted for completeness in this table, though their presence in the Florida series can not yet be demonstrated.

THICKNESS AND DIP OF THE STRATA.

Little is known of the dip of the rocks in Florida. In the northern part of the State, from the constantly greater depth at which water-bearing strata are found in artesian wells as one goes southward, a moderate southerly dip has been frequently assumed. In the south the dips follow the curves of the gentle folds of the strata. On the east coast it is questionable whether the great depth of the Eocene at the Lake Worth well is due to its steep eastward dip, or to a coastal erosion more or less masked by incumbent talus. The probabilities seem in favor of the latter view.

The thickness of the Pleistocene beds in Florida may be generously estimated in assigning it a maximum of 100 feet anywhere on level ground.

The Caloosahatchie beds will not much exceed 25 feet, and as much more would be a liberal allowance for the De Soto beds.

The Appomattox is not yet positively known to cross the northern boundary of the State, though it is stated to have been traced to Mobile Bay by L. C. Johnson, and McGee believes he has recognized it around Tallahassee.

The thickness of the Sopchoppy limestone is unknown, as the rock is known only by specimens, and the locality has not been visited by any geologist.

The existence of the Grand Gulf group in Florida is probable, but not yet sufficiently proved. The lignitic sand at Alum Bluff, perhaps of this age, is only about 10 feet thick. The Gnathodon bed discovered by Johnson is presumably of no great thickness.

The Jacksonville limestone and associated beds are about 500 feet thick at that point, but only about 200 feet at St. Augustine; the Ecphora bed at Alum Bluff only about 30 feet. On the Manatee River the bed corresponding in age to the Jacksonville rock is only 2 or 3 feet thick.

The Alum Bluff beds at the original locality are 15 feet thick.

The Tampa beds can hardly claim a greater allowance than 30 feet, and the Chipola beds perhaps half as much more.

For the Ocheesee beds Langdon has allowed 250 feet, while we may assign a maximum of 125 feet for the Hawthorne beds.

The total thickness of the Neocene rocks of Florida may be estimated to be less than 1,000 feet as a maximum, which agrees very well with the discovery of the Vicksburg beds at 1,000 feet deep in the Lake Worth artesian well. Over most of the peninsula these beds will not exceed one-quarter, and in many places one-tenth, of the maximum above noted.

The Eocene has been penetrated to 1,066 feet in organic limestone at St. Augustine without reaching the base of the Vicksburg beds. There is no reason to doubt that the Eocene will rival the Miocene in thickness, and perhaps exceed it, in Florida, as in most other States.

ALABAMA.

GRAND GULF GROUP.

In this State two very distinct formations are assigned a Neocene age. The older of these[1] consists of a fossiliferous deposit observed some 20 miles northwest of Mobile bay, and forms probably an eastern extension of the "Grand gulf" of Mississippi. Farther to the north and east, along the Tensaw River in west Baldwin County, the researches of Artemas Bigelow[2] have brought to light the existence of a sandstone formation which, in one locality not over "a rod square," contains "abundant but very obscure impressions of shells, apparently all bivalves." This, Dr. Hilgard[3] surmises, may belong to the "Grand Gulf" group, and, if so, may afford a clew for determining its age by paleontologic evidence.

The geographical distribution of this formation in Alabama has not yet been carefully investigated; but the southern extension of the Vicksburg group would of necessity confine it to a small area in the extreme southwestern part of the State.[4]

LAFAYETTE FORMATION.

The second and more recent formation is composed of perezonal sands, clays, gravels, etc., regarded by McGee as belonging to his "Appomattox formation" (since called Lafayette). A few of its more interesting and typical outcrops in this State were recently discussed before the Geological Society of America (December 27, 1889),[5] and are here given in abstract: At Girard, opposite Columbus, Ga., and at Tuscaloosa the unconformability of this formation with the "Columbia" above and the "Potomac" below is very marked. At the former "the distinctive cross bedding outlined in the laminæ of clay or lines of pellets of the same material is exceptionally conspicuous," and the pebbles are larger, more abundant, and less waterworn than usual. At the latter locality the pebbles are small, slightly waterworn, and comprise "cherts, siliceous dolomites, and a rather unimportant element of quartzite, but no true crystallines." At Cottondale, 7 miles east of Tuscaloosa, this formation and the Potomac intergrade. To the north of Eutaw it becomes sandy and friable, like the underlying Cretaceous, while to the southwest, where it occupies scattered patches upon the Rotten limestone, its clays and sands are intermingled with calcareous particles. Finally, the "Appomattox" appears between St. Elmo and Grand Bay, in the extreme southwestern corner of the State. It here consists of "undulating bosses, knolls, and plateaus rising above and evidently protruding through the sand." These remnants of ancient topography consist

[1] Johnson in Litt.
[2] Am. Jour. Sci., 2d. ser., 1846, vol. 2, pp. 420–421.
[3] Ibid., 1867, vol. 43, pp. 40,41.
[4] See Bull. U. S. Geol. Survey, No. 43, 1887. Map of Ala., opp. p. 134.
[5] Published in full in Am. Jour. Sci., 1890, vol. 40, pp. 23–26.

of regularly and rather heavy bedded loams, sands, and clays, commonly orange-hued, but weathering to darker reds and browns, and evidently represent a somewhat erratic phase of the Appomattox—erratic in (1) the complete assortment of the material, (2) its fineness, (3) regularity in stratification, (4) lack of cross-bedding.

It will be noticed that here the Appomattox approaches very near to the coast, while its altitude above tide is reduced at Grand Bay to but little over 25 feet. The comparatively high banks of Mobile Bay[1] doubtless owe their origin to this formation, though it is covered by more recent deposits. The small elevation of this deposit here and its undisturbed condition afford a strong confirmation of the view, elsewhere expressed (p. 141), that the present northern Gulf coast and the peninsula of Florida have not been subjected to any great disturbance of level, either of elevation or depression, since the Pliocene epoch.

Shell beds of Mobile County.—D. W. Langdon, of Cincinnati, Ohio, has recently called attention[2] to the fact that overlying certain "recent" shell beds on Mon Louis Island and making the surface soil throughout Mobile County are series of cross-bedded sands and loams, usually very light colored and devoid of clay or pebble beds. These beds are about 15 feet thick, and are quite similar to the beds of sandy loam found in the western part of the city of Mobile. McGee has determined these last-named loams as belonging to his Appomattox group, and should his identification prove correct it would change the age of the Appomattox (Lafayette) to a more recent date than he now seems to suppose.

"It establishes, however, a further extension inland than that marked by the present coast line and a fluctuation in the elevation of the floor of the Gulf in post-Tertiary times, which fact is believed to have not been previously noted."

The small shells belonging to recent species, which were examined by Dall, from dredgings in Mobile Bay, and which are supposed to have been derived from the "shell beds" above referred to, can not be regarded as settling the age of the deposit. Many of them are found in Miocene marls and range upward into recent seas. A fuller collection from this shell bed will be required to determine its position in the system.

MISSISSIPPI.

In this state, as in Alabama, two very different formations have been assigned a Neocene age. The older of these, the "Grand Gulf," was named by Wailes[3] from the place of its typical outcrop on the Mississippi, and was described at length by Hilgard in his "Report on the

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[1] M. Tuomey, Second Biennial Rept. Geol. of Ala., 1858, p. 148.

[2] Am. Jour. Sci., 3d ser., 1890, vol. 40, p. 238.

[3] Agric. and Geol. of Miss., by B. L. C. Wailes, State Geologist, 1st Rep. 1854, p. 216.

Geology and Agriculture of the State of Mississippi" (1860). The following pages therefore consist of a brief generalization of the facts there presented, together with those brought to light by more recent investigations.

THE GRAND GULF FORMATION.

This underlies the greater part of the State south of a line passing in a general way through Vicksburg, Raymond, Byram, Brandon, Raleigh, and Waynesboro, or, in other words, south of the Vicksburg formation.

At their line of contact the Vicksburg and Grand Gulf rocks consist almost throughout of lignito-gypseous, laminated clays, passing upward into more sandy materials; they are not sensibly unconformable in place, but while the Vicksburg rocks at all long exposures show a distinct southward dip of some three to five degrees, the position of the Grand Gulf strata can rarely be shown to be otherwise than nearly or quite horizontal, although in some cases faults or subsidences have caused them to dip, sometimes quite steeply, in almost any direction.[1]

The superior durability of the arenaceous deposits of this formation over those of the Vicksburg series has caused a well marked ridge running diagonally across the state along their line of contact. This falls off abruptly to the north,[2] but descends very gradually toward the gulf.

All, or at least the greater part of this formation, is characterized by the presence of gypsum and salt and generally also magnesian salts.[3] This is the case with many of the solid sandstones, which, upon exposure to the weather become covered with a saline efflorescence. These sandstones frequently contain small concretions of iron pyrites, which oxidize and swell when the rock is exposed to the air, sometimes breaking up large blocks in this way. Carbonate of lime is a rare ingredient, and the deposits containing it are always quite limited.

In the northwestern part of its development in Mississippi, i. e., northwest of a line drawn from Fort Adams to Raleigh, this formation abounds in sandstone and arenaceous deposits, but to the southeast of this line it consists almost exclusively of clays.

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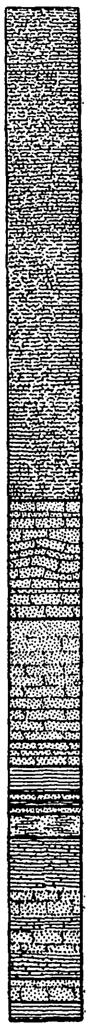
[1] Hilgard, E. W.: Am. Jour. Sci., 3d ser., vol. 22, p. 58.
[2] Ibid., p. 59.
[3] Agric. and Geol. Miss., 1860, pp. 147, 148.

At Grand Gulf the following section occurs:[1]

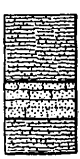


No.	Feet.	
12	60 to 70	Calcareous silt of the Bluff formation, forming the hilltops. (Loess.)
11	14	"Grand Gulf sandstone," in ledges 10 inches to 2 feet in thickness; stratification often discordant and curved.
10	15	Gray sandy material, sometimes soft sandstone, with an argillaceous cement; alternating with harder ledges, 6 to 10 inches thick, of friable, whitish sandstone.
9	2½	Solid whitish sandstone, of good quality.
8	2½	Greenish gray clay, with veins of $CaCO_3$.
7	1	Soft white sandstone.
6	½	Grayish yellow pipeclay.
5	1	Dark gray, brittle sandstone.
4	3	Gray, semiindurate clayey sand.
3	17	Gray and yellowish sands and clays, semi-indurate, interstratified.
2	3	Semiindurate gray sand.
1	2	Greenish gray clay, with veins of $CaCO_3$.

FIG. 23.—Section at Grand Gulf, Mississippi.

The characters of the minor divisions of this section are very changeable, so that 50 yards away the lower portion of the section especially might appear very differently. It is only the upper bed (No. 11) that possesses the peculiar structure which characterizes the "Grand Gulf sandstone," viz, grains of pellucid quartz, containing rather coarse sand, imbedded in an opaque, white, enamel-like mass of silex, which forms quite half of the bulk of the rock. This peculiar rock has been observed in several localities in this vicinity, but toward the interior of the State it is replaced by ordinary siliceous sandstone, sometimes compact but more often friable, with alternating layers of even softer material, such as sands, clays, lignites, etc.

North of Terry, about a half a mile, Meyer[2] obtained the following section of this formation:



Feet.	
10	Light sandy clay.
7	Sandstone, hard above, softer below, containing small nodules of green clay or corresponding cavities.
5	Green sandy clay.

FIG. 24.—Section one-half mile north of Terry, Mississippi.

At Loftus Heights, Fort Adams, Wilkinson County, the Grand Gulf rocks appear at the base of the exposure as follows:[3]

[1] Hilgard: Agric. and Geol. of Miss., 1860, p. 148.
[2] Meyer, Otto: Am. Jour. Sci., 3d ser., 1886, vol. 32, p. 20.
[3] Hilgard: Agric. and Geol. Miss., 1860, p. [illegible]0.

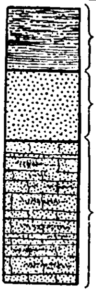


FIG. 25.—Section at Loftus Heights, Fort Adams, Mississippi.

In the northwesterly part of the Grand Gulf area silicified wood, especially that of the palm, is by no means rare; lignite, too, is fairly common in the more argillaceous beds. The latter contain also "impressions of fresh-water, bivalves" in a few instances, as cited by Meyer,[1] and a cast of *Unio*, from Stonington Station, Clairborne County, Miss., is in the National Museum collection.

To the south and east of the line before referred to as separating the arenaceous from the argillaceous areas of the Grand Gulf formation, there are but few if any compact sandstone beds to be found, though the clays contain various proportions of friable sand.

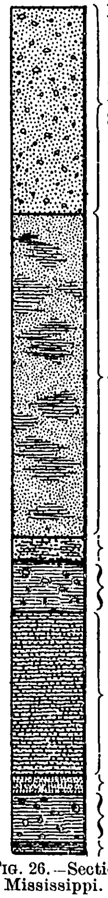


FIG. 26.—Section at "Barnes's white bluff," Marion County, Mississippi.

The color of these clays is various, though usually of a lighter shade than those of the "Northern Lignitic;" blue, white, and even green shades are not uncommon. They contain lignite, pyrite, potash, soda, magnesia, and some times calcium carbonate. The last named ingredient is notably rare except at one point, viz, "near Mr. Ben. Barnes's place, Secs. 2 and 35, T. 4 and 5, R. 12 E., Marion County." It was here that Hilgard[2] found the "chelonian bones" that have been so often cited as the only fossil vertebrate remains found in this formation. A section of the various strata in this immediate vicinity is given by Hilgard (Fig. 26).[3]

The 6-foot bed containing carbonate of lime (No.

[1] Meyer, O.: Am. Jour. Sci., 3d ser., 1886, vol. 32, p. 25.

[2] Hilgard: Agric. and Geol. of Miss., 1860, p. 151.

[3] Ibid., p. 179.

5) has been used to a limited extent as a fertilizer, and is often called "marl."

Another excellent exposure of these clays may be seen on Strong River, Simpson County, Sec. 6, T. 10, R. 20 W. At this place a local western dip of 15°–20° gives an exposure of about 110 feet, although the outcrop is nowhere over 40 feet high. "The materials here contain abundant vestiges of leaves, but so poorly preserved as to be generally unrecognizable; the only form made out with certainty was a fragment of fan-shaped palm-leaf."[1]

On the Chickasawhay and Pascagoula rivers Hilgard found[2] but few outcrops of the Grand Gulf formation. The most northerly of these, 2 miles south of Winchester, Wayne County, is of the highest importance on account of the well preserved lignitized trunks of trees found on the spot where they grew with their roots imbedded in the ancient soil. Successive layers of leaves are to be seen covered by thin sheets of whitish sandy clay. The whole is covered by about 20 feet of Orange sand.

Section at Sam. Power's, near Winchester, Mississippi.

Feet.	Inches.	Character of strata.	No.
18	....	Yellow sand with pebbles in its lower portions (Orange sand)	5
....	18	White sand with nodules of pipe clay.............	4
....	1	Black clay with leaves..........................	3
3	....	Grayish white sand with vestiges of leaves on stratification lines..................................	2
5	....	Bluish sandy clay, with roots and trunks of *Cupuliferæ, Coniferæ, and Palmæ*	1

Gnathodon bed in Greene County.—Though Hilgard examined this region more or less closely to the Gulf shore, we owe to L. C. Johnson the discovery of a very important bed in Sec. 27, T. 1, R. 7 W., Greene County (not far from Vernel), which contains an abundant lamellibranch fauna[3]. The bed, which we have called the Gnathodon bed, consists of a brownish clayey sand, packed with a small undescribed species of *Gnathodon*, while *Mactra lateralis* Say, of the existing southern type, and an oyster of gigantic proportions, resembling *Ostrea titan* of the west coast, are by no means uncommon. It is probable that these

[1] Hilgard: Agric. and Geol. of Miss., 1860, p. 151. Similar leaves were obtained by Burns from the lignitic sand bed above the *Ecphora* bed at Alum Bluff, Florida.

[2] Agric. and Geol., Miss., 1860, p. 153, and Am. Jour. Sci., 2d ser., vol. 2, p. 401.

[3] See specimens in U. S. Nat. Mus.

beds[1] may represent the same horizon as do the obscure bivalve impressions of Baldwin County, Ala., discovered by Mr. Bigelow fifty years ago.[2]

The Grand Gulf group has usually been regarded as Miocene, since it lies above the Eocene Vicksburg group and passes beneath the "Coast Pliocene." It is so considered by McGee, who regards[3] as probably Pliocene the superincumbent Orange sand which forms part of his Lafayette. Hilgard, however, in one of his more recent contributions to the subject,[4] says: "Clearly the Grand Gulf rocks alone represent on the northern borders of the Gulf the entire time and space intervening between the Vicksburg epoch of the Eocene and the stratified drift," the latter of which he regards as Quaternary. In the same article he estimates its thickness as not over 250 feet.

It is obvious that the Grand Gulf formation constitutes a typical perezone, bordering the lower part, at least, of the great Mississippi embayment, the landward portion consisting of the sandy beach formation on or near which grew palmettos, swamp cypresses, and pines; where tortoises wandered; where there were occasional lagoons of which the water was not muddy enough to destroy all the oyster embryos, and where the mud-loving *Mactra lateralis* and *Gnathodon* found a congenial retreat. Seaward the terrigenous deposits from the Mississippi drainage were laid down in argillaceous strata, which, like those laid down by the same great river to-day, contain hardly a trace of organic life.

The lignitic sand, with impressions of palmetto leaves, which occurs above the *Ecphora* bed at Alum Bluff, seems likely to represent the eastern feather-edge of this formation. If this be so, the age of the upper part and later condition of the Grand Gulf perezone would be not older than the latest Miocene. This supposition harmonizes with the presence of *Mactra lateralis*, which is a Pliocene and recent rather than a Miocene species.

Parallelism of later terrigenous deposits.—An interesting fact in this connection is the almost complete parallelism of the present extension, at the bottom of the Gulf of Mexico, of the terrigenous deposits from the Mississippi Valley drainage with that of the Grand Gulf group as at present understood. The present deposits of mud cease[5] at a point a little westward of the Appalachicola River mouth on the one hand, and on the other, in the vicinity of Vera Cruz, Mexico. The coarser material forms an inner band, while the finer silt borders it to seaward, just as do the sandy and clayey beds of the Grand Gulf. The latter, however, was deposited for the most part in relatively shallow water, and contains material more coarse than anything which at present is being laid down off the Gulf coast.

[1] Johnson in his MS. reports to the U.S. Geological Survey names this fossiliferous bed, with other adjacent strata, the "Pascagoula Group."

[2] Artemas Bigelow, Am. Jour. Sci., 2d ser., 1846, vol. 2, pp. 419-422.

[3] Am. Jour. Sci., 3d ser., 1890, vol. 40, p. 32.

[4] Eug. W. Hilgard, Am. Jour. Sci., 3d ser., vol. 22, p. 59.

[5] Agassiz: Three cruises of the Blake, 1888, vol. 1, p. 286, chart 191. See also Coast Survey Report for 1880.

THE LAFAYETTE FORMATION.

The second and more recent formation in this state which has been assigned a Neocene age is a continuation of the series of cross-bedded gravels, sands, and clays, termed by McGee the Appomattox (more lately Lafayette) formation (Orange sand partim of Hilgard).

This formation, according to McGee, characterizes the greater part of the surface of this State. Its thickness and constituent materials depend very largely upon the ancient topography and lithological features of the beds upon which it was deposited. It generally prevails over the terrane of the Potomac formation "despite the considerable altitude and high local relief, save in the valleys of the largest rivers." Over the less elevated terrane of the Eutaw sands it is more frequently and more widely cleft by drainage ways, and its remnants are thinner; over the next newer formation (the Tombigbee chalk), which lies flat and low, the greater part of the Lafayette has been carried away from northeastern Mississippi to beyond the Alabama River, so that it is commonly represented only by isolated belts and irregular patches, which, as Smith has shown, most frequently lie on the northern slopes. Over the terrane of the Eufaula sands, in which the local relief again increases, the remnants of the Lafayette quickly increase in number and expand until the formation once more forms the prevailing surface on the uplands, though the Cretaceous deposits are laid bare along most streams and form the prevailing lowlands. Over the eight or nine lower Eocene formations into which the Lignitic of Hilgard has been divided by Smith and Johnson, and among which clay is the predominant material, the Lafayette still further expands until it forms almost the entire surface, highland and lowland alike, save in the valleys of the larger rivers. Still farther south lies the great siliceous deposit of the middle Eocene, commonly known as Buhrstone—the Choctaw buhrstone of Smith; its rocks are the most obdurate of the entire Neozoic series within the Gulf slope, and so its general surface is elevated and sculptured into a complex configuration of pronounced relief and sharp contours; yet, despite these conditions so exceptionably favorable to degradation, the Appomattox frequently maintains its integrity over considerable areas. Beyond the hill-land of the Buhrstone lies the lowland formed by the predominantly calcareous newer Eocene formations—the Claiborne, Jackson, and Vicksburg—over which the Lafayette is again trenched by almost every water way and reduced to ragged remnants only more extensive than those overlying the Tombigbee chalk; but upon the silico-argillaceous terrane of the Grand Gulf the remnants once more expand until they form the greater part of the surface, save along the larger water ways, as about Hattiesburg in central Mississippi.

In short, the formation is generally preserved over loamy and clayey terranes, much more seriously invaded by erosion over sandy terranes, and largely degraded over calcareous terranes.[1]

[1] McGee: Am. Jour. Sci., 3d ser. 1890, vol. 40, pp. 29-30.

The thickness of this formation is obviously extremely variable. Perhaps the greatest known thickness is at the University of Mississippi where, from well-borings, it was found to be somewhat over 200 feet.[1]

Regarding the position of this formation in the geological scale, McGee makes[2] the following statements:

> No fossils have thus far been found in the Appomattox formation except at Meridian, where Johnson has found it to contain well preserved magnolia leaves apparently identical with those of trees now growing in the same vicinity. Its stratigraphic position, unconformably below the Pleistocene and unconformably above the (probable) Miocene Grand Gulf formation, indicates an age corresponding at least roughly with the Pliocene.

Hilgard has constantly maintained that his "Orange sand" (a more comprehensive group than the Lafayette) belongs to the Quaternary age. He finds in it fossils from the Silurian rocks up, but none which he regards as characteristic of the deposit itself. Its distribution, local characteristics, probable origin, and so forth, are discussed at great length in his report on the Agriculture and Geology of the State of Mississippi.[3]

These difficulties and the conditions of occurrence indicate that the Lafayette formation is perezonal in its nature and that its deposition is due to a depression of the surface which occurred after the Grand Gulf had been laid down and which was followed at a later time by an equivalent elevation. These movements may have been synchronous with the slight depression during which the middle Pliocene beds of South Florida were laid down. But in the latter region the vertical movements were slight, while north of the Floridian region their range was evidently much greater.

LOUISIANA.

The two formations that characterize the Neocene Tertiary in Alabama and Mississippi appear likewise in Louisiana.

GRAND GULF GROUP.

East of the Mississippi River, the seaward argillaceous phase of the Grand Gulf formation presumably extends some distance into this State; yet thus far we fail to find that any outcrop has been noted. Hopkins states in a general way[4] that it "reaches the strata of the Bluff period, in about township 4 or 5 south, on both sides of the river," and so he represents it on his "Preliminary Geological Map of Louisiana." The artesian well at New Orleans, sunk[5] to the depth of 630 feet, failed to reach this formation or even the "Orange sand."

[1] E. W. Hilgard: Agric. and Geol. Miss., 1860, p. 6.

[2] Ibid., p. 33.

[3] Op. cit. pp. 5-46. See also Am. Jour. Sci. 2d ser. 1866, vol. 41, p. 311. Ibid., 3d ser. 1871, vol. 2, p. 398.

[4] Louisiana State Univ. Rep. for 1870, containing 2d Ann. Rep. Geol. Surv. La., by Dr. F. V. Hopkins; p. 18.

[5] Rep. on the Geol. Miss. Delta, by E. W. Hilgard, in the Rep. of the Chief of the Engineer Corps U. S. A., to the Secretary of War, 1870.

West of the Mississippi no Grand Gulf rocks appear for some distance, owing to the breadth of the "bottom lands" along the Mississippi and its great tributaries. They reappear, however, on Sicily Isle, near Harrisonburg, Catahoula Parish, and between this point and Sabine River occupy a large triangular area, as shown by Hopkins's map, and as minutely described by him in his First Annual Report of the Louisiana State Geological Survey, in 1869.

Here, as in Mississippi, the northerly portion of this formation is characterized by a predominance of arenaceous material, producing a series of escarpments[1] that break down abruptly on to the marine, calcareous Eocene, whereas,[2] toward the south, argillaceous matter predominates and the descent toward the Gulf is barely perceptible. In general, the Grand Gulf rocks of this State are the exact homologue of those in Mississippi. To illustrate, a section is here given of the various beds exposed at Harrisonburg.[3]

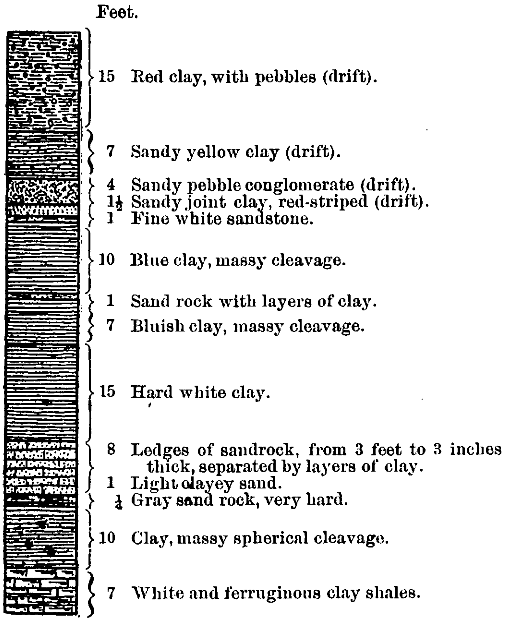


FIG. 27.—Section at Harrisonburg, La.

In some localities, however, a very white clay is not uncommon, which, owing to its general appearance, has usually been termed "chalk." The following section represents its stratigraphic relations[4] at the "Chalk Hills," Sec. 6, T. 10 N., R. 5 E.

[1] 2d Ann. Rep. Louisiana Geol. Surv., 1870. F. V. Hopkins in La. State Univ. Rep., 1871, pp. 18–20.
[2] Hilgard, E. W.: Am. Jour. Sci. 3d. ser., 1869, vol. 2, p. 397.
[3] 1st Ann. Rep. Louisiana Geol. Surv., 1869, F. V, Hopkins in La. State Univ. Rep., 1870, p. 99.
[4] Hopkins, F. V.: 1st Ann. Rep. Louisiana State Geol. Surv., in La. State Univ. Rep., 1870, p. 100.

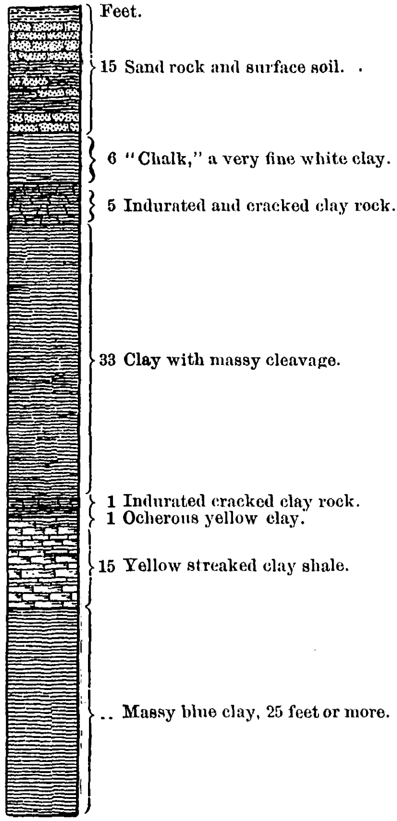


FIG. 28.—Section at the Chalk Hills, La.

Pure white shales are not uncommon. These, together with the "chalk," become very noticeable in the "Fayette beds" of Texas.[1] Calcareous matter, too, is more abundant in this State than in Mississippi, while it is far less so than in Texas. Anacoco prairie,[2] in the southwestern part of Sabine Parish, and the so-called "black land spots," are produced by the outcropping of "marl" beds.

The thickness of this formation cannot be ascertained with any great degree of accuracy from surface estimates, owing to a lack of continuity in its constituent strata; nevertheless, Hopkins has estimated[3] that near Harrisonburg it is about 182 feet thick, while south of Cloutierville and on the Bayou Kisatchie it may be 325.

"The strata are generally nearly horizontal, but many places show slight southeast dips. The disturbances, though noticeable enough where the hills are high, as at Harrisonburg, are by no means as great as in the older members of the Tertiary."[4]

The absence of this formation at Kirkman's, and the Louisiana Oil Company's well, on the west fork of the Calcasieu River, is somewhat remarkable, since Port Hudson, Orange sand, Vicksburg, and Cretaceous groups were penetrated in one if not in both wells.

On this point Hilgard remarks:[5]

The rocks of the Grand Gulf age should have appeared in these profiles directly beneath the drift materials, but nothing has been found resembling them in the least, and since, of all the Tertiary groups, this one is the most persistently uniform in its lithological character, its absence might be taken as proved—it having, doubtless, been removed through the agency of the drift currents.

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[1] Penrose: 1st Ann. Rep. Geol. Surv. Texas.
[2] Hopkins, F. V.: 2d Ann. Rep. Louisiana State Geol. Surv., etc., p. 20.
[3] 2d Ann. Rep. Louisiana State Geol. Surv., etc., p. 19.
[4] Hopkins, F. V.: 1st Ann. Rep. La. State Geol. Surv., etc., p. 101.
[5] Hilgard, E. W.: Final Rep. Geol. Reconn. Louisiana, 1873, p. 41.

Although Hopkins found[1] no fossils in this terrane capable of specific determination he follows most writers on the subject and attributes to it a Miocene age. This view he believes to be strengthened by the following considerations: The formation is stratigraphically above the Eocene. Its upper surface evidences a long period of aerial erosion before the drift (Quaternary) was deposited upon it. This period directly before the Quaternary was the Pliocene. Hence the formation itself was laid down during the Miocene period.[2]

LAFAYETTE FORMATION.

Overlying the Grand Gulf and all the older formations of this State, save where their beds are highly calcareous,[3] is a deposit of water-worn pebbles, sands, and clays termed by Hilgard[4] and Hopkins[5] "Orange sand" or "Drift." Its thickness here, as in Mississippi, is extremely variable, but increases generally toward the gulf.

Thus at Carolina Bluffs it is about 50 feet thick, at Grand Écore and Harrisonburg about 25 feet thick, and in the cuts on the Shreveport and Marshall Railroad it is seen to vary from a few feet to a few inches, as it follows the double contour of the ancient and present hills.[6]

In Kirkman's well, on the West Fork of the Calcasieu River, it is over 96 feet thick, and in the Louisiana Oil Company's well it is about 174 feet.[7]

A few slight outcrops of this formation have been noticed on Weeks and Petite Anse Islands, near the gulf border. These are indeed somewhat erratic, since generally in the southern part of the State the Port Hudson group overlies the Orange sand with a considerable thickness of deposits; e. g., at the Louisiana Oil Company's well above cited, the Port Hudson group is 160 feet thick; in the Kirkman's well, 354; at New Orleans[8] no Orange sand was encountered at a depth of 630 feet.

Not knowing how much of this formation will ultimately be classified as "Lafayette," we forbear from discussing it more in detail.

TENNESSEE.

LAGRANGE GROUP.

As yet we are unable to state with certainty whether there are any deposits in Tennessee that can properly be classified as Neocene, but inasmuch as McGee[9] has recognized the Lagrange group of Safford[10] as

[1] 1st Ann. Rep. Geol. Surv., etc., p. 100; 2d Ann. Rep., pp. 20-21.
[2] Hopkins, F. V.: 2d Ann. Rep. Louisiana State Geol. Surv., 1870, in Rep. La. State Univ., p. 21.
[3] Am. Jour. Sci., 2d ser., 1869, vol. 48, p. 334.
[4] Suppl. and Final Rep. Geol. Reconn. State of La., 1873.
[5] Hopkins: 1st Ann. Rep. Louisiana State Geol. Surv., 1869, p. 104.
[6] Hopkins: 2d Ann. Rep. Louisiana State Geol. Surv., 1870, p. 23.
[7] Hilgard, E. W.: Suppl. and Final Rep. Geol. Reconn. Louisiana.
[8] Hilgard, E. W.: Rep. to the Chief of Engineers, U. S. A., Gen. A. A. Humphreys, on the Geol. Age of the Miss. Delta, 1870.
[9] W. J. McGee: Orally.
[10] Jas. M. Safford: Am. Jour. Sci., 2d ser., 1864, vol. 37, p. 369.; and Geol. Tenn., 1869, p. 424.

belonging to the Lafayette formation it will here be briefly noticed. This group occupies more than a third of the entire surface of west Tennessee; it includes a belt about 40 miles wide, which runs in a north-northeasterly direction through the central portion of this division of the state. As seen in bluffs, railroad cuts, gullies, and in nearly all exposures, it is generally a great stratified mass of yellow, orange, red, or brown and white sands, presenting occasionally an interstratified bed of white, gray, or variegated clay. It often contains vegetable matter, trunks of trees, lignite, etc. It is typically exposed at Lagrange, where a section 100 feet in height may be seen.

Safford assumed the thickness of this group to be 600 feet. He, moreover, supposed it to dip slightly to the west, and to underlie his "Bluff Lignite." The incorrectness of the latter supposition has recently been pointed out by Loughridge,[1] who holds that the Porter's Creek group (Flatwoods) and the "Bluff Lignitic" are really one and the same formation "as shown in the bluff of the Ohio on the Illinois shore at Caledonia, as well as by the continuity of the belt on the east, north, and west of the Purchase region."

No fossils except the remains of plants have been obtained from this group.

Among the fourteen species of fossil leaves obtained by Lesquereux from near Somervillle and Lagrange, three only were identified with living forms.[2] In 1861 he expressed the opinion that they probably belong to an upper Miocene horizon.[3] Safford, however, still classifies this group as Eocene Tertiary.[4]

KENTUCKY.

LAGRANGE GROUP.

The Lagrange group of Safford (Lafayette formation) is found well developed in that portion of this State lying between the Tennessee and Mississippi rivers,[5] where it occupies a broad belt passing north and south through the central and western part of this region, and lies, as it were, in a deep trough in the Lignitic deposits (Bluff Lignitic or Porters Creek group of Safford). It is generally covered by Quaternary deposits, yet is frequently met with along the courses of streams, in cuts, wells, etc. It consists of light colored, cross-bedded sands and white pipe clays, the former of which predominate, are usually fine, nonmicaceous, and sometimes variously colored, while the latter are frequently highly gypsiferous.

Loughridge,[6] though strongly inclined to regard these beds as "lowest of the Quaternary stratified drift," nevertheless places them provisionally in the Tertiary, though above the Eocene division. From

[1] R. H. Loughridge: Geol. Surv. Kentucky. Jackson Purchase region (F), 1888, p. 41.
[2] Geol. of Tennessee, 1869, p. 425.
[3] Am. Jour. Sci., 2d ser. 1864, vol. 37, p. 370.
[4] Am. Geol. Railway Guide; Jas. Macfarlane, 1890, p. 401.
[5] R. H. Loughridge: Report on the Jackson Purchase region (F), Geol. Surv. of Kentucky, 1888, p. 53
[6] Ibid., p. 52.

the specimens of fossil leaves sent by him from Boaz station, Graves County, to the U. S. Geological Survey,[1] Lesquereux made[2] five identifications, viz, *Ficus multinervis* Heer, *Laurus californica* Lx., *Sapindus falcifolius* Al. Br., *Quercus* cf. *cuspidata* (Rossm.) Ung., *Quercus neriifolia* Al. Br. These are all extinct species, but they render no great aid in the determination of the age of their horizon, though they perhaps do indicate a preglacial age.

Thus far this group has yielded no other fossils. Its stratigraphic and lithologic characteristics are well defined in Loughridge's report on the Jackson Purchase region, while its geographical distribution is shown on an accompanying sheet.[3]

ILLINOIS.

Tertiary sands and clays.—A Tertiary series of stratified "sands and clays of various colors" is mentioned by Worthen[4] as best developed in Pulaski County, though found to some extent in Alexander and Union counties. Whether any part of them will be found to belong to the Lafayette formation can not at present be determined. There seems to be no ground for supposing that any other Neocene deposits exist in this State.

MISSOURI.

A series made up of clays, sands, and iron ores, more or less indurated, extends in bluffs skirting along the bottom lands from Commerce, Scott County, westward to Stoddard, and thence south to Chalk Bluff, Arkansas. No fossils have been found in these beds, but Swallow[5] has referred them provisionally to the "Tertiary" without attempting to designate the subdivision.

TEXAS.

Considered from a genetic standpoint, there are three very distinct groups of post-Eocene Tertiary deposits in this state, viz, (1) the brackish-water Fayette (Grand Gulf) beds, (2) the perezonal Lafayette formation, (3) the interior lake deposits. These will be considered in the order mentioned.

GRAND GULF GROUP.

In 1871, Prof. E. W. Hilgard presented to the geological section of the American Association for the Advancement of Science[6] a "Geological Map of the Mississippi Embayment," illustrative of an article "On

[1] Geol. Surv. Ky., Jackson Purchase region, 1888, p. 56.
[2] Proc. U. S. Museum, 1888, pp. 11, 12.
[3] See Map No. 1, accompanying Geol. Surv. Ky. (F), etc.
[4] Geol. Surv. Ill., vol. 1, 1866, pp. 44–46 and pp. 417–423.
[5] G. C. Swallow: Proc. Am. Assoc. Adv. Sci., 1857, vol. 11, II, p. 2–3, and Parker, "Missouri as it is in 1867," p. 123.
[6] See the proceedings, vol. 20, map opp. p. 222.

the Geological History of the Gulf of Mexico." On this map the Grand Gulf group was represented in Texas as occupying a belt of varying width, just inland from the Port Hudson, from the Sabine River to Camargo on the Rio Grande. The correctness of this partly hypothetical distribution was proved by Dr. R. H. Loughridge,[1] who eight years later, while making a reconnaissance of the state in connection with the agricultural investigations of the Tenth Census, noted the occurrence and character of this formation at Trinity on Trinity River; at Chapel Hill and Brenham, Washington County; at Lagrange, Fayette County; near Cuero, De Witt County; and from hearsay traced its extension through Live Oak and Duval counties to Rio Grande city on the Rio Grande.

In 1889 Mr. R. A. F. Penrose, jr., published "A preliminary report on the geology of the Gulf Tertiary of Texas, from Red River to the Rio Grande," in the first annual report of the geological survey of Texas, wherein he designates[2] the formation under consideration "The Fayette beds," though acknowledging their equivalency to Hilgard's "Grand Gulf."

This report describes in detail the characters of these beds as they crop out along the Colorado, the Brazos, and the Rio Grande.

Colorado River section.[3]—In going down the river, the first typical exposure of Fayette beds is seen in a bluff at the mouth of Barton Creek, though low clayey banks appear some distance above. The various strata at this point appear as follows:

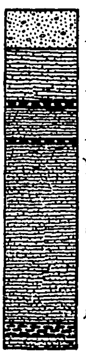

FIG. 29.—Section at mouth of Barton Creek, Colorado River, Texas.

The whole formation is much faulted and jointed, and dips 2° to 5° southeast. Farther down the river the so-called "Chalk bluffs," 12 and 6 miles above Lagrange, respectively, contain about the same material, though the proportion of white clays and sands, or those that become white, is so great as to give the exposures a chalky appearance. Gypsum, sulphur, and lignite are common at both of these bluffs. The latter, however, is characterized by numerous leaf impressions, especially in its lower portion.

Four miles by river, above Lagrange, is "Palm Bluff," about 100 feet high. Its upper 30 feet is composed of sand, in places hardened into

[1] Census Reports of 1880, vol. 5, p. 679.
[2] Op. cit., p. 47.
[3] Ibid., p. 52.

a friable sandstone. This is composed of sharp siliceous grains, sometimes coarse, the size of mustard seed or larger. Many impressions of palm or palmetto leaves as well as silicified stems and trunks are found in this sand. Toward the middle of the bluff clays and calcareous seams appear; the lower portion is covered by detritus.

Lagrange Bluff, 2 miles below the town, is the most southerly exposure described. It is very similar to Palm Bluff. State Geologist Dumble, however, has noted the occurrence of Fayette sands as far south as Wharton, Wharton County.

Brazos River section.—The Fayette beds first make their appearance on this river near the mouth of the Little Brazos. Here a slight rapid is formed by their cross-bedded indurated sands. The same watery green and chocolate colored clays, with sands, lignites, and silicified wood appear on this river as on the Colorado. Sulphur Bluff, 9 miles below Moseley's Ferry, in the eastern part of Burleson County, contains the following bed:

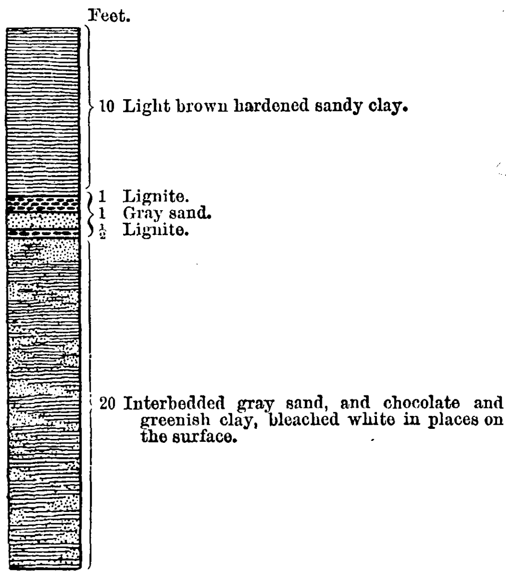

FIG. 30.—Section at Sulphur Bluff, Brazos River, Burleson County, Texas.

Still farther down the river, at points respectively 8 and 3 miles above the mouth of Yegua Creek, similar bluffs of clays, sands, and lignites appear. About 2 miles below this creek, a low bluff occurs, capped with a coarse sandstone containing fragments of silicified wood, small shark teeth, and worn pieces of bones one-half to 2 inches long. A mile and a half below this a hill rises 100 feet above the river bottom that closely resembles the Lagrange Bluff. Similar strata are seen as far down as the southern part of Washington County. The coarse sands passed through at considerable depths in artesian wells at Houston and Galveston belong probably to this formation.

Rio Grande section.—The "Fayette beds" on this river are very similar to those on the Colorado and Brazos. The first undoubted beds of this series are seen 5 miles below the town of Roma; though it is possible that certain strata above this place as far as the Rio Salado and Carrizo should be included here. Light sea-green clays, containing many impressions of leaves, predominate at first. Three miles below these clays are overlain by 15 feet of sandstone, with concretions, fragments of silicified wood, and a few broken pieces of oyster shell. Rio Grande city is situated on a bluff of hard white clay, which probably represents the sea-green clays of the Fayette beds, and has become indurated by exposure to heat in a dry climate. The most southern exposure of Fayette sands is at Hidalgo, Hidalgo County.

Such, then, are a few of the more important characteristics of the Fayette beds as seen along the banks of three great rivers. To the east of the Brazos Mr. Penrose's observations seem not to have extended. Between this river and the Colorado he notes briefly the topography, flora, and general features of the soil. Between the Colorado and Rio Grande he cites the observations of Loughridge.

Among the various inferences he has drawn from his study of the Fayette beds are the following: (1) The minimum thickness of these strata is 350 feet and probably nearer 400. (2) The lower part of the series is clayey and sandy; often hard, producing rapids in the water courses and a comparatively broken surface along the northern line of outcrop. Higher up in the series clays predominate, then suddenly the sands assume predominance and chiefly make up the upper half of the formation. (3) There is far more calcareous matter in these beds than in the Grand Gulf of Mississippi or Louisiana. (4) The clay at the base of the series is much thicker than in those States. (5) There are no indigenous fossil remains in these beds. The fragments of oysters, sharks' teeth, etc., appear to have been washed in from subjacent formations.[1] (6) The formation is continuous, occupying a bed often 60 or even 100 miles wide, from the Sabine to the Rio Grande.

If Mr. Penrose's measurements of dip be reliable the formation may prove to be considerably over 400 feet thick, since the general amount of dip along the Colorado and Brazos seems to be about 2° or 3° to the southeast.

Lafayette group.—Penrose has noted the occurrence of gravel deposits high up on the banks of the Brazos, Colorado, and Rio Grande, where they are from 1 to 15 or more feet in thickness. They contain limestone, flint, quarts, silicified wood, jasper, chert, etc., and are presumably the Texan representative of Hill's "Plateau gravel" in Arkansas,[2] though they seem to be more confined to the large water courses, their only representatives on the hills being a few scattered pebbles. To what extent these may be included in the Lafayette formation remains for future investigation to determine.

LAKE BEDS OF THE INTERIOR.

We believe there can be no doubt that during later Tertiary times the broad sheets of fresh water that flooded the plains of the West extended southward well into the State of Texas. Such has been the opinion of those who have studied the lake deposits of this period, though their observations were mainly confined to the regions farther north, in Kansas, Colorado, Nebraska, and Dakota.

[1] Exception must be taken to this rule if we include among the Fayette beds the beds about Roma in which the numerous specimens of *Ostrea georgiana?* are found, and also the "*Meretrix*" found by Buckley in the central part of Washington County. Cf. Buckley's First Annual Report, p. 63.

[2] Ark. Geol. Surv., Ann. Rep., 1888, vol. 2, p. 35.

"Mr. Robert T. Hill has made brief mention in three short papers of a very interesting fact concerning the age of the Staked Plains, and the extent of the fresh-water Tertiary formations of the West eastward into the Texas region. The whole of the great mesa known as the Llano Estacado and some of the basins of the trans-Pecos region, near El Paso, are composed of sandy loams, grits, and pebbles of this formation. This area in western Texas and eastern New Mexico extends in places eastward to the one hundredth meridian, and is a direct continuation southward of the same formation in Kansas and Nebraska. Its southern limit on the Rio Grande is near Del Rio, and the whole area, which is as large as New England, has been colored Cretaceous and Jurassic upon previous maps. The formation has afforded fossil bones in various places, but these, as yet, have been unstudied. It rests unconformably upon the Comanche series, the Jura-Trias, and the various rocks in the mountain ridges. Everywhere at its base it affords an abundant supply of well water, which has proved of great value to the settlers who are now rapidly locating on the Staked Plains. The Fort Worth and Denver road traverses the formation from Clarendon to Tascosa, and the Texas and Pacific from Sweetwater to the Colorado valley, and thence westward. This additional knowledge upon the former extent of the great inland lakes of Tertiary times is important, in that it nearly doubles the areal extent hitherto acknowledged, and enables us to locate the narrow continental divide between the Gulf of Mexico and the Tertiary lakes with greater accuracy. Dr. Otto Lerch has corroborated the extent of these beds in a recent article on the Concho country in the *American Geologist* for 1890.[1]"

Hill gives the thickness of these beds as between 100 and 300 feet. He styles them the "Staked Plains formation."[2]

Farther south, in Washington, Bastrop, and Navarro counties, many osseous fragments have been found in digging wells from 20 to 50 feet deep. Some of these Dr. Leidy[3] has studied, described, and referred to the "Miocene" or "Pliocene," generally, however, to the latter, or to the horizon of the extensive deposits of Niobrara and Little White rivers and Bijou Hill. The identification of *Hipparion speciosum*, *Procamelus occidentalis*, and *Merychippus insignis*, may be regarded as indicative of this horizon; *Rhinoceros meridianus*, according to Leidy, "presents much the general aspect of the Mauvaises Terres fossils of White River, Dakota, with which it is probably of contemporary age."[4]

[1] Am. Nat., 1891, vol. 25, p. 49. The "three short papers" referred to in this quotation are as follows: (1) Notes on the Geology of Western Texas: Bulletin Texas State Geol. Soc., Sept., 1888; (2) Topography and Geology of Texas Region: Pro. Am. Ass. Adv. of Sci., 1889, and (3) Classification and Origin of the Chief Geographic Features of the Texas Region: Am. Geol., 1890, vol 5, pp. 9, et seq. In these, however, we fail to find some of the points made in the above quotation.

[2] Am. Geol., 1890, vol. 5, p. 28.

[3] U. S. Geol. Surv. Terr., vol. 1, "Fossil Vertebrates," 1873, pp. 247, 248, 258, and Jour. Phila. Acad. Nat. Sci., 1869, (2) vol. 7, pp. 219, 229, 402.

[4] Jour. Phila. Acad. Nat. Sci., 2d ser., 1869, vol. 7, p. 229.

These fossils are generally found in a calcareous sandstone formation, the extent of which is unknown.

Southwestern Texas, especially Nueces County, has furnished numerous vertebrate remains that have been referred to the widely distributed Equus beds. Of these Cope[1] has described or identified five species of *Equus*, two of *Mastodon*, one of *Cistudo*, and one of *Glyptodon* (*G. petaliferus*).[2]

Concerning the distribution of the first-mentioned genus, Cope remarks:

> Of the five species of Equus of southwestern Texas, four have been found in the Pliocene of the valley of Mexico, and one is peculiar to the Pacific coast and basin of North America. Of the characteristic species of the eastern United States, *E. fraternus* and *E. major* the former only has been found.

The latter, however, Leidy[3] has reported farther east, in Hardin County, "from an asphaltum deposit and from a stratum of clay beneath, * * * associated with the remains of *Mastodon* and other extinct animals."

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[1] Am. Nat., Dec., 1885, vol. 19, pp. 1208–1209, and 1888, vol. 22, pp. 345–346.
[2] Compare this fauna with that of Peace Creek, Florida. (See discussion of that State.)
[3] U. S. Geol. Surv. Terr., 1873, vol. 1, p. 244.

CHAPTER III.

GENERAL CONSIDERATIONS ON THE LATER ATLANTIC TERTIARIES.

CORRELATION OF AMERICAN AND EXOTIC NEOCENE.

Having completed the historico-geologic summary of the epoch assigned to us, in its relation to the political divisions of the eastern United States, it has seemed desirable to consider briefly the formations, their genesis, and their relations to the present continent as a whole.

It may be premised that our present knowledge of the Neocene faunas of North America is so far from being thorough or complete that it is entirely inadvisable to attempt in this place any correlation of American and European stratigraphical units in the Neocene. Carpenter[1] called attention to the relations which he believed to exist between the recent fauna of the Californian coast and that of the British Crag, and the writer, in common with Pourtalès, Jeffreys, and others, has indicated[2] a certain community of species which exists between the fauna of some of the Pliocene beds of southern Italy and that now living, off shore, near our southern and southeastern coasts. In a general way it is supposed, though as yet hardly demonstrated, that the American invertebrate faunas exhibited in Cenozoic and especially post-Eocene strata lag behind those of the transatlantic region in their development up to a given stage. From this it would seem as if the strata called Pliocene in south Europe might be older than those denominated by the same term in America, at least in part, or at all events that it can not be reasonably assumed that they were wholly synchronous.

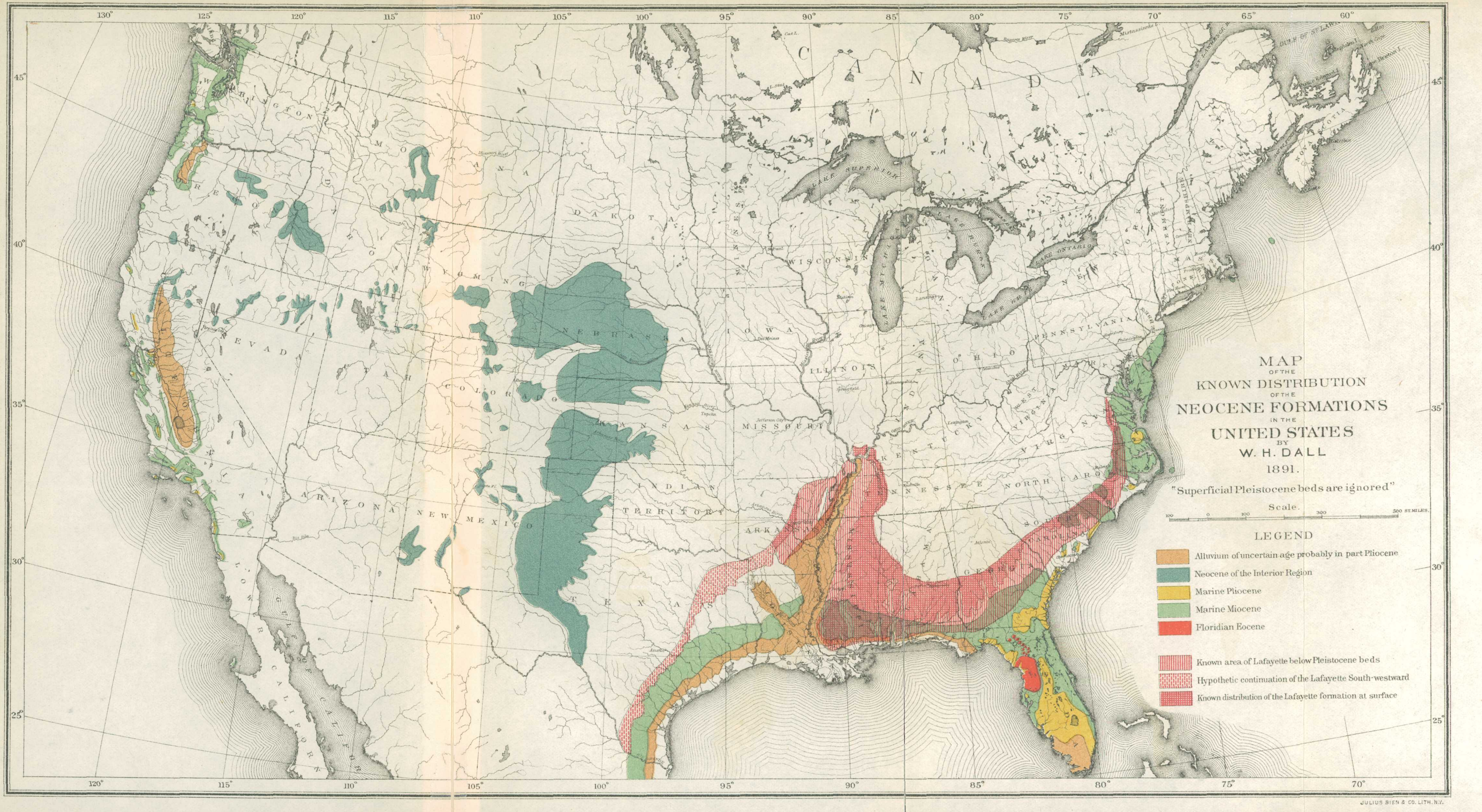
CLASSIFICATION BY LYELL AND DESHAYES.

The attempt of Lyell, following Deshayes, to classify the Cenozoic strata in three categories, according to the percentage of living forms represented in them by fossils, I have stated[3] to be at the present time on the face of it impracticable, illogical, and misleading. It was origi-

[1] Suppl. Rep. British Assoc., 1863, p. 682.

[2] Bull. Mus. Comp. Zool. Reports on the Molluska of the "Blake" Expeditions, by W. H. Dall; 1881, vol. 9, No. 2, and 1886, vols, 12, Nos. 6 and 18, 1889.

[3] Am. Jour. Sci., 3d ser., 1887, vol. 34, p. 162.



JULIUS BIEN & CO. LITH. N.Y.

nally a working hypothesis, based on the assumption that species are and always have been definite entities, about the individuality of which there could be no reasonable doubt in most cases, and which could therefore be appropriately used for numerical calculations. If this assumption were justified the rest would logically follow as a matter of course. There is no doubt that Lyell's hypothesis has been of great use in settling early Neozoic nomenclature, and has generally hitherto been applied in a manner to which little exception could be taken. But the old conception of the mathematical individuality of species has passed away, never to return, and the numerical estimates based upon it are no longer practicable in the absence of any method of determining the personal equation of different paleontologists in their estimates of what constitutes a species.

That this personal equation is in some cases a very large one, all workers are now well aware; and that it is subject to decided changes during the career of any single student is a matter of common observation. Furthermore, the specific contents of the best known faunas are subject to material enlargement from time to time, and, no matter what estimate of specific limits be in use for the time, the percentages can not remain uniform. The increase of our knowledge of geographical and bathymetrical distribution of organic beings has proved that discrepant faunas now exist simultaneously in closely adjacent regions, and that similar faunas are by no means necessarily synchronous.

The Lyellian nomenclature has, however, become an integral part of geological literature and classification. There is no good reason, as yet, why it should be disturbed. The formations originally designated by it will continue to retain their names; not because of their alleged percentages of living species, whether accurately determined or not, but because they are stratigraphic entities which have been so named and which are now recognized by those names and characterized by a recognizable assemblage of organisms.

The classification retaining these names is no longer numerical, but stratigraphic and developmental, and the formations classified under a given name are, for the writer at least, not necessarily synchronous, except where stratigraphically continuous, or synchronic only in a very wide and general sense.

It is believed that American geologists are well agreed that the minor subdivisions of the systems can not in America at present be subjected to any rigid parallelism with the minor subdivisions of other lands, and that the difficulty of correlation increases with the differences of latitude and distance. Concurring in this opinion, theoretically and practically, no attempt at such correlation has been attempted by the writer within the geological limits assigned to him.

The southeastern extremity of the United States, on the whole, presents that series of Cenozoic deposits which appears to have been laid down with the least disturbance and local denudation and the greatest vertical stratigraphic continuity of any within our geographic limits. For this reason, though our knowledge of it is still regretably imperfect, I have used the geological succession of this region as a provisional type or standard by which that of more distant portions of the country might be measured and discussed. The provisional nature of this standard must be emphasized; it is a working hypothesis, nothing more, though based upon facts more or less certainly determined.

GROWTH OF THE CONTINENTAL BORDER.

The growth of the borders of the continent has been ably discussed by Alexander Agassiz, who gives[1] conclusive reasons for supposing that in later Mesozoic time the Gulf of Mexico was connected with the Pacific Ocean across the continental divide of the present day, and therefore that some portion of the equatorial current of the Atlantic swept across wide regions now occupied by dry land and mingled its waters with those of the Pacific basin.

That this connection persisted into Eocene time there is excellent paleontologic evidence, combined with indications that the connection became less and less intimate and perhaps terminated with the Eocene. Cleve has shown[2] that powerful volcanic action was in progress in the West Indian region during the deposition of its Cretaceous strata, which are there the oldest fossiliferous rocks. To more or less synchronous disturbances of level, unaccompanied, however, by violent action of a Plutonic character, may be ascribed the unconformity, stratigraphic and faunal, which serves as the bench mark for the beginning of Neozoic time along the greater part of our Atlantic border. That in the Antilles these disturbances continued with less energy during the Eocene period, the Eocene strata, where they remain, bear evidence.

By inspection of a general geological map of the eastern United States it will be observed that the coasts along which the early Tertiary sediments were laid down, with the exception of the peninsula of Florida and the deep Mississippi gulf, reaching to southern Illinois, roughly approximate to those of the region at present, the discrepancy due to the existing belt of Tertiary rocks being least at their northeastern extreme, near the mouth of the Hudson, and greatest on those shores confronting the Gulf of Mexico. This generalization holds good if to the shore lines of the map we add the submarine areas necessary to fill out the true continental area, except that the region where the Tertiary belt is narrowest is then slightly further south, off Cape Hatteras, from which it gradually widens both northward and southward.

Agassiz holds, very justly, that modern researches have shown that, to such an immensity of prolific life as existed in the sea in which the Eocene limestone of Vicksburg age was laid down, the presence of a

[1] Three cruises of the Blake. Boston, 1888. I, Chapters III–VI.

[2] K. Svensk. Vetensk. Akad. Handl., 1871, Bd. IX, No. 12.

vigorous marine current, bringing food and fresh supplies of oxygen, must be regarded as necessary. In the greater freedom of the warm equatorial currents and the wider sweep of their branches possible at that epoch he finds the needed factors supplied. Judging by modern faunas we conclude that the water in which these limestones were deposited may not have been very deep; certainly similar organisms flourish at present in waters not exceeding 500 feet in depth, and often much less. There can be little doubt that the sea bottom gradually and quietly sank under its load, the bottom preserving an approximately similar distance from the surface of the sea, rather than that these organisms were the means of filling up a depth of water originally equal to the final thickness of the deposit.

THE EOCENE ISLAND OF FLORIDA.

In the Floridian region the survey of the sea bottom shows an immense triangular plateau which unites Florida, the Bahamas, and Cuba, and extends from the northern end of the Bahamas toward Hatteras, as another portion of the same platform does to the westward of Florida, with a breadth equal to that of the present peninsula. Artesian borings in western Florida leave little room for doubt that the mass of this great platform (as well as of the similar plateau which includes Yucatan and its reefs) was laid down during the "Vicksburg" period of the later Eocene; that the surface, in part now deeply submerged, was once more nearly level and covered with comparatively shoal water, and that the channels which now divide Florida from Cuba and the Bahamas, though possibly initiated by fracture of the earth's crust, were chiefly cut out by a scouring process exerted by the ocean currents. Toward the end of the Eocene it is certain that the process of elevation had proceeded far enough to raise above the sea part of the summit of the western anticline of Florida, if not of both of the great Floridian anticlines, and that, during the deposition of the Nummulitic beds, this elevation (probably in the form of a chain of islets) had continued long enough for these islets to acquire a land-shell fauna as far south as about latitude 29° north. The absence of the Nummulites from the top rock of the Eocene beds farther north, between the soft Orbitoides limestone and the Chattahoochee group of rocks, is probably a purely faunal difference, as the Nummulitic beds appear to have an exact equivalent in the siliceous layers of the uppermost Georgia Eocene. Whether this be the case or not, it would seem as if in this region the Miocene was ushered in by a moderately evident stratigraphic change which is more vividly reflected in the discrepancies of the fauna than in unconformities of the rocks. The Nummulitic and Miliolitic limestones of central Florida appear to be restricted to very limited areas, and perhaps represent purely local faunal conditions which promoted the multiplication of these foraminifera toward the close of the Vicksburg epoch. The fact that nearly all the molluscan fossils of the typical

Vicksburg or Orbitoides limestone persist unchanged into the Nummulitic, and that no stratigraphic break is known between them, makes strongly for this view. The existence in the Ocala Nummulitic beds of well developed pulmonate land shells, identical in species with those which abound in the upper part of the older Miocene of the same region, shows that a certain area of dry land had here appeared which was sufficiently elevated to be beyond the reach of the tide. It is now certain that the dry land of central Florida held toward the shore line of the main continent at that time much such a relation as the Bahamas at present hold to Cuba and Florida.

At the end of Eocene time the continental shoreline appears to have bordered the Atlantic in a generally northeast and southwest direction from the Hudson to the Chattahoochee. Omitting the North Carolinian projection and the Floridian peninsula, the present Atlantic coast retains a general parallelism with that which existed during the Eocene between these two rivers. There was a well marked indentation in southeastern Georgia, while from the vicinity of the Chattahoochee the shore rounded to the west, northwest, and north, forming the eastern coast of the great Gulf of Mississippi (as the embayment may for convenience be denominated) which extended to the meeting of the Ohio and Mississippi rivers in the region now constituting the southern extreme of the state of Illinois. From this vicinity the shore extended in a southwesterly direction, without striking irregularities, to the Rio Grande. At the culmination of the Eocene a movement of elevation seems to have taken place, which, without any destructive dislocation, raised this shore to an extent which gave the continental margin a notable addition to its area. In conformity with what would have been expected from the hypothesis of Prof. Agassiz, the most important additions in point of area were to the southwest and on the shores of the Gulf of Mississippi. The area between the central Florida banks and the mainland was not elevated above the sea, though doubtless made much more shoal. Thence northeastward the dried Eocene border gradually narrowed, becoming a mere ribbon beyond North Carolina and reaching its vanishing point at the estuary of the Hudson.

THE GREAT CAROLINA RIDGE.

Broad off the chief mass of the southern Appalachians, in the direction of the northwest-southeast axis of South Carolina, there exists an elevated ridge of perhaps very ancient origin, and whose extension may be seen in the contours of the sea bottom far off the coast. That it is fundamentally of pre-Tertiary rocks is probable from the fact that the power of the Gulf Stream has been insufficient to cut a passage through it, and that mighty current therefore pushes up and over it. That the ridge has long been elevated may be gathered from the fact that the base of the Eocene upon it is reached at Charleston, S. C., in less than 400 feet below the present surface,[1] while to the south, at Lake Worth, on the eastern edge of the central Floridian area, the base of the uppermost member of the Eocene has not been reached at 1,300 feet. That the fluctuations of level of this ridge have been less than occurred either north or south of it may be inferred from the extreme thinness of the Neocene strata and the relatively slight elevation of its quota of the Pleistocene Columbian perezone, as reported by McGee.

CONTACT OF EOCENE AND MIOCENE.

The character of the contact at the surface of the Eocene and the Miocene is too obscure and insufficiently known, as yet, between Florida and the Carolinas; too much denuded, as in South Carolina, or more or less rémanié, as at some localities in North Carolina, to give clear evidence as to the conditions at the epoch of change. But we learn from Rogers[2] that in Virginia the Miocene Tertiary is separated from the Eocene below it by a band of pebbles or coarse sand, sometimes cemented into rock by iron peroxide. Excepting this thin band of comparatively coarse material (probably due to the acceleration of erosion by the slight elevation which closed the Eocene) there is no evidence of physical violence having intervened between the close of the Eocene and the commencement of the Miocene deposits. None of that trenched and channeled character of surface conspicuous on the pre-Eocene sandstones is here met with, but the smooth and unbroken level of the Eocene after receiving the pebbly band referred to was evenly covered by the successive Miocene strata. Yet the change in the fauna was almost complete, the Eocene species disappearing with perhaps only one or two exceptions, and a far greater variety of Miocene forms taking their place. Rogers concludes that there can be no doubt that some important physical revolution intervened at the end of the Eocene, for the distinct evidence of which we are, perhaps, to look to other and more distant regions.

The elevation of the ridge connecting North America and South America, if not so as to constitute an absolutely complete barrier, yet so as to turn the course of the equatorial current exclusively to the Atlantic, seems to furnish an abundantly sufficient cause and to be in harmony with the known facts, even if to be regarded as still insufficiently established.

In southwestern New Jersey an examination of the older Miocene marls shows them to have been laid down in a district subjected to the energetic and tumultuous action of conflicting currents, presenting almost exactly such a facies as does the material dredged off the similarly agitated area seaward from Cape Hatteras, North Carolina, at the present day. The meeting of northern currents with the Gulf

[1] Section of Charleston artesian well to accompany the report by Prof. James Hall, in the City Yearbook for 1884.

[2] Geol. of the Virginias, 1884, pp. 266-267.

Stream, which now takes place near Hatteras, may at that time have occurred between the Potomac and the Hudson.

WARM AND COLD WATER MIOCENE.

With the elevation which closed the Eocene and added so broad a margin to much of the continent, an acceleration of erosion over the whole area elevated was necessarily begun. The different branches of the equatorial current no longer able to escape in the direction of the Pacific must have been turned northeastward. In the deeper channels, as between the Floridian banks on the one hand and those of Cuba on the other, a scour must have been inaugurated which cut a fair way for the waters through the loosely aggregated organic sediments of the Eocene epoch. According to Cleve [1] the Miocene epoch in the southern and eastern Antilles was a time of continuous quiet and continuous gentle sedimentation with a profusion of animal life. On either side of Cuba, however, active submarine erosions must have been in progress. North of the Floridian banks it was probable that the water was too shallow to admit of the passage of any considerable current. The character of the Miocene strata and their contained fossils bears evidence in favor of this supposition. The increased sedimentation of terrigenous matter in the Gulf of Mississippi wafted eastward by the northern branch of the equatorial current (analogous to that now known as the Gulf Stream) and deposited on these shallows is probably responsible for the argillaceous character of the older Miocene beds of this region, which also, over a considerable region, carry a fauna appropriate to shallow and muddy waters. This fauna and that of the immediately succeeding beds in Florida is strongly Antillean in type, as might be anticipated on shores washed by strong currents from the West Indian region. A few Antillean species (e. g., *Cumia woodii* and various species of *Volutidæ*) penetrated the northern waters even as far as New Jersey. At no succeeding epoch do we find such tropical or semitropical littoral mollusks extending northward to such a distance from their present range. This fact may authorize the suspicion that the newer leaf-beds of Greenland and other parts of the Arctic sea, indicating a time when walnuts ripened on shores which now support the burden of the Inland ice-sheet, if really Miocene as has been claimed, may have been contemporaneous with the warm-water Old Miocene above described.

It is not improbable that, with the increasing elevation of northern Florida, in the absence of the present southward extension of the peninsula, and with the probable synchronous elevation of the Great Carolinian ridge, above described, a change was inaugurated. In the presence of such modifications of the coast, necessarily involving a modification of the direction of its flow, it may be surmised that the

[1] K. Svensk. Vetensk. Handl., 1871; Bd. IX, No. 12; Agassiz: Three cruises of the *Blake*, vol. 1, p. 109.

course of the Gulf Stream in the main was gradually turned more off shore than before or at present, and that, concurrently, there arose a greater opportunity for the influx of a cooler northern current inshore in a southerly direction. To this may be ascribed the development of the succeeding newer Miocene fauna, characteristic of the beds of what has been called in this essay the Chesapeake group, chiefly developed in Virginia, Maryland, and North Carolina. The preceding Eocene fauna, as well as the Old Miocene, was southern, or, at least, one which might nowadays be expected in fairly warm waters. The influx of colder northern waters, brought about as above suggested, might exterminate almost the whole of such a fauna by being too cool for the development of the invertebrate embryos, even in so widespread and adaptable a creature as the common oyster. Brooks has shown that a fall of a few degrees in the temperature of the water at spawning time will prevent the survival of the embryos subjected to it.[1] It is not necessary to postulate a very cold or Arctic current, only a current less warm by a certain amount than the antecedent sea temperatures. In this we might find an explanation of the phenomena noted by Rogers. This is the more likely because in the Floridian region, where the waters must have continued to be fairly warm, we find a very considerable percentage of Eocene species surviving into the Miocene beds. The change from clear sea water to that containing a considerable amount of clay and other sediments would induce much such a change in the fauna as we actually find in the northern Floridian region.

The Chesapeake fauna seems to have crept gradually southward. Profusely developed in the Chesapeake region, it becomes more sparse as we follow the beds southward where the temperature of the water would be less rapidly and completely changed. The difference is noticeable in North Carolina and still more so in South Carolina, as pointed out by Tuomey, Heilprin, and others.

The deposition of the older Miocene about the Florida islands or banks was accompanied by an increase in the area of land and a probably very slow and gentle elevation. With this was developed a profuse land-shell fauna, while the fresh-water lakes, which took the place of former marine lagoons, afforded a synchronous fresh-water fauna.

Subsequently to this the extended islands of the Florida banks became the seat of enormous rookeries of birds, seals, and other animals. The fresh guano supplied by these, washed by the constant rains, penetrated the porous organic limestones of which the land was composed, and thus was secured that precious store of phosphoric acid which is now bringing wealth to the owners of Floridian lands. The reception of the guano must have been after the deposition and elevation of the old Miocene strata, because they are the most generally and consist-

[1] The adult animal flourishes well in San Francisco Bay in spite of the low temperature of the water, but no one has ever succeeded in propagating the eastern oyster there. This is an excellent example of the far-reaching effect on a fauna of small differences of temperature.

ently phosphatic of any of the Floridian strata. But the underlying Eocene rocks received their share, and when the latter, as in the most elevated places, formed the top rock, no Miocene intervened. From the rehandling of detritus from the Miocene and Pliocene beds is probably derived the minuter proportion of phosphate of lime which is occasionally found in the newest of Floridian limestones.

At the end of the period of elevation, which characterized this epoch in Florida, an equally gentle and probably moderate depression followed. Over the area near Tampa, where the land shells had flourished, 15 or 20 feet of marine limestone was laid down; though all the land was not submerged, for a few land shells, such as love sea beaches, are found in this limestone to the very top. The marine fauna is largely mingled with species common to the rocks of the period of elevation. On the northern border of the Gulf of Mexico then existing and the southern sea margin of Georgia, this period was marked by sediments of erosion; in the Floridian region by organic sediments faunally connected with those which had preceded them. This fact, with others which might be noted, points toward an orographic independence of the central Floridian region, which is very noteworthy when contrasted with the inter relations in orogenic growth of the continental beds, and their much greater vertical fluctuations which seem to be indisputable.

Invasion of the Chesapeake fauna.—At the conclusion of the operations by which the sediments of the Tampa group were laid down, a very marked change took place, analogous to the change noted by Rogers in Virginia between the Eocene and Miocene faunas. Whether the small depression noted in Florida was synchronous with a greater one northeastward, or whether some other factor must be invoked to account for the facts, it is, at all events, certain that the shores of Florida, east and west, those of the northeastern part of the Gulf of Mexico, and those of the Georgia embayment, whether still continuous with the gulf or not, experienced a wholesale invasion by the fauna of the Chesapeake group. This, in connection with the evidence of depression on the mainland shore of the gulf at the same period, indicates that the northern cooler inshore waters for a time were able to penetrate even to the Gulf of Mexico, bringing the northern fauna with them. However brought about or explained, this change, from the older to the newer Miocene, is the most marked and extensive mutation which is traceable in the fossil invertebrate faunas of the Floridian and Gulf region, after the Eocene, in the whole of Neocene time.

Our present information permits us to assert with positiveness that, after the end of the older Miocene, the Floridian banks and their associated islands remained still insulated from the continent to the northward. All the facts that we have point toward such an insularity accentuated by orogenic independence. That an elevated region, from which detritus is constantly being transferred seaward to the base level of erosion, must submit to fluctuations of level in the portions most affected by such transfers of material, seems almost certain. If to this be added occasional vigorous orogenic action, then to distinguish in local stratigraphic records the changes due to general continental movement from those to be ascribed to more local causes, becomes very difficult. That more or less constant changes did take place on the continental border there is abundant evidence.

On the other hand the broad and level Floridian banks, built of organic sediments, could not have been subjected to transferrence of large bodies of detritus in such a fashion. The peculiar character of the rocks, elsewhere more fully described, led to erosion by solution instead of attrition; and the whole surface, in a general way, suffered equally; so that the factors were wanting which would bring about changes like those occurring locally on the continental border. To this in great part may be ascribed the apparent freedom from minor fluctuations presented by central and southern Florida. To general continental movements the mass of the banks would seem to have responded in some degree, but much less energetically than the continental border nearer the centers of disturbance. In the Georgia embayment, at that time the Atlantic entrance of a broad and shallow strait connected more or less directly with the Gulf of Mexico, a considerable mass of sediments was laid down during the Chesapeake period. At Jacksonville, which represents a point toward the southeastern portion of the embayment, about 400 feet of Miocene limestone, apparently of this age, has been drilled through in artesian wells. This would seem to represent a deposit formed in only moderately deep water, while that on the west coast of the Floridian banks and the north shore of the Gulf of Mexico did not reach any such thickness. Farther south, at St. Augustine, the deposit reached less than 200 feet. On the continental shore, to the northward, 30 or 40 feet seems to be the extreme thickness yet observed there.

It is notable that on the continental shore the bluish gray matrix and grayish white color of the fossils of the Newer Miocene agree exactly with those of the Chesapeake region, while the deposits containing the same fauna on the insular Floridian area partake more of the color and texture of the other beds of which that area is composed.

GRAND GULF PEREZONE.

The drainage of the continent entering the Gulf of Mississippi then as now brought with it abundant sediment, clay, sand, and gravel. These would have contributed not merely to the general shallowing of the gulf but also to a deposit along the neutral zone where the tides and currents of the Gulf of Mexico, dominated by the Gulf Stream, introduced a disturbing factor into the circulation and dispersion of the brackish and muddy waters of the estuary. The termination of the Chesapeake invasion, through changes of level accompanied by changes of water temperature, which seems probable, if accompanied by an upward movement on the south, would harmonize well with the formation of a brackish water perezone at the time indicated.

The estuarine sands and clays doubtless began to be laid down at a much earlier time and through the Chesapeake period served as a barrier to westward migration of the Chesapeake fauna. The elevation which terminated the deposition of the Chesapeake beds on the shores of the Gulf of Mexico was probably that which definitely united the Florida banks with the continental margin adjacent to them, and may have begun while those beds were still forming, as seems to have been the case in part of the region included in Central America. A striking illustration of the elevation which terminated the Miocene is afforded by the little state of Costa Rica, as described by the late Dr. William M. Gabb, who says:

> The geology of Costa Rica is extremely simple, the formations being few and the structure with but few complications. The greater part of the rocks are sedimentary, of Tertiary age, the remainder being eruptive, of comparatively recent origin. The oldest sedimentary rock, that which makes up nearly all of the interior mountain chains and in all probability underlies all of the great plains, is of Miocene age. It is pushed up into steep dips in the mountains of Talamanca by an intrusion of granitic rocks, which have been laid bare by denudation, falls into gentle undulations in the lower hills and becomes level on the flat ground. Bordering this on the coast are small deposits of later age. Near Moen, on the railroad, between there and Limon, there is a deposit of clay of Pliocene age, abounding in fossils.
>
> The granitic rocks are confined to an irregularly shaped, long, narrow mass, which has been intruded after the deposition of the Miocene, forcing the central portion up to a height of nearly 12,000 feet, the lowest exposure of the granite being no less than 3,000 feet above the sea.
>
> Volcanic rocks form a prominent feature of the geology of Costa Rica, breaking through and often covering the Miocene sedimentary beds. Dikes of porphyritic material are common. A large part of the mountainous region is of volcanic origin.
>
> The communication between the Atlantic and Pacific in the region of Costa Rica was interrupted in the Pliocene or subsequent to the deposition of the mass of the Miocene strata.[1]

On the Chattahoochee we have, overlying the Ecphora bed, a thin stratum of lignite-bearing sand with impressions of palmetto leaves. Within 50 miles westward from this river, in an area still geologically unexplored, we have the eastern termination of the formation known as the Grand Gulf group, characterized by clayey and sandy or siliceous sediments bearing fossil wood and particles of lignite, a few oysters and other brackish or fresh-water shells, and impressions of palms or palmettos. Whether the lignitic sand of Alum Bluff represents the thinned-out eastern margin of the Grand Gulf beds or not, it is not improbable that it may. The definite cutting off of any exit for the currents from the Gulf of Mexico north of the main body of the Florida banks must have confined those waters to much such a field as they at present occupy. It is therefore by no accidental coincidence that we find the modern terrigenous deposits of the Mississippi drain-

[1] Gabb, W. M.: MS. Report on the Geology of Costa Rica, in archives of the U. S. Geological Survey. See also Am. Jour. Sci., 3d ser., 1875, vol. 9, pp. 198, 320.

age, on the northern floor of the gulf, parallel to and coinciding in east and west extension with the Grand Gulf perezone.

The elevation which brought these beds to the surface and insured the silting up of the Gulf of Mississippi was not necessarily very great in vertical extent. It perhaps coincided with some depression to the north, since there we find beds representing Grand Gulf silts laid down upon a basis of fragmentary limestone derived from Vicksburg Eocene beds below[1] and with no trace of the Miocene which, to the southward, intervenes between them.

That the formation of the Altamaha grits of the Chesapeake beds and of the Grand Gulf beds was to some extent synchronous can hardly be doubted and would accord with the fact that over both the latter in the gulf region and over the Chesapeake beds in Virginia is laid down, according to McGee, Johnson, Hilgard, and other authorities, a single great perezonal formation. There is no doubt that directly in contact with the Grand Gulf beds in the Gulf States and with the Chesapeake group in Virginia lies the formation variously recognized under the names of Lafayette or Orange Sand of Hilgard,[2] Lagrange of Safford, or Appomattox of McGee. If the Grand Gulf sedimentation went on for any great interval of time after the conclusion of the Chesapeake beds it would seem inevitable that something should be found above the Chesapeake group in the north and below the Lafayette to correspond with that interval; which, so far as we are informed, is not the case.

LAFAYETTE PEREZONE.

The Lafayette from McGee's investigations, which are more comprehensive than any antecedent studies of the formation, consists of sediments of erosion derived chiefly from subjacent or closely adjacent rock masses. The distribution of these sediments corresponds with the inner margin of the coastal plain from Virginia southward and around the southern end of the Appalachian uplift, marginating the Gulf of Mississippi. Though not yet traced in the field, it is undeniable that this formation must have traversed Arkansas, Louisiana, and Texas in the same perezonal form as on the east of the Mississippi gulf. It or its remains will be found there on proper investigation.

The formation is more or less colored with iron oxide, which characterizes it almost everywhere. It is narrow in Virginia and North Carolina, where it is said to reach between 100 and 200 feet in thickness. As it traverses the region of the Great Carolinian ridge it widens and doubles or trebles in thickness. To the south it becomes thinner again until it crosses the main axis of the Appalachian uplift, where again it is said by McGee to reach a thickness of 450 to 550 feet, thus presenting the peculiarity of being thicker over the ridges and thinner along

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[1] L. C. Johnson in Am. Jour. Sci., 3d ser., 1889, vol. 38, p. 213.

[2] Barring some not very important subtraction of Tuscaloosa beds.

the flanks of the highlands. It has few fossils, except those derived from other formations. Such as are autogenous are chiefly like those of the Grand Gulf beds, fragments of lignite and leaf impressions. Its material is largely cross-bedded or obscurely stratified, and consists chiefly of sands and clays with occasional stream gravels. Its lowermost portion is not greatly elevated above the sea; on the authority of L. C. Johnson it is said to reach tidewater in Mobile Bay; while in the Gulf of Mississippi and on a large part of the Atlantic coast it is supposed to average 25 to 50 feet above the level of the tide, reaching an extreme basal elevation of 150 feet at some localities in Virginia and the Carolinas.

The immense mass of material which would seem to constitute this formation must, to some extent, have been laid down in water. The relation of the local beds to the local older beds show that the erosion was not violent, though it may have been long continued. The characteristics assigned to it would seem to necessitate a subsidence of some 500 or 600 feet of the whole continental Atlantic and gulf border, the reconstitution of the Gulf of Mississippi, and a long-continued period of moderate erosive processes. To account for the absence of a marine fauna in any part of it would seem difficult, unless it be assumed that the subsidence and sedimentation were synchronous and practically so equal as to keep this sandy perezone in the condition of a fresh or brackish water estuarine formation from its inception to the succeeding period of elevation.

The Floridian region south of the Suwanee strait still seems to have been exempt from the experiences of the region north of it, to which view the close approximation of the Lafayette to the sea level on the northern shores of the gulf would seem to lend a further shade of probability. The organic limestone of the peninsula at any rate would afford no such sediments as constitute the Lafayette beds, and even if erosion took place it would assume a different form and the results would possess none of the continental characteristics. If the northern part of Florida was during Lafayette time again depressed it may be that a part of the arenaceous covering which now envelops it was received at that time, affording material for subsequent rehandling up to the present moment. In any case in Florida the depression was moderate in amount and gentle in its progress and reaction, so far as we can judge from the recorded data in the region concerned. The continuity of the marine fauna of the coasts was not greatly interrupted. The bulk of the Chesapeake fauna had disappeared, but many forms had become permanently acclimated and still persist. This is especially the case with a number of the largest bivalves, which would be particularly liable to extinction by any sudden elevation of the coast, even if it were of but moderate vertical extent. With this evidence we may safely conclude that the change of level was gradual. Whether the disappearance of the newer Miocene beds from a large part of the Carolinian region was due to causes connected with this period of elevation, or to those of a subsequent epoch we are not in a position to decide. Perhaps the latter is the most probable surmise. The changes which followed the Lafayette sedimentation can not yet be clearly discerned except in special details.

It is certain that the elevation which resulted in or followed the end of the operations connected with the formation of the Lafayette, added considerably to the area of southwestern Florida and probably dried out the Gulf of Mississippi and the Georgian embayment.

PLIOCENE DEPOSITS.

The marine Pliocene fauna which succeeded the Chesapeake Miocene, was of a more tropical character than that of the latter, and its members indicate clearer water and a greater abundance of food. The presence of numerous corals lead to the inference that the motion of these waters, perhaps part of the Gulf Stream, was felt more strongly; as it might be if by the elevation its exit-way had become more straightened.

This fauna, as I have elsewhere urged, reached South Carolina and perhaps even to the southeastern extreme of Virginia, but nowhere do the deposits containing it seem to have reached more than a few feet of thickness. In South Carolina it would seem as if a subsequent denudation had removed the greater part of the little which was deposited.

In Florida the accessible evidence points toward an extensive development of fresh-water ponds or lagoons in which species of *Planorbis*, *Physa*, and *Vivipara* multiplied to a remarkable degree. The evidence of a certain proportion of such ponds in close proximity to the sea, from a very early period in the marine Pliocene, is definitely established. The gradual change in the character of the marine fossils from below upward in the beds shows that a gradual shoaling of the water took place, probably from a slight motion in elevation of the land, until the species proper to a moderate depth were replaced by those characteristic of muddy shallows and tidal flats, and finally by an exclusively fresh-water fauna. The latter condition was not attained without some trifling fluctuations, which may, however, merely represent temporary inroads of the sea after exceptional storms upon lagoons which, under ordinary circumstances, were filled with fresh water.

It seems reasonable to associate the epoch of the Planorbis rock of southwestern Florida with that of the great Lake De Soto or the several large lakes which seem to have occupied the medium syncline of the peninsula a little to the northward. The last evidences of the Pliocene are comprised in the relics of the lakes and the silicification of the Planorbis rock.

Before the termination of the marine Pliocene deposits the permanent connection of the peninsula with the continent was accomplished and the lowlands invaded by a host of large vertebrates. The rhinoceros, the wild horse, the llama, the Columbian elephant, the mastodon, the glyptodon, and various enormous tortoises wandered along the shores of the lakes and through the marshes, while the saber-toothed tiger lay in wait. To what extent, if any, this fauna was affected by the glacial epoch of the north is unknown, but there would seem to be no reason why these animals should not continue to flourish in the warm marshes of Florida, notwithstanding the presence of an inland ice sheet in Pennsylvania and the Ohio valley. The subsequent depression of much of the continental border, during which the Columbia sands of McGee were laid down, may perhaps be as fairly regarded as a reaction corresponding to a northern rise after a melting of the first ice sheet has relieved the north from its weight as in any other way. But here we are wandering, so far as the southern Atlantic border is concerned, in a maze of hypothesis.

What we know is that before the deposition of the marine Pliocene strata of south Florida was ended (whether synchronous with other strata elsewhere called Pliocene or not) the invasion of these vertebrates began; that their remains lie below marine Pliocene strata as well as under the whole belt of superficial sands (in Florida and inferentially also in South Carolina), imbedded in the Alachua clays or associated with remnants of older phosphatic rocks in the Peace Creek phosphate beds and the Carolinian marls; that at a later time a general, though slight, depression of the peninsula began, without any obvious change of plane from the previous general horizontality, or any general change of fauna among the invertebrates, except the extinction of a number of the largest and most striking species of mollusks, chiefly gastropods. The great lakes perhaps were emptied; but their trough was apparently not filled with salt water, which encroached chiefly on the seaward margins of the peninsula and of the Atlantic coast northward. In Florida beds of incoherent marl and sand were deposited containing nothing but recent species. Farther north the discrepancy in vertical motion during such changes, when compared with that of Florida, is again manifested; on the whole increasingly so, as we go northward, excepting over the great Carolinian ridge.

At last the reaction came, and Florida rose again apparently about as much as it had been depressed, but with indications of a slight tilting or inequality which elevated the Atlantic border with its reefs more than the gulf shores. Since then the work of geologic forces has been chiefly exerted in the building of coquina and vermetus rock, in the solidification of æolian sandstone and battered coral reef, in the formation of modern oolitic rock, and the slow cementation of loose material by iron oxides. Waste has gone on in the old way by the slow and gentle processes which lead to solution and decay; and growth, chiefly by chemical precipitation of dissolved lime carbonate, by organic sediments and by wind-blown or sea-tossed sands.

The details of these processes, briefly and in many cases but provisionally indicated here, are for the future. Perhaps in no way better than by such an attempt to sketch their broader outlines can be made plain the imperfections of the record and of our knowledge of it.

TABLE SHOWING THE VERTICAL RANGE OF THE NEOCENE FORMATIONS OF THE ATLANTIC COAST.

Eocene.	Miocene. L	Miocene. M	Miocene. U	Pliocene. L	Pliocene. M	Pliocene. U	P. P.	Formations.
					—			Alachua clays.
	—	—						Altamaha grit.
		—						Alum Bluff beds.
					—	—?		Appomattox formation.
				—	—			Arcadia marl.
—	—	—	—	—	—	—		Atlantic group.
					—	—		Caloosahatchie beds.
		?—	—					Carolinian.
	—?							Cerithium rock.
	—	—						Chattahoochee group.
	—							Chattahoochee limestone.
			—					Chesapeake group.
	—	—						Chipola beds.
		—						Chipola marl.
				—	—			De Soto beds.
			—					Ecphora bed.
			—					Fayette beds.
	—							Ferruginous gravel.
				—	—	—		Floridian.
			—	—?				Gay Head series.
		—						Gnathodon bed.
		?—	—					Grand Gulf group.
			—					Grand Gulf sandstone.
—	—	—	—	—	—	—	—	Gulf group.
	—							Hawthorne beds.
		—						Infusorial earth.
		?—	—					Infusorial stratum.
			—					Jacksonville limestone.
					—			Lagrange group.
		?—	—					Marylandian.
	—	—	—					Mississippi clays.
					—?			Nashaquitsa series.
						?—	—?	Naushon series.
	—							Ochesee beds.
					—	—		Orange sand group.
	—							Orthaulax bed.
					—			Oyster marl.
			—?					Patuxent beds.
				—	—			Peace Creek bone bed.
			—					Perna beds.
						—		Planorbis rock.
	—							Shiloh marls.
	—							Sopchoppy limestone.
			?—					St. Mary's beds.
			—	—	—	?		Sumter beds.
		—						Tampa beds.
	—	—						Tampa group.
		—						Tampa limestone.
					—			Turritella marl.
						—		Venus cancellata bed.
			—					Virginian.
			—					Waldo formation.
					—?			Weyquosque series.
	—	—						White Beach sand rock.
						?—	—	Yellow sand.

CHAPTER IV.

SUMMARY OF OUR KNOWLEDGE OF THE NEOCENE OF THE PACIFIC COAST OF THE UNITED STATES AND CANADA, CONSIDERED BY STATES.

CALIFORNIA.

The geology of the State of California is still very imperfectly known, so much so that a general view of it is at present impracticable. The details here given are gathered from various sources, the most important of which are the reports published by Prof. J. D. Whitney, late State geologist, and those associated with him on the survey of the State; and subsequent researches by various members of the U. S. Geological Survey. The State mining bureau has recently issued a petrographic and geologic map of California, which, however, presents but little that had not been previously made known. The earlier reports by Trask, Antisell, and others were chiefly economic, and much of their information is of a general character, but they have been occasionally referred to in default of more specific data. The compilation which follows is derived almost exclusively from the literature, and for the reasons above given it can not appear otherwise than fragmentary.[1] There is some reason to suspect that much of the fossil fauna referred to as Pleistocene by Gabb, in his Paleontology of California, may prove from the number of extinct species included in it, analogous rather to what has been regarded as Pliocene on the Atlantic border, or that, as at Santa Barbara, species from two horizons have been confounded. It will be understood that in referring to various formations, as Miocene or Pliocene, the compilers accept no responsibility beyond that of correct statement of what has been recorded by others, except where otherwise indicated.

THE GREAT VALLEY OF CALIFORNIA.

California west of the one hundred and eighteenth meridian west from Greenwich, consists essentially of a great valley extending 450 miles northwest and southeast, with an average width of about 50 miles,

[1] It is known that the same type of geologic structure extends for some distance south of the boundary between the United States and the Mexican territory of Lower California. In the vicinity of Todos Santos Bay 50 miles south of the boundary, Cretaceous, Miocene and Pleistocene fossils have been collected, but nothing referable to the Eocene. The Miocene fossils are largely silicified, appear on the surface not far above the sea level, and belong to the same epoch, apparently, as those which have been collected in the vicinity of San Diego, California. Cerros Island also affords Miocene fossils, in a sandstone.

walled in on the east by the high and rugged Sierra Nevada, on the north by the Siskiyou Mountains, and on the west by the less elevated Coast ranges which at the south recurve toward the southwestern spurs of the Sierra. The valley of California, drained by the Sacramento and San Joaquin rivers, has a single outlet, the Golden Gate, the entrance of San Francisco Bay. This divides the Coast ranges into two groups, which are most conveniently taken up separately. The Coast Range, composed of a large number of small folds having a trend generally parallel with the coast, incloses here and there a number of small valleys, reproducing in miniature the topographic type of the great valley. Along much of the coast the mountains come close to the shore, and the sea is bold-to, so that there are neither harbors nor even landings.

The region east of the one hundred and eighteenth meridian is largely arid and partakes, except near the coast, of the character of the adjacent desert or semidêsert region of Arizona and Nevada.

Recent changes of level.—All the evidence indicates that this region has undergone remarkable changes of level and orogenic activity at a very recent geologic period. There is no doubt that since the end of the Pliocene, part of the coast of San Diego County, for instance, has been at a level 600 feet lower than at present.[1] Farther north much greater fluctuations are reported. The Santa Barbara Channel separates by 25 miles from the mainland, a group of islands which in early Pleistocene times were connected with the mainland and afforded pasturage for the mammoth. Since man first made his appearance in this region the whole topography of the country has suffered material change to an extent unparalleled, so far as known, in any other part of the world. In spite of all this the submarine topography is so abrupt, immediately off the coast, that the continuity of the invertebrate fauna has been relatively but little interrupted by these violent physical changes, and quite as large a number of recent species appear in the Miocene fauna as one would expect to find in regions of very much less disturbance.

Before proceeding to take up the highlands in their order, a few notes may be recorded in regard to the great interior valley. They are derived from the experience of Mr. Jerome Hawes, of Stockton, California, whose specialty has been for many years the boring of artesian wells for water, oil, or natural gas. No one else has so thorough a knowledge of the underground conditions of the valley of California.

According to Mr. Hawes,[2] in boring in the valley away from the foothills, the strata exhibit great uniformity everywhere. They consist of clays and sands, the beds of clay becoming thicker as one bores deeper, and the beds of sand, usually 6 to 8 feet, remaining unchanged, so that the proportion of clay gradually increases, sometimes reaching 100

[1] Dall, Proc. U. S. Nat. Mus., 1878, vol. 1, p. 3.
[2] Verbal communication to W. H. Dall, in August, 1890.

feet without a break in the bed. The layers appear perfectly horizontal. Gravel is rare. In the city of Stockton, in the very center of the valley, at a depth of about 100 feet, there is a layer of which the pebbles reach the size of cobbles. At the well in the yard of the courthouse, in the center of the city, this layer is 58 feet thick, and also at the Hawes gas well; but, laterally from a line drawn between these two it diminishes in thickness and runs out to a few feet at a distance of a few blocks from this axis. From this down to about 1,400 feet there are merely alternating layers of clay and coarse sand. At about 1,400 feet there is more gravel with rounded pebbles, usually not exceeding 2½ inches in diameter, mostly quartz or clay porphyry, and often with a thin black coating of iron oxide. The greatest depth yet bored is about 2,100 feet, but no rock has been reached at that depth. At 1,100 feet the water begins to be somewhat saline, and contains magnesia, sodium chloride, some borax, traces of petroleum, and bubbles of gas. At 1,400 feet there is less salt, so that it is hardly perceptible to the taste, but there is more borax, and the water has a temperature of 90° or thereabouts. Below the gravel it becomes more saline again. It is not potable below 1,100 feet. Stockton, it may be stated, is but little above the level of the sea, the influence of the tide being felt there in the river daily.

Twenty miles east from Stockton, at the edge of the foothills of the Sierra, at a depth of 200 feet the drill struck a layer of water worn granite cobblestones in a volcanic matrix. After boring through this over 100 feet, gravel and sand as in the valley were reached, and no more rock was found when drilling ceased at a depth of 900 feet.

According to Mr. Hawes the gravel is traceable to the Sierras. The sand and clay from the Sierra side is different in texture and color from that on the Coast Range or western side of the valley. But on the west, after boring through about 500 feet of Coast Range detritus the drill comes to Sierra gravel and thereafter continues in it, showing that the latter underlies the Coast Range talus.

At the southern end of the valley the flow of water is purer, more powerful and more profuse than in the northern part. The decrease northward is so gradual that Mr. Hawes supposes the artesian water of the valley proceeds more from the south than from any other direction.

No fossils have been found in the valley borings and only once when boring at the edge of the hills. Small twigs and particles of wood are occasionally brought up, but no large pieces. The harder nodules of the clay are sometimes perforated with holes about half an inch in diameter like the tunnels of some animal. These sometimes have a limy coat internally.

The indications of these data are that the valley as an estuary is older than the volcanic conglomerate and than the present elevation of the Coast ranges; that its bottom has been depressed below its original level either by mountain-building forces or by subsidence; that deposition first from the Sierras and subsequently also from the Coast ranges has gone on continually and without any notable tilting of the deposited material; that the ejection of the volcanic conglomerate did not interrupt the general detrital action which is still going on; and, lastly, that during this period the valley has for the most part maintained a perezonal character, not supporting marine life nor affording favorable conditions for the existence of fresh water shells. Much of it is doubtless filled with deposits of Pliocene age, if not even older, though the superficial portion of course belongs to the most recent times. The sandy and gravelly layers are covered with a rich blackish loam in great part of vegetable origin and very fertile. This is most abundant and thickest away from the hills, near which it gradually disappears giving place to more barren detrital soil, or even to basaltic rock or volcanic conglomerate almost bare of soil.

This valley in later Mesozoic time was occupied by an arm of the sea, and this condition was maintained to some extent at least as long as to the latter part of the Miocene. The marginal marine beds beginning with those referred to the Chico have been much broken up, eroded, and contorted, as a result of the physical changes which have taken place. At the northern end of the valley, where the Mesozoic sea washed the base of the Siskiyou schists of that epoch, something of the old state of things can be made out.

Near Redding, along the line of the railroad between that town and the station called Middle Creek, the valley begins to widen, showing its floor to be composed of irregular edges of the upturned schists laid bare by the floods which annually pour down the canyon of the upper Sacramento. They are more or less covered by coarse reddish gravel, containing many rather large cobbles. One-third of the way from Middle Creek station to Redding the schists come to an end and against them unconformably abut the somewhat crumpled sandstones of the Chico, mostly a good deal tilted, dipping to the south and west, and containing characteristic Upper Cretaceous fossils.

Over these lie a 10 or 12 foot stratum of gray sand with enough clay in it to give the mass stability. This bed is certainly Neozoic. It is remarkably uniform in texture, free from pebbles or other fragments, and shows no fossils. Though crumpled, it is less disturbed than the sandstones below it, and, on the whole, more horizontal. Half a mile of it is visible in the section. Conformably over it lie the same coarse gravels which farther north overlie the schists and which in some places have been incorporated with volcanic outflows, forming a sort of conglomerate very common around the valley. The lava flows which have brought this about are probably to a large extent Pleistocene.

The elevation of the Coast ranges has taken place to a certain degree since the beginning of the Miocene, but it is by no means probable that this was its first elevation. On the contrary, they are largely based upon schistose ridges, like the Siskiyous, which are of older origin, but which are still imperfectly known.

A large part of the Coast ranges is formed of fossiliferous Miocene sandstones more or less altered, contorted, and tilted up. On these at high altitudes are frequently found marine Pliocene and even Pleistocene fossils. The fluctuations and changes of level which have characterized the coast of this region since the beginning of the Neozoic, as the fossils prove, can hardly be realized except by the observer in the field, and any attempt at description would read like vagaries of a vivid imagination.

Notwithstanding their comparative youth, the valleys of the Coast ranges are not unlike the great valley of California on a minor scale. A few notes on the Livermore valley[1] will serve to illustrate their general features.

THE LIVERMORE VALLEY.

The Livermore valley is the largest valley of the Coast Range north of Mount Hamilton, and unlike most of the valleys of this range is well watered, agriculture requiring no irrigation, the rainfall amounting to some 12 inches per annum. The entire watershed is discharged into San Francisco Bay through Niles Canyon by the so-called Alameda Creek. Within the valley are a large number of branches of this creek, each draining a smaller valley or canyon of its own.

Of these the southeasternmost is the Arroyo del Viaje, or Valle, which discharges by a permanent stream into a small rounded basin, from which there is a narrow passage into the Livermore valley proper. Here the hills are composed of gravelly strata covering Miocene sandstone. The lower layers, near or in the bed of the creek, are composed of river pebbles, mixed with worn and broken Miocene fossils; oysters, *Venus*, *Tapes*, and other bivalves predominating, crushed together with many smoothly worn quartzite pebbles. The rock is very hard and the material obviously is the compacted result of the mixture of stream gravels with beach worn marine fragments. The strata are a good deal contorted, but those above lie conformably upon them. The dip is entirely variable, but preferentially eastward to some 30°.

A mile or two up the canyon one meets contorted schists, much crushed and cut in every direction by larger and smaller veins of quartz and jasper. These veins furnish the pebbles found in the later sandstone and clayey strata, together with cobbles composed of the harder water-worn fragments of the metamorphic schists. The sandstones lie unconformably on and against the schists, somewhat as at Redding. Their lower layers as described are full of fragments of shell but none in their natural shape, condition, or position. The upper layers vary in composition, but are more largely sandy and with numerous sandy concretions surrounded with thin layers of iron oxide and here and there traces of vegetable remains, but offering very few pebbles and practically destitute of fossils. The layers vary in thickness, yet the fluctuations appear

[1] Made by W. H. Dall in September, 1890.

to succeed each other with something like regularity. The upper beds are frequently pale greenish or whitish where weathered, or a little blue internally. They weather easily, and fragments exposed to the air gradually slack up into loose sand. Here and there are clayey layers or lenticular masses which intercept the infiltrated iron and are often very hard. The uppermost beds as a rule seem rather more horizontal than those below, as if the series had been deposited while changes of level were in progress.

Above the rocks, lying unconformably upon their eroded edges, is a layer (5 to 10 feet thick) of clayey soil full of pebbles of all sizes up to cobbles, mixed with weathered concretions from the underlying sandstones. The beds of the brooks are full of gravel and pebbles which were first derived from the schists, but which have been utilized more or less in all the subsequent strata and may have been washed out from any of them.

The talus of the steep hills is often composed almost wholly of this gravel, the finer materials having been carried away. The above description of the Miocene rocks of this particular locality will give a very fair idea of the Miocene beds as they appear in many places in the State; the differences chiefly arising from the greater or less amount of disturbance which the strata have suffered, or the more quiet and even sedimentation originally possible in some more favorable localities free from the influence of streams and surf.

The more level floor of the valley away from its borders is largely composed of brown loam, derived from the uppermost clayey layer above referred to, mixed with vegetable soil. Farther north there is in the valley and on many foothills a very deep layer of the so-called "black adobe," a black clayey loam, which is extremely fertile, but which in wet weather forms an almost impassable mire and in dry weather shrinks, forming deep vertical cracks running in all directions.

The Miocene sandstones of this vicinity attained a thickness of several hundred feet. Near the mouth of the Tessajara Canyon the stream cuts deeply into the level plain, affording a good section. The material derived from the adjacent hills is deposited in nearly horizontal layers covered with 5 to 10 feet of black adobe. Worn fossils derived from the adjacent sandstones are sparsely scattered through the alluvium. As the traveler goes from the hills toward the middle of the valley the land is seen to be more and more fertile. As he approaches the schists it becomes less and less fertile, until it is practically barren.

The Arroyo Mocho is next northeast from the Arroyo del Valle, and most of the rocks are tilted sandstones; but about 9 miles from Livermore, on the crest of the ridge, as the road runs, the schists make their appearance at an elevation of about 1,800 feet. They are much contorted, and graduate upward into a clayey rock containing much iron, which has been ground for paint. The mineral springs of Agua Vida, 10 miles from Livermore and 1,750 feet above the sea, issue from the schists.

The above notes will convey some idea of the character of the California valleys, and it now remains to recapitulate the information we have been able to compile in relation to the distribution of the Neocene rocks.

For this purpose it is necessary to take up the various sections of the State in some regular order, and the following arrangement has been adopted: The coast ranges are divided into those north and those south of the Golden Gate, and the different short ranges which make up this assembly are successively referred to, passing in a general way from north southward.

Then follow notes on the southern border of the State and the Santa Barbara Islands, and lastly the Sierras with their foothills and the region of the Auriferous gravels, Death Valley, and the rest of the desert region to the south and east.

STRATIGRAPHY—COAST RANGES.

DIVISION NORTH OF THE GOLDEN GATE.

But little is known respecting the distribution of the Tertiary series on the western side of this range to the north of San Francisco Bay. It appears that the most northern outcrops of marine Neocene rocks have been found in Humboldt County; Cooper[1] has catalogued various molluscan species from Eagle Prairie, Danger Creek, and Eel River in this county, and has assigned them a Pliocene age. At Eagle Prairie, near the town of Rio Dell, both Miocene and Pliocene are reported. Still less is known regarding the geology of Mendocino County, though the existence of Tertiary deposits here may be inferred from Whitney's general statement: "The great bituminous slate formation, of Tertiary age, extends through California, from Los Angeles as far north as Cape Mendocino."[2]

Farther to the south, in Sonoma County, Gabb[3] cites several molluscan forms as coming from "Russian River" and "Santa Rosa," while Whitney generalizes on these localities as follows:[4]

> The valley of Petaluma extends through to Russian River, being separated from that of Santa Rosa Creek by hills so low that the divide can hardly be recognized. This valley is in the direct line with the Tertiary strata of the Contra Costa hills, and is probably an excavation in that belt, with metamorphic Cretaceous and eruptive rocks on both sides.

Between Petaluma and the entrance of Tomales Bay the surface is generally depressed. The rocks exposed are mainly metamorphic, upon which here and there in mere patches rest, unconformably, sandstones of Tertiary age. The latter are well exposed at Estero San Antonio,[5] about 3 miles north of Tomales. Here the sandstone is soft yellow, with some hard, blue, calcareous nodules, and forms a bluff 250 or 300

[1] J. G. Cooper, M. D., 7th Ann. Rep. Cal. State Min. Bureau, 1888, pp. 223-308.
[2] J. D. Whitney, Geol. Survey Cal., Geol., 1865, vol. 1, p. 117.
[3] Gabb, W. M.: Geol. Survey Cal., Pal., 1869, vol. 2, pp. 69-110.
[4] Whitney, J. D.: Geol. Survey Cal., Geol., 1865, vol. 1, p. 108.
[5] Ibid., pp. 83-84.

feet high. Fossils are numerous and are classified by Gabb as Miocene.

To the west and south of Tomales Bay, in Marin County, beds of sandstone, presumably of this age, occur, resting nearly horizontally upon granite.[1] At White's Gulch the sandstone is overlain by white argillaceous slates, resembling the bituminous and infusorial strata of Santa Cruz and Monterey.

Near Suscol,[2] Napa County, the prevailing Cretaceous rocks are often hidden by volcanic material. Between the two, especially at the place just mentioned, sedimentary Tertiary rocks intervene, whose distribution is as yet but little known.

Finally, near the head of Pleasant Valley, the Cretaceous rocks are frequently covered by layers of volcanic ash, interstratified with gravel, conformable throughout, with a slight dip to the east. "They appear to be of Pliocene age, and identical in most respects with the sedimentary-volcanic beds to the north of Kirker's Pass.[3]

Of one area, that north of the Napa Valley and east of the Mayacmas Range, at an elevation of 1,310 feet above the sea, we are fortunate enough to have a special geological study by Dr. George F. Becker, of the U. S. Geological Survey.[4]

No Miocene strata have been detected in this region, and Dr. Becker inclines to the belief that during the Miocene this was a land area.

Cache Lake beds.—An extensive area, of which the limits have not been precisely ascertained, is occupied by fresh-water sediments, to which the name above cited has been applied. The body of water in which these were laid down overlapped the area at present occupied by Clear Lake, with which Dr. Becker shows its geologic history has been continuous.

These beds consist, first, of conglomerates carrying pebbles of metamorphic rock identical with that which underlies them, and of pyroxene andesite, which can not be discriminated from that of the adjacent "Chalk Mountain;" secondly, of sand beds, and, thirdly, of argillaceous and calcareous deposits. For the most part, the strata are little compacted and may be reduced to powder in the hand, but there are frequently nodular masses which are consolidated to firm rock. * * * Occasionally considerable areas of sandstone fully solidified are met with. The impression conveyed by the prevalent distribution of the more extended and irregular hardened masses is that they represent the local action of cold calcareous or siliceous waters upon the surrounding rock, an action which if sufficiently prolonged would result in the complete petrifaction of the whole series of beds.

The Cache Lake beds have been subjected to comparatively little disturbance. They are tilted at angles varying from about 10° to about 40°, but the inclination seldom changes rapidly, and there is very rarely anything which can be regarded as contortion. Within the area of the map, too, no faulting was traced, though more or less important disturbances of this nature occur near Chalk Mountain and

[1] Whitney, Geol., 1865, vol. 1, p. 84.
[2] Ibid., pp. 102–3.
[3] Ibid., p. 106.
[4] Monographs of the U. S. Geological Survey, vol. XIII, Geology of the quicksilver deposits of the Pacific slope, Washington, the Survey, 1888, 486 pp., 4°, and atlas, folio, cf., pp. 233–290.

on the north fork of Cache Creek, east of the map limit. The thickness indicated by measuring the strata, perpendicularly to the planes of stratification, is very great—some thousands of feet. I confess myself unable either to comprehend this or to ignore its significance. There is certainly no confusion between these beds and others of marine origin, since fresh-water shells were found in them at widely separated horizons; but the accumulation of several thousand feet of sediment in any lake except one of vast dimensions seems an impossibility. A careful search was made for faults without finding any. The probabilities, however, seem to me in favor of the supposition that these really exist, but thus far have escaped detection. Even on this assumption I believe it impossible to reduce the estimate of this deposit below 1,000 feet.[1]

The fossils found in these deposits comprise some vegetable remains, fresh-water shells identical with species now common to the region, and a few bones referred by Prof. O. C. Marsh to the horse, camel, and elephant or mastodon. Prof. Marsh's report seems to show conclusively that they are not Pleistocene, and they must therefore represent the close of the Pliocene.

The beds are extensively eroded, and near Cache Creek have been terraced. On and near the north fork of the creek they are covered unconformably by a deposit of gravel usually 50 feet or less in thickness.

This is somewhat obscurely stratified, unconsolidated and has been tilted, though less than the underlying lake beds. It presents no strata in which there would be any hope of finding fossils, and its origin is not certain. It may possibly represent the very last stages of Cache Lake, or, as seems to me more probable, the earliest river deposits after the close of the Cache Lake epoch.[2]

These beds are to a considerable extent overlain by andesitic eruptives and basalt. The former lie conformably upon the lake beds and the latter have been more or less metamorphosed, apparently rather through the action of hot water or springs than by any direct contact with heated lava. Similar results are noticeable where the basalt has come in contact with the lake beds. The metamorphosed deposits yield a red soil full of white masses of calcareous material which is said to be very fertile.

The later andesite overlies the Cache Lake deposits and also underlies the Clear Lake sediments. As previously noted, the vertebrates of the lake beds are Pliocene, while the amount of erosion and relation to the modern sediments show they are upper or later Pliocene. The date of the eruption is thus fixed at about the close of the Pliocene epoch.

The eruptions of basalt of the Clear Lake region were greatly inferior in volume to those of andesite, even more so than would appear from an inspection of the map, as owing to the fluidity of these lavas the layers are thinner. These rocks are regarded by Becker as entirely Pleistocene, resting as they do unconformably upon the uplifted Cache Lake beds.

[1] Becker, op. cit., pp. 239 et seq.
[2] Op. cit., p. 241.

DIVISION SOUTH OF THE GOLDEN GATE.

Valley of San Francisco Bay.—In volume VI of the Pacific Railroad reports Prof. Newberry[1] gives the following section, obtained somewhere along the southern shore of San Pablo Bay, though its exact location is unfortunately not stated:

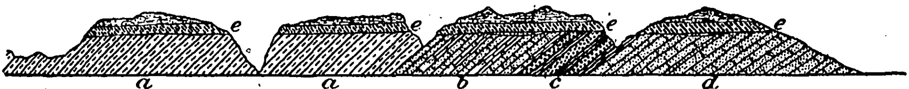

FIG. 31.—Section along southern shore of San Pablo Bay, California.

The fossiliferous strata are said to contain *Pecten pabloensis* Con., *Pecten nevadensis*, a *Mactra*, *Natica*, *Nucula, and Tellina.* All have an eastern dip of from 30° to 35°.

This is probably the same locality referred to by Whitney[2] in discussing the post-Tertiary deposit about Benicia. He says:

> Similar beds, with oysters, were observed on San Pablo Bay between Point Piñole and the Embarcadero; at this locality the beds containing oysters, which rest horizontally on upturned strata of the Tertiary, are elevated twenty-five feet above the level of the water in the bay.

In another place the same author states[3] that the Rodeo Valley marks the limit of the Cretaceous, going west from Martinez, and that here it is succeeded by comformable Tertiary strata, all dipping southwest.

Southeast from San Pablo Bay, a series of elevations, commonly known as the Contra Costa Hills, extends into Alameda County, where it blends into the Monte Diablo Range. Its northern portion is made up for the most part of Miocene sandstone, often highly fossiliferous,[3] and along its southwestern margin more or less thoroughly metamorphosed. The dip of the strata in this region is to the northeast. The localities most frequently quoted by Gabb[4] as furnishing molluscan remains are "Walnut Creek" and "San Pablo," though one specimen at least is cited "from the hills back of Oakland."

A short distance south of the pass between Oakland and Lafayette, rocks of uncertain age[5] occur, and form the central part at least, of this series of elevations until it merges into the Mount Diablo Range. Whitney is inclined to refer these to the "Cretaceous"[6] from the fossiliferous contents of bowlders apparently derived from them.

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[1] Explor. R. R. route from Sacramento Valley to Columbia River; Pacific R. R. reports, 1855, vol. 6, part 2, pp. 13–14.

[2] Whitney Geol. Survey Cal., Geol., 1865, vol. 1, p. 102.

[3] Ibid., p. 12.

[4] Geol. Survey Cal., Pal., 1869, vol. 2.

[5] Geol. Survey Cal., Geol., 1865, vol. 1, p. 17.

[6] Ibid., p. 18.

To the southeast of Martinez, Gabb found the "Cretaceous" and "Tertiary" formations occupying a syncline, as follows:

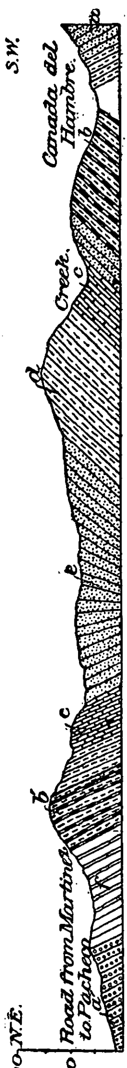

FIG. 32.—Section from near Pacheco to the Canyon del Hambre. Length, 4 miles. *a*, Lower Cretaceous, dipping southwest; *b*, Upper Cretaceous, dipping northeast; *c*, brown sandstone, without fossils; *d*, fine grained gray sandstone, with a few Tertiary fossils; *e*, Tertiary sandstone, containing *Ostrea titan*, etc.; *b'*, Upper Cretaceous sandstones, with numerous fossils; *f*, nonfossiliferous sandstones; *a'*, Lower Cretaceous sandstones, in low hills 1 mile north of Pacheco, containing numerous fossils.—Geol. Surv. Cal., Geol., vol. 1, p. 14.

Mount Diablo Range.—About 15 miles south from Martinez is the lofty summit of Mount Diablo. The central portion of this eminence is composed of metamorphic, probably Cretaceous, rock, while flanking it on all sides rest unaltered stratified deposits. These are tilted, but otherwise little disturbed. To the north both Cretaceous and Tertiary beds appear (according to the California Geological Survey) and present no marked unconformability.

The Miocene series consists chiefly of beds of sandstone heavy bedded at base, resting upon siliceous deposits of uncertain age, and grading upward with apparently no interruption into thinner and more fossiliferous deposits, referred by Gabb to the Pliocene. The latter are particularly well exposed near the east end of Kirkers Pass, whence so many Pliocene forms have been cited.[1]

Resting upon these are beds of stratified volcanic materials several hundred feet thick to the west of this pass, often dipping at angles of 25°, 30°, or even 50°. To the southeast they form a series of rounded and bare hills, stretching along near the edge of the San Joaquin plains.

A special study of the geology of the vicinity of this mountain has recently been published by Mr. H. W. Turner[2] of the U. S. Geological Survey.

According to Mr. Turner, the Miocene beds are largely coarse gray sandstone containing *Ostrea titan* Con., with Pectens, and Echinoderms and conglomerates containing pebbles of rhyolite, quartz, and metamorphic rocks. The Pliocene strata of the same region contain marine fossils and also fossil leaves, silicified wood, and hornblende-andesite tufa and pebbles. The marine fossils have been collected at three localities, viz, Kirkers Pass on the north, the Railroad ranch reservoir on the south, and Corral Hollow, about 25 miles southeast of the mountain.

In the finer layers at Kirkers Pass there are also numbers of fossil leaves, wood, etc., which have been described (Proc. U. S. Nat. Mus.,

[1] Geol. Survey Cal., Pal., 1869, vol. 2; Geol., 1865, vol. 1, p. 32.

[2] The Geology of Mount Diablo, California. Bull. Geol. Soc. of Am., March, 1891, vol. 2, p. 383-414, pl. 15. Rochester, the Society, 8°, with a supplement on the Chemistry of the Mount Diablo Rocks, by W. H. Melville.

vol. 1, p. 35, 1889) by Lesquereux, who considered them Pliocene. Leaves from Corral Hollow were referred to the Miocene by Lesquereux, but were regarded as Pliocene by Prof. Whitney, in which opinion Turner concurs on stratigraphical evidence.

The Tertiary strata discussed by Turner are regarded by him as conformable with each other and with the Chico beds of the same region, though the Pleistocene deposits are thought to be unconformable.

The Tertiary rocks are greatly tilted, and in some places reversed so that, as in a section east from Tessajara Creek to Lone Tree Valley the Tejon and Chico beds overlie the Miocene.

South of Mount Diablo, the Miocene forms a high ridge some miles in extent, which subsides toward the south, giving place to the Amador and Livermore valleys.[1] Connecting the latter with the valley of California is the Livermore pass, which crosses the Monte Diablo range at right angles. The rocks here exposed are soft Tertiary sandstone, dipping to the west of the ridge in a southwestern direction, while on the opposite side this dip is reversed.

From this pass southward along the Monte Diablo range, these Tertiary deposits extend apparently without interruption as far at least as Corral Hollow; they extend to altitudes of 2,400 to 2,500 feet above the sea, are often much dislocated, and in some places contain the large *Ostrea titan*[2]. North of "Camp 61" impressions of leaves and silicified wood have been noted in beds referred by Whitney to the Pliocene. For some distance to the south of this "hollow" Cretaceous rocks give an abruptness of outline along these hills to near the mouth of Orestimba Canyon, where they fall away and are overlain by more yielding Neozoic deposits. The latter near the eastern end of the canyon appear to lie conformably upon the Cretaceous, and to dip eastward toward the San Joaquin at an angle of 45°.[3] From this point southward along the eastern slope of the Monte Diablo range very little is known regarding the character and distribution of the Neozoic series till the vicinity of New Idria is reached.

Nevertheless, it seems to be generally agreed that such deposits do exist,[4] though to what extent is unknown, owing to the development of overlying Quaternary deposits, and the limited number or entire lack of observations. Near New Idria, Gabb[5] identified several molluscan species and referred them to the Miocene.

Whitney[6] states in this connection:

The road from Griswold's to New Idria keeps along pretty near the line between the Tertiary unaltered rocks and the metamorphic Cretaceous. Large masses of the former are seen in the hills on the eastern side dipping at an angle of 45° to the

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[1] Geol., Survey Cal., Geol., 1865, vol. 1, p. 33.
[2] Ibid., p. 38.
[3] Ibid., p. 44.
[4] See Pac. R. R. Rept., vol. 7, pt. 2, Geol. by Thos. Antisell, pl. I, fig. I. and map at the end of pt. 2; also vol. 5, pt. 2, Geol., by Wm. P. Blake, map at end. See also Trask's Rept. for 1854, pp. 28–29.
[5] Geol. Survey Cal., Pal., 1869, vol. 2, and Geol., 1865, vol. 1, p. 57.
[6] Geol. Survey Cal., Geol., 1865, vol. 1, p. 57.

north and northeast. * * * Everything indicates a considerable widening of the Tertiary belt, forming the eastern edge of the chain, as we proceed southward, and the mass of these sandstones appear to dip toward the plain of the San Joaquin.

Hilgard reports abundant well preserved marine (Pliocene?) fossils in unconsolidated sand on the eastern slope of the range along the road leading from Bakersfield to San Luis Obispo.

Having traced the Neozoic deposits along the eastern slope of the Monte Diablo Range, a few words must be added in reference to similar deposits upon the opposite side. Beginning, therefore, at the locality where this range merges into the Contra Costa hills, whose geology has already been discussed, we find here, as farther to the northwest, a ridge of more or less metamorphosed Miocene sandstone[1] extending along the eastern border of the valley of San Francisco Bay. Its southeastern extension has been traced some distance beyond the latitude of San José mission; its dip is toward the northeast, often at a high angle; it is often thoroughly metamorphosed in one locality and entirely unaltered close by it; its fossils, though numerous, are in a bad state of preservation.

Farther to the south, in the river valley above Tres Pinos, immense detrital deposits have been noted by Whitney which may belong to the Pliocene.[2] They fill the valley for 10 or 12 miles, are unconsolidated and unfossiliferous.

Santa Cruz Range.—This range has been but little explored from a geological standpoint; but its general structural features have been ascertained, and may be stated as follows:

From the Golden Gate, metamorphic beds, mostly Cretaceous, extend to the southeast through northeastern San Mateo and southwestern Santa Clara counties; in the latter they form a lofty ridge occasionally rising into such summits as Mounts Bielawski, Umunhum, and Bache. Their northeastern slopes exhibit several patches of Neozoic rocks, of which material their southwestern slopes are almost wholly made up.

The New Almaden district has been carefully studied by Dr. George F. Becker,[3] of the U. S. Geological Survey. Here upon the metamorphic rocks lie some areas of soft Miocene sandstones of a yellowish color and containing a good many poorly preserved fossils. They are considerably disturbed, lying unconformably on the metamorphic rocks, of which they contain fragments. There also exists along the border of the Santa Clara valley a small quantity of conglomerate, composed of metamorphic pebbles imbedded in an arenaceous matrix, which is similar to the Miocene sandstone. According to Becker (op. cit. p. 313) this rock may be a remnant of Miocene, but more probably represents

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[1] Geol. Survey Cal., Geol., 1865, vol. 1, p. 51–52.

[2] Ibid., p. 54. In his Auriferous Gravels, Whitney states without any qualifications that they are Pliocene; op. cit., 1879, p. 21.

[3] U. S. Geological Survey, Monograph, 1888, vol. 13, Geology of the quicksilver deposits, chapter x, pp. 310–318.

Pliocene, though it would, in the absence of positive evidence, be rash to map it as such.

A long and tolerably regular dike of rhyolite, a light yellow, tufa-like substance, hardly distinguishable at a distance from the sandstones, was discovered in the northern part of the district by Dr. Becker. He regards this rock as certainly post-Miocene, for if it had been earlier it must have shown the effects of the post-Miocene uplift. As a rule the rhyolites of the Pacific slope are, as pointed out by Richthofen, younger than the andesites. If this rhyolite is younger than the andesites of Mount Diablo and Napa County, it is Pleistocene, but there is no direct evidence that this is the case. On the whole the probabilities are that it is recent or late Pliocene, but all that is certain is that it is not older than the Pliocene. All the quicksilver deposits of the district occur along a rather simple fissure system, which was probably formed at the time of the rhyolitic eruption, to which Becker also attributes the genesis of the ore.

Farther to the west, a high range of granite hills[1] may be seen, beginning near Santa Cruz and stretching away to the northwest nearly to the Pescadero Creek. Still nearer the coast,[2] extending from Santa Cruz to a point 3 miles northeast of Spanish Town is a belt of bituminous slate, containing interstratified beds of sandstone and narrowing rapidly in going northward.

Going southward from San Francisco, the first deposits met with which are probably of Tertiary age are found along the seacoast from near Lake Merced to Mussel Rock.[3] They consist of a bluish sandstone, resting unconformably on metamorphic strata below and overlain by unconformable Pleistocene deposits. Upon the evidence of the fossils they contain, these have been assigned to the Pliocene. Gabb, moreover, has mentioned several species from "near San Francisco" and "12-Mile House below San Francisco" as belonging to a Pliocene horizon.[4]

Farther to the south, both Pliocene and Miocene forms are cited by this author from Half Moon Bay. The regular belt, however, of bituminous Miocene shale, begins at a point 3 miles northeast of Spanish Town where it caps a mass of granite.[5] No fossils of any particular value for determining the horizon of this bed were found here, yet from lithologic resemblance and structural position, they belong with little doubt to the Miocene belt well developed farther south.

In a section from San Mateo to Half Moon Bay at Spanish Town, Whitney found[6] that west of the granitic axial ridge there is a low ridge of friable sandstone, dipping to the west at an angle of 40 degrees.

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[1] Geol. Survey Cal., Geol., 1865, vol. 1, p. 72–73.
[2] Ibid., pp. 74 and 75.
[3] Ibid., p. 79.
[4] Geol. Survey Cal., Pal., 1869, vol. 2, p. 79.
[5] Geol. Survey Cal., Geol., 1865, vol. 1, p. 74.
[6] Ibid., p. 75.

Proceeding toward the coast, this dip is reversed, with a pitch of 50 degrees which diminishes all the way toward Spanish Town, and finally it is nearly horizontal on the seashore. The character of the rock also changes, becoming more and more argillaceous toward the bay. These beds probably belong to the Miocene series, since they are in line with the bituminous shaly belt referred to above, though characteristic fossils have so far been found only in the immediate vicinity of Half Moon Bay. Nevertheless, Whitney remarks,[1] "the fossils found in the strata show that they belong to the Miocene."

The same formation has been seen well developed along the trail from Pescadero to Searsville; near the latter place the occurrence of *Ostrea titan* has been noted among other molluscan forms.[2]

At Pigeon Point a gray compact sandstone appears, which, upon paleontological evidence, has been referred to the Miocene.[3] Another sandstone occurs just north of New Year's Point ranch house, which, according to Gabb, should be referred to a Pliocene horizon.[3] Bituminous shales have again been seen along Scott's Creek,[3] and again at Santa Cruz.

Upon the northeastern flank of the metamorphic region, mentioned above, there are several local exposures of Cenozoic deposits, all of which have been classified as Miocene.[4] Of these the more important are: (1) A patch on the ridge from Mine Hill to Mount Umunhum, and (2) those in the vicinity of McCartyville.

Gavilan Range.—This is in trend only a southeastern continuation of the Santa Cruz Range just described, being separated from it only by the valley of the Pajaro River. In its northern part it is well separated from the Monte Diablo Range, on the east by the San Juan and San Benito valleys, and from the Santa Lucia Mountains on the west by the Salinas.[5]

In the valley of the Pajaro Whitney has observed the bituminous belt of shale[6] so frequently referred to, as well as Miocene sandstone. Antisell makes no reference to shales, but reports the "basal rock" to be "felspathic granite" upon which the sandstone rests, though their juncture has not been observed. These sandstones form in the vicinity low foothills of the Gavilan Range. In them Antisell notes the occurrence[7] of *Venus pajaroana*, described by Conrad and referred to the Miocene Tertiary. Whitney remarks:

Portions of the formations are fossiliferous; but all the shells found were in such a bad state of preservation that little or nothing could be made of them. There is not much doubt, however, that these rocks form a part of the Miocene Tertiary, so extensively developed in the Coast ranges.[8]

[1] Geol. Survey Cal., Geol., 1865, vol. 1, p. 75.
[2] Ibid., p. 72.
[3] Ibid., p. 73.
[4] Ibid., p. 67–68.
[5] Ibid., p. 159.
[6] Ibid., p. 165.
[7] Pac. R. R. Rept., vol. 8, pt. 2, p. 37.
[8] Geol. Survey Cal., Geol., 1865, vol. 1, pp. 159–160.

To the south, near the trail from Canyon San Juan to Natividad ranch, these rocks become metamorphic. Finally, Antisell has given a somewhat hypothetical section,[1] extending due east from Point Pinos to San Joaquin Valley, which, of necessity, crosses this range still farther to the south. The Gavilian Range is here represented as being made up of (1) a central axis of "orthose granite," flanked on either side by (2) metamorphic limestone, which in turn is overlain by (3) "Dosinia sandstone."

Little is known regarding the geography or geology of this range along its southern extension; it is assumed, however, to blend into the Monte Diablo Range in the vicinity of San Lorenzo. The foothills that are found along its western margin, just to the east of the Salinas River, are said by Antisell to extend southeastward to the mission of San Miguel, making their entire length 80 or 90 miles. Their lithological character and stratigraphic relations are the same throughout as represented in the section referred to above.

Finally, molluscan forms have been collected in the Estrella Valley, which Conrad referred to the Miocene—an opinion in which Gabb concurs.

Sierra de Salinas.—This chain of hills, so named on the Pacific Railroad maps, begins a little northwest of Monterey and extends in a southeasterly direction to the confluence of the San Antonio and Salinas rivers. Its structural features are given very differently by Whitney and Antisell in their respective reports, while the statements of Trask and Marcou are too general to be of service here, the former designating it as "an extensive group of the serpentine formations."[2]

Whitney[3] has described at considerable length the geology of the immediate vicinity of Monterey in his report of 1865 (pp. 160 et seq.).[4] Suffice it to say that this region shows all stages of metamorphism in its rocky material, and that the junctions of the granitic masses with the Miocene slates and conglomerates are well exposed.

Extending east from Monterey, and flanking the Palo Escrito Hills (such being the name applied to the northern part of the Sierra de Salinas) on the north is a series of sandstones and conglomerates several hundred feet in thickness, which dip more or less to the north and northeast, and in places are quite fossiliferous. "These rocks appear to belong to the upper division of the Miocene." Between the mission of Carmel and Monterey the Palo Escrito Hills consist of unaltered bituminous slate, light in texture and containing some fossil remains.

By these Whitney[5] determined the age of this formation so extensively developed throughout the Sierra de Salinas. They belong to the

[1] Pac. R. R. Rept., 1857, vol. 7, part 2, Geol., pl. 1, fig. 1.
[2] John B. Trask; Assemb. Doc. No. 9, 1854, "Rept. on Geol., etc." p. 21.
[3] In Pac. R. R. Rept., 1856, vol. 5, part 2, pp. 180 et seq. Blake has also described this vicinity.
[4] For description infusorial strata in this vicinity see Proc. Phila. Acad. Sci., 1855, vol. 7, pp. 328–331.
[5] Geol. Survey Cal., Geol., 1865, vol. 1, p. 154.

Miocene. This confirms the speculations of Blake[1] and Conrad published nine years before.

Farther to the southeast, in the vicinity of mission Soledad, the rocks on the east side of this chain are nearly all metamorphic, "consisting chiefly of mica slate, in places interstratified with gneiss, while the western slope is made up partly of metamorphic rocks and partly of unaltered bituminous slate." Still farther in the same direction, between the San Antonio and the Salinas, the rocks consist almost exclusively of bituminous slate.[2]

In general it appears, from the remarks of Whitney, that these beds have on the whole a northeastern dip, though they are often much folded and broken and dip, locally, in various directions.

Santa Lucia Mountains.—This chain of mountains rises suddenly from the ocean level at Point Carmel and extends in a southeasterly direction parallel to the coast for over 100 miles without a single break. Much of it rises abruptly from the sea. It has been very little explored. It is known, however, to have a granitic axis from the outcrops along the coast from the point just mentioned to El Sur and from bowlders of

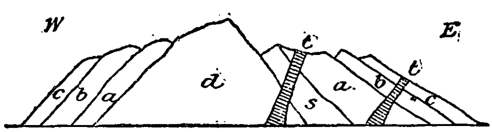


FIG. 33.—Section near San Miguel, California. *d*, central axis, felspathic granite; *a*, *b*, *c*, sandstones (*c*, the *Dosinia* bed); *s*, serpentine; *t*, dikes of felspathic (augitic) trap.

this material washed down from its heights into the San Antonio and Nacimiento rivers. Resting on the granite is a Cenozoic sandstone (probably Miocene) and very extensively metamorphosed. Stratigraphically above this, as may be seen on the Carmelo and the Arroyo Seco rivers, rest thick deposits of bituminous slate. These continue southeastward and are well developed along the Nacimiento, some 6 or 8 miles from its mouth. They in turn are here overlain by a group of rather soft sandstone, sometimes calcareous, with a thickness of over 1,000 feet. These beds are fossilferous in places, containing species of *Pecten* in particular abundance. Among these the Miocene *P. pabloensis* is most common.

This sandstone is probably the one referred to by Antisell in his "Section of Antonio Hills," from which Conrad describes four species of *Dosinia*. Unfortunately nothing more definite is given regarding the locality of this section than that it is "near the mission San Miguel." Such being the case it seems scarcely exact to apply to it the name "San Antonio Hills," since they, according to Whitney, are found only

[1] Pac. R. R. Rept., 1856, vol. 5, part 2, p. 182, and Appendix, p. 317.
[2] Geol. Survey Cal., Geol., 1865, vol. 1, p. 150.

at some distance below, viz, near the mouth of the San Antonio River. The section, however, is given in Fig. 33.

Farther to the south, in the Santa Margarita Valley, a quartzitic sandstone has been observed, which contains oysters and pectens, and on Atascadero ranch the fossils are supposed to be Pliocene.

Fig. 34.—Section from Santa Margarita Valley to San Luis Bay. Horizontal scale same as perpendicular. Length, 16 miles. *a*, San Luis Bay; *b*, San Luis Range, of slate; *c*, limestone bed, with fossil oysters; *d*, serpentine and metamorphic rock of north base of San Luis Range; *e*, *f*, sandstones underlying the San Luis Valley; *g*, serpentine butte, southeast of the town; *h*, *i*, *k*, metamorphic rocks, with the serpentine belt (*i*) intercalated in them; *l*, serpentine at the base of the Santa Lucia Range; *m*, unaltered slates, dipping north; *n*, fetid limestone; *p*, serpentine; *q*, slates in Santa Margarita Valley, dipping north.—Geol. Surv. Cal., Geol., vol. 1, 1868, p. 144.

Deposits supposed to belong to the bituminous slate formation have also been observed here. Fig. 34 shows the structure of the Santa Lucia Mountains, between Santa Margarita Valley and San Luis Bay.

Another section apparently somewhat farther to the south is given by Antisell. (See Fig. 35.)

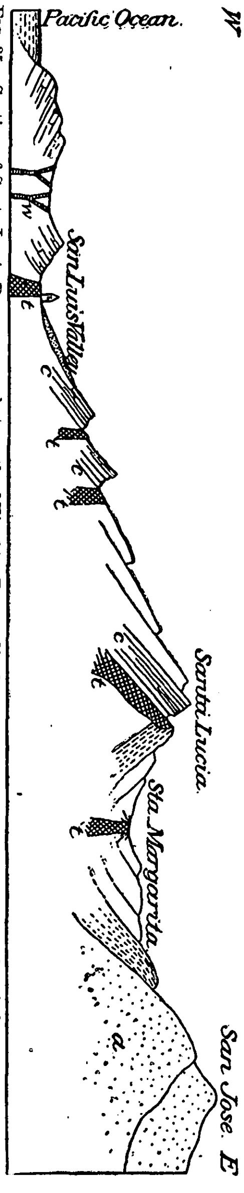


Fig. 35.—Section of Santa Lucia Range somewhat south of Fig. 34. Perpendicular scale exaggerated. *w*, veins of asphalt, passing through the bituminous group of San Luis Obispo Valley; *t*, trappean and augitic rock; *c*, serpentine layers; *a*, granitic rock.—After Antisell.

The continuity of this range to the southeast has not been traced with certainty far beyond San Luis Obispo, yet it may perhaps be regarded as blending into the Sierra San Rafael.

To the east of this range Antisell has described at some length his "Sierra San José" as extending from the Margarita Valley to the "mountain mass of San Emidio. It has a granitic axis, which is flanked with serpentine, slates, conglomerates sandstone," etc.[1] Along the western borders of the Santa Lucia Range, a series of so-called "buttes"[2] are found which are very sharp in outlines, being made up of trachyte and trachytic porphyry, as well as metamorphic sandstone and serpentine.

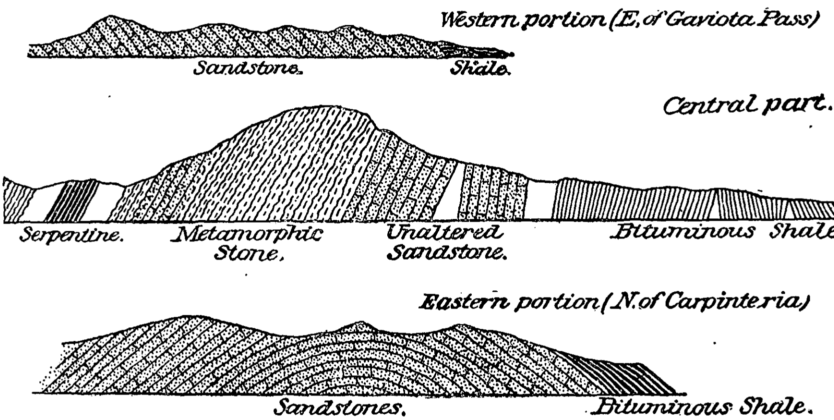
[1] Pac. R. R. Rept., 1857, vol. 7, part 2, pp. 47 et seq.
[2] Geol. Survey Cal., Geol., 1865, vol. 1, p. 139.

Southwest of the San Luis Valley a low chain of hills separates the valley from the ocean. To this Whitney has given the name "San Luis Range."[1] Its structure may be seen in his section given above (Fig. 34). It often contains vast quantities of *Ostrea titan.*[1]

This region is one in which the influence of both the northwest-southeast trend of the mountain ranges already described, and the east-west trend of the ranges about to be described, are quite apparent. The result is a general complication of the stratigraphy.[2] It is almost wholly unknown.

Santa Inez Mountains.—This is a well defined mountain chain, geographically speaking, and one whose structure is simple and fairly well known. It consists chiefly of Miocene sandstone and shale, as do the ranges of the San Rafael, Cuyames and others in the region of complicated stratigraphy to the north.

The following three sections will suffice to show the structure of this range:



FIGS. 36,[3] 37,[4] 38.[5]—Sections across the Santa Inez Mountains.

The asphaltum and bituminous substances of such common occurrence along the shore of the Santa Barbara channel at the base of the Santa Inez Range, have received much attention from Dr. Antisell, as may be seen from Chapter XVI, in volume VII of the Pacific R. R. Reports, as well as from his work on "Photogenic Oils."

There is another interesting feature of the geology of the coast of this region, and that is the development in some localities, especially in the vicinity of Santa Barbara Mission,[6] of Pliocene deposits which lie unconformably upon the upturned edges of the bituminous slate series.

[1] Geol. Survey Cal., 1865, vol. 1, p. 140.

[2] Ibid., pp. 110, 111.

[3] Ibid., p. 135. For a detailed description of Gaviot Pass, see vol. 7, Pac. R. R. Rep., pt. II, chap. 10, pl. 4.

[4] Ibid., p. 129.

[5] Ibid., p. 128.

[6] Ibid., p. 130. For Conrad's description of the Miocene and its fossils at this locality, vide Proc. Phila. Acad. Nat. Sci., 1855, vol. 7, pp. 267 and 441.

They are often fossiliferous; their stratigraphic relations may be illustrated by the following section:

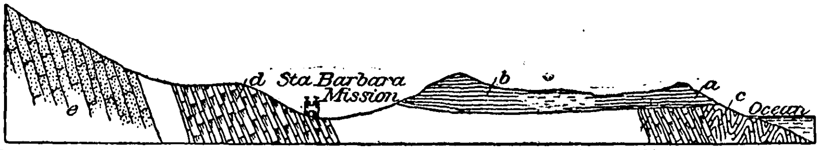


FIG. 39.—Section from the Pacific to the Santa Inez chain, at Santa Barbara. Distance about 3 miles. *a*, *b*, Pliocene and Pleistocene strata; *c*, bituminous slate, much contorted; *d*, bituminous slates and fine grained sandstones; *e*, sandstone, dipping south.

Tulare Valley.—Before proceeding further with remarks on the Neocene formations as they are found in the ranges and plains near the ocean, it seems well to refer briefly to some deposits of this age, found some distance to the northeast, at the head of Tulare Valley.

Between the eastern terminus of the Santa Inez Mountains and the Tulare valley, the geologic as well as geographic features are little known. Antisell's section (Fig. 6, Pl. IV, Pacific R. R. Reports, pt. 2, Vol. 7), from San Buenaventura to Cañada de las Uvas, may perhaps serve to give a general idea of the stratigraphy along this line, yet allowance must be made here as elsewhere for the tendency of this author to classify among igneous rocks many which later surveys would lead us to regard as metamorphic.

San Emidio Canyon.—Along San Emidio Canyon, to the north of Mount Pinos, Tertiary deposits are developed as follows:[1]

"The belt of Tertiary extends along the flanks of the mountains eastward for about 20 miles from San Emidio Canyon, passing out into the plain, and terminating in a range of hills to the northwest of the mouth of the Cañada de las Uvas." West and northwest of this canyon "a wide belt of Tertiary rocks may be seen skirting the coast ranges and worn into rounded hills, which are generally barren." "A spur runs out into the plain to the west and northwest of Buenavista Lake, and widens out near Paso el Roble, extending down the valley as far as the eye can reach."

Many of the sandstone beds, presumably Cenozoic, are nonfossiliferous, while others contain a great number of fossils, though generally in a poor state of preservation. The whole group must have considerable thickness, since it is said to dip northward at an angle of 60° or 70° for about 2 miles. The up-

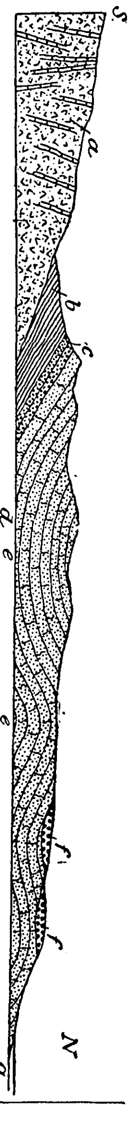


FIG. 40.—Section at San Emidio Canyon. Length, 10 miles. Horizontal and vertical scales nearly equal. *a*, granite, mica slate, and metamorphic rocks; *b*, Cretaceous sandstones and shales; *c*, nonfossiliferous sandstones; *d*, Miocene sandstones; *e e*, Tertiary sandstones without fossils; *f f*, horizontal deposits of gravel; *g*, Tulare plain.

[1] Geol. Survey Cal., 1865, vol. 1, p. 189.

per members "consist of sandstone and conglomerates, the latter abundant and coarse, and appearing to be more recent than Miocene; they are probably of Pliocene and post-Pliocene age. All these are disturbed and upturned, to the very mouth of the canyon."

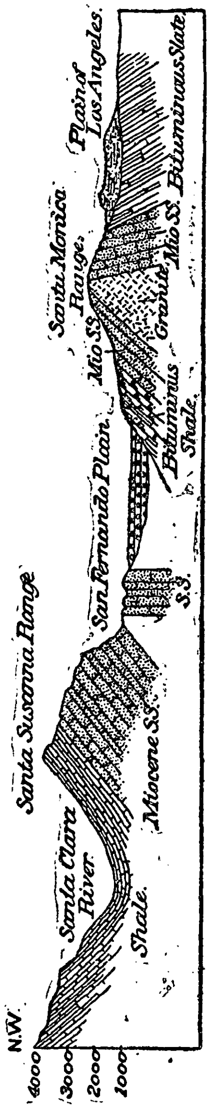


FIG. 41.—Section across the Santa Monica and Santa Susanna ranges, extending northwest from the plain of Los Angeles. Length 40 miles.

Not far from the region under consideration, viz, near Cañada de las Uvas, the granitic axes of the Sierra Nevada and the Coast Range appear to unite,[1] and extend thence in a southeastern direction, forming the backbone of the San Gabriel, the San Jacinto, the subordinate ranges to the west of the latter, and of the great San Bernardino Range to the east. It should be borne in mind, however, that these minor granite upheavals were not synchronous, so that they may represent several distinct periods of disturbance resulting in the apparent blending of the two more important ranges.

San Gabriel Range.—Passing southeastward from the Cañada de las Uvas,[2] the first presumably Neocene deposits met with are found about the base of the San Gabriel Range.[3] They consist of immense masses of sandstone and conglomerate, penetrated in some instances by granite dikes, and often turned up at a very high angle in almost any direction. The metamorphic rocks of this range are referred by Whitney to the Cretaceous.

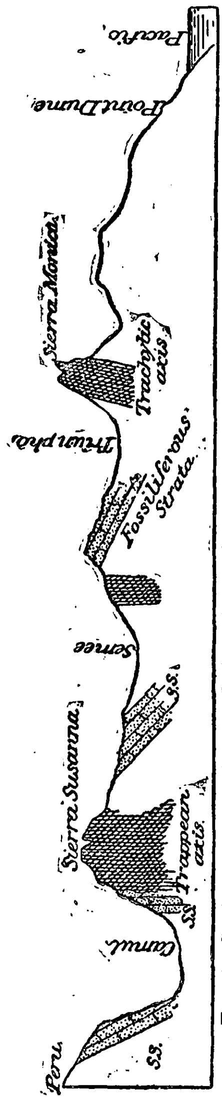


FIG. 42.—Section across the "Sierra" Monica and Santa Susanna ranges, extending northward from Point Dume.

[1] From this locality southward into Lower California Antisell calls this range "The Cordilleras." Pac. R. R. Rept., vol. 7, pt. 2, p. 87, 1857.

[2] For a geological map of the region about these passes, see Blake, Pac. R. R. Rept. 1856, vol. 5, pt. 2 p. 197.

[3] Geol. Survey Cal., Geol., vol. 1, pp. 171 et seq.

The topography about this range is evidently little known, for the authorities give widely varying accounts of its relations to the different sierras in this region. Whitney regards it as continuous with the Santa Susanna and Santa Monica ranges on the west.[1]

Santa Susanna and Santa Monica ranges.—The structural features of these two mountain ranges, especially the last mentioned, are fairly well known. The main characteristics are shown in the sections given in Figs. 44 and 45. The first, after Whitney,[2] is across their eastern portion, while the second, taken from Antisell,[3] is farther to the west, extending northward from Point Dumel.

These sandstones and shales belong for the most part to the Miocene. Gabb, however, has referred a certain deposit, north of the east end of the San Fernando valley, to the Pliocene.[4] To this age also are referred certain conglomerates at the opposite or western end of the valley. Here a low transverse range of hills seems to connect the Santa Susanna and the Santa Monica ranges. They are made up for the most part of Miocene shales and sandstones, some of which are highly metamorphosed, while on the hills north of Cayeugas ranch there are beds of light colored sandstone containing numerous Pliocene fossils. In and around the San Buenaventura or Santa Clara valleys the light colored, bituminous shales are extensively exposed. These and the region about Los Angeles have been studied with some care by Antisell in reference to the "bituminous effusions" already referred to.[5] The geology about Los Angeles is briefly described by Whitney.

Cordilleras.—Under the head of "Geology of the Cordilleras," Antisell has given a few general remarks on the geology of the granitic range under consideration, between the San Gabriel Mountains and the Lower California boundary line. None, however, materially assist in working out the character and extent of the Cenozoic deposits of this region. Whitney has devoted several pages to Santa Ana and Temescal ranges in the first volume of his report. Both these ranges are found to have axes of granite, with more or less metamorphic material, referable, perhaps, to the Cretaceous; and near the Santa Ana River thick deposits of coarse sandstone and conglomerates are found, with imperfect Tertiary shells supposed to be Miocene.

A geological map of the coast range, from the San Gabriel Mountains south to the boundary line of Lower California, is given by Blake in his report on the geology[6] for 1855. This shows the distribution of "Tertiary and detritus" about the borders of the Colorado desert and

[1] Geol. Survey Cal., Geol., 1865, vol. 1, p. 171.

[2] Ibid., p. 121.

[3] Pac. R. R. Rept. 1857, vol. 7, part 2, Geol., pl. iv, fig. 5.

[4] Geol. Survey Cal., Geol., 1865, vol. 1, p. 121. (Is this the locality whence Gabb cites so many Pliocene specimens? See Pal., vol. 2.)

[5] Pac. R. R. Rept., 1857, vol. 7, pt. 2, Geol., chapter xvi, and "Photogenic Oil."

[6] Rept. P. R. R. Exped., 1856, vol. 5, pt. 2, map opp. p. 228.

along the western slope of the range in question, i. e., between it and the Pacific Ocean.

San Diego region.—From specimens collected at San Diego by this expedition, Conrad was led to infer[1] that some phase of the Miocene series may here be represented. In a subsequent volume[2] he repeats the same impression, though making it perhaps slightly more definite.

In 1874, W. H. Dall published in the proceedings of the California Academy of Sciences[3] a list of 69 molluscan forms, which were obtained from a depth of 140 to 160 feet in a well sunk at San Diego. Concerning these forms he remarks:

> On an examination of the list it will be seen that of 69 species only three are strictly Miocene, while many are reported by Gabb as extending from the Miocene to the present epoch. * * * The age of the deposit, in general terms, may be taken as Pliocene.

From various localities in this vicinity, as Pacific Beach, False Bay, Ocean Beach, and Roseville, Orcutt[4] has given lists of "Tertiary fossils" without further attempt at correlation.

On the eastern slope of these mountains a very fossiliferous bed has been found, occupying the upper part of a sedimentary deposit which is found along Carrizo Creek. The whole bed is largely made up of the shells[5] of *Ostrea vespertina*, *O. heermani*, *Anomia subcostata*, and *Pecten deserti*, all of which were described by Conrad, and assigned to the Miocene,[6] though Gabb[7] regards these fossil oysters as Pliocene species. Orcutt is inclined[8] to regard them as Cretaceous. This completes the available data on the geology of the Coast Range; but, before taking up the Sierra Nevada we may consider the islands off the coast of Santa Barbara.

Santa Barbara Islands.—There are several small islands near San Pedro which have afforded a good many well preserved fossils. These have been referred en masse by some authors to the Pleistocene or Miocene, but recent observations by M. B. Williamson indicate that some confusion has occurred, a view which is supported by the character of the fossils. It appears that on Deadman Island, near Point Fermin, at least three distinguishable strata appear, the uppermost of which is certainly Pleistocene, while the others are Neocene, and the middle layer probably Pliocene.

The western portion of Anacapa is supposed[9] by Yates to consist in part of sandstone similar to the late Tertiary beds on Santa Rosa.

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[1] Pac. R. R. Rept., 1856, vol. 5, pt. 2, art. 2, app. p. 317.
[2] Vol. 7, pt. 2, p. 188.
[3] Vol. 5, pp. 296-299.
[4] The West American Scientist, July, 1889, vol. 6, pp. 70, 71.
[5] Pac. R. R. Rept., 1856, vol. 5, pt. 2, p. 122.
[6] Ibid., p. 235.
[7] Geol. Survey of Cal., Pal., 1869, vol. 2, p. 107.
[8] Tenth Ann. Rep. State Mineralogist Cal., 5, 1890 p. 91.
[9] Lorenzo G. Yates: 9th Ann. Rept. Cal. State Mining Bureau, 1890, pp. 172, 173.

On Santa Cruz, bits of slate and asphalt have been noted by Goodyear[1] in several places; at one locality, near Smugglers Cove, "unmistakable bituminous shale" has been observed.

On Santa Rosa various deposits have been observed by Yates, which are referred by him to the Tertiary.

In the Smithsonian Report for 1877[2] will be found a few notes on the geology of this island, from the observations of Yates. Among the stratified deposits he finds (1) a barren sandstone; (2) impure limestone containing *Ostrea titan;* (3) a fossil-bearing deposit beneath the Pleistocene on the northern part of the island, and (4) Pleistocene fossiliferous beds.

Mr. W. G. Blunt found an elephant's tooth and tusk on this island, the former of which was presented to the California Academy of Sciences,[3] and, more recently, Voy has collected other remains[4] of *Elephas* here. Dr. Yates reports having found the following species in the sandstones of this island: *Hinnites giganteus*, *Turritella ineziana*, *Neverita callosa*, *Pecten pabloensis*, *Liropecten estrellanus*, *Venus kennerlyi* and *Turbinella cœstus.*[5]

Catalina Island is largely composed of metamorphic schists, with serpentine and steatite. It is believed that Cenozoic sandstones also exist, though largely removed by erosion. Pleistocene gravels are found sparsely around the borders of the island.

The island of San Miguel is also partly schistose, with beds of gravel masking the underlying rock, and the presence of sandstone is inferred from fragments found on the beach.

This island, within historic times, was inhabited by Indians, and was covered with a coating of turf and vegetable soil. The introduction of sheep, after the expulsion of the natives, has had the effect of gradually killing the vegetation, which prevented the inroads of the beach sands. The latter are spreading over the island of San Miguel, as well as the other off-shore islands, and already cover to a considerable depth on the lower part of it the dead remains of the former turf, while on the hills the sheep are gradually destroying the remainder. With the destruction of the protective coating the erosive forces will begin to operate in a somewhat different and more energetic manner, and the whole series of operations offers an instructive instance of the modifications due to human interference, which may affect geologic action.

THE SIERRA NEVADA.

In this area will be included that portion of the State lying to the east of the Cascade Range, the Sacramento and San Joaquin rivers, and the Cordilleras.

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[1] W. A. Goodyear: 9th Ann. Rept. Cal. State Mining Bureau, 1890, p. 159.
[2] See also Am. Geol., 1890, vol. 5, p. 49.
[3] Proceedings, vol. 5, p. 152.
[4] Now in the cabinet of the State University at Berkeley.
[5] Ninth Ann. Rept. Cal. State Min. Bur., 1890, p. 173.

Colorado desert.—Blake suspects that some of this area, especially about its periphery, is underlain by Tertiary deposits.[1] The map accompanying his report on this region is so colored as to give his idea of the distribution of these beds.

Death Valley.—Gabb cites at least one species, *Natica recluziana*,[2] from this region, and refers it to the Miocene.[3]

Foothills of the Sierras.—It will be recalled that in discussing the Coast Range, attention was called to the extensive Miocene beds in the vicinity of San Emidio Canyon, which extend eastward nearly to the mouth of the Cañada de las Uvas. From this point eastward, if they exist at all, they must pass beneath the Quaternary deposits of the plain until the vicinity of Kern River is reached. Here extensive deposits of soft, friable sandstones may be seen, forming rounded hills from 200 to 600 feet high which rest upon upturned edges of the granitic and metamorphic beds of the Sierra. This sandstone extends continuously as far to the north as White Creek, but is best developed and has been most thoroughly studied in the vicinity of Posé or Ocoya Creek. Blake has devoted several pages in his report[4] to this district. The fossil mollusca, which exist only in the form of casts, were submitted to T. A. Conrad, while the shark's teeth were sent to Agassiz. Both these authorities concluded the horizon represented was doubtless Miocene, a view confirmed by the researches of the California Geological Survey.[5]

The general features of this formation will be found in the following section, compiled by Blake,[6] near "Dupont camp," on the south side of the creek:

		Feet.
n.	Gray sand, with layers of pebbles	20
m.	Gravel and pebbles, with sand	1
l.	Sand, with clay nodules	20
k.	White clay and fine sand	2
j.	Pumice sand or volcanic ashes, very fine and white in thin strata	15
i.	Fine white sand, derived from pumice stone, with intercalated layers of pumice in nodules and in powder	25
	Fine sand, with small spherical and ellipsoidal masses of white pumice stone. Thin layers of charcoal, in fragments	0·6
h.	Fine sand, with curved layers of oxide of iron	4
g.	Argillaceous sand, filled with small nodular masses of clay, from one-fourth of an inch to three inches in diameter	1
f.	Fine gray sand, with an occasional layer of pebbles (this stratum is partly hid)	41
e.	Fine gray sand, cross stratification distinct, contains nodules of clay	24
d.	Casts and molds of fossil shells in sesquioxide of iron, gravel, and sand, layers oblique	1·4

[1] Pac. R. R. Rept., 1856, vol. 5, pt. 2, pp. 234–235; map opp. p. 238 and section sheet 6.

[2] Geol. Survey Cal., Pal., 1869, vol. 2, p. 77

[3] King regards the immense series of upturned fresh-water deposits in the vicinity of Cajon Pass as Miocene: Explor. 40th Parallel, System. Geol., vol. 1, 1878, p. 413.

[4] Pac. R. R. Rept., 1856, vol. 5, pt. 2, pp. 164–173.

[5] Geol. Survey Cal., Geol., 1865, vol. 1, p. 203.

[6] Pac. R. R. Rept., vol. 5, pt. 3, p. 167.

	Feet.
c. Sand, stained with iron, includes a thin layer of pebbles	2
Gravel and sand, inclosing casts of fossils, obliquely stratified, and all strongly cemented with sesquioxide of iron..................	0·7
b. Sand, in thin layers, stained with oxide of iron	0·6
a. Fine, friable, gray sand, stained with lines of oxide of iron, and inclosing nodules of various sizes encased in oxide of iron.........	2
Level of Posé Creek.	

North of White Creek this or a similar formation extends along the base of the Sierra, forming low detached foothills as far north perhaps as San Joaquin County, though this portion of their extension has been little studied.

THE AURIFEROUS GRAVELS.

Beds of incoherent Pliocene sands and gravels have already been referred to in connection with our description of the Coast ranges. They have as a rule been found to lie nearly horizontally upon the upturned strata of the Miocene or earlier date, and are usually unfossiliferous.

On the western flank of the Sierra Nevada, extending from Mariposa to Plumas County, a distance of 175 miles, is a district containing numerous patches of sands, clays, and gravels, which, on account of the gold they contain and their generally coarse materials, have usually been termed "Auriferous gravels." Their mode of occurrence, their fossil contents, their probable geological age, etc., were noted with some care in the first volume published by Whitney on the geology of California, but have since been elaborately discussed by the same author,[1] and the able paleobotanist, Leo Lesquereux,[2] in volume VI of the Memoirs of the Museum of Comparative Zoology at Harvard College, 1878-'80. It accordingly seems unnecessary to go into details here regarding the geology of the gravels. The State Mining Bureau of California has been collecting material regarding these gravels for the last ten years, and this has been published in the annual reports of the State mineralogist. It relates almost entirely to economic matters, so that for general geological and paleontological features of these deposits reference must be had to the works of Whitney and Lesquereux.

Neocene lake beds.—Farther north, however, in Plumas, Lassen, Shasta, and Tehama counties, the researches of J. S. Diller have brought to light the existence of various beds of volcanic detrital and ordinary fresh-water sedimentation, which in some instances are auriferous, and doubtless are synchronous with the "Auriferous gravels" to the south. In discussing these deposits Mr. Diller[3] subdivides them into "Miocene" and "Pliocene," though on a local map, including the Lassens Peak district, he colors them all as "Neocene" without distinction. This author says:

[1] J. D. Whitney: The Auriferous Gravels of the Sierra Nevada of California. Memoir, etc., vol. 6 No. 1, pt. 1, 1879. Same, part 2, 1880.
[2] Leo Lesquereux, Rept. on the Foss. Plants, Aurif. Grav. Deposits, etc. Memoir, vol. 6, No. 2, 1878.
[3] 8th Ann. Rept. U. S. Geol. Surv., 1889, pt. 1, pp. 413, 422.

During the Miocene the northern portion of the Sacramento Valley was occupied by an extensive fresh-water lake, which stretched far to the northeastward through Lassen Strait, that marks the limit between the northern terminus of the Sierras and the Coast Range and is now occupied by the volcanic uplift of Lassen Peak. A similar body of water existed northeast of Indian Valley, in the country now occupied by the very crest of the Sierras, northwest of Honey Lake, at an elevation of nearly 7,000 feet. From the fact that the lacustrine deposits on both sides of Lassens Peak pass beneath its lavas, it is believed that they are continuous and were all laid down in the same lake, which at that time covered a large portion of what is now the northern end of the Sierras and extended from the Sacramento valley far into Oregon. Clarence King[1] has called attention to the wide distribution of Miocene lacustrine deposits in that region, extending from beyond the Columbia River south, through Oregon into Nevada and California, and it may now be added that they passed, through the gap separating the north end of the Sierras from the Coast range, into the northern portion of the Sacramento Valley. To the large body of fresh water in which these sediments were found King gave the name of Pah Ute or Piute Lake. The Piute Lake deposits reach much higher up on the Sierras than the littoral deposits of the Chico epoch, indicating clearly that between the close of the Chico epoch and the beginning of the Miocene there was a change in the relative elevation of the Sacramento valley and the Sierra region. This change was effected by the elevation of at least part of the region of the Coast Range, and apparently also of the Cascade Range, so that the oceanic waters were excluded and the formation of Piute Lake was rendered possible. That this elevation occurred at the close of the Cretaceous is rendered altogether probable by the fact that the Tejon group has not yet been recognized within the Piute Lake region. Perhaps we may yet find in the earlier deposits of that lake the fresh-water equivalents of the Tejon group of western Oregon and southern California.[2]

In this Miocene lake there were deposited, at least within the Lassen Peak district, first, shales and sandstones, and afterwards conglomerates. A typical exposure of these beds is found on Little Cow Creek, in Shasta County, at an elevation of about 2,900 feet. At one place a fine shaly bed is intercalated between the sandstone, and contains fossil leaves, some of which have been identified by Lesquereux and by him referred to the Miocene. With these was found *Anodonta nuttalliana*, according to the identification of Dr. R. E. C. Stearns.

The whole thickness of the Miocene here exposed is not less than 500 feet. Its contact with the Chico beds has not been seen, but the relative positions of two at adjacent exposures indicate that they are slightly unconformable.

The prominent ridge between Bear Creek and the south fork of Cow Creek affords an unusually interesting exposure of the upper portion of the Miocene. At the very base of the hill, in the beds of both streams, Chico fossils have been found, so that the hill undoubtedly rests on the Cretaceous. Above the fossiliferous beds is a considerable thickness of sandstone capped by a heavy layer of conglomerate, and overlying this is usually found a remarkable flow of tufaceous rhyolitic lava. The conglomerate at this point shows apparently a greater development than anywhere else within the district. It has been mined for gold, but without marked success. * * *

South of Bear Creek the Miocene is not so extensively developed nor so well exposed.[3]

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[1] U. S. Geol. Explor. of the 40th Parallel, vol. 1, 1878, pp. 451-454.

[2] Ann. Rept. U. S. Geol. Surv., 1889, pp. 420-421.

[3] Ibid., pp. 414, 415.

Similar deposits have been seen in the vicinity of Mountain Meadows and Light Canyon. Near the former, a few fossil leaves have been found, and likewise auriferous gravels.

A short distance north of the road, where it crosses the summit between Light Canyon and Susanville, at the head of a stream which flows into Susan Creek, the gravel is cemented into a firm conglomerate. It is about 350 feet thick and dips slightly to the eastward.[1]

Some fossil leaves were found here in lenticular masses of shale imbedded in the consolidated gravels. Others were found in a clayey stratum in the Monte Christo mine, accompanied by a species of fresh-water fish. All these plants have been identified by Leo Lesquereux, who states that "by the presence of a large number of *Laurineæ* the flora becomes related in its general characters to that of a region analogous in atmospheric circumstances to Florida. With this view Prof. Lester F. Ward also fully agrees."

Within the Lassens Peak districts deposit of Pliocene age have not been definitely distinguished from those of the Miocene, but their presence is rendered altogether probable by several considerations. The auriferous gravels were regarded by Prof. Whitney as accumulating upon the western slope of the Sierras throughout the whole of the Tertiary, reaching their culmination in the Pliocene. This view is very probable, indeed, for although the mass of the gravels of the gold belt are Pliocene, it appears to be evident that other portions, especially that at Cherokee as well as about Mountain Meadows and near the head of Light Canyon, belong to the Miocene.[2]

The tufa of which the Pliocene is composed is often distinctly stratified, clearly indicating that its deposition took place in water.

In the canyon of Mill Creek and also in that of Deer Creek, near the mountains, where the tufa has a thickness of nearly 1,000 feet, it is roughly divisible into three parts, as indicated in Fig. 17. The upper and lower portions are agglomerate, and between them the stratified arrangement of the tufa is clearly discernible. In all parts the sediments are essentially the same, being composed largely and perhaps chiefly of fragmental material ejected from volcanoes.

It is apparent that the water body about the northern terminus of the Sierras during the Pliocene was shallower and more extensive than the Miocene lake, and differed also in the character of its deposits.[3]

The small Pliocene area represented on the map some distance south-west of Honey Lake has recently been described by Mr. Turner before the Washington Philosophical Society.

The Neocene area represented on Klamath River is supposed by Diller to be continuous with that on Pit River, the intermediate development being wholly concealed by lava outflows.

HUMAN REMAINS IN THE AURIFEROUS GRAVELS.

It seems inadvisable to close this sketch of what is known of the Californian Neocene without some reference to the presence of the remains of man associated in the gravels with the bones of Pliocene mammals, fossil leaves, etc., of which a full account to date of publication has been given by Whitney in his work, already cited.

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[1] 8th Ann. Rept. U. S. Geol. Surv., 1889, p. 417.
[2] Ibid., p. 422.
[3] Ibid., p. 423.

Since the publication of that work other testimony has come to hand[1] which leaves no valid reason to doubt the occurrence in the gravels of human bones and articles of stone and shell of human handiwork, which are of course as strong an evidence of man's presence as a skeleton would be. These remains are found under a basaltic layer covering the gravels and of which large masses remain forming "table mountains" protected from erosion by their basaltic capping. The remainder of the basalt and much other material has been carried away by erosion, leaving these mountains like islands, 1,000 to 2,000 feet above the intervening valleys. As we have seen in the case of the Clear Lake basalts, the eruptive rock is without doubt Pleistocene, and comparatively late Pleistocene, if the term Pliocene be held to have the same meaning in California that it has hitherto had elsewhere.

Cope has pointed out that among the vertebrates from these gravels one (*elotherium*) is not Pliocene nor even Upper Miocene, but belongs to the Eocene or lowest Miocene (White River group), while *Mastodon obscurus* is Upper Miocene.[2] So it is obvious that the gravels, even if man be left out of the question entirely, contain vertebrate remains belonging to more than one epoch. It has been suggested by Becker that in California the Pliocene animals survived after glaciation in the northeastern part of the continent had resulted in extermination or migration and, as in the case of Florida, there is nothing inherently improbable in this view. But that man was contemporaneous with them is a proposition as yet unsupported by direct evidence and a priori improbable.

The really marvelous thing in the discovery of man in these gravels is the unimpeachable evidence of the enormous lapse of time since he wandered in the river valleys of Pleistocene California, which is afforded by the known facts. This offers us no new idea, for geologists have long discussed periods of Pleistocene time which mount up into the tens or hundreds of thousands of years. But the vividness of the testimony offered by these discoveries lends a reality to the assumption which is startling in its emphasis and brings it home to us in a manner which no merely mathematical calculations can approach.

It should not be forgotten that a somewhat similar association of flint implements with Pliocene vertebrate remains was discovered in Oregon,[3] though in this case the formation was not sealed from disturbance by an impermeable covering of lava such as fixes the authenticity of the assembly in the Californian gravels.

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[1] See George F. Becker, Am. Geologist, April, 1891, vol. 7, p. 258; also Bull. Geol. Soc. Am., Feb. 1891, vol. 2, pp. 189-200, and Geo. F. Wright, Atlantic Monthly, April, 1891, p. 501.

[2] Am. Naturalist, January, 1880, vol. 14, p. 62.

[3] Cf. Cope, Am. Naturalist for 1878, p. 125, and for 1880, p. 62. See also, U. S. Geol. Surv. Terr., Bull. No. 4, p. 389, and No. 5, p. 48.

OREGON.

PACIFIC BORDER.

The fresh-water Tertiaries of eastern Oregon will be considered in chapter VI, where they naturally belong.

Along the ocean border of this state three detached areas of Neocene deposits have thus far been recognized.

The first, going northward from the California line, appears just north of Port Orford,[1] and is more or less continuous to Cape Blanco.[2] It is an arenaceous deposit forming a narrow strip, and is said by Newberry to resemble closely the shales and sandstones of Astoria referred by Conrad to the Miocene.

The second appears in the vicinity of Coos Bay,[3] eastward, inland 4 or 5 miles from the ocean.[4] Immediately upon the shore fossiliferous beds are exposed which, as Dr. White[5] has shown, belong without doubt to the Eocene. These dip eastward, presenting their upturned edges to the sea, the eastward slope being formed by the superincumbent Miocene.

The third area of Neocene is exposed on the shore, a little south of Yaquina Bay, whence it is more or less continuous northward as far as the Columbia River, except where broken by recent lavas. In this section of the coast Prof. Condon states that no Eocene rocks appear to crop out.

At Tillamook Head Dana[6] has noted the occurrence of an argillaceous cliff 900 feet in height. Its lower two-thirds appears dark and shaly, while above it is light and chalky. These beds doubtless belong to the same geological horizons as the series displayed at Astoria, to be described hereafter. It seems that Prof. Condon has obtained an *Aturia ziczac* from Tillamook, indicating the presence there of Eocene rocks.

COLUMBIA RIVER.

Three distinct formations along the Columbia have been referred by Dana to the Tertiary period.

Astoria shales.—The first consists of clayey or sandy shales of various colors and various degrees of consolidation. On weathering they become soft and clayey, and so appear along the banks at Astoria. At the time of Dana's visit and until a few years ago numerous Eocene fossil remains were obtained at the water's edge by collectors in the town of Astoria. These came from a single very thin stratum below the Miocene shales. Owing, however, to the fact that the specimens

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[1] Pac. R. R. Rep., 1857, vol. 6, pt. ii, p. 59, and Trans. Acad. Sci., St. Louis, 1860, vol. 1, p. 120.
[2] According to Prof. Thos. Condon, 1890.
[3] Pac. R. R. Rep., 1857, vol. 6, pt. ii, p. 63, and Trans. Acad. Sci., St. Louis, 1860, vol. 1, p. 122.
[4] As verbally described by Prof. Condon, 1890.
[5] U. S. Geol. Survey, Bull, 1889, No. 51, p. 30.
[6] Wilkes's Expl. Exped., Geology, by Dana, p. 653.

were contained in calcareous concretions, which, on account of the scarcity of limestone in this region, have been carefully collected and burned for lime, while the beach has been built over and entirely covered, this bed is no longer accessible, and the supply from this source has virtually been cut off. The same expedition also collected Miocene fossils from the beds above. Specimens inferior in preservation from the superincumbent Miocene beds may still be seen in the banks near Tongue Point at the Bluffs behind the schoolhouse, and at other localities about Astoria; yet the gradings, wharfage, buildings, etc., have concealed to a considerable extent many of these exposures. Collections of molluscan remains were made in this region over forty years ago by both Mr. J. K. Townsend[1] and the United States Exploring Expedition, under Captain Wilkes,[2] and were turned over to Mr. T. A. Conrad. This authority did not hesitate to pronounce them all Miocene; not because he actually found known species of this age among them, but because their nearest analogues were from the Miocene of Virginia and England.

Aturia bed.—Of late Dr. C. A. White has pointed out[3] the great similarity between certain Chico-Tejon forms and those figured by Conrad from the Townsend collection; the Miocene character of the fossils collected by the Wilkes expedition, except the *Aturia*, is not called in question. At a later date collections were made by Prof. Condon from both the Eocene and the Miocene horizons at Astoria, and are still preserved in his collection at the State University and properly discriminated. The presence of *Aturia ziczac* and other apparently Eocene forms among those obtained at Astoria and referred by Conrad to the Miocene has led to the suspicion that the whole series of beds might really be of Eocene age,[4] but this evidence, for which we are indebted to Prof. Condon, explains the discrepancy which has been so long a mystery.

Astoria sandstones.—The second formation along the Columbia consists of a series of sandstones which occurs on both sides of the river above Astoria, though best developed on the north or right bank, while the Astoria shales[5] above described are most prominent on the left or south bank. The sandstones are granular, brittle, or friable, sometimes very compact and hard, usually of a brownish color. Dana[6] regards the sandstones as more recent than the shales, a view which is strengthened by the fact that fissures in the shales are still filled with sand resembling that of which the sandstones are composed.

[1] Am. Jour. Sci., 2d ser., 1848, vol. 5, pp. 432–433.

[2] Wilkes Expl. Exped., Geology by Dana, 1849, p. 659. These were collected at Astoria proper, as at present understood, but the locality of Townsend's fossils is given as "near Astoria." They were very probably from the north bank of the Columbia, opposite Astoria.

[3] U. S. Geol. Survey, Bull. No. 51, 1889, p. 31.

[4] Conrad himself at a later date inclined to this opinion and referred the Astoria beds to the Eocene. Proc. Acad. Nat. Sci., Phila., for 1865, pp. 70–71.

[5] Named by Prof. Condon, Am. Naturalist, 1880, vol. 14, p. 457.

[6] Geol., Expl. Wilkes Exped., 1849, pp. 553–556.

Astoria group.—The impression produced on the mind by an inspection of these rocks,[1] though without the opportunity to examine any large district with care, was that the shales and sandstones form a part of a single series varying in the character of its beds or layers according to fluctuations in the sedimentation, the shales being more argillaceous, the sandstones more arenaceous, neither possessing an exclusive character, the fossils appearing to be the same Miocene species in both, with a tendency to form concretions around them in the shale and to be represented by casts in the sandstones. The name of Astoria group is proposed to include them both, but not the subjacent Eocene Aturia bed.

As Astoria is a classical locality for the geology of this coast, it may be well to give a few descriptive notes taken by W. H. Dall on a recent visit for the purpose of examining these beds.

The Aturia bed, as before explained, is no longer accessible, its outcrop having been close to the water's edge under the most elevated part of the (anticlinal?) high bluffs behind the town, which is strung along on a narrow talus or built out on piles over the river, there being hardly any level land between the bluffs and the water.

At Smiths Point, west of the town, the shales are very low, the vertical face not exceeding 15 feet. They dip about 16° in a southeasterly direction, and are composed of thin layers of chiefly bluish gray shale with numerous fractures lined with peroxide of iron which develop more numerously as the surface dries, while the iron causes the face to weather of a brownish color. The layers mostly contain a little sand; some do not show any. The fluctuations appear to succeed each other with a certain regularity. Here and there a little gravel is mixed in one of the layers, and in these gravelly layers are also small fragments of bivalve shells, the most perfect and numerous being those of a small concentrically undulated *Pecten* of the section *Pseudamusium; Acila* and *Waldheimia* were also observed.

In the upper layers of the shale the clayey parts occasionally form lines of concretions along a bedding plane, partly fossiliferous. The most common fossil here is a species of *Macoma.*

Above the shales at this point is a bed of 8 to 20 feet in thickness of a yellowish clayey sand with irregular, mostly rounded fragments of a harder sandstone, maculated with peroxide of iron with a few traces of marine fossils, and more or less gravel not regularly bedded, and penetrating into fissures in the shaly rock below in the form of dikes. The beach in this vicinity is composed of the pebbles, nodules, and small bowlders of the hard sandstone washed out of this layer, and a few volcanic fragments. Near Tongue Point, at the other end of the town, 2 miles away, the same beds were recognized, but the gravelly layer seemed thicker and the shale much broken up. The same beds seem to compose the bluffs between Tongue and Smiths points, though from

[1] Wm. H. Dall, in August, 1890.

the way the town is built they are difficult of access. The bluffs at their highest point near the high-school building rise perhaps 150 feet. Here a fine section shows 30 to 40 feet of the shales exposed at an angle of 45° to 60°, dipping about 26° south southeast, though the dip is not invariable. The yellowish sandstone gravel overlies the shales to an equal thickness and descends into them in dikes here and there. The upper margin of the shales is sometimes indistinguishable, the clayey and sandy layers merging into one another and being similar in color. It is notable that in the upper part of the shales some of the shells seem to have been fossilized in a sandstone, washed out and reimbedded in the clays. Between the valves, or on one side of a single valve of a bivalve shell, there will be a soft coarse sandstone, while the fossil is otherwise entirely imbedded in a dark waxy clay shale.

Tongue Point itself is a basaltic mass, and on the ridge behind the town, according to Prof. Condon, there is an extensive layer of Pleistocene basalt, fragments of which appear on the beaches. On the south side of the street from the Union Pacific dock and one block west, a fire had destroyed some buildings and a part of the planking of the roadway, revealing a fine solid basaltic rock 10 or 12 feet square and 15 feet high. The original beach at its base was abundantly strewn with fragments of the same material.

These shales and sandstones have much general similarity to those of California and Alaska of Miocene age. A similar rock exists on the west coast of Vancouver Island, British Columbia, containing some of the same species which appear at Astoria, specimens of which have recently been received by the geological survey of the Dominion of Canada.

From a point a few miles south of Oregon City, Clackamas County, Shumard[1] has described a Miocene *Leda* under the name of *L. oregona*.

The Aturia bed and the superincumbent Miocene of the Astoria group appear on the north bank of the Columbia in a good many places, apparently more elevated than on the Oregon side.

The third deposit regarded by Dana as Tertiary consists of a basaltic conglomerate, which is found on this river high up at the Cascades and even beyond. It will be referred to later.

WILLAMETTE RIVER.

Both Dana[2] and Newberry[3] inform us that a sandstone formation extends up the Willamette valley with but slight interruptions at least as far as the Calapooya Mountains. Both note its intrusions of trap, its more or less disturbed condition, its apparent want of fossil remains, its eroded condition, and its lithological resemblance to the various Tertiary sandstones so well developed in California and Oregon.

In 1885 Dr. C. A. White[4] published from information received from

[1] Trans. St. Louis Acad. Sci., vol. 1, 1860, p. 121.
[2] Wilkes Exploring Exped., Geol. by Dana, pp. 651 et seq.
[3] Pacific R. R. Rep., vol. 6, pt. 2., 1857, pp. 58, 59.
[4] Bull. U. S. Geol. Survey, No. 18.

Prof. Thomas Condon an account of the occurrence of *Cardita planicosta* at Albany, Oregon, and remarks incidentally that "strata which bear characteristic Miocene fossils are found in the valley of the Willamette only a few miles away."

During the summer of 1890 Wm. H. Dall collected at several of these Miocene localities, and by the assistance of Prof. Condon has been able to note a wider distribution of the Eocene than has heretofore been recognized in this State.

Miocene rocks are well exposed at Smith's quarry, 1 mile east of Eugene City, and at Springfield bridge, 2 miles farther east. At the former locality the rocks consist of grayish hard sandstone weathering to a yellowish color, irregularly bedded above, but massive below, dipping about 6° southeast, with a total exposure of about 37 feet. The fossils—*Mytilus*, *Modiola*, *Mactra*, *Solen*[1], *Natica*, *Neverita*, *Purpura*, and *Lirofusus*—are crowded or crushed together along certain lines or layers, and are usually in form of molds recrystallized into spar.

The second locality, or that near Springfield, affords an excellent exposure of nearly a mile in length, extending southward from the abutment of the new bridge. The rocks have an easterly dip of from 5° to 8° and form a total perpendicular exposure of about 160 feet; they are overlain unconformably by 5 or 10 feet of alluvial matter which lies on their eroded edges. In the hilly regions, according to the observations of Prof. Condon, they are capped with basalt.

A basaltic conglomerate has already been referred to as occurring in the Cascade Range along the Columbia. In southern Oregon, in the "Boundary Range," according to Dana,[2] this conglomerate graduates into Tertiary sandstone containing fossil remains. The latter Dr. White has recently referred to the Chico division of his Chico-Tejon series.[3]

It is stated in the American Naturalist[4], from Prof. Condon's manuscript notes, that the backbone of the Coast Range consists of argillaceous Miocene shale, which contains fish remains and invertebrate fossils. These Prof. Condon identifies with the outcrops at Astoria, and names the Astoria shales. Above these lie extensive Miocene beds, rich in fossils, which Prof. Condon calls "Solen beds." On the flanks of the highlands there are also Pliocene deposits containing some of the fossils of the Equus beds.

WASHINGTON.

The little that is known regarding the Neocene geology of this State can be most conveniently considered under two heads, viz, (1) geology

[1] It was probably on account of the presence of this genus in rather unusual abundance that Prof. Condon has applied to the chief Miocene fossiliferous bed of the Willamette Valley the name of "Solen bed." It is not improbable that it may be found to constitute one of the series of beds which are above designated as the Astoria sandstones. Their upper surface is always eroded.

[2] Wilkes Expl. Exped., Geol. by Dana, 1849, pp. 646, 653.

[3] Bull. U. S. Geol. Survey, No. 51, 1889, p. 29.

[4] Vol. 14, 1880, p. 457.

of the Pacific border and (2) geology of the central basin. Although inferences may be drawn from King's works regarding the existence and probable Neocene age of certain volcanic materials in the mountain ranges of this State, yet it is not deemed advisable to indulge in such speculations, and this brief notice will be restricted to what is actually known respecting the sedimentary Neocene deposits.

PACIFIC BORDER.

Siliceous casts of molluscan fossils have been collected at various points on Shoalwater Bay,[1] which show a synchronism of the deposits in which they are found with both the Eocene and the Miocene clay-shales of Astoria. The Aturia bed crops out at Bruceport and elsewhere. A Pliocene deposit has been observed by Dr. Condon in this vicinity, which, from its most characteristic fossil, may be called the Mytilus bed. It furnished specimens of *Buccinum cyaneum*, *Mytilus condoni*,[2] *Crepidula*, *Pecten*, and *Panopæa;* this is immediately overlain by a Pleistocene formation, the level of which is from 30 to 40 feet above the sea.

CENTRAL BASIN.[3]

Lignite beds.—In Dana's geology of the Wilkes Exploring Expedition[4] reference is made to the similarity of structure of the Cowlitz valley and the Willamette. A coal deposit is also noted and an analysis of the coal is given.[5] Newberry also speaks of the parallelism of various west coast river basins, and adds that the "lignite" is found near the mouth of the Cowlitz, implying also that the accompanying strata are sandstone and shale.[6]

Farther to the north, along the Nisqually and Chehalis rivers, "bluffs of soft sandstone and crumbling clay" were reported by a Mr. Eld to Dana while on the Wilkes Exploring Expedition.[7]

The extensive coal and lignitic deposits about Puget Sound have been referred by Newberry[8] and White[9] to a group transitional from Cretaceous to Eocene, or to the Laramie or Puget group (Chico?). Still farther to the north, on the Dwamish River, the deposits belong without doubt to a higher horizon, for none but proper Tejon fossils are represented. Mr. Willis,[10] by purely stratigraphic study, arrived at the same conclusion.

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[1] Dr. Leidy figures in the U. S. Geol. Surv. Terr., "Fossil Vert.," vol. 1, pl. 33, fig. 19, an upper molar tooth from the "lignite beds of Shoalwater," which is "undistinguishable from the corresponding part of the domestic horse," op. cit., p. 246.

[2] Nautilus, Dec., 1890, vol. 4, pp. 88, 89; notes by Wm. H. Dall.

[3] In addition to the geological facts given under this head, Cope describes *Taxidea sulcata* from the Pliocene of Washington Ter., but gives no definite locality. Proc. Am. Phil. Soc., vol. 17, 1877, p. 227.

[4] Op. cit., 1849, pp. 616-621, 626.

[5] Ibid., p. 658.

[6] Pac. R. R. Rep., 1857, vol. 6, pt. 2, p. 57.

[7] Op. cit., p. 628.

[8] Bull. U. S. Geol. Surv., No. 51, 1889, p. 51.

[9] Ibid., pp. 49 et seq.

[10] Ibid., p. 56.

Certain deposits in the vicinity of Bellingham Bay were long ago referred by Leo Lesquereux[1] upon paleontological evidence to the Miocene. In this interpretation both Heer[2] and Newberry[3] concur. They may, however, be referable to the Kenai group.

From a manuscript report of Lieut. W. P. Trowbridge, Blake[4] gives the following description of the coal beds.

The coal strata exposed to view on Bellingham Bay are situated in latitude 48° 43′, and occur in a series of stratified rocks, which dip at an angle of 70° from the horizon, and strike E. 15° N., the thickness of the series being about 2,000 feet. The coal beds enter the bank at right angles to the shore line, and rise with a gradual slope to the height of about 350 feet, at the distance of half a mile from the shore, where they are broken in a direction oblique to that of the beds, and fall off in abrupt ledges to their original level.

The total thickness of the coal strata was estimated by Trowbridge as being 116 feet. Blake, however, was inclined to suspect that some of the beds may have been duplicated by dislocation.

But few invertebrate fossils have been observed at this locality. Blake mentions having seen "two well preserved shells of the genus Pecten[5]" in a sandstone block shown him by Lieut. Trowbridge. Dall was informed that an *Aturia ziczac* had been collected here, though the specimen was not accessible. Both the Aturia bed of the Eocene and the Miocene shales will probably be found represented at Bellingham Bay as at Astoria.

Puget group.—During the progress of the Northwest boundary surveys (1858–1862) various naturalists and geologists visited the Puget Sound region. Among them was Dr. Hector, who reported to Col. Palliser on the geology.[6] Mr. Richardson, Dr. Dawson, and others have visited this region for geological researches, and from the sum total of available information, published or otherwise, the latter has prepared a geological map including, in addition to the geology of the British Columbian region just north of the State, a considerable part of Washington. On this map, issued by the Dominion Geological Survey in 1884, the marine Miocene is represented as forming a border along the ocean coast, the shore of Fuca Strait, and the western half of Puget Sound, inclosing the mass of the Olympic Mountains and the coast ranges north of the Columbia. The shores of Puget Sound eastward as far as the bight on which Tacoma is situated, and at the North Whidbey Island and the shore east and southeast from it, and hence northward to Bellingham Bay, Birch Bay, and the international boundary, are indicated as marine Miocene on this map. This may, perhaps, be regarded as covering all post-Cretaceous strata in an approximate way, for it is certain that within the area thus broadly indicated a

[1] Am. Jour. Sci., vol. 27, 1859, pp. 359 et seq.
[2] Ibid., vol. 28, 1859, pp. 85 et seq.
[3] Boston Jour. Nat. Hist., 1860, vol. 7, pt. 2, p. 509.
[4] Pac. R. R. Rep. 1856, vol. 5, pt. 2, p. 285.
[5] Ibid., p. 287.
[6] Proc. Geol. Society, in Quart. Jour. Geol. Soc., vol. 17, pp. 388–445, and plate xiii. See page 435.

considerable part must be referred to post-glacial deposits, while the presence of Eocene rocks has already been indicated.

It may be added that on the map referred to nearly the whole of eastern Washington, including the Cascade Mountains and the entire region east of them and south from the Wenatchee, Columbia, and Spokane rivers, is represented as occupied by volcanic rocks of Miocene age. The determination of the age of these beds can not be said, however, to be conclusive, in view of what is known of the very recent origin of analagous eruptives in California, but at present we are not in a position to discuss the question on account of the paucity of our information.

BRITISH COLUMBIA.

NEOCENE OF THE COAST.

But little relating to the Neocene on the coast of British Columbia has been put on record. As previously stated, a clayey sandstone with fossils of the Astoria group has been collected on the west coast of Vancouver Island. Doubtless the same rocks occur at various points along the coast of British Columbia and the adjacent islands, though the glaciation and violent changes of level to which this region has been subjected in Pleistocene time have probably resulted in the erosion and disappearance of most of the softer Neozoic beds which were deposited along its shores.

One locality of marine Miocene beds is that near Sooke, on the west coast of Vancouver Island, in about west longitude 124° from Greenwich. The area is small. A larger area appears in the northern part of the Queen Charlotte Islands, forming that part of Graham Island east of Masset Inlet and north of Skidegate Inlet. West of this Graham Island is largely composed of volcanic rocks, which on the geological map of the Geological Survey of the Dominion of Canada[1] are colored as belonging to the Miocene, and which overlie sandstones or shales and hard clays with lignites. At a single locality near the north end of Graham Island beds with numerous marine fossils occur.

These, in so far as they admit of specific determination, represent shells found in the later Tertiary deposits of California, some of which are still living on the northwest coast; and the assemblage is not such as to indicate any marked difference of climate from that now obtaining. * * * The Tertiary rocks of the coast are not anywhere much disturbed or altered. The relative level of sea and land must have been nearly as at present when they were formed, and it is probable that they were originally spread much more widely, the preservation of such an area as that of Graham Island being due to the protective capping of volcanic rocks. The beds belong evidently to the more recent Tertiary, and though the paleontological evidence is scanty, it appears probable from this and by comparison with the other parts of the west coast that they should be called Miocene.[2]

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[1] Descriptive sketch of the Physical Geography and Geology of the Dominion of Canada, by A. R. C. Selwyn, director, and G. M. Dawson, Dr. Sci., associate. Montreal, Dawson Bros., 1884. 55 pp., 8°, and large map in two sheets geologically colored. See Part II, by Dr. G. M. Dawson, pp. 52–55.

[2] Dawson, op. cit., 1884, p. 53.

Tertiary rocks also occupy a considerable area about the mouth of the Fraser River, extending northward from the 49th parallel, forming the boundary to Burrard Inlet, where thin layers of lignite occur, but in seams too thin to have much value. Fossil plants from Burrard Inlet are described[1] by Newberry and Lesquereux in connection with those from Bellingham Bay, Washington, and are supposed to indicate a Miocene age for the beds.

NEOCENE OF THE REGION EAST FROM THE COAST RANGES.

East from the Coast ranges Tertiary rocks, according to Dawson,[2] are very extensively developed. They have not, however, yielded any marine fossils and

They appear to have been formed in an extensive lake or series of lakes which may at one time have submerged nearly the entire area of the region known as the interior plateau. The Tertiary lake or lakes may not improbably have been produced by the interruption of the drainage of the region by a renewed elevation of the coast mountains proceeding in advance of the power of the rivers of the period to lower their beds; the movement culminating in a profound disturbance leading to a very extensive volcanic action. The lower beds are sandstones, clays, and shales generally pale grayish or yellowish in color, except when darkened by carbonaceous matter. They frequently hold lignite, coal, and in some even true bituminous coal occurs. These sedimentary beds rest generally on a very irregular surface, and consequently vary much in thickness and character in different parts of the extensive area over which they occur. The lignites appear in some places to rest on true "underclays," representing the soil on which the vegetation producing them has grown, while in others, as at Quesnel, they seem to be composed of driftwood, and show much clay and sand interlaminated with the coaly matter.

In the northern portion of the interior the upper volcanic part of the Tertiary covers great areas, and is usually in beds nearly horizontal, or at least not extensively or sharply folded. Basalts, dolerites, and allied rocks of modern aspect occur in sheets, broken only here and there by valleys of denudation; and acidic rocks are seldom met with except in the immediate vicinity of the ancient volcanic vents. On the lower Nechacco, and on the Parsnip River, the lower sedimemtary rocks appear to be somewhat extensively developed without the overlying volcanic materials. The southern part of the interior plateau is more irregular and mountainous. The Tertiary rocks here cover less extensive areas, and are much more disturbed, and sometimes over wide districts, as on the Nicola, are found dipping at an average angle of about 30 degrees. The volcanic materials are occasionally of great thickness, and the little disturbed basalts of the north are, for the most part, replaced by agglomerates and tufas, with trachytes, porphyrites, and other feldspathic rocks. It may, indeed, be questioned whether the character of these rocks does not indicate that they are of

[1] Geol. Survey Dom. Canada, Rep. of Progress, 1876–'77, p. 190.

[2] These beds are obviously to be referred to the Kenai group, since they contain essentially the same flora. *Limnæa*, *Physa*, and *Sphærium* have also been noticed at Vermilion Cliff. Localities for the occurrence of plant beds and lignites of the Kenai group in the southern part of British Columbia may be mentioned as follows: The vicinity of Okanagan Lake; the Coal Brook Indian reserve on the north Thompson River (p. 113); Kamloops Lake (p. 114); Vermilion Cliff 3 miles up the north fork of the Similkameen River (p. 130), and also the south fork (p. 132); on Ninemile Creek and Hat Creek (p. 121); 20 miles north of Osoyoos Lake, where 3,000 feet of sandstones and shales have been observed (p. 129); on Tenmile Creek coal is noted (p. 126), and also near the junction of Nicola and Coldwater rivers (p. 122); on the Fraser near Lillooet, and on the upper part of Kettle River (p. 160). Dawson also notes the complete absence of marine Eocene beds (p. 167).

See Dominion Geological Survey, Report of Progress for 1877–1878, Montreal, Canada, 1879; pp. 1–188B, by Geo. M. Dawson (to which above page references refer), including a list of Tertiary plants from various British Columbian localities, by J. W. Dawson, LL. D., op cit. pp. 186–188B.

earlier date than those to the north, but, as no direct paleontological evidence of this has been obtained, it is presumed that their different composition and appearance is due to unlike conditions of deposition and greater subsequent disturbance.

No volcanic rocks or lava flows of post-Glacial age have (1884) been met with, though I believe that still farther to the northwest the rocks are of yet more recent origin than any of these here described, and I have even heard a tradition of the Indians of the Nasse River which relates that at some time very remote in their history an eruption covering a wide tract of country with lavas was witnessed.

The organic remains so far obtained from these Tertiary rocks of the interior consist of plants, insects, and a few fresh-water mollusks and fish-scales, the last being the only indication of the vertebrate fauna of the period. The plants have been collected at a number of localities. They have been subjected to a preliminary examination by Principal Dawson and several lists of species published. While they are certainly Tertiary and represent a temperate flora like that elsewhere attributed to the Miocene, they do not afford a very definite criterion of age, being derived from places which must have differed much in their physical surroundings at the time of the deposition of the beds.

Insect remains have been obtained in four localities. They have been examined by Mr. S. H. Scudder, who has contributed three papers on them in the Geological Reports, in which he describes forty species, all of which are considered new. None of the insects have been found to occur in more than a single locality, which causes Mr. Scudder to observe that the deposits from which they came may either differ considerably in age, or, with the fact that duplicates have seldom been found even in the same locality, evidence the existence of different surroundings and an exceedingly rich insect fauna.

Though the interior plateau may at one time have been pretty uniformly covered with Tertiary rocks, it is evident that some regions have never been overspread by them, while, owing to denudation, they have since been almost altogether removed from other districts, and the modern river valleys often cut completely through them to the older rocks. The outlines of the Tertiary areas are, therefore, now irregular and complicated.[1]

ALASKA.

As might be expected, the geology of this territory is most imperfectly known,[2] but the little which has been recorded leads to the inference that to a great extent the operations of mountain-building forces and the deposition of sediments along the coast of Alaska, south of and including the peninsula, were carried on in a similar and probably generally synchronous manner from Mexico to Bering Sea.

So far we have not been able to find any record of the discovery of marine fossils belonging to the Eocene in Alaska, though of the Miocene marine and leaf-bearing beds with lignitic coal, etc., there are abundant instances.

GENERAL NOTES ON THE ROCKS.

In general, along the southeastern coast of Alaska, the sequence of the rocks where undisturbed appears to be about as follows in descending order:

1. Soil and Pleistocene beds.

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[1] For additional information on the Tertiary rocks of the interior see Reports of Progress, Dominion Geol. Survey for 1871–'72, p. 56; for 1875–'76, pp. 70 and 225; for 1876–'77, pp. 75 and 112B; Dawson, op. cit., pp. 53–55.

[2] Geological notes in this section, except where otherwise stated, are from the unpublished observations of W. H. Dall.

2. Brown Miocene sandstones with marine shells, cetacean bones and water-worn Teredo-bored fossil wood (Astoria group, Nulato sandstones, Crepidula bed).

3. Beds of conglomerate, brown and iron-stained, alternating with gravelly and sandy layers, the finer beds containing fossil leaves of *Sequoia* and other vegetable remains (Kenai group, Unga beds).

4. Bluish sandy slates and shales with a rich Miocene plant flora, interstratified with beds of indurated gravel, fossil wood, and lignitic coal (Kenai group).

5. Metamorphic quartzites and slaty rocks, illustrating the geological series probably from the Jurassic to the upper Cretaceous, with perhaps part of the lower Eocene (Chico-Tejon).

6. Granite and syenite in massive beds, usually without mica and apparently in most instances forming the "backbone" of the mountain ridges or islands, but occasionally occurring as intrusive masses, which have thrust up the metamorphic rocks above them into arches, cracking them and filling the fissures with the syenitic material (Shumagin granite).

Intrusive granites.—Through all the Tertiary beds in various parts of the territory are found penetrating volcanic dikes and larger outflows, sometimes injected between sedimentary strata and sometimes overflowing them, much as in California, Oregon, and elsewhere in western America. The later eruptions, mostly Pliocene and Pleistocene, are generally of a basaltic character.[1]

The occurrence of intrusive syenite later than the metamorphic rocks and penetrating fissures in them is well exhibited at an arch of metamorphic rock near the beach at Granite Point, on the south side of the entrance to Sanborn harbor, Nagai Island, in the Shumagin group, where it was noted by the writer while surveying the harbor in 1872. Instances of the occurrence of the syenite as a massive body forming the fundamental rock are offered in many places, as the Diomedes Islands, Bering Strait, and most of the mountain masses of the Siberian side of the same strait; the central ridge of the island of Unalaska; the islands and hills of the eastern Shumagins, as Little Koniushi Island, and of Port Althorp, Cross Sound, in the Alexander Archipelago.

The age of the intrusive granites is yet undetermined, but in the case of the mass forming the celebrated Treadwell mine of Douglas Island, near Juneau, Alaska, which is of this character, Dr. Dawson refers the slaty rocks through which it has broken to the Vancouver series of Triassic rocks,[2] and the Shumagin quartzites may belong to the same group. At all events it is hardly likely to be Tertiary, and in this connection need not be considered further.

Early observations on Alaskan geology.—The Neozoic strata of southern Alaska were first noticed by Portlock and Dixon who, on their

[1] See Dall, Note on Alaska Tertiary Deposits, Am. Jour. Sci., 3d ser., July, 1882, vol. 24, pp. 67, 68.

[2] Notes on the ore deposit of the Treadwell mine, Alaska, Am. Geologist, August, 1889, pp. 84–93.

voyage to the northwest coast of America in 1785, entered English Bay or Port Graham, Cooks Inlet, and named it Coal Bay, from the lignitic beds exposed in its shores. In the following year the marine Miocene was observed by the naturalists of La Perouse's party, who collected in Lituya Bay at the height of 200 toises above the sea specimens of one of the large Miocene pectens.[1] The first general summary of existing knowledge of geology and geognosy of this region is comprised in the work of Grewingk,[2] who enumerates the localities for the Tertiary rocks among others and illustrates and enumerates many of the fossils. The paleobotany of the region was subsequently treated of by Göppert[3] and Heer.[4] Later, Eichwald[5] reviewed the subject and introduced a certain amount of confusion into the paleontological side of the question by referring to the Cretaceous (Turonian) all the marine Tertiary fossils described by Grewingk, many of which belonged to Miocene beds, but which Eichwald appears to have regarded as of the same age as the Tejon beds of California, which, following Gabb, in the Paleontology of California, he referred with the Chico to the Mesozoic epoch.

MIOCENE OF THE KENAI GROUP.

The coal-bearing Miocene beds best exhibited on the shores of Kachekmak Bay, Kenai Peninsula, Cooks Inlet, but widely spread in British Columbia and over the coast of Alaska and its adjacent islands, are regarded by Heer as the equivalent of the Atane leaf beds of Greenland, the Spitzbergen Miocene plant beds, the Braunkohl of east Prussia and the lower Rhine provinces, and the lower Molasse of Switzerland.

The Unga conglomerate.—On the island of Unga, Shumagin group, Alaska, they are conformably overlain by the brown conglomerates with *Sequoia* which are obviously younger and the result of a somewhat different series of conditions; though the sedimentation appears to have been measurably continuous. To these last I would give the name of the *Unga conglomerate;* but since in the present imperfect state of our knowledge we are unable to specify the exact horizon of most of the leaf beds reported by various observers, the whole series will be treated here under one head. The coal beds of southern Alaska and of the Yukon Valley, so far as identified, all belong to the interbedded lignites of the Kenai series, yet it is quite probable that some older beds are included in the list. In the case of the coal of Kake Strait, Admi-

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[1] Cf. voy. La Perouse, vol. 1, p. 395.

[2] Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der nordwest Küste Amerikas; Verh. Min. Ges. zu St. Petersburg für 1848-'49, 351 pp., 8°. Separately issued by Karl Kray, St. Petersburg, 1850.

[3] Abh. Schles. Ges. für Vaterl. Kultur., 1861, 2, p. 201, and 1867, p. 50.

[4] Flora fossilis Alaskana, Kongl. Svenska Vetensk. Akad. Handl. Bd. 8, No. 4, Stockholm, 1869, 4, pp. 41, 10 pl.

[5] Geogn. Pal. Bemerkungen über die Halbinsel Mangischlak und die Aleutischen Inseln, St. Petersburg, Kais. Akad. Wiss., 1871, 8°, pp. 200, pl. xx; cf. pp. 88-137.

ralty island, there appear, according to Newberry[1] to be several species identical with those of Kenai.

The most southern points which have been noted by us for the occurrences of these sandstones depend for their location on the reports of prospectors and on specimens observed in the mineralogical collection of the Russian-American Company at Sitka in 1865, a duplicate of which is included in the Imperial Zoological Museum of St. Petersburg. The Sitka collection was scattered in 1868.

Localities noted are as follows: The eastern arm of Whale Bay, Baranoff Island, the west shore of Kuiu Island in about the same latitude, the northern shore of the Lindenberg Peninsula, Kupreanoff Island, the mainland opposite the last mentioned locality, St. Johns Bay, on Baranoff Island north of Sitka, the southeastern extreme of Chichagoff Island on Chatham Strait, Kake Strait, Admiralty Island, and the shores of the northern part of Seymour Canal, Admiralty Island. These comprise the localities in the Alexander Archipelago. The Russian governor, Furuhjelm, upon whose collection in the main Heer's descriptions are based, visited a locality near Sitka, perhaps the one above mentioned at St. Johns Bay,[2] one on Kake Strait, and a third on Kuin Island. Of the latter a description and section are given from Furuhjelm's notes by Heer.

Beds of Kuiu Island.—The outcrop is between tide marks and consists of a sandstone with remains of a Hazel (*Corylus McQuarrii*), dipping inland about 25° or 30°, which contain thin layers of blackish gray shale in pairs, inclosing in each pair a layer, varying from 6 inches to 7½ feet in thickness, of brown coal or lignite. The shale contains plants, especially conifers. Above these and rising above high-water mark is a coarse grained sandstone overlain by a coarse conglomerate covered by about 15 feet of humus and turf. The whole section includes a belt of somewhat more than 200 feet wide, on the eroded surface of which are strewn numerous erratic blocks of granite. The section has a good deal of resemblance to that exposed at Coal Bay, Unga Island, at least in the succession of the plant beds, coal and conglomerate.

The shales from this locality afforded *Sequoia langsdorfii*, and species of *Glyptostrobus*, *Pteris*, and *Castanea*. The coal contained 16 per cent of water, about 3 per cent of ash, about 35 per cent of volatile, and 45 per cent of fixed carbonaceous matter, according to Genth.[3] The occurrence of lignite near Sitka is also noted by Erman[4] without precise identification of locality.

Beds of Lituya Bay.—North of the Alexander Archipelago, Cenozoic

[1] Brief descriptions of fossil plants, chiefly Tertiary, from western North America, by Dr. J. S. Newberry, Proc. U. S. Nat. Mus. vol. 5, pp. 502–514; February, 1883. The author describes five species from Cooks Inlet, two from Admiralty Island, Seymour Canal and one from Kake Strait, near Kootznahoo, Alaska.

[2] See report on the Geology of Alaska, House Ex. Doc. 177, Fortieth Congress, second session, February, 1868, pp. 314–325, by Theodore A. Blake.

[3] K. K. Geol. Reichsanstalt, Wien, 1868, p. 397; Heer, op. cit., p. 4.

[4] Reise um die Erde, 3, p. 213.

strata are first reported from Lituya Bay, where they were observed, and a fossil *Pecten* collected at a height of 200 toises by the naturalists of La Perouse's party. In May, 1874, while making a reconnaissance of the bay, W. H. Dall landed on Cenotaph Island, which appeared to be chiefly composed of the ordinary marine Miocene sandstones, rather soft, but not at this point fossiliferous. This island lies directly in the trough of this extraordinary bay, and is remarkable in that it shows no evidences either by erosion or in the presence of erratics, of having been glaciated, which, if the bay had ever been filled with ice, must have happened. It would seem as if only a very small amount of erosion would have been sufficient to remove the whole of the relatively soft material of which this small and rather high islet is composed. The mass of the material on the beaches and brought down by the ice from the numerous enormous glaciers which discharge into the bay, appears to be schistose, or syenitic, the comparatively narrow strip of relatively lowland and foot hills, in front of the main range parallel with the coast, probably containing all the Cenozoic beds remaining there. On the main shores of Lituya Bay the basal rocks appeared to be massive syenite or granite overlain by stratified mica slates above which was clay slate with very obscure traces of fossils, and lastly coarse sandstone and conglomerate probably of Miocene age, but from which no fossils were collected. The stratified rocks seem conformable with one another and dip to the northwest at angles of from 15° to 75°. Their surfaces showed no traces of glaciation, though these, if ever present, might have been weathered away.

Port Graham lignite beds.—Passing over temporarily the newer formations observed in the vicinity of Yakutat Bay by Israel C. Russell (1890) and at Middleton Island by Dall (1874), the next locality in geographical order where the Miocene plant beds have been explored, is on the eastern shore of Cook's Inlet, forming the western border of the Kenai Peninsula. Here at Port Graham or English Bay, first visited by Portlock and Dixon in 1785, lignitic beds have long been known to exist, and for a time the coal was mined by the Russian American Company for use in their steamers. The beds at this locality are on the north side of the harbor, just within the entrance. Here Furuhjelm collected a large number of plant remains which formed the chief basis of Heer's[1] report.[1] These beds lie unconformably in depressions in felsitic rock and greenstone, nearly horizontally as follows:

1. Humus and turf.
2. Sandstone with pebbles.
3. Bluish sandy clay with pebbles.
4. Plastic clay.
5. Gray, fine grained sandstone, 5 to 7 inches thick.
6. Lignite, 9 to 11 feet thick.
7. Laminated clay shale, partly bituminous.
8. Light gray, rather soft limestone, with few plants.

[1] Flora fossilis Alaskana, cf. ante.

9. Laminated clay.
10. Hard limestone, with many plant impressions.
11. Brecciated porphyry and greenstone in limy matrix.
12. Felsite and greenstone base.

The coal is black and brilliant, with conchoidal fracture, resembling that of Disco in Greenland. It contains occasional grains of honey-yellow amber rarely more than a centimeter in diameter.

The plants are all terrestrial or fresh-water species. One of the most common is a species of *Trapa* represented by many of its fruit. With them were found *Unio* (*Margaritana*) *onariotis* Mayer, a species probably related to *Margaritana margaritifera* L.; *Ammicola abavia* Mayer; and *Melania* (*Goniobasis?*) *furuhjelmi* Mayer, together with elytra of a beetle described by Heer under the name of *Chrysomelites alaskanus*. Among the plants are both coniferæ and broad-leaved trees, the total number of species amounting to forty-four. The deposit appears to have been formed at the bottom of a lake. The leaf-bearing strata crop out below the level of the sea and are accessible only at extreme low water. They dip slightly to the northward.

Kachekmak Bay lignites.—Northward from Port Graham is the entrance to a large inlet, Kachekmak Bay, on the southern side of which four glaciers extend nearly to the sea level. The rocks on this side of the inlet, as observed by Dall in 1880, are schistose or crystalline, but the northern shore is of a different character. It is formed by the bold edge of a plateau which, in latitude 59° 42′, rises to about 1,800 feet at a distance of 2 miles from the shore. At the shore near Coal Point (a low, sandy spit behind which an anchorage may be had), the bluffs rise abruptly about 200 feet. The line of bluffs extends north and east for some 30 miles and the Miocene plant beds crop out at many points. In some places the bluffs come down to the beach; in others there is a small talus between them and the water which is extremely shallow for some distance out. The lignite beds dip slightly to the northward and are intercalated between sandstones and shales with fossil plants remains, and conglomerates or coarser sandstones above. The largest seam of coal which was observed near Coal Point was about 7 feet thick, with a few thin streaks of shale in it. It is bright, clean to handle, light, and tends to break up in cubical fragments when dried. It resembles anthracite in appearance, but not in weight. Farther up the bay better outcrops were reported, and the coal was pronounced good by the engineers of Sir Thomas Hesketh's yacht, *Lancashire Witch*, who used it for steaming purposes in 1880, and also found it to burn well in an open grate in the cabin.

From this locality most of the plants described from Port Graham by Heer were identified from Dall's collection by Lesquereux[1] and also nine others, making fifty-three species.

[1] Contributions to the Miocene Flora of Alaska, by Leo Lesquereux. Proc. U. S. Nat. Mus., 1882, vol. 5, pp. 443–449, pl. vi–x.

Other Kenai beds.—If the indications of Wossnessenski (in Grewingk) are correct there would seem to be a succession of about four gentle folds from Port Graham to Cape Kassiloff, a distance in a northerly direction of some 35 miles. The plateau previously referred to, representing the western flank of the Kenai Peninsula, is thus composed chiefly of the marine sandstones, shales, and conglomerates, which make up the Kenai group. The lignite beds crop out at many places along the western shore of this area. At Anchor Cape (Kasnatchin) the northern head of Kachekmak (or, as it is sometimes called, Chugachik) Bay the coal is under water, but rises northward with the flexure of the strata. At Anchor Cape Furuhjelm obtained fossil teredo-bored bituminous wood. At Cape Nenilchik, near a small native settlement, the lignite beds are about 35 feet above the sea, and at one place burned for many years. From this locality also many fossil plants have been obtained. The leaves occur in a soft, pale gray clay slate, which can be cut with the knife, but which, where burned, becomes hard and red. Still farther north on the same shore, at Fort Kenai, Capt. Howard, of the revenue marine, obtained several fossil plants which have been described by Newberry.[1] Five of these were new, which raises the number of species actually obtained on the Kenai Peninsula to fifty-eight.

At Cape Staritchkoff two parallel beds of coal are visible for a long distance. The lower one is about 112 feet above the beach and is separated by 9 to 12 feet of sand and clay from the upper coal bed, above which the bluff rises 40 to 70 feet higher. At Cape Nenilchik the upper bed covers about 18 feet of fine yellow sand and is separated from the lower bed by about 20 feet of sand and clay. At this locality an *Anodon* (*A. athlios* Mayer) was found in making Furuhjelm's collection.

Deferring for the present any discussion in regard to their geological age, the other localities for the occurrence of this flora may be referred to. The Kenai beds, from the number of their contained species and their excellent illustration by Heer, will always be regarded as typical for the group.

Beds of Alaska Peninsula and Kadiak Island.—Along the shores of Alaska Peninsula, west and south from Cook's Inlet, lignite beds, doubtless associated with plant impressions, are not uncommon, but the exploration of this shore has been very imperfect. On the main shore behind Takli Island (north latitude 58° 05′) is a good anchorage according to the Russians, and here they report "good coal and plenty of it," which would indicate the existence of the lignitic beds at this place.

On the island of Kadiak marine Miocene strata are found, and among the specimens brought back by Wossnessenski were clay ironstones containing plant remains referable to the Kenai group. These stones were used by the native women for reddening the inner surface of dressed skins, and the only indication of locality for them is that they came from the northern part of the island. About the middle of the island,

[1] Proc. U. S. Nat. Mus. vol. 5, pp. 502–514, 1882.

surrounding Ugak Bay, at the old settlement of Orlovsk, and on the northern shore of Miliuda Bay next southward, and on the opposite side of the island, part of the shores of Uganuk Bay and of Uganuk Island in the bay, sandstones with lignite in thin seams, overlain in places by marine sandstones like those of Unga, are reported on the authority of Kharitonoff and other Russians familiar with the island.

On the south shore of the peninsula, in west longitude 157° 10′, is a small bay called Yantarnie, near which, in the lignite-bearing beds, amber was found and traded by the natives of the peninsula with the Kadiak Eskimo. It may not be inappropriate to state here that in times preceding the Russian conquest amber was regarded of great value by the natives of this region, a very small bead of this substance being worth in native estimation forty or fifty sea-otter skins, equivalent at present values to some $10,000 of our money. Consequently the localities where it might be found were places of great interest to the aborigines, and the traditions still current are often useful in identifying the presence of beds of this age. A few of these beads are still extant. The largest known is in the possession of W. H. Dall. It was obtained from a grave on the island of Kadiak, traditionally regarded as that of a celebrated prehistoric chief of the tribe. It is about 2 inches long, ovate, roughly three-sided, and an inch in diameter. It has been bored for the passage of a suspensory thread, but otherwise is apparently in its original state. It is clear and of a rich wine color, resembling Levantine amber. The surface, though slightly irregular, is polished. Small grains of the same color, but too small for use as ornaments, are not rare in the lignite beds of this region.

On the south side of Chignik Bay, a little to the westward of the southwestern headland, is a small anchorage surveyed by Dall in 1874, situated in about latitude 56° 20′ and west longitude 158° 24′. Here an outcrop of sandstone belonging to the Kenai group was observed, from which a number of fossil plants were collected. The bluffs here are about 500 feet high, consisting of a series of sandstone, slates, and conglomerates, with thin leaves of lignite, the whole nearly horizontal and extending several miles to Tuliumnit Point. From the specimens obtained six species of plants were identified by Lesquereux.[1]

A short distance southwestward (west longitude 159°) the leaf and lignite beds crop out again on the south shore of the peninsula at Coal Cape. Southwest of this cape lies the small group of Chiachi Islands, surveyed by Dall in 1874. Here the bedrock is syenite unconformably overlain in places by sandstones and conglomerates, the latter sometimes of water-worn material and sometimes of sharp gravel, with vegetable remains. The sandstones are often altered by outbreaks of reddish lava in large masses, and all the rocks at this locality appear much contorted and metamorphosed.

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[1] Proc. U. S. Nat. Mus., 1882, vol. 5, pp. 443-449.

Still farther west (west longitude 160° 35′) the south coast of the peninsula is indented by Portage Bay, at the head of which a large stream comes in and a low divide affords a portage to Herendeen Bay, a branch of Port Möller, which indents the shore of the peninsula from Bering Sea on the north. West of Portage Bay other inlets enter from the south in the following order, namely, Beaver and Otter bays, Coal Bay, and Pavloff Bay, the latter connected by a very low divide with the head of Herendeen Bay, and thus indirectly with Port Möller. The vicinity in which these bays are found is of extreme geologic interest. From Port Möller several active volcanoes are in view, among the rugged flanks of which may be seen a number of glaciers. Hot springs flow into the bay from a small peninsula, on which are extensive shell heaps indicating prehistoric occupation of the locality by a population of some magnitude. Near the head of the bay Mesozoic fossiliferous strata come down to the beach. On the east are Tertiary sandstones belonging probably to the Kenai group. Fragments of lignite and bituminous shale are not rare on the beach. At the head of Portage Bay, a few miles away, lignite beds are reported by Veniaminoff, and, as the name indicates, they also exist at Coal Bay.[1] On the portage between Pavloff Bay and Herendeen Bay extensive beds of coal (one report says 4 feet of clear coal) are reported, and offer such advantages that a corporation in San Francisco is actually building the first railway in Alaska to transport the product of the mine they have opened to the nearest point where vessels can receive it. These beds are said to be cut by volcanic dikes in such a way as to form out of the lignite a natural coke, which promises to have commercial importance. The Pavloff volcano is a high peak emitting smoke and occasional flames, and is situated on the west side of the bay. From the vicinity of the mountain Wossnessenski obtained "good stone coal" according to Grewingk (op. cit., p. 57), and this is also one of the localities reported to afford amber. When visited in 1874 by the Coast Survey parties, the shores of Port Möller were inhabited by large numbers of brown bear and reindeer, the rivers were alive with salmon, and hundreds of walrus sunned themselves on the sand bars near the sea. It will be seen that for the naturalist and geologist it would be hard to find a place combining more interesting features.

Unga and Popoff Island beds.—South of Portage Bay, across Unga Strait, lies the island of Unga, the principal island of the large Shumagin group, which extends some 50 miles to the south and east, and is noted for its cod and sea-otter fisheries. The eastern islands are granitic; those in the middle of the group largely composed of metamorphic quartzites and schistose rocks. On the island of Unga and the adjacent Popoff Island, Tertiary beds are well exposed.

The principal exposure of the plant beds on the island of Unga is on the western shore of Zacharoff, Zakhareffskaia, or Coal Bay, which indents the northern end of the island for about 3 miles. This locality

[1] See U. S. Coast Survey Chart, No. 806, by W. H. Dall, 1882.

was visited by Dall in 1865 and also in 1871, 1872, and 1873. The earlier observations of Wossnessenski and others are enumerated by Grewingk (op. cit., p. 97), but his details are very incomplete.

The following section was obtained by Dall in 1872. The total height of the cliff is between 500 and 600 feet; two-thirds of it is precipitous, the rest more sloping; the crest is perhaps a third of a mile westward from the water's edge. The strata are somewhat waved in a north and south direction, and dip to the westward from 5° to 20°:

	Feet.
1. Turf and soil	} 200
2. Conglomerate of fine pebbles	
3. Conglomerate of larger bowlders	
4. Sandstone with marine fossils (1 foot)	
5. Thin friable sandy shales (6 inches)	
6. Conglomerate like No. 2	
7. Very coarse conglomerate (2 feet)	
8. Sandy shale with indistinct plant remains	$\frac{1}{8}$
9. Thin leaves of lignite aggregated into three series of 3 feet each, interstratified with beds of sand and gravel of variable thickness, with some pyrites and peroxide of iron, total about	40
10. Soft sandstone and gravel without large pebbles and little indurated	150
11. Another series similar to No. 9, but with none of the coal more than 8 inches in thickness, very pyritiferous	200
12. Clay ironstones with leaf impressions to the beach	4

Below ordinary low water another seam of coal is said to exist. The best veins of coal in the cliff are about a foot thick, hard, clear, and black except where weathered. It slacks up on exposure into small cubical fragments. There are three of these foot veins, separated by about 10 feet of sand and gravel. Over the middle vein is very friable blue shale, about 4 feet thick. Over the upper vein is a 4-inch layer of sandy shale containing many plant impressions, from which the collection submitted to Lesquereux was chiefly derived.

The coarser conglomerate (Nos. 3 and 7) contains some iron and weathers black on the face of the cliff. In a section published in a prospectus of a coal-mining company these black bands, which can be seen miles away on the face of the cliff, were indicated as coal veins; as in fact a distant observer would take them to be until otherwise informed.

The species of plants collected at this locality were examined by Lesquereux, and proved to be identical with those from Cooks Inlet; eight species were identified.

In the conglomerate (Nos. 6 and 7) many pieces of rolled silicified wood were found, some of which were bored by *Teredo*. These beds are evidently a beach formation, presaging the depression which followed in which the marine bed above them was laid down. I have called them the Unga conglomerates, and the marine stratum, which will be referred to later, from the great abundance of *Crepidula prœrupta* Conrad, I have called the Crepidula bed. It conformably overlies the others and there can be no doubt of the continuity of the sedimentation through the whole series of lignitic and marine strata in this locality.

Fossil wood, referred to *Pinus pannonicus*, has been obtained at Delaroff harbor, in the southern part of Unga, and some large pieces, collected on the beaches and forwarded to Dr. Newberry in 1873, were stated to be apparently Cycadaceous. These may have been derived from adjacent Mesozoic strata. According to John Dix, a miner at the coal vein referred to, the mountains inland from the bay consist largely of similar sandstones.

The northeastern extremity of Unga Island and the northwestern part of Popoff Island are composed of sandstones and conglomerates similar to the upper part of the bluff in Zacharoff Bay, but they rise to only about 50 to 75 feet above the sea, and are broken and cut by dikes and larger intrusions of basaltic lava and diorite, and near the contacts much altered and intersected by veins of chalcedonic quartz.

On the western edge of Nagai similar rocks exist above the metamorphic schists and quartzites, but they are greatly altered and contorted and cover but a small area in comparison with underlying beds. It is probable that part of the island of Sannakh is composed of similar strata.

LIGNITIC BEDS OF THE ALEUTIAN ISLANDS.

In the chain of islands extending westward from the peninsula there are many which are more or less volcanic, but the chain is older than the volcanoes and volcanic islands it contains, and many of the islands are composed of sedimentary or metamorphic rocks. The chain doubtless marks a very ancient line of weakness or faulting in the earth's crust; and most of the volcanoes are relatively very modern developments, due to geological changes which have been in progressive operation since early Mesozoic time.

Akun.—Proceeding westward, the first island upon which lignitic beds are reported is Akun, where Postels[1] states he was told that coal exists.

Unalaska.—The northern part of the island of Unalaska is better known than the rest. The principal harbor, Captains Bay, is surrounded with massive beds of clay porphyry and some basaltic lava. But several localities in the interior of the island, according to tradition, afforded amber and consequently should possess lignitic deposits. In the autumn of 1871 Dall endeavored, with a small party and an Aleut guide, to discover one of these so-called amber beds. The expedition reached the main ridge of the island some miles south from Captains Bay, and found the rocks to consist almost exclusively of syenite in mountain masses, overlain in some places by thin beds of clay and sand, apparently the result of decomposition of the syenite itself. The amber lake of Aleut tradition is a small body of water connected with two others. Above the lake rose a precipitous crag of conglomerate, 2,000

[1] Voy. Séniavine, 1836, vol. 3, p. 21.

feet in height by estimation, the horizontal layers very distinctly bedded, graduating toward the top into hard altered sandstone, very black and flinty. No fossils could be found in it, but the weather became so inclement as to render it necessary to return without making an exhaustive search, and these beds may eventually prove to belong to the leaf-bearing series. The Aleuts declare that the disintegrated sandstone in former times afforded occasional bits of amber, which were obtained from the gravel around the edge of the lake.

Another locality for amber, and inferentially for lignitic strata, is reported by Veniaminoff, from statements by the Aleuts, to exist in the western part of the island in the mountains near the head of Makrofski Bay. Here there is said to be a lake containing an island of friable sandstone and unconsolidated gravel, out of which the Aleuts formerly obtained small pieces of amber.

Marine Miocene beds exist on Makushin Bay, near the north-northwest base of the volcano of the same name, but no leaf beds are reported at this place. On the eastern shore of Port Levasheff Wossnessenski obtained small fragments of lignite, which he supposed to have been brought down by streams from lignite beds in the interior of the island, the adjacent rocks being clay porphyry.

Slate Point, 2½ miles eastward from the entrance to Chernoffski Harbor, is composed of a black stratified material, perhaps belonging to this series, but which has not been closely scrutinized.

Umnak.—On the northwestern end of the island of Umnak, the next westward in the chain, near Tulikskoi Volcano, is a lake overhung by a cliff of unconsolidated beds. The Aleuts were in the habit of stretching a seal hide between two kayaks and dislodging this earthy material, which would fall upon the hide, and was carefully washed for amber. Near Cape Yegorkoffski, Eschscholtz and Chamisso collected fossil dicotyledonous wood from the bed of a lake which had been drained by changes due to an earthquake.

Atka.—Westward from Umnak many of the smaller islands are volcanic, and but little is known of any of them until the island of Atka is reached (174° west longitude). On the western side of the north part of this island it is indented by Korovinski Bay, from which several small arms extend southward and northward. The north shores are composed chiefly of nearly horizontal layers of volcanic breccia dipping slightly to the northeast and rising to 1,000 feet, interstratified with beds of ashes, cinders, and solfataric clays, in some of which marine Miocene fossil shells occur. On the south shore, especially on the east shore of Sandy Bay, are found pieces of fossil wood of a gray color, which burn slowly, and other pieces which are silicified. They appear to lie under the soil, between the latter and a conglomerate resembling that of Unga, chiefly composed of rounded porphyritic pebbles, capped on the eastern portion with partly columnar basalt.

Nazan Bay, on the east side of the island, opposite Korovinski Bay, and separated from it by a low isthmus, exhibits highly altered beds of conglomerate and volcanic breccia, nearly horizontal and dipping slightly to the northwest. A more compact, flinty, greenish metamorphic rock, with a similar dip but more contorted and much intersected by dikes of basalt, is the material of which the south shore and the islets protecting the anchorage are composed.

Adakh.—On the west side of the island of Adakh is a harbor called the Bay of Islands, the northern shores of which are composed of coarse sandstones like those of the Kenai group, dipping in general to the northeast. They are greatly altered by basaltic and frothy lavas, which have burned the sandstones overlaid by them to a red color. No fossils were found in them when examined by Dall in 1873.

Amchitka.—The island of Amchitka is notably low and level compared with most of the Aleutians. At Constantine Harbor, on the northeastern shore, the rocks forming its eastern coast are crystalline and probably volcanic. The west side of the harbor appears to be composed of low bluffs, not exceeding 60 feet high, of a much-altered conglomerate. Westward about a mile is Kiriloff Bay, a small, rocky indentation, formerly the site of a village (1849), but now deserted. Here the conglomerate and sandstones are less altered, and specimens of lignite and fossil wood were collected by Wossnessenski. Still farther west small veins of lignitic coal with plant remains are reported by Shayeshnikoff.

Kiska.—The island of Kiska has a fine harbor (west longitude 182° 30′), which is protected on the east by the island of Little Kiska. The shore belonging to the main island borders on the water in many places as steep bluffs to 200 feet high, composed of a coarse conglomerate, of which the upper layers merge into a breccia of volcanic material but obviously arranged in water. These are broken through by eruptive clay porphyries of a greenish color, rising to 150 feet, and capped over all by a basaltic or coarsely crystalline syenitic rock, in some places 300 feet thick. On the bluff of Little Kiska, facing the harbor, the porphyrite appears toward the southwest unconformably over them, and dipping northward are sandstones resembling those of the Kenai series, but in which, in 1873, Dall found no fossils. Covering those, and extending to the northwest point of Little Kiska, is a magnificent cliff of the crystalline eruptive rock before referred to, which here forms enormous prisms, five-sided, from a foot to 20 inches in diameter, standing vertically in the cliff-like organ pipes, and sometimes continuous as a single prism to the length of more than 50 feet.

Attu.—The westernmost of the Aleutian chain is the island of Attu, which is destitute of modern volcanic rocks. The harbor of Chicagoff, at the northeastern end of the island, is surrounded chiefly by metamorphic slates and quartzites, diorite, serpentine, and clay porphyry, probably Mesozoic, and much contorted. It was reported by the natives that fossil wood was occasionally found on the beaches toward the western part of the island, but no Tertiary rocks or sandstones were observed by Dall's party.

Nunivak Island.—Northward from the Alaskan Peninsula little is known of the geology until the island of Nunivak is reached. At the northeastern extreme of this island is an anchorage surveyed by Dall in 1874. Here the shores, though abrupt, are low, and composed of much-altered sandstones, nearly horizontal and more or less overlain by recent basaltic lavas. In the interior small volcanic cones, or hills resembling volcanic cones, were observed and supposed to be the source of these lavas. From their appearance and relation to the lavas it is probable that these sandstones belong to the Kenai group.

In the Yukon valley, and thence to the shores of Norton Sound, a large area is occupied by lignite and leaf-bearing sandstones of the Kenai group, a smaller portion of which are overlaid by the Nulato marine sandstones analogous to the Crepidula bed of Unga in age, but containing a different series of fossil shells.

On the seacoast between Unalaklik and Tolstoi Point these strata are exposed, much contorted, and dipping generally at high angles. At Tolstoi Point they are met by the later basalts which southward form the shores of the sound, St. Michael and Stephens islands, and adjacent islets. In October, 1867, these exposures were examined by Dall, from whose notes and sections made at the time the following description is condensed.

Southward from the mouth of the Unalaklik River, along the seashore for 6 miles, stretches a low, level plain of sand, soil, and turf, horizontal and from 5 to 20 feet thick. Then the alluvial layer rises, and below it is visible bluish or yellowish clay, soft, but distinctly bedded and dipping north by east 28° to 45°. It is 30 to 40 feet thick, covered by about 3 feet of soil. The lower layers of the clay contain fragments of silicified wood and lignite, sometimes preserving the original form of the trunk, but commonly broken. This continues a quarter of a mile to a small creek (No. 1), on the farther side of which appear beds of indurated sandstone, overlain by the clay and soil and underlain by a blackish shale, the succession being as follows:

	Feet.
1. Soil and clay, the latter sometimes absent	3
2. Greenish sandstone, dipping north 35°–40°	25
3. Blackish sandstone, dipping north 35°–40°	20
4. Shale, dipping 30° easterly	10

This series continues about 3 miles to Creek No. 2, along the shore, but the shale only comes up so as to be exposed for about 200 yards.

From Creek No. 2, along the shore, we find for half a mile blackish sandstone, with seams of shale 20 feet thick dipping southeast 80°, covered with clay and soil. This is succeeded by a gray sandstone 30 to 40 feet thick, with a northeast dip of 45° for nearly a mile, followed by

200 yards of the black sandstone, 40 feet thick, dipping southeast 65°. Then a turreted bluff of gray sandstone, vertical, 50 feet high, with seams of quartz and layers of shale and fragments of carbonized vegetable matter. Under this the black sandstone shows again on a level with the beach, both dipping northwest 85° for half a mile. The clay and two kinds of sandstone continue to crop out, with occasional layers of dark colored shale and slaty rock dipping from north by east round to southeast 30° to 85°, to Tolstoi Point, the last 2 miles being formed of clear gray sandstone in bluffs 30 to 70 feet high, dipping northwest 70° to 80°, until the lava is reached at the point.

Topanica beds of Norton Sound.—Creek No. 2 is locally known as Topanica, and at its mouth is a camping place where the natives go to catch fish.

Following Topanica Creek easterly into the hills the greenish and blackish sands dip more and more steeply to the east, interleaved with shaly layers containing leaves and vegetable remains, among which leaves of *Platanus nobilis* Newberry, a foot across, were collected in a fine state of preservation.

Farther inland the same rocks become vertical and then dip toward the west, the beds resembling the radiating ribs of a fan. About 2,000 feet of these beds are continuously exposed without faulting, with the same fossils at intervals all the way. These beds extend inland between the sea and the Yukon River, where they appear again.

Ulukak River beds.—Starting from Unalaklik up the river of the same name, a branch called the Ulukak, about 2 miles above the Indian village of Iktigalik, affords a fine exposure of these rocks, as follows, the whole series dipping conformably north-northwest 25° to 55°, the section beginning at the base:

	Feet.
1. Argillaceous unfossiliferous slaty rock, the layers of which become progressively harder downward	220
2. Shale, with some lignite, showing black	2
3. Argillaceous shale, with leaves of *Platanus*	15
4. The same, without fossils	15
5. White sandstone (probably marine)	20
6. Sand and soil to surface	10

This is the only locality on the river between Unalaklik and the village of Ulukak (some 30 miles in a direct line, but 60 by the river) where fossils were observed. The rocks, as on the coast, were more or less folded, and the dip is irregular.

Lower Yukon valley outcrops.—The Yukon valley affords numerous exposures of the same group of sandstone along the right bank of the river. The first locality noted in ascending the river is just below Andreiffski fort, an old Russian trading post. High bluffs of black sandstone come down to the river just above the fort and continue for 10 miles, and just below the fort is the last small exposure, where a seam of bituminous shale about 6 inches thick was observed by Dall in 1868.

This had been worked a little for fuel by the Russians, but abandoned, as the material was too impure to burn well. It dips in a westerly direction. Ascending the river, the sandstones are next observed along a stretch of about a mile near the native village called by the Russians "Starry Kwikhpak." Two miles and a half below Ikogmiut mission the sandstones along a strip of 3 or 4 miles alternate with older metamorphic and later trachytic rocks. Some layers of the sandstones here weather of a whitish color, dipping in a northwest direction with more or less folding and alteration by the action of the eruptives. Similar exposures appear near Koserski village, and at Lofkas which is nearly in the same latitude as Tolstoi Point, Norton Sound (previously described) the sandstones begin to form the main mass of the strata exposed along the river, though the quartzites appear here and there. The sandstones in general dip toward the northwest, at angles varying from 20° to 45°. A short distance below Kaltag a small seam of lignite occurs.

Exposures on the Upper Yukon and at Nulato.—Above Kaltag the bluish sandstones of the Kenai group are overlain by brownish marine sandstones which are best exposed just above Nulato and hence have been named in Dall's notes the Nulato sandstones. They occur in successive waves or folds extending in a northwest and southeast direction, and cut nearly at right angles by the river. At some points eruptive rocks have forced their way through, tilting the sedimentary rocks nearly vertical and altering them near the contact with the eruptives. The blue sandstones occasionally appear above the level of the water.

About 7 miles below Nulato, on the south side of a level space or flat, a small bluff appears, at the extreme end of which the sandstones are nearly vertical. Here, between two contorted layers of shaly rock, a small coal seam was examined in December, 1866. It has been squeezed out above and below, forming a mere pocket about 2 feet thick and not over 20 feet long on the exposed face. The shales contained obscure vegetable remains, but were much altered, probably by the heat evolved at the time they were folded. The average dip is north 45°. The coal is good, but there are apparently only a few tons of it. The shales are conformable with the brown sandstone, which, however, is a marine formation in which this deposit of lignite is a very exceptional incident.

Nulato marine sandstones.—Above Nulato appears to be exposed the highest of these sandstones, which there form bluffs 60 to 100 feet high, and farther up the river reach to 200 feet. In May, 1866, Dall obtained from the upper part of these beds *Modiola*, *Tellina*, *Mytilus*, *Gastrochæna*, and *Mya*, with worm tracks and obscure vegetable remains. The general appearance indicated a littoral formation.[1] These sandstones extend along the river from Kaltag to the Koyukuk Mountain and westward to the Kuthlatno and Ulukak rivers and the eastern base of the Shaktolik Hills, forming a sort of patch, approximately 90 miles northeast and

[1] Cf. Dall in Am. Jour. Sci., 2d ser., 1868, vol. 45, pp. 97–98.

southwest and not more than 30 miles wide, lying on a much larger area of Kenai sandstones. The latter form the mass of the hills between the Kutelno and Kuthlatno rivers and of the Shaktolik Hills. They extend on the Yukon above the Koyukuk Mountain, which is apparently of intrusive crystalline rock, eastward on the north bank to the Melozikakat River. Above Nulato they first appear about 5 miles above the bluff above mentioned as affording marine fossils, and there conformably underlie the marine sandstones and are themselves underlain by a hard black slate.

Near Melozikakat the bluffs appear also on the left bank, which is rarely the case on the Yukon below the Ramparts. Russell[1] has also noted the leaf beds 15 or 20 miles below the mouth of the Melozikakat, on the right bank of the Yukon, in connection with an interesting series of faults which they exhibit.

Colville brown lignite.—In connection with this lignite-bearing series a note on another lignite deposit may be in place. The party commanded by Lieut. Stoney, U. S. Navy, while exploring in the vicinity of the headwaters of the Colvile, the Noatak, and Kowak rivers, north of the Yukon, were obliged to traverse large areas of barren, treeless tundra, and here they found on the surface rather abundantly scattered masses of a brown lignitic material resembling powerfully compressed peat, recalling pitch in hardness and weight, but not brilliant nor disposed to melt with heat, but making a clean cut, like "plug" tobacco when whittled with a knife. This material was sufficiently inflammable to ignite and burn with a steady flame on applying a match to a corner of it, so that in their cold and weary journey it formed a most welcome substitute for wood or other fuel for the campfire. The geological relations of this substance are unknown; it presented no traces of organic structure under an ordinary magnifier, but its nature and geographic location suggest that it may be connected with the lignite-bearing beds to the south of it, which we have just described.

Kowak River lignites.—About 75 miles above the mouth of the Kowak River, which empties into Kotzebue Sound through Hotham Inlet, extensive deposits of lignite, associated with sandstone, shale, and conglomerate, were discovered by Lieut. J. C. Cantwell, U. S. Revenue Marine, and party, while exploring under direction of the Treasury Department in 1884. The coal belt on this river is about 30 miles wide, and passes through a series of high and partly timbered hills. It is often exposed along the river bank, and is frequently associated, as at Kenai, with beds of clay. It is soft, friable, and jet black in color. These beds lie directly in the trend, northwesterly from the main body of beds of the Kenai group north of the Yukon, and there can be little if any doubt that they belong to the same series. The opinions which would connect them with the beds of Paleozoic coal on the Arctic coast, near Cape Lisburne, are, of course, erroneous. It has been determined by

[1] Bull. Geol. Soc. Am., 1890, vol. 1, p. 108.

the observations of *Corwin* party,[1] in 1885, that the coal beds of the Kowak do not extend to the valley of the Noatak, and can not, therefore, be continuous with those at Cape Lisburne.

CAPE BEAUFORT COAL MEASURES.

In regard to these last it may be noted in passing that Silurian fossils, brachiopods, corals, and crinoids have been collected by Buckland, Fischer, Kupreanoff, and Dall at Cape Lisburne and the adjacent Cape Thompson. A few miles farther up the coast coal is found about a quarter of a mile away from the beach at Cape Beaufort. This coal is of a very different quality from the lignites of the southern part of Alaska, and from the presence of corals, apparently referable to the epoch of the Carboniferous period, which were collected from the débris of the rocks adjacent, it has been assumed to be of that age. Similar coal crops out below low-water mark in many places northward to Point Belcher, and is pushed up on the beaches by the grounded icefloes so that in some places nearly the whole of the beach gravel is made up of small fragments of coal. From this region Lesquereux[2] has described *Iritis alaskana*, collected at Cape Lisburne by Henry D. Woolfe, and Newberry[3] enumerates from the same locality and collector ten species which he regards as Neocomian, and which Prof. Ward,[4] enumerating publications on Alaskan Paleobotany, considers to indicate a Lower Cretaceous or possibly Upper Jurassic age. It seems tolerably certain that strata covering a considerable range on the geologic column, beginning with the Silurian, are represented in the vicinity of Cape Lisburne, and that the coal-bearing strata may be Mesozoic rather than Paleozoic.

While referring to the subject of Alaskan paleobotany, it may noted that a few species of fossil plants are enumerated[5] by Prof. Lesquereux as collected at Sitka by E. W. Nelson, but some doubt exists as to the correctness of this locality, though the specimens are doubtless Alaskan. J. Felix[6] has described a fossil wood (*Pityoxylon inæquale*) from the "basalt mountain south of Danaáku," Alaska, a locality which I have not been able to identify.

CORRELATION OF THE KENAI SERIES.

Having indicated the extent and position of beds in Alaska belonging to the Kenai group, as far as our imperfect knowledge of them will permit, it is now in order to discuss their geological age upon the basis of the facts presented. This will of necessity be largely dependent

[1] Cruise of the *Corwin* in 1885, House Ex. Doc. No. 153, 49th Cong., 1st sess. Washington, 1884; see p. 76.
[2] Proc. U. S. Nat. Mus., 1887, vol. 10, p. 36.
[3] Proc. U. S. Nat. Mus., 1888, vol. 11, pp. 31–33.
[4] Eighth Annual Report, U. S. Geol. Survey, 1889, pt. 2, pp. 924–926.
[5] Proc. U. S. Nat. Mus., 1887, vol. 10, pp. 35–37.
[6] Zeitschr. Deutsch. Geol. Gesell., 1886, Bd. 38, pp. 483–484. Leipzig.

upon data other than the similarity of flora, which has been conclusively shown to have little value as a test of synchrony between widely separated geological deposits. Of the 54 species enumerated from the Kenai peninsula by Heer, 30 were previously known from Miocene strata in other parts of the world. Of those from Kuiu and Unga, 65 species, 31 were previously known as Miocene. According to Heer, no doubt can exist as to their Miocene age, in which conclusion Lesquereux agrees, remarking:

The plants described by Heer, representing 56 species, are of marked interest by their intimate relation with those of Atane in Greenland on one side and with those of Carbon in Wyoming and of the Bad Lands of Dakota on the other. They comprise a small group which supplies an intermediate point of comparison for considering the march of the vegetation during the Miocene period, from the Polar circle to the middle of the North American continent, or from the thirty-fifth or fortieth to the eightieth degree of latitude. The remarkable affinity of the Miocene types in their distribution from Spitzbergen and Greenland to the middle of Europe had already been manifested by the celebrated works of Heer. But the Alaska flora has for this continent the great advantage of exposing in the Miocene period the predominance of vegetable types, which have continued to our time and are still present in the vegetation of this continent. (Op. cit., p. 443.)

In his later publication on the same subject Lesquereux[1] remarks:

Alaska has 73 species, of which 13 are found in the Bad Lands, 4 at Carbon (Wyoming), and 2 in and the Chalk Bluffs (California). * * * Of the 13 species common to Alaska and the Bad Lands, 9 are Arctic, of these 6 are European also; and besides *Populus latior*, *P. glandulifera*, and *Juglans nigella* are European, but not yet found in the Arctic flora. The Bad Lands group, therefore, is truly Miocene and shows scarcely any deviation from that of Alaska. The 3 species mentioned as not Arctic may be indicative of a somewhat warmer climate. * * * As the fossil floras of Carbon and the Bad Lands are related by 10 identical species, and those of the Bad Lands and Alaska by 13, these three groups apparently represent the same stage of the North American Miocene. The flora of Carbon has only 4 species identified in that of Alaska; but this lesser degree of affinity may be ascribed to difference in latitude.[2]

Of the 73 species enumerated by Lesquereux from Alaska 21 are tabulated by him as common to Greenland and Spitzbergen also, and 31 as common to the Miocene of Europe and Alaska.

The term Miocene, as used by Heer, seems to have been based primarily on the stratigraphic nomenclature of Switzerland. His method of inferring the age of a given plant bed from the fact of its showing a number of equivalent species with those of any Swiss bed would invariably lead to the conclusion that the possession of a flora in common is sufficient evidence of a general synchrony between the two formations. But I am informed by Prof. L. F. Ward that the vertical range of many fossil plants is very great, and that such conclusions can not safely be reached except by the aid of corroborative evidence in addition to a partial similarity of flora.

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[1] Contributions to the fossil flora of the western Territories, part 3 the Cretaceous and Tertiary Floras, Rep. U. S. Geol. Survey of the Terr. by F. V. Hayden, 1883, vol. 8, Washington, 4°, cf Miocene Flora, pp. 219–277.

[2] Op. cit., p. 275.

The beds of Carbon, Wyoming, with which Lesquereux compared the Kenai group, are by Dr. C. A. White, as he informs me, referred on stratigraphic grounds to the Laramie. Prof. Ward[1] agrees with this conclusion, and in his tables places the Carbon beds between the typical Laramie and the Fort Union beds, all of which are included under the general term Laramie.

The newer leaf beds in Greenland have lately been regarded as Eocene by Mr. J. Starkie Gardner, and as equivalent in the main to the flora of the Basaltic (Eocene) beds of Britain.[2] The Spitzbergen beds would naturally follow those of Greenland. But the inferential reference of the plant remains of the Pliocene gravels of California to the Eocene by Mr. Gardner somewhat weakens the force of his opinion on other fossil floras, since it is impossible that the Californian plant remains can be Eocene.

I have already pointed out the probability that, if Miocene at all, the leaf beds of Greenland referred to would be synchronous with that geological epoch during which the old Miocene warm-water invertebrate fauna of the Atlantic coast penetrated as far north as New Jersey.

Since that time it is highly improbable that any temperate conditions, such as the flora would indicate for the Atane period, have obtained in the latitude of Greenland. In other words, the Greenland beds are not later than the Old Miocene, though this does not preclude a reference of them to an older horizon than the Miocene, for during the Eocene also the conditions in the extreme north might have been favorable to such a flora.

In Alaska, at Cook's Inlet, at Unga Island, at Atka, and at Nulato in the Yukon valley, we find the leaf beds of the Kenai group immediately and conformably overlain by marine beds containing fossil shells which are common to the Miocene of Astoria, Oregon, and to middle and southern California.

It is then certain that the Kenai leaf beds immediately preceded and their deposition terminated with the depression (probably moderate in vertical range) which enabled the marine Miocene fauna to spread over part of the antecedently dry land. Further researches along the Alaskan coast will doubtless enable us to determine whether the leaf beds themselves are underlain by marine Eocene beds or not. We know that the Aucella beds underlie the Kenai series, but whether there are any beds representing the marine phase of the Eocene between them is yet uncertain, though very probable. Eichwald's references to the age of the Alaskan Neozoic marine fossils are more or less confused and should not be taken into account in any discussion of the subject, as he has referred most of them indiscriminately to the Cretaceous, by which he means Gabb's Chico-Tejon series.

What may be considered as reasonably certain is that the period dur-

[1] U. S. Geol. Survey, 6th Ann. Rep. for 1884-'85, p. 539.

[2] Proc. Royal Society, 1884, pp. 22, 23. See also Nature, 1879, vol. 20, pp. 10-13.

ing which in the Arctic regions the last temperate flora flourished was in a general way the same for all parts of the Arctic. It would seem highly improbable that a temperate climate should exist in Spitzbergen and not at the same time in Greenland and Alaska, or vice versa. If Alaska was covered by the sea at this time we should find a temperate marine fauna, if it was dry land a temperate flora, and so with the other Arctic localities, and these indications should, it would seem, represent an identical and synchronic phase of geological history in the Arctic regions.

The distribution and character of this group have been somewhat fully discussed because, up to very recently, authorities were practically unanimous in referring it to the Miocene, a view which can not yet be said to be definitely refuted. But when we consider how the Eocene Aturia bed is immediately and conformably overlain at Astoria by shales and sandstones, undoubtedly equivalent to the Alaskan marine Miocene, and that the latter conformably and immediately in like manner overlies the Kenai group, it must be conceded that the view that the latter is probably of Eocene age does not appear unreasonable.

MIOCENE OF THE ASTORIA GROUP.

The marine Neozoic beds overlying the leaf beds and conglomerates of the Kenai group appear indubitably referable to the Miocene series represented in the sandstones and shales of Astoria, though probably to the upper or newer portion of these beds. Eichwald[1] has confounded the unquestionably Neocene species figured by Grewingk with Cretaceous forms collected by Dr. Blaschke in Alaska, and referred the whole to the Turonian or Upper Chalk. The fact that nearly half of Grewingk's species are still found living is quite sufficient to establish the correctness of his original reference of them to the Tertiary, while they are derived, as previously shown, from beds overlying the leaf beds referred by Eichwald himself to the Miocene.

This does not conflict with the possibility that the Blaschke collection, other than those described by Grewingk, may be referable to the Chico or other part of the Cretaceous, which is well known to occur in various parts of Alaska. It is possible that two of Grewingk's species, *Nucula ermani* and *Tellina dilatata* of Girard from Atka, may not belong to the same horizon as the others, though of this there is no proof, and the fossils themselves are not distinctive.

The following table will indicate the known species and their relations:

[1] Geogn. Palaeont. Bemerk., St. Petersburg, 1871, pp. 117-137.

Table showing distribution of the fauna of the Astoria group.[1]

Names of species identified.	Localities of Alaskan Miocene.												Miocene.			Plio-cene.	Pleis-tocene.	Recent.	
	Nulato.	St. Paul Island.	Nushagak.	Port Möller.	Atka Island.	Unalashka.	Morzhowi.	Pavloff Bay.	Unga Island.	Katmai.	Kadiak Island.	Lituya Bay.	B. C.	Oreg.	Cal.	Cal.	Cal.	N.	S.
Ostrea tayloriana Gabb					×			×	×		×				×				
Ostrea veatchii Gabb					×				×						×	×			
Pecten pabloensis Conrad								×	×		×	×			×				
Mytilus middendorfii Grewingk									×		×								
Mytilus mathewsonii Gabb	×							×							×				
Modiola multiradiata Gabb	×		×						×					×	×				
Modiolaria nigra Gray									×										
Pectunculus kashevaroffi Grewingk		×							×		×								
Pectunculus patulus Conrad		×	×					×						×	×	×			×
Nucula teunis Lamarck		×	×															×	
Nucula (acila) ermani Girard		×			×														
Cardita aleutica Girard?					×														
Astarte borealis Gray		×																×	
Crassatella collina Conrad							×	×			×				×				
Cardium decoratum Grewingk		×			×			×	×		×		×						
Serripes gronlandicus Beck		×	×						×		×		×					×	
Liocyma fluctuosa Beck		×																×	
Tapes staminea Conrad		×						×	×						×	×	×	×	
Lioconcha sp		×				×	×												×
Tagelus sp		×																	
Soletellina sp		×																	
Tellina carlottensis Whiteaves	×	×	×			×							×					×	
Tellina alternidentata Brod. and Sby		×			×	×	×		×									×	
Macoma middendorfii Dall		×	×	×			×		×									×	
Macoma inconspicua Brod. and Sby		×											×			×	×	×	

Names of species identified.	Localities of Alaskan Miocene.												Miocene.			Plio-cene.	Pleis-tocene.	Recent.	
	Nulato.	St. Paul I'd.	Nushagak.	Port Möller.	Atka I'd.	Unalashka.	Morzhowi.	Pavloff Bay.	Unga I'd.	Katmai.	Kadiak I'd.	Lituya Bay.	B. C.	Oreg.	Cal.	Cal.	Cal.	N.	S.
Macoma nasuta Conrad	.....	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	×	×	×	×	×	×	....
Mactra albaria Conrad	.....	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	×	.....	.....	.....	.....	....
Lyonsia arenosa Möller	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	×	....
Kennerlyia grandis Dall	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	×	....
Mya præcisa Gould	×	.....	.....	.....	×	×	×	×	×	.....	×	.....	.....	.....	.....	.....	.....	×	....
Mya truncata L. (var.)	.....	.....	.....	.....	.....	.....	×	×	×	.....	×	.....	.....	.....	.....	.....	.....	×	....
Saxicava arctica L.	.....	×	×	.....	×	.....	×	×	×	.....	×	.....	.....	.....	.....	.....	.....	×	....
Teredo sp.	.....	×	×	.....	.....	.....	.....	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
Gastrochæna sp	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
Cylichna (alba Brown?)	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
Buccinum plectrum Stimpson	.....	×	.....	.....	.....	×	.....	.....	.....	×	.....	.....	.....	.....	.....	.....	.....	×	....
Chrysodomus (altispira Gabb?)	.....	.....	.....	.....	.....	.....	.....	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
Odostomia sp	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
Litorina (sitkensis Phil. var.?)	.....	.....	.....	.....	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
Galerus sp	.....	.....	.....	.....	.....	.....	.....	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
Crepidula prærupta Conrad	.....	.....	.....	.....	.....	.....	.....	.....	×	.....	.....	.....	×	×	×	×	.....	.....	....
Lunatia (pallida B. and S.?)	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	×	....
Neverita saxea Conrad	.....	×	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	×	×	×	.....	.....	.....	....
Natica clausa Brod. and Sby	.....	×	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	×	.....	×	....
Margarita striata Brod. and Sby	.....	×	.....	.....	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	×	....
Margarita sp	.....	×	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....

[1] The synonymy of the species enumerated has been modernized, though the details of the process are reserved for a more appropriate occasion. All Grewingk's species are included, though some of them appear under names different from those he used. Of the forty-six species recognized in Alaskan beds, sixteen occur in the Miocene of British Columbia, Oregon, and California; of these a few are known from the Californian Pliocene, though when the latter fauna is better known this number will doubtless be much enlarged. The table has been enriched by an examination of specimens collected at St. Paul Island by Messrs. Palmer, Townsend, and Elliott; at Nushagak by the late C. W. Mackay; and at Nulato, at Zakharoff harbor, Unga, and the adjacent shores of Popoff Island, by W. H. Dall.

It will be noted that of the forty-six species known twelve belong to genera not now represented in such cold waters as those of Bering Sea, and of these, two species may possibly survive in Californian waters, the remainder being presumably extinct. The nineteen species known to survive in the recent fauna are all forms which belong to northern waters, and are capable of surviving low temperatures, though sometimes ranging farther south. We may then conclude that in Miocene times the waters of this region were warmer than at present, and that the still colder epoch, near the end of the Pliocene or the beginning of the Pleistocene, weeded out the more delicate forms.

ENUMERATION OF SPECIAL LOCALITIES.

The localities where this fauna has been noticed and the marine beds more or less certainly identified, will now be enumerated, beginning at the south.

On the south side of Dixon's entrance at Skookum Point, near Massett, Queen Charlotte Islands, Hon. J. G. Swan collected specimens, now in the National Museum, showing the presence of these beds.

The occurrence of beds of this age at Lituya Bay has already been alluded to (p. 236). Cenotaph Island, in the bay, is chiefly composed of them, and Lamanon collected a species of *Pecten* with other marine fossils from a height of 200 toises above the sea level.

Kadiak.—On the island of Kadiak, north of Tonki Cape, on the south coast from the shores of Igatskoi Bay, Wossnessenski collected a number of species of this fauna, which were imbedded in a volcanic tufa about 10 feet above the sea. On the opposite side of the island near the settlement of Uganak similar beds were found containing analogous fossils.

On the portage from Katmai Bay, across the ridge of Aliaska Peninsula, on the trail to Naknek Lake, the same beds occur, from which the same collector collected *Buccinum plectrum*.

Crepidula bed of Unga and Popoff islands.—One of the most prolific and best known localities is situated at Zakharoff (sometimes called Coal) Bay on the northern end of the island of Unga, one of the Shumagin group. A section on the west shore of this bay has already been described in detail (p. 241) where the marine Miocene is represented in the upper part of the bluff by a layer of sandstone about a foot thick, densely crowded with specimens of *Crepidula prærupta* Conrad, sometimes referred to as *C. princeps* Conrad, which has been erroneously identified with the recent *C. grandis* Middendorf. From the vast number of these shells of which the layer is made up the name of the Crepidula bed is suggested for it.

This layer appears at a much lower level on the northern shore of the northeastern part of Unga, east from Zakharoff Bay. The sandstones lie horizontally or nearly so, except where disturbed by intrusions of later basaltic lavas, which sometimes overflow the sedimentary beds or invade them vertically or laterally, altering the rock at contact and for some distance beyond the lavas.

On the shore of Popoff Island next eastward from Unga and separated from the latter by a narrow strait, the same bed is continued, with a thickness varying from 6 inches to 2 feet, carrying oysters, *Crepidula*, *Chrysodomus*, etc.; it is here separated from the conglomerates above and below by a layer 10 to 25 feet thick, of hardly consolidated sand. The upper conglomerate is of variable thickness and much altered by heat from a bed of lava and volcanic breccia 300 feet thick which overlies it. The special character of the igneous material varies rapidly from point to point horizontally and vertically. The lower part seems more like a cooked conglomerate of pieces of clay-porphyry in a basaltic matrix while the upper portion is composed in part of sharp fragments of porphyrite and dolerite cemented by a thin, glossy, vitreous lava. The strata are roughly conformable and dip 10° to 15° to the eastward. The lowest bed visible in the section exposed appeared to correspond to layer No. 6 of the section p. 241.

The fossiliferous layer here contained *Ostrea veatchii*, *O. tayloriana*, *Crepidula prærupta*, *Galerus*, *Pecten*, *Modiola*, *Modiolaria*, *Drillia?*, and *Chrysodomus*, all rather scarce except the oysters. The latter were frequently bored by *Cliona*. The fossils were generally fairly well preserved, and mixed with fragments of silicified or carbonaceous vegetable matter in the matrix of more or less argillaceous sandstone. A cetacean vertebra was also found.

Peninsula of Aliaska.—It can hardly be doubted that these strata reappear on the peninsula north of Shumagin Islands as the Kenai beds do. Grewingk speaks (Geogn. Palaeont. Bemerk. p. 58, foot note) of their existence on the shores of Portage Bay and at Port Möller, while at other points on the north shore of the peninsula in that vicinity, Postels[1] speaks of horizontal fossiliferous strata carrying many bivalve shells, reaching a thickness above the sea level of 300 feet. These are doubtless of the same age as the Crepidula bed of the Shumagin Islands. At Pavloff Bay, both on the flanks of the Pavloff volcano and near the settlement, Wossnessenski obtained a large number of fossil bivalves belonging to this fauna.

Walrus Bay.—On Morzhowi or Walrus Bay, in the first bluff eastward from Sannakh Strait (or Isanotski Strait, as it is also called), at 50 toises above the level of the sea, lies a horizontal bed containing the same species of fossil bivalves previously noted at Pavloff Bay. This layer is covered by about 50 toises more of sand and clay. The same layer is noted by Lütké (Partie nautique, p. 272) on the west shore of Cold Bay.[2]

Unalaska.—On the island of Unalaska at the NNW. foot of the volcano of Makushin the same beds occur again, and from them the char-

[1] Lütké, Voy. Séniavine, vol. 3, p. 27.
[2] Cf. Veniaminoff, t. i., pp. 222 and 236.

acteristic fossils have been collected by Wossnessenski, Kastalski and Dr. Stein.[1] They are also reported to exist in one of the bays near Chernoffski, in the western part of the island.

Atka.—The most western point where they have been recognized in the Aleutian chain is on the western side of the island of Atka, on a small inlet known as Sand Bay, which extends from the northern part of Korovinski Bay. Here the beds are near the sea level, but near by, on the western slope of Koniushi volcano, they appear at an elevation of about 30 feet and consist of hard argillaceous and indurated sandy layers with the usual fossil bivalve shells.

Nushagak.—Proceeding northward along the main land at the head of Bristol Bay, the Nushagak River enters an inlet some miles in extent. At the head of ship navigation is the location of the Russian trading post of other days called Fort Alexander. On the shore of the river in this vicinity, but of which we have no more precise information, a small collection of fossils in an indurated clayey matrix was obtained by the late C. W. McKay. They agree in every respect with those from the Pribiloff Islands, and add some species to our list. The presence of these beds at this place is therefore definitely established, but nothing is known of their extent.

Saint Paul Island.—Nearly due west from Bristol Bay, in the midst of Bering Sea, rises the Pribiloff group of islands, celebrated for their fur-seal fisheries. The settlement on Saint Paul Island is situated on the neck of a small peninsula, on either side of which is a stretch of sand beach bounded by crags of basaltic rock and lava. On the east side of this peninsula, which forms the southeastern extreme of the island, is a bluff or crag known as Black Bluff, which, according to the observations of Wossnessenski in 1847–'48, is composed of horizontal layers of a hard claystone, with others in which lime preponderates, forming a pale gray, fine grained, clayey limestone, or in which a conglomerate of pebbles of volcanic origin is bound together in a limy matrix.[2] Over these are layers of black or brown volcanic breccia and vesicular lava. These bluffs rise abruptly to a height of 60 to 80 feet above the sea at their base. From the limestone and argillite marine fossils have been obtained by Wossnessenski, Elliott, Dall, W. Palmer, and C. H. Townsend, of which a collection exists in the National Museum, enumerated in table on p. 253. About twenty-eight species are known from this locality, which is stated to be the only spot in the whole group where any fossiliferous rocks occur,[3] the remainder of the islands being composed of volcanic rocks and alluvium of very recent origin.

Recent observations by Mr. J. Stanley Brown, special agent of the Treasury Department, in 1891, convinced him that at present no distinct trace of any limy stratum is perceptible in the Black Bluff. The fossils obtained by him were contained in rounded, apparently water-

[1] Growingk, op. cit. p. 123; Trudi, Mineral. obst. St. Petersburg, 1830, pp. 382–383.
[2] Grewingk, Beitrag, p. 190.
[3] Cf. H. W. Elliott, Condition of Affairs in Alaska, 1875, p. 70.

worn pebbles, which were indiscriminately included in a general mass of volcanic ashes and other eruptive matter of which the bluff is formed. No extinct species appeared in the collection brought back by Mr. Stanley Brown, while several are noted from the material of the earlier collections. It would seem possible that pebbles of more than one geological epoch may be included in the mass, or that the wear of the waves for half a century has cut away enough of the bluff to hide or destroy the limy stratum referred to by Grewingk, and which may have been of limited extent. It is certain that, from an examination solely of the material collected in 1891, the fossils might be referred to an age as late as the post-Pliocene, which would not agree very well with the fauna reported by Grewingk and others. The fossils collected by Mr. Stanley Brown and not included in the earlier collections are as follows: *Buccinum tenue* Gray?, *B. polare* Gray?, *Admete couthouyi* Jay?, *Leda* sp., *Yoldia limatula* Say, *Lepton grande* Dall, *Cardium islandicum* (very abundant), *Macoma sabulosa* Spengler, and a fragment possibly of a *Panopea*. All these occur living at moderate depths in the Bering Sea, immediately adjacent to the island, at present. Owing to the doubt as to their age they have not been included in the table of fossils of the Astoria group (p. 253).

Commander Islands.—On the Commander Islands, west of the Aleutians, rocks of the same age probably occur, since on Bering Island Stejneger collected some specimens of a conglomerated hard gravel of highly polished pebbles united by a limy cement, containing fragments of bivalves (*Saxicava?*) and a single piece of claystone with the imprint of a bivalve not yet identified.

Other localities.—The islands northward from the Pribilof group do not appear to contain fossiliferous strata. St. Matthew and its adjacent islets are composed of porphyritic, granitic, and volcanic rocks. Pinnacle Island is a volcanic chimney, still smoking. St. Lawrence is chiefly granitic, though slate is reported to exist at its southeastern extreme. The island as a whole is composed of reddish granitic domes united by stretches of débris, due to weathering alluvium and sea sand. The Diomedes are massive domes of a white or grayish syenite. The statement of Muir[1] that they have been glaciated is without foundation in fact, and the same may be said of other islands to the south.

Returning to the mainland, the last area in which rocks of the Astoria group are known to occur is that of the Nulato sandstones on the Yukon River between Kaltag and the Koyukuk Mountain. These have already been described in connection with the Kenai beds of the same region, and it seems unnecessary to recapitulate the data here.[2]

It may be added here that there is every reason to believe, notwithstanding the imperfect data which are on record, that the Kenai group

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[1] Cruise of the Corwin in 1881, Washington, Treasury Dept., 1884, 4°, 147 pp. Treasury Dept. Doc. No. 601; see pp. 140–142.

[2] See page 247.

and the Astoria group are both represented by analogous beds on the southern part of the peninsula of Kamchatka and on the northern shores of the Japanese island of Yesso, though the discussion of those exotic localities is outside of the limits of this essay.

PLIOCENE.

BEDS OF MARINE ORIGIN.

Identifiable Pliocene appears to be remarkably rare north of California. The small patch noted by Dr. Condon at Shoalwater Bay, Washington, lying conformably between beds of marine Miocene and Pleistocene, appears to be the only locality for many miles. In common with the more extended beds in California, its fauna indicates a colder water temperature than at present, and contains a large proportion of species which have since receded northward some hundreds of miles at least and now find a congenial habitat in the Aleutian chain and Sitkan archipelago.

St. Elias Alps.—In his geological researches on the St. Elias Alps and the region westward from the Yakutat Bay, Mr. I. C. Russell has discovered fossiliferous rocks elevated to 5,000 feet above the sea, containing fossils which all belong to recent species, yet which, since they belong to a more northern fauna than at present is known to inhabit that locality, are probably referable to the Pliocene rather than the Pleistocene, a view which is to some extent supported by the enormous elevation to which they have been subjected. Our ideas of what shall constitute Pliocene on the Pacific coast are still rather vague and may be said to involve the idea of a marine fauna containing a certain proportion of extinct species. Hereafter we may be better able to define the period in terms of dynamic geology, but at present both the recent and fossil faunas are but approximately known, and all determinations of the age must be taken as provisional. It can not be safely assumed that either the supposed Pliocene or the glacial and postglacial epochs on the Pacific coast where wholly synchronous with those periods on the Atlantic coast, to which the same appellations have been assigned. We may, however, be not far wrong in assuming that the Pliocene epoch was intimately associated with those great movements of elevation which have been more or less definitely recognized along the whole Pacific coast from California northward.

Middleton Island.—This small island lies broad off Prince William Sound on the continental shelf, at a distance of some 65 miles from the main shore. It was visited by a Coast Survey party directed by W. H. Dall in 1874. It is low and nearly flat, except that the table land formed by the southern half slopes northward to the northern extreme, which is hardly raised above the sea. The southern end of the island is about 2 miles wide and 100 feet high, very flat above, falling to the sea in a perpendicular cliff, at the foot of which in some places is a narrow, steep beach of shingle or bowlders. The middle portion of the island is three-quarters of a mile wide, rather low near the beach, grassy bluffs rising a few rods inland. On the table land are a few small knolls, seemingly dunes, now grassy. There are no trees, but the herbage is extremely luxuriant. A single leaf of *Symplocarpus* measured 48 inches long and 24 broad, with a stalk 4 inches in diameter; the same plant on the mainland has leaves usually not exceeding 14 inches in length, The island is composed of nearly horizontal layers of soft clayey rock, containing many pebbles and even bowlders of syenite and quartzite, some rounded and others of angular shape. Above the claystone is a layer of gray sand covered with several feet of mold and turf. Below the sea level some of the rock appeared to be quartzite in place and very hard. Whatever its nature, it extends in reefs and shoals to a distance of several miles from the island in different directions. No fossils were found in the claystone, but from its character it was suspected to be post-Miocene and possibly Pliocene.

THE GROUND ICE FORMATION.

A remarkable formation has been recognized in many places in the northern part of Alaska, in which solid beds of ice of considerable thickness perform the functions of rock strata and are covered by beds of blue clay containing numerous remains of Pleistocene mammals, or by beds of alluvium which sustain a layer of turf, with ordinary profuse herbage of the region, or even small thickets of birch, alder and other small Arctic trees.

Eschscholtz Bay ice cliffs.—This formation was first noticed by Kotzebue, during his exploration of the sound which bears his name, in the year 1816.[1] The remains of animals which were associated with the clays above the ice were described in his appendix on the natural history by Eschscholtz.[2] The locality at which the original discovery was made is known as Elephant Point, Eschscholtz Bay, the bay being an arm of Kotzebue Sound.

This locality was visited by H. M. S. *Blossom*, Capt. F. W. Beechey, in 1826,[3] and observations on the ice formation were made by Surgeon Collie of the expedition, which, with the vertebrate remains collected, were discussed by Dean Buckland in the appendix to the narrative of the voyage. Kotzebue and Eschscholtz correctly described the formation as interbedded ice. Beechey's party, deceived by the mantle of clay which at the time of their visit had fallen so as to mask the main body of the ice face, concluded that the ice was a superficial deposit. They noted similar deposits of clay more or less associated with ice at numerous other points on the Arctic coast.

[1] Kotzebue, Voy. of Discovery into the South Sea and Beering's Straits, London, Longmans, 1821. 3 v., 8°. vol. 1, p. 220.

[2] Op. cit., vol. 3.

[3] Narrative of a voyage to the Pacific and Beering's strait, by F. W. Beechey, R. N., London, Colburn & Bentley, 1831, 742 pp., 4°. Cf. Part 1, pp. 257-259, and for Buckland's discussion, see Appendix to the same, pp. 593-612; also Zoology of Capt. Beechey's Voyage, London, H. G. Bohn, 1839, 180 pp., 4°, 46 pl. For Collie's geological notes on the ice cliffs, see Geology, pp. 169-173, and Pl. I.

In 1848 Capt. Kellett, in H. M. S. *Herald*, accompanied by Berthold Seemann and Dr. Goodridge, visited Kotzebue Sound and Elephant Point with the narratives of Kotzebue and Beechey in their hands, and fully confirmed the views expressed by Kotzebue and Eschscholtz as to the interstratified position of the ice and the relation to it of the bone-bearing clay. Their results were subsequently discussed at length by Edward Forbes and Sir John Richardson.[1] The fossil mammals were fully described and illustrated in their publication.

In 1880 W. H. Dall, commanding the U. S. Coast Survey cutter *Yukon*, visited Kotzebue Sound, and carefully examined this classic locality. His report was subsequently printed by direction of the superintendent of the survey.[2] As these notes give the fullest account of this formation at its typical locality they will be cited verbatim:

We landed at a small low point [on the south shore of Eschscholtz Bay, west from Elephant Point][3] near some old huts and proceeded along the beach for about a mile, the banks being chiefly composed of volcanic breccia or a slaty gneissoid rock. They rose 15 to 50 feet above the sea, rising inland to hilly slopes without peaks, and probably not attaining more than 300 or 400 feet anywhere in the vicinity.

As we passed eastward along the beach a change took place in the character of the banks. They became lower and the rise inland was less. From reddish volcanic rock they changed to a grayish clay, containing much vegetable matter, which in some places was in strata in the clay and in others indiscriminately mixed with it. Near the beginning of these clay banks, where they were quite low, not rising over 20 feet above the shore, we noticed one layer of sphagnum (bog moss) containing fresh-water shells belonging to the genera *Pisidium*, *Valvata*, etc. This layer was about 6 inches thick. The clay was of a very tough consistency, and though wet did not stick to or yield much under our feet. The sea breaks against the foot of these banks and undermines them, causing them to fall down, and the rough irregular talus that results is mingled with turf and bushes from the surface above. A little farther on a perpendicular surface of ice was noticed in the face of the bank. It appeared to be solid and free from mixture of soil, except on the outside. The banks continue to increase slowly, but regularly, in height as we passed eastward. A little farther on another ice face presented itself on a larger scale. This continues about 2½ miles to Elephant Point, where the high land turns abruptly to the south and west, and we followed it no farther. The point itself is boggy and low, and is continued from the foot of the high land, perhaps half a mile to the eastward, forming the northwest headland to a shallow bay of considerable extent.

To return to the "cliffs": These, for a considerable distance, were double; that is, there was an ice face exposed near the beach with a small talus in front of it, and covered with a coating of soil 2 or 3 feet thick, on which luxuriant vegetation was growing. All this might be 30 feet high. On climbing to the brow of the bank, the rise from that brow proved to be broken, hummocky, and full of crevices and holes; in fact, a second talus on a larger scale ascending to a second ice face, above which was a layer of soil 1 to 3 feet thick covered with herbage.

The brow of this second bluff we estimated at 80 feet or more above the sea. Thence the land rose slowly and gradually to a rounded ridge, reaching the height of 300 or 400 feet only, at a distance of several miles from the sea, with its axis in a north and south direction, a low valley west from it, the shallow bay at Elephant

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[1] Zoology of the voyage of the *Herald*, edited by Edward Forbes, Vertebrals by Sir John Richardson, London, Lovell Reeve, 1854, 171 pp., 4°, 33 pl.

[2] Notes on the vicinity of Bering Strait, Am. Jour. Sci., 1881, vol. 21, pp. 104-111.

[3] Phrases inclosed in brackets are now added for clearness.

Point east from it, and its northern end abutting in the cliffs above described on the southern shore of Eschscholtz Bay. There were no mountains or other high land about this ridge in any direction; all the surface around was lower than the ridge itself.

About half a mile from the sea, on the highest part of the ridge, perhaps 250 feet above high-water mark, at a depth of a foot, we came to a solidly frozen stratum, consisting chiefly of bog moss and vegetable mold, but containing good-sized lumps of clear ice. There seemed no reason to doubt that an extension of the digging would have brought us to solid, clear ice, such as was visible at the face of the bluff below; that is to say, it appeared that the ridge itself, 2 miles wide and 250 feet high, was chiefly composed of solid ice overlaid with clay and vegetable mold. It was noticeable that there was much less clay over the top of the upper face than was visible over the lower one, or over the single face when there was but one, and the land and the bluff were low near the beach. There also seemed to be less vegetable matter. Near the beach six or eight feet of clay were observed in some places, without counting what might be considered as talus matter from further up the hillside. In one place only did we notice a little fine, reddish gravel, and nowhere in the talus or strata any stones.

The ice face near the beach was not uniform. In many places it was covered with clay to the water's edge. In others, where the bank was less than 10 feet high, the turf has been bent without breaking after being undermined, and presented a mossy and herbaceous front, curving over quite to high-water mark.

The ice in general had a semistratified appearance, as if it still retained the horizontal plane in which it originally congealed. The surface was always soiled by dirty water from the earth above. This dirt was, however, merely superficial. The outer inch or two of the ice seemed granular, like compacted hail, and was sometimes whitish. The inside was solid and transparent, or slightly yellow tinged, like peat water, but never greenish or bluish like glacier ice. But in many places the ice presented the aspect of immense cakes or fragments, irregularly disposed, over which it appeared as if the clay, etc., had been deposited. Small pinnacles of ice ran up into the clay in some places, and, above, holes were seen in the face of the clay bank, where it looked as if a detached fragment of ice had been and had been melted out, leaving its mold in the clay quite perfect.

In other places the ice was penetrated with deep holes, into which the clay and vegetable matter had been deposited in layers, and which (the ice melting away from around them) appeared as clay and muck cylinders on the ice face. Large rounded holes or excavations of irregular form had evidently existed on the top of the ice before the clay, etc., had been deposited. These were usually filled with a finer grained deposit of clay, with less vegetable matter, and the layers were waved, as if the deposit had been affected by current action while going on.

In these places were noticed, especially, the most unexpected fact connected with the whole formation, namely, a strong, peculiar smell, as of rotting animal matter, burnt leather, and stable manure combined. The odor was not confined to the spots above mentioned, and was not quite the same in all places, but had the same general character wherever it was noticed.[1] A large part of the clay had no particular smell. At the places where the odor was strongest it was observed to emanate particularly from darker, pasty spots in the clay (though permeating elsewhere), leading to the

[1] This phenomenon was observed by Kotzebue, Beechey, and the Herald party, and lends further probability to the view that the animals were mired in the clay and thus met their death. Since, if the clay contained merely the accummulated bones of animals which had died and decayed on the surface of the ground, it is unlikely that so much animal matter would have been hermetically sealed in the clay and kept on ice to offend the nostrils of later visitors. On the other hand, if the ice had not been present and the temperature not kept so low it is unlikely, even in the clay, if animal matter could have been preserved for such an enormous period of time in a condition to give out so ammoniacal a stench. All the circumstances point toward the view that the ice preceded and subsequently coexisted with animals whose remains are now found in its vicinity.

supposition that these might be remains of the soft parts of the mammoth and other animals, whose bones are daily washed out by the sea from the clay talus.

At or near these spots, where the odor was strongest, a rusty, red lichen, or lichen-like fungus, grew on the wet clay of the talus in extensive patches. Some of these, of the bad-smelling deposit, and as many bones of the mammoth, fossil buffalo, etc., as we could carry, were secured. These included a mammoth tusk, with both ends gone, but still 5½ feet long and 6 inches in diameter. Dwarf birches, alders, 7 or 8 feet high, with stems 3 inches in diameter, and a luxuriant growth of herbage, including numerous very toothsome berries, grew with the roots less than a foot from perpetual solid ice.

The formation of the surrounding country shows no high land or rocky hills, from which a glacier might have been derived and then covered with débris from their sides. The continuity of the mossy surface shows that the ice must be quite destitute of motion, and the circumstances appear to point to one conclusion, that there is here a ridge of solid ice, rising several hundred feet above the sea, and higher than any of the land about it, and older than the mammoth and fossil horse, this ice taking upon itself the functions of a regular stratified rock. * * * Though many facts may remain to be investigated, and whatever be the conclusions as to its origin and mode of preservation, this formation certainly remains one of the most wonderful and puzzling geological phenomena in existence.

From the character of some of the bad-smelling deposit which was brought home and appeared to be exclusively composed of vegetable fiber finely comminuted, no doubt is felt that it represents dung of the mammoth or some other herbivorous animal which had been preserved in pockets on the surface of the ice where it was probably dropped, and and by its dark color attracting the rays of the sun had sunk in, as is usual with dark objects dropped on an exposed ice surface. It may be reiterated that the bones, as noted by previous observers, are contained in the clay above the ice; never in the ice itself. They are exposed by the melting away of the ice face and the consequent fall of the superincumbent clay, which is afterward disintegrated by the action of the waves, leaving the bones exposed on the broad, flat, muddy beach. The remarkably fresh appearance of the bones is amply accounted for by the low temperature and dense character of the clay in which they are imbedded, in which the animals may have become mired and so perished.

The report of Dr. Goodridge, which appears to have been prepared with great detail, was unfortunately not printed. In some extracts from it given by Richardson it is stated that at one of the ice cliffs a section was exposed showing 50 feet of pure, clear ice above, and behind it layers of drifted material, peat, covered with a thick bed of broken sticks and vegetable matter, over which lay a stratum of red river gravel, over which lay a bed of argillaceous earth capped by dry, friable mold and surface peat, with the usual turf and herbage. The sticks were larger than any growing in the vicinity, but they may have been drifted from the wooded region of the interior. At another place the ice wall was 80 feet high. E. W. Nelson, who visited this locality in 1881 with the U. S. S. *Corwin*, also observed such an accumulation of sticks, and noted that some of them had been gnawed by beavers. The following list of species is mainly extracted from Richardson's report, those marked with an asterisk having been obtained by Dall in 1880. The nomenclature has been somewhat modernized.

**Elephas primigenius* Blumenbach.
Elephas columbi Falconer.
Equus major De Kay.
Alces americanus Jardine = *machlis* Ogilby.
**Rangifer caribou* Baird.
**Ovibos moschatus* Blainville.
**Ovibos maximus* Richardson = *O. cavifrons* Leidy.
**Bison crassicornis* Rich. = *B. antiquus* Leidy.

Other localities.—Analogous beds of clay, sometimes with vertebrate remains, were observed by Beechey's party at the following localities: [1]

On the north shore of Eschscholtz Bay, and also on the west from it, on the south shore of Spafarieff Inlet and Good Hope Bay; at Shishmaref Inlet, west-southwest from Cape Spanberg; Cape Blossom; northward from Kotzebue Sound, at Point Hope; at various points between Cape Beaufort and a point 20 miles east from Icy Cape; and near Point Belcher, in north latitude 71°.

From information gathered from several masters of vessels in the whaling fleet and derived from experience gained in the effort to dig graves for seamen who have died aboard vessels on this shore from time to time during the last twenty years, it would appear that somewhat north of Cape Beaufort the land between the low hills and the sea is low and the soil chiefly a sort of gravel. "At a depth of 2 feet is a stratum of pure ice (not frozen soil), of unknown depth. This formation extends, with occasional gaps, north to Point Barrow, and thence east to Return Reef, where the ice layer is about 6 feet above the level of the sea. It goes south at least as far as Icy Cape without any decided break, and is found in different localities as far south as Kotzebue Sound." At Point Barrow, near the international station, under the direction of Lieut. P. H. Ray, U. S. Army,[2] a shaft was sunk to a depth of 37 feet 6 inches, which passed through successive layers of mud, sand, and fine gravel, with fragments of drift-wood and marine shells, showing here and there large fragments of pure fresh-water ice, but no continuous stratum of ice. The formation here was clearly a beach alluvium, and relatively modern, a pair of Eskimo wooden snow goggles with a sinew string still attached to them being found at a depth of 27½ feet. The temperature of the earth varied from − 5° to + 17.5° F.; below the influence of the external air the temperature of the earth was quite steady at 12° F. for nine months. The earth was frozen and was extremely hard and tough. Blasts put into the side of the shaft blew out without shattering the frozen earth around the drill hole. It is probable that excavations farther inland might have revealed the ice layer, which at the locality of the station did not exist.

Kowak River ice cliffs.—After that at Elephant Point, the most re-

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[1] Op. cit., p. 603.

[2] Report of the International Polar Expedition to Point Barrow, Alaska. Washington. House Ex Doc. No. 44, 48th Congr., 2nd Sess., 1885, 4°; cf. pp. 24, 338, 339.

markable exhibition of the ground-ice formation which has yet been recognized is situated on the lower part of the Kowak River, which empties into Hotham Inlet. The cliffs are situated along the bends of the river, which is extremely tortuous, almost exactly due north from Elephant Point near where a line drawn from Elephant Point to Deviation Peak cuts the Kowak River. They have been illustrated and briefly referred to by Lieut. John C. Cantwell,[1] U. S. Revenue Marine, who discovered them in 1884 and revisited them during the following year. They are composed of solid ice, covered by a layer of dark colored earth, uniformly about 6 feet thick, the whole rising to the height of 15 to 150 feet, with trees 4 to 8 inches in diameter growing on the surface. Up to this point, and for some distance farther, not a stone or pebble was to be seen, the bluffs along the river appearing to be composed of clay or soft earth, which fell in large masses where undermined by the river.

THE KOWAK CLAYS.

At a point on the river in about west longitude 158°, a remarkable clay bluff, three-quarters of a mile long and 150 feet high, was reached on the left bank of the river. Quantities of mammoth tusks were observed in this clay and its débris, where undermined by the stream. These clays were doubtless of the same age as those in which the mammoth remains are found at Elephant Point over the ice cliffs. Their position is significant, being near the lower end of a tract of open tundra, below the low divides leading northward to the Noatak River and southward to the Selawik Basin, and near where the Kowak River enters a defile which later becomes a sort of canyon obstructed by rapids.

Returning to the ice cliffs, during the explorations of 1885 it was observed that "for miles along the river in this portion of its course these icy cliffs appear and disappear at regular intervals, so that they recur in bends that are parallel with each other." An east-northeast and west-southwest magnetic line drawn through one of the cliffs if prolonged will cut all the others as well as the analogous formation at Elephant Point far to the southward. "Climbing to the top of one if these ice cliffs" Messrs. Cantwell and Townsend pushed their way "through the dense thickets of willow and luxuriant growth of grass into the interior for about 1 mile where we found a shallow lake about a mile in diameter." If the travelers stood still on the peaty soil for any length of time "the spongy moss became saturated and soon a pool of dark-colored water made our position untenable" (op. cit., pp. 48-49). The formation does not extend to the Noatak River, which was explored by McLenegan in 1885.

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[1] Report on the cruise of the Corwin in the year 1885, by Capt. M. A. Healy, U. S. Revenue Marine. Washington. House Ex. Doc. 153, 49th Cong., 1st Sess., 1887; cf. Lieut. Cantwell's Report, pp. 48, 49. Also Science, Dec. 19, 1884, vol. 4, No. 98, pp. 539, 551-554; Jan. 30, 1885, vol. 5, No. 104, pp. 92-93; and Oct. 30, 1885, vol. 6, No. 143, p. 380.

See also Russell (I. C.) Ice Cliffs on Kowak River, Alaska, American Geologist, July, 1890, vol. 6, No. 1, pp. 49-50, and letter of Lieut. Cantwell, following, pp. 51-52.

For these clays, whether independently deposited or found superposed on the ground ice formation, the name of the *Kowak clays* is suggested.

DISTRIBUTION OF FOSSIL VERTEBRATES.

Other Alaskan localities for the animals associated with the clays are the Kotlo River, a stream entering the Yukon from the south above old Fort Yukon and close to the Arctic circle; the valley of the Inglutalik River, which empties into Norton Bay, and of the Ulukak River, which enters Norton Sound at Unalaklik. A lake near Nushagak is stated on Russian authority to afford abundance of similar bones. They are reported from the upper part of the Knik or Fire River, which debouches into Cooks Inlet; and on the Arctic coast, in latitude 71°, at a point called Skull Cliff, Beechey's party obtained remains of an elephant in a clay overlying a low stratum of ice. Wossnessenski collected tusks, teeth, and bones of *Elephas primigenius* and *E. columbi*, near Topanica Creek, Norton Sound. Other remains of the same sort have been picked up on the coast between Bristol and Norton Sound. Teeth of the elephant, bones of *Bison antiquus*, and especially of the musk ox, are not rare on the tundra of the Yukon valley, whence specimens were brought by Dall in 1868. But the Kotlo and Inglutalik rivers have the reputation of affording these bones in extraordinary numbers. Along the Arctic coast, east from Point Barrow, where the bones and ivory occur frozen into the clays, they are so common as to serve the Eskimo carvers for economic purposes. Dall obtained in 1880 a deep ladle, as large as a child's head, carved, handle and all, out of a solid tusk of mammoth ivory by these people. It was said to have come from the mouth of the Colvile River.

Last, but by no means least important, come the discoveries of a mammoth tooth on the island of St. George of the Pribiloff group in 1836, vouched for by Veniaminoff (Unal. I, p. 106) and of tusks and teeth on the island of Unalaska in 1801 according to the report of Dr. Stein.[1] The Ground Ice formation and the Kowak clays have been considered here for several reasons. Though the former may be correlated with the glacial epoch of cold and the latter with the post-glacial era, yet there are certain reasons why this, even if probable, is not inevitable.

ORIGIN OF THE ICE AND CLAY FORMATIONS.

In our ignorance of the chronology of the Alaskan geology it is well to consider alternatives. The fact that the Californian marine Pliocene indicates a colder sea than do the invertebrates of the Pleistocene and that this is confirmed by the evidence of the Oregon and Yakutat fossils which we have called Pliocene in this essay, has been already alluded to. It is quite certain that an elevation of the shores of Bering Sea and the continental shelf lying off them if carried to 200 feet would unite Asia and America; if to 300 feet, would connect the eastern Aleu-

[1] Trudi, mineral. Obst., St. Petersburg, 1830, pp. 382, 383.

tians as far as Umnak and the Pribiloff Islands with America; and would lay bare an enormous level plain covering the northern half and most of the eastern third of the present area of Bering Sea. The diminished body of water which would be left in such a case, in connection with the prevalence of the northwest trade winds over this area, would give to this region such a dry climate as characterizes much of Siberia and the Yukon valley in Alaska. If the elevation took place at the end of the Miocene, as it did in California and Oregon, and as the location and condition of the Nulato sandstones suggests, and if the greatest elevation were toward the west and gradually diminished eastward, we should have conditions favorable for the following results: First, a small precipitation with little snow which with extreme cold and an almost level surface would be unfavorable to the formation of glaciers. Second, the formation by the drainage of the Yukon and other streams coming down from the east of vast shallow lakes of muddy water, the remnants of which in winter, after the escape of the surplus water, might, as now occurs in the same region, freeze solidly to the bottom. Third, the ice thus formed might to a certain extent persist, especially if protected from the sun of the short Arctic summer by a deposit of clay from the spring freshets. Fourth, with a return of a milder climate, though the great mass of this ice might melt and escape with the drainage, that in the more northern and colder region, especially where protected by the clays, might be to some extent conserved and over the clay bogs above it a carpet of Arctic vegetation gradually extend.

The wandering vertebrates, attracted by the luxuriant herbage which we know to flourish in such places, might be trapped in the quagmires which the grasses treacherously conceal. Further elevation by affording better drainage would tend to preserve rather than to waste the hidden stores of ice, while the rivers gradually cutting down their channels would expose the formation when it lay along their path.

That the moderate elevations which exist in the region were insufficient to start the ice thus formed into motion, and thus inaugurate glaciers, may be accounted for on several grounds. First, under the assumed circumstances the ice would always be formed on the lowest places of the level lowlands, coming there as water, and not as snow pressing from slopes. Second, the ice under conditions of very low temperature is without doubt much more rigid than at higher temperatures and by the hypothesis would more or less thoroughly be incorporated at its base with the tough and rigid frozen mud upon which it formed; in fact the ice and soil would practically form one body, while ice formed from snow would always behave more like a body extraneous to the soil. Lastly, the very level character of the region would be unfavorable to motion in the ice, as at present on the Arctic coast where we know the land ice is stationary; while in particular localities, where some motion might take place, the character of the Miocene sandstones upon which most of it must have rested in the absence of alluvium is not well suited to retain any evidence of it.

These suggestions are offered as a basis for discussion, in considering the anomalous geological conditions of northwestern Alaska, until a greater knowledge of the facts may afford a foundation for some more applicable hypothesis.

VOLCANIC PHENOMENA.

It is impracticable to attempt any extended discussion of the volcanic phenomena which have played so important a part in the geological history of Alaska. Much information has been brought together by Grewingk, while later observers have added much more to the total. Volcanic activity still continues, as evidenced by the recent formation of a new peak,[1] the Grewingk volcano, in the immediate vicinity of Bogosloff, itself less than a century old, and to which Grewingk subsequently became joined. It is extremely probable that volcanic action has been long continued in this region, from the time of the Triassic granites to the porphyrites, andesites, and modern basalts. But from the facts which are already known, it seems highly probable that the most profuse and extensive outpourings of basaltic and vesicular lava in Alaska, as in Oregon, Idaho, and California, were of Pleistocene age, and in less intensity have continued subsequently to recent historic times.

NOTE ON THE MAP.

Owing to the small scale of the map upon which the notes could be laid down, but little more has been attempted than to indicate approximately the localities where the specified rocks occur. Only in the Yukon valley and on the peninsula of Kenai has any attempt been made to indicate the boundaries of the areas represented.

PLEISTOCENE.

The epoch of the Pleistocene is practically outside the scope of this paper. It might be said, briefly, that it included in Alaska great changes of level and marked volcanic activity, much as in the case of California. Recent papers by G. M. Dawson,[2] W. P. Blake,[3] I. C. Russell,[4] and G. F. Wright,[5] bear on this topic and may be consulted with advantage.

[1] See A new volcano island in Alaska, by W. H. Dall, in Science, Jan. 25. 1884, vol. 3, No. 51, pp. 89-93; and also Geo. Davidson, in Science, Mar. 7, 1884, vol. 3, No. 57, pp. 282-286, also Aug. 15, 1884, vol. 4, No. 80, pp. 138-139. Also the report on the voyage of the *Corwin* in 1885, previously cited, in which the new and old islands are illustrated.

For observations on the ash and lava of this eruption see:

On Hornblende andesites from the new volcano on Bogosloff Island in Bering Sea, by George P. Merril, Proc. U. S. Nat. Mus. for 1885, pp. 31-33.

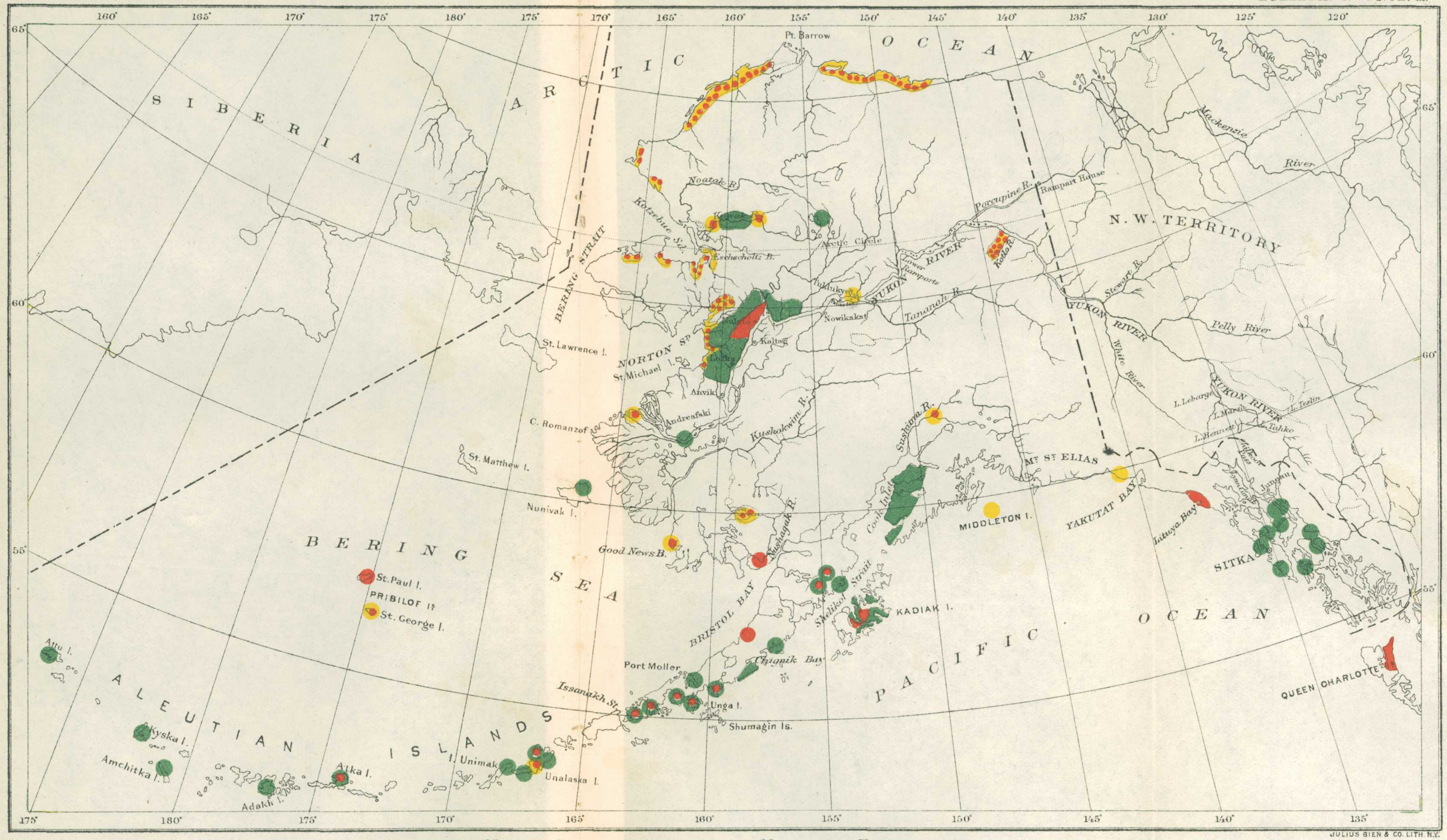
The volcanic sand which fell at Unalaska Oct. 20, 1883, by J. S. Diller, Science, Mar. 30, 1884, vol. 3, p. 651; and lava from the new volcano on Bogosloff Island, by J. S. Diller, Science, Jan. 23, 1885, vol. 5, p. 66.

[2] Transactions Royal Society of Canada, 1890, vol. 8, sec. 4, pp. 3-74.

[3] Glaciers of Alaska, in Am. Jour. Sci., July, 1867, 2d ser., vol. 44, No. 130, pp. 96-101, and Notes on the geography and geology of Russian America and the Stickeen River, H. Ex. Doc. 177, 1868, part 2, Washington, 19 pp., 8°. Also, T. A. Blake, "General topographical and geological features of the northwest ern coast of America," etc., in Coast Survey Report for 1867, App. 18, E., 1869, pp. 281-290, Washington; and W. Libbey, jr., Bull. Amer. Geog. Soc., New York, 1886, 1887, No. 4, pp. 279-300.

[4] Notes on the surface geology of Alaska, Bull. Geol. Soc. of Amer., March, 1890, vol. 1, pp. 99-162, Washington, 8°.

[5] The Muir glacier, Am. Jour. Sci., Jan., 1887, 3d ser., vol. 33, pp. 1-18; also, Bull. Soc. Alaskan Ethn., 1888, No. 2, 8°, 22 pp.



MAP OF THE KNOWN DISTRIBUTION OF THE NEOCENE FORMATIONS IN ALASKA.

BY

W. H. DALL.

Scale

0 100 200 300 400 500 600 MILES.

1891.

- Ground-Ice formation and Kowak Clays with fossil vertebrates (Pleistocene ?)
- Pliocene
- Kenai Group (Miocene ?)
- Kenai Group capped by Astoria beds
- Astoria Group, Miocene, Nulato and Unga beds.

CHAPTER V.

GENERAL CONSIDERATIONS ON THE CENOZOIC EPOCH ON THE PACIFIC COAST OF NORTH AMERICA.

CALIFORNIA, OREGON, AND WASHINGTON.

The conditions prevailing on the Pacific coast during later geologic time, have been considered by Whitney,[1] Becker,[2] G. M. Dawson,[3] and J. L. Le Conte,[4] from whose publications on the subject the following notes have been extracted or condensed.

Except in certain portions of California, the stratigraphical geology is so imperfectly known that all general considerations must be regarded as of a merely approximate character. Much still remains to be learned in regard to the Neozoic faunas before us before we shall be in a position to express positive opinions upon their sequence, faunal peculiarities, and especially their relations to synchronous Atlantic faunas.

Beginning at the south, in California, according to Becker [5]—

> Both the Sierra Nevada and the coast ranges were above water and underwent erosion [in the Cretaceous] during the interval between the Knoxville and the Chico epochs. Both ranges also sank just before the beginning of the Chico, admitting the ocean over a great part of the Coast ranges and over considerable areas at the base of the Sierra. Both appear to have risen partially and gently before the Tejon [Eocene] particularly toward the north; at least the rocks of this epoch as far as is known, are confined to the southern extremity of the Sierra and to the Coast ranges south of the Martinez.
>
> A slow subsidence would seem to have taken place before the Miocene, rocks of this age extending along the Sierra far to the north of the Tejon localities, while in the Coast ranges they lie directly upon the metamorphic at a great number of points, clearly indicating for the Miocene a lower general level than during the preceding epoch. During the Pliocene very little of either range was below water.[6]

Dr. Becker concludes that the information of record necessitates the reference of the Sierra and Coast ranges to a single orogenic system.

> The Coast ranges are, and probably always have been, of less altitude than the great Sierra, and they have consequently been more extensively immersed, just as

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[1] Geological Survey of California; Geology by J. D. Whitney, 1865, vol. 1; also, the Auriferous Gravels of the Sierra Nevada of California, by J. D. Whitney; Mem. Mus. Comp. Zool., 1879; vol. 6, No. 1; and the Climatic Changes of later Geological times, Mem. Mus. Comp. Zool., 1880–'82; vol. 7, No. 2, 4°.

[2] Monographs of the U. S. Geol. Survey, vol. 13, Geology of the Quicksilver deposits of the Pacific slope, Washington, the Survey, 1888. 4°.

[3] On the later physiographical geology of the Rocky Mountain region in Canada, etc.; Trans. Royal Soc. of Canada, 1890, vol. 8, sect. 4. 4°.

[4] Tertiary and post-Tertiary changes of the Atlantic and Pacific coasts: Bull. Geol. Soc. America, 1891, vol. 2, pp. 323-330, Rochester, the society. 8°.

[5] Op. cit. pp. 211–212.

[6] Ibid., pp. 211–212.

would be the case if both were now to sink any given number of thousand feet. Between the Miocene and Pliocene periods the Coast ranges also suffered disturbances in which at least the western base of the Sierra has not shared perceptibly. The Sierra, too, has undergone some faulting in which neither the Coast ranges nor the Basin ranges are known to have shared, but these differences do not appear to me sufficient to counterbalance the important coincidences in the history of the ranges.[1]

A great nonconformity certainly exists between the Mesozoic Knoxville beds and the Miocene, but none such is found between Chico-Tejon and Miocene. The Miocene, as at New Almaden, contains abundant pebbles manifestly derived from the surrounding metamorphic rocks. The post-Miocene uplift traced by Prof. Whitney has folded, faulted, and broken the Tertiary and newer Mesozoic rocks, as well as the older strata upon which these were unconformably deposited, so that it is usually far from easy to make out the effects due respectively to the earlier and to the later disturbances. The earlier was much the more violent, but the comparatively gentle post-Pliocene upheaval certainly extended throughout the Coast ranges of California and Oregon.

Whitney states that the Miocene and Tejon Eocene seem everywhere mutually conformable. Marcou considers that there is an unconformity between them in the vicinity of Fort Tejon. There would not be any necessary reason for supposing that occasional local unconformities may not exist coincidently with a general conformity to which so many observers have borne witness.

Becker observes:[2]

No sensible nonconformity is known to exist between the Tejon and the Miocene, yet the distribution of these two formations appears to indicate a change of level at or near the period which separates them, for the Miocene frequently rests upon the metamorphic rocks without intervention of other beds. During the Tejon these areas of metamorphic rock must have been land, and the subsidence must have been a gradual one. It may have been more rapid in some localities than in others, however, and it thus appears not unlikely that an appreciable lack of conformity may yet be detected[3] at some point or points between the Tejon and the Miocene.

The Miocene occurs on both sides of the Coast ranges and on the lower western flank of the Sierra. It is but sparsely represented in the northern part of California on the coast, and has not been recognized in the northern part of the valley of California, which appears to have been occupied, if at all, by fresh water at this period. The marine beds are composed in large part of sandstones more or less irregular in texture and color, and usually distinctly differentiated from the older rocks. A great area, however, is mostly occupied by extremely fine-grained schists. These are associated with bitumen in the southern part of the State and extend up the coast to Santa Cruz and beyond. These are unusually barren of fossils, while the sandstones often contain almost incredible quantities of shells. The San Benito valley is very remarkable in this respect.

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[1] Op. cit., p. 212.
[2] Op. cit., p. 218.
[3] As in the case observed by Prof. Marcou, above cited.

The Pliocene of the Coast ranges is rather limited in extent, and lies, as shown by Whitney, unconformably upon the Miocene, which is itself greatly disturbed. The combination of these facts shows that a great uplift took place between the two. As before stated, it is often difficult to distinguish in detail the effects of this upheaval from those of the disturbances which preceded the Chico, and Becker adds:

Still later uplifts further confuse the structure of the Coast ranges. In certain localities * * * these effects can be somewhat satisfactorily compared, and it then appears that the Tertiary upheaval, important as it was, was far less violent than that which took place near the beginning of the Cretaceous. * * * Along the western base of the Sierra the effect of the post-Miocene upheaval of the stratified rocks is scarcely perceptible. It does not follow that it produced no effect in this region; on the contrary the absence of known Pliocene beds from the Sierra foothills seems to show that the range was raised considerably at this epoch, though the energy of this movement was insufficient to produce considerable flexure in the beds. At the eastern side of the range, on the other hand, the fresh-water Truckee beds were thrown into bold folds, their dip reaching 30°. The same upheaval was felt throughout western Oregon, where it has the same comparatively gentle character as in the Coast ranges.[1]

In Oregon, as in the south, the Miocene bays and inlets seem at this time to have been definitely shut out from the sea, no marine Pliocene being noted in this region except from the western slopes of the extreme coast.

In California, from the southern border of the state both north and south, marine Pliocene beds have been shown to exist at various points in the Coast ranges and along the shore. The elevation of these beds above the present sea level or below it shows extraordinary variations, the Pliocene of San Diego well extended through at least 20 feet 140 to 160 feet below the surface. At Deadman Island, Santa Barbara County, Pliocene fossils occur near the sea level. On the Monte Diablo range, as elsewhere noted, they have been reported at altitudes of 2,400 to 2,500 feet above the sea in indurated material.

At Shoalwater Bay, Washington, marine Pliocene occurs at about 35 feet above the sea, the fossils exhibiting a boreal facies. If the fossils collected by Mr. I. C. Russell, of the U. S. Geological Survey, near Mount St. Elias, at Pinnacle Pass, be correctly referred to the Pliocene, as seems probable, they are there elevated some 5,000 feet above the sea. The modifications of the shores which have produced such results are such as the mind finds it difficult to grasp when it is considered that the fossils to a very great extent belong to still surviving species of the marine fauna of the coast.

Of the eruptive disturbances in California incident to this series of changes on the eastern side of the Coast ranges the earliest, according to Becker, is a pyroxene andesite, which may have accompanied the post-Miocene upheaval or may have followed it after an interval, probably early in the Pliocene or just before it. It probably was contem-

[1] Becker, op. cit., p. 219.

poraneous with an orographic change which dammed back the large body of fresh water which has been termed Cache Lake, in which, according to Becker, at least a thousand feet of lake sediments with fresh-water fossils were laid down. A few vertebrate fossils, according to Prof. O. C. Marsh, indicate that the beds represent the close of the Pliocene. At the close of this period another eruption took place, accompanied by an orographic change which shifted the waters, which are represented now by Clear Lake, while the lava rests in places upon the older fresh-water strata, which have been shown to correspond to the end of the Pliocene.

From the relation of the eruptive rocks to the sedimentary strata Becker concludes that they are comparatively recent. The andesitic rocks appear at Mount Diablo; at Steamboat Springs, Nevada; they form the mass of Mount Shasta and Mount St. Helens, as well as of the eruptives about Clear Lake. The basaltic eruptions are later and much inferior in volume, though more widely distributed through the region between Clear Lake, San Francisco Bay, and the Panoche Valley. Their emission continued well into the recent epoch.

At the close of the Miocene great masses of soft sandstones were elevated and subjected to erosion, which, from the nature of the material, might be rapid. Becker intimates that the conditions in the Coast ranges do not exclude the hypothesis that the relief of pressure due to the rapid erosion of these soft rocks brought about by fusion of the lavas.

Joseph Le Conte has also touched on this subject.[1] His views in essentials do not appear to differ greatly from those of Whitney and Becker. In brief, he believes that the Sierra was formed at the end of the Jurassic, but during the Cretaceous and Tertiary this range was cut down to a very moderate height, with gentle eastward and westward slopes. The coast ranges were formed at the end of the Miocene, and the Pliocene was a period of fluvial erosion. Orogenic changes took place about the end of the Pliocene in both ranges, latterly accompanied by enormous outpouring of the lava and displacement of the river courses. These changes did not greatly affect the river courses of the Sierra region until the lava streams interfered and the faulting of the Sierra steepened the western slope. Subsequent continental subsidence submerged the deserted channels of the Pliocene rivers at the coast and preserved their traces in the sea bottom. Elevation since then has been insufficient to restore the old levels, and these channels still remain below the sea.[2]

The relative heights of the various marine beds and character of the deposits, both on the coast and in the interior, as described by Becker and Diller, show that the northern and southern parts of California did not participate equally in the changes of level, and that the changes were probably not altogether synchronous.

[1] Tertiary and post-Tertiary changes of the Atlantic and Pacific coasts. Bull. Geol. Soc. of Am., Mar., 1891, vol. 2, pp. 323-330, Rochester, the society.

[2] Op. cit., pp. 325-327.

In Oregon the variations in a vertical sense seem to have been less marked than was the case in southern California or in the southern part of Alaska, while the changes on the coast of British Columbia seem to have been somewhat intermediate between those exhibited in Oregon and those of Alaska.

BRITISH COLUMBIA.

For information in regard to the British Columbian region, we are chiefly indebted to Dr. George M. Dawson, of the Dominion geological survey. Dawson's views have appeared in his important paper on the Rocky Mountain region of Canada.[1] According to him, in the region of the fortieth parallel surveyed by King, during the Eocene period many thousand feet of beds holding characteristic fossils were laid down in a series of lakes between the Rocky Mountains and the Sierra Nevada, but no such deposits have been met with in any part of the northern Cordillera. The whole sweep of country from the Laurentian region possibly quite to the now submerged edge of the Continental Plateau on the Pacific side thus became and continued to be throughout the earliest Tertiary an area of denudation, within which, if any small area of deposition occurred, the beds formed in these have either been subsequently removed or have become concealed by later deposits. The main result referable to this period of denudation is the first interior plateau or peneplain, as Davis has called the proximately level denudation surface thus formed. Extensive though more or less disconnected fragments of this still exist. The limits of the Interior Plateau of to-day near coincide with the limits of the drainage system, which probably discharged in a northerly direction. A good deal of erosion is supposed to have occurred before the initiation of Miocene sedimentation.

By an interruption of the drainage produced in some way, perhaps by the post-Eocene disturbances, of which the effects have been noted in California, great Miocene lakes were formed in that portion of British Columbia lying between the Coast and the Gold ranges. The character of the Miocene flora seems to indicate that the land did not stand at any great height and that the climate was temperate. The Interior Plateau became the seat of a series of lakes of greater or less dimensions, some of which were formed later than others. As far northwest as the Francis River and quite beyond the limit of the Interior Plateau deposits which are referred to the Miocene have been found, and beds which are believed to belong to the same stage again occur on the Porcupine branch of the Yukon. Lakes which are with some probability referred to the same period also existed in some parts of the Columbia-Kootanie valley and in that of the Flathead River, though no definite paleontological evidence of their age has been obtained.

[1] In the notes here given the data bearing on the British Columbian Neocene have been briefly summarized from Dawson's discussion, op. cit., pp. 3-74.

Had the conditions remained permanent the lacustrine phase of the Interior Plateau would have terminated by the filling up of some lake basins and the drainage through erosion of the effluent river beds of others. Before this had taken place volcanic action recommenced on a grand scale and in a varied manner, while large areas were covered with sheets of lava, which flowed out in great volume. The principal centers of action appear to have been aligned along the eastern base of the Coast ranges, where some of the old volcanic vents may still be recognized.

According to evidence produced by Becker the great andesite lava flow of California took place near the end of the Pliocene and may be regarded as terminating that epoch. He shows that the basaltic eruptions of that region at least are considerably later. Prof. Le Conte believes that the ejection of basalts in Oregon took place earlier, at the close of the Miocene or early in the Pliocene.[1] The last-named region closely corresponds with the interior plateau of British Columbia, but here, according to Dawson, the evidence of the blending of the Miocene lake beds, with the eruptives is in some places so distinct as to justify us in assigning the earliest eruptives to the Miocene period itself. In intervals of the periods of eruptive activity lakes or ponds were formed and have left their traces. Some of these may yet afford organic remains of later date than the Miocene. The recurrence of volcanic phenomena during a considerable length of geological time is shown by the cutting out of valleys in the basalts and the refilling of these by later basalts as in the Stikine region. That volcanic action may have continued into the Pliocene period can not be denied, and we may add to Dawson's observation that in view of the almost continuous action of this sort to the present epoch in the regions both north and south of British Columbia on the Pacific coast, it would be most extraordinary if it did not. Still no proof of Pliocene eruptions in British Columbia has yet been obtained, though owing to the uncertainty which attaches to the definition of Miocene and Pliocene on the northwest coast and the absence of distinctive physical changes by which a strict subdivision of the Cenozoic strata could be established, such negative evidence is not of great weight.

Taken as a whole, in regard to the interior plateau of British Columbia, the Miocene was a period of lacustrine sedimentation followed by an outpouring of eruptive matter so complete as entirely to obliterate the old Eocene and earlier Miocene valleys of which it is doubtful if any one has since been eroded in exactly its old course for any considerable distance.

Toward the end of the Miocene, local folding of the strata, volcanic or otherwise, took place in various directions, after which without any considerable change of the general level, the drainage began to outline an entirely new series of river and stream valleys. The general erosive

[1]Am. Jour. Sci., 3d ser., vol. 19, p. 189, and vol. 32, p. 177.

action thus inaugurated was probably long continued and brought the interior plateau again nearly to the base level of erosion.

The early Miocene valleys, where they may yet be studied, according to Dawson, present all the characters of a drainage system which has been long maintained under stable conditions of the surface.

At a later time in the Pliocene it is evident, that a very considerable and general elevation of the Cordilleran region occurred, bringing it considerably higher than it is at the present day. The gradients of all the rivers being thus increased, the streams, armed with new power of erosion, began to cut channels, which, as they were cut rapidly, were made both deep and narrow. To this time Dawson assigns the cutting out of the deep valleys which now exist as fiords of the coast. Admitting that these fiords may have been to some extent locally enlarged by ice during the later period of glaciation, their depth is such as to convince him that during all the main period of their formation in the Pliocene, the land stood relatively to the Pacific about 900 feet higher than it does now.

Important changes in the drainage system of northwest America were produced by this Pliocene elevation, and to the subsequent erosion, the genesis of the deep preglacial auriferous gravels is assigned with much probability.

The results of Pliocene erosion are geographically very important, as the whole effect of subsequent events can be shown to have been relatively insignificant and the main features of much of the country still remain much as they were at the close of this epoch.

On the seacoast it appears probable that as a result of the Pliocene uplift referred to, a belt of low land wide enough to include Vancouver Island and the Queen Charlotte Islands was formed. Across this the rivers issuing from the Coast ranges cut their way to the sea.

Meanwhile over the interior, in place of lacustrine sedimentation such as King described[1] south of the boundary, Dawson regards the known data as indicating for most of the Pliocene a process of reduction by waste. Certain deposits of gravel, sand and silt found in a number of places in the districts of Alberta and Assiniboin have been named by McConnell the South Saskatchewan gravels. They rest indifferently on various formations and lie beneath the lowest Glacial bowlder clays. These deposits have been assigned to the Pliocene on the ground that any preglacial beds should be so referred. Their material is derived from the antecedent Miocene beds and has been rearranged in the beds of streams or lakes.

It would appear, according to Dawson, that the Pliocene uplift of the Cordilleran region of British Columbia did not materially affect the interior plateau. This uplift in itself he does not regard as sufficient to bring about a glaciation, but considers it possible that at the end of the Pliocene a second uplift may have taken place, though this has

[1] Expl. 40th parallel, vol. 1, pp. 542, 756.

probability rather than ascertained facts in its favor. If as suggested, the Pliocene was terminated by such an uplift with the inauguration of glaciation as one of its results (the presence of other factors coinciding to promote glaciation being assumed), the interior plateau seems not to have participated, but rather to have suffered a possibly compensatory subsidence.

ALASKA.

In Alaska we are chiefly dependent on the information summarized in the earlier part of this essay for our knowledge of any changes which have taken place.

Since no marine Eocene beds are known from any part of Alaska, it must be assumed that the coasts of the territory which had been elevated at the end of Mesozoic time stood at an elevation not less than they do at present, and probably considerably higher, since the material accumulated in the 2,000 to 3,000 feet of strata of the Kenai group which were laid down in the lakes or marshes must have been derived from higher ground. At the end of the Kenai period the shores at least would seem to have stood at only a moderate elevation above the sea, since the marine sandstones of the Astoria group appear conformably above them, and all the circumstances indicate for the early Miocene only a very gentle and vertically small depression, as the beds are everywhere thin, and toward the south disappear altogether. This would point toward a stationary condition in southern Alaska, a moderate depression near the peninsula and to the north in the Yukon valley a greater subsidence, since there the marine strata are the thickest.

At the end of the marine Miocene the elevation which followed appears to have been somewhat proportional to the previous subsidence, i. e., it was greater in the north where no part of the present land surface is known to bear any later beds of marine origin, moderate to the south, and perhaps on the coast of southernmost Alaska and British Columbia no very great changes took place, or if there did, most of the traces have been since removed by glacial action.

After the inauguration of the Pliocene, some part of the southern coast subsided slightly, and marine beds indicating a moderate depth of water were laid down. Later on there was a moderate elevation of the same region. At the end of the Pliocene southern Alaska participated in the throes which agitated the rest of the Pacific border and an enormous uplift of the recently formed strata followed, attended or rapidly followed by great volcanic activity. Elevation to the north was apparently much less marked.

There does not appear to be any positive evidence of marked vertical motion in southern Alaska since this time, and to the north also the early Pleistocene appears to have been a time of comparative rest.

Later, both north and south eruptive movement became very active, though not necessarily associated with any great changes of level. In comparatively recent times a moderate subsidence seems to be probable in northern Alaska, though at present there are indications that the coast is rising. But local volcanic action has brought about minor changes of level in many places, while toward the south denuding agencies seem to have had the field almost wholly to themselves.

In glancing over the appended table it will be observed that the entire coast seems to have felt certain vertical motions, while at other times action in that sense seems to have alternated more or less along the coast. In the present imperfect state of our knowledge, however, it would be inadvisable to insist too urgently on the significance of apparent changes, of which the details are yet unknown.

Table indicating conditions existing during Cenozoic time in regard to changes of level and the prevalence of volcanic emissions on the Northwest coast.

Epoch.	Southern California.	Northern California.	Oregon.	British Columbia.		Southern Alaska.	Northern Alaska.
				Coast.	Interior.		
Upper Cretaceous	Depressed	Depressed	Depressed	Depressed	Depressed	Depressed	· (?)
Tejon Eocene	Stationary	Elevated	do	Stationary (?)	Elevated	Elevated	Elevated.
Leaf beds of Kenai	Depressed (?)	Stationary (?)	Stationary	Mod. elevation	Stationary	Mod. elev	Mod. elev.
Astoria Marine Miocene	Depressed	Mod. depression	Depressed	Mod. depression	Stationary (?)	do	Depressed.
End of the Miocene	Mod. uplift, V	Gt. uplift, V	Uplift, V	Uplift, V	Gt. eruptions	Stationary	Uplift.
Marine Pliocene	Mod. depression	Mod. depr	Mod. depr	Stationary (?)	Stationary, V	Mod. depr	Stationary.
Later Pliocene	Mod. uplift	Mod. uplift	Mod. uplift	Mod. uplift	Mod. uplift (?)	Mod. uplift	Stationary, V.
End of the Pliocene	do	Gt. uplift, V	do	Gt. uplift	Stationary (?)	Gt. uplift, V	Mod. uplift.
Early Pleistocene	Gt. depr., V	Mod. uplift	Mod. depr	Elevated	Depressed (?)	Stationary	Stationary.
Later Pleistocene	Gt. uplift	Stationary (?), V	Mod. uplift	Stationary	Stationary	Stationary, V	Mod. depr., V.

In this table "depressed" means stationary at a low level; "Mod. depression" that a moderate subsidence occurred; "elevated" means stationary at a high level; "Gt.," "Mod." or simply "uplift" that a great, moderate, or other movement of elevation took place; "V," indicates that the period was one of volcanic or eruptive activity. It will be borne in mind that in making the table attention has been concentrated rather on the coastal region and the changes indicated by sediments with fossils, than on the more interior country and the changes in the crests of mountain ranges.

Table showing the vertical range of the Neocene formations of the Pacific coast.

	Miocene.			Pliocene.				Formations.
	—	—	—					Astoria group.
	—	—	—					Astoria sandstones.
	—	—						Astoria shales.
—								Aturia bed.
?—	—?	—?	—	—	—	—	?	Auriferous gravels.
						—	—	Cache Lake beds.
?								Calamite beds.
			—					Crepidula bed
						?—	—?	Dalles group.
						—	—	Ground Ice formation.
—	—?							Kenai group.
						—	—	Kowak clays.
						—		Mytilus bed.
	—							Nulato sandstones.
—?								Puget group.
			—					Solen beds.
—	—?							Unga conglomerate.

CHAPTER VI.

SUMMARY OF OUR KNOWLEDGE OF THE SUPPOSED NEOCENE OF THE INTERIOR REGION OF THE UNITED STATES, CONSIDERED BY STATES.

Many difficulties are encountered in attempting to correlate the various formations which have been recognized and named in the Great Interior region. Not only are many of the formations imperfectly known and described in the literature, and some of them unmapped, but many of them are characterized by their local lithologic or stratigraphic peculiarities, and the fossils they contain are not of a sort to be depended upon as indices of stratigraphic position.

Furthermore, some of the localities have been indicated only in the most general manner, so that it has been impracticable to record them on the map; and in regard to the age of formations exposed at these localities the most eminent authorities are uncertain or differ widely in their conclusions. Hence the present attempt to present a summary of what is known is offered with a full appreciation of its imperfections, which the compilers have been unable to remedy.

The States and Territories have been taken up in geographic sequence, beginning with the region of eastern Oregon and passing eastward by Idaho, Montana, the Dakotas, south through Nebraska, Kansas and Indian Territory, north again through New Mexico, Colorado, and Wyoming, concluding with Utah and Nevada.

OREGON.

FRESH-WATER TERTIARIES.

We have already referred to the fact that in northern California old lake deposits of Miocene or Pliocene age have been to a considerable extent overspread and concealed by vast sheets of lava. In Oregon the sequence of deposition and concealment was practically the same; yet, owing to the fact that these lake deposits contain numerous well-preserved and characteristic vertebrate remains, we can speak with much more confidence regarding the age of their subdivisions than we could of their probable representatives in northern California.

John Day valley.—Perhaps the most important and interesting locality where these lake-beds are exposed is in the valley of the John Day River, a southern tributary of the Columbia. It is clear that the Blue Mountains formed the eastern and perhaps southern shores of the lakes whose deposits are now referred to, but their other limits are rendered indeterminable by the successive outflows of volcanic rocks. The Rev. Thomas Condon discovered[1] and first explored these beds, but they have subsequently been visited by Marsh, Wortman, Sternberg, and Bendire, all of whom have made extensive collections.

Amyzon group?—The oldest Tertiary deposit of this basin is a series of fine grained shales, varying in color from white to reddish brown, and containing plant and fish remains. The plant remains have been reported upon by Lesquereux in the proceedings of the U. S. National Museum for 1888, under the head of "Specimens from Van Horn's ranch, John Day Valley, Oregon, collected by Capt. Chas. Bendire, U. S. Army" (pp. 13–19). The age of the bed whence these specimens are derived is said to be "Miocene; probably latest Miocene." Some of the fish remains were found to be in a condition sufficiently good for identification. "They include," says Cope,[2] "four individuals which belong to a single species of the genus *Plioplarchus*," *P. septemspinosus*. This author continues:

> As the shales are, according to Condon, below the John Day beds of the Middle Miocene, they can not be the Upper Miocene of the vertebrate scale. *Plioplarchus* has not been found in the Amyzon beds, and the plants of that horizon are, according to Lesquereux, different from those from Van Horn's ranch. The shale may then represent a horizon later than the Amyzon beds, but earlier than those of the John Day. In spite of the evidence of the plants, they may be even older than the Amyzon beds, since the bed of the Dakota *Plioplarchus whitei* is not distinguishable stratigraphically from the Laramie at its summit, according to Dr. White, a statement which I can confirm by personal observation.

John Day group (?=Truckee group).—This group, according to Marsh,[3] attains an enormous development in the valley under consideration. Prof. Cope characterizes its mammalian fauna as follows: "Presence of *Nimravidæ*, *Poebrotheriidæ*, *Tragulidæ*, *Elotheriidæ*, *Suidæ*, *Muridæ*, and *Saccomyidæ*. Absence of *Lemaroidea* and *Creodonta*, of *Hystricidæ*, *Felidæ*, *Ursidæ*, *Camelidæ*, *Equidæ*, and *Proboscidia*." Its vertebrate remains are numerous and have received much attention from Marsh,[4] Leidy,[5] and Cope,[6] all of whom agree that the fauna was in part contemporaneous with that of the White River group of South Dakota. Cope and King,[7] moreover, have no hesitation in correlating it as a whole with the Truckee beds of Nevada.

In a recent publication[8] Drs. White and Stearns have determined a few species of land and fresh water mollusks which were found by

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[1] Marsh, Am. Jour. Sci., 3d ser., 1875, vol. 9, p. 52.

[2] Am. Nat., 1889, vol. 23, p. 625.

[3] Am. Jour. Sci., 1875, 3d ser., vol. 9, p. 52.

[4] Am. Jour. Sci., 1873, 3d ser., vol. 5, 409–410; also, Am. Jour. Sci., 1874, 3d ser., vol. 7, p. 249–250; also, Am. Jour. Sci., 1875, 3d ser., vol. 9, p. 242, 248, 249; and Am. Jour. Sci., 1877, 3d ser., vol. 14, p. 248.

[5] U. S. Geol. Survey Terr., 1873, vol. 1, p. 210.

[6] Proc. Am. Philos. Soc., Dec. 1, 1878 (Paleont. Bull. No. 30); see also Am. Nat., Dec. 1, 1878, p. 833; and Bull. U. S. Geol. Survey Terr., 1879, vol. 5, pt. 1, pp. 55–67; U. S. Geol. Survey Terr., 1884, vol. 3, bk. 1.

[7] U. S. Geol. Explor. 40th Parallel, 1878, vol. 1, p. 413, 458.

[8] U. S. Geol. Surv. Bull. No. 18.

Messrs. Wortman and Condon associated with vertebrate remains *Unio condoni* and *Helix* (*Mesodon?*) *dalli* are described as new to science, while *Helix fidelis*, *Helix perspectiva*, and *Gonostoma yatesii* are well known living forms. The modern aspect of this fauna is indeed remarkable when we take into consideration not only its supposed synchronism with the unique faunas of Fossil Hill, Nevada, and Snake River, Idaho and Oregon, but also when we consider what remarkable physical changes have taken place in this region since these mollusks existed.

Truckee group.—Deposits classified under this head are typically exposed in northern Nevada and are supposed by King[1] and others to be synchronous with the John Day group of Oregon. The arguments for or against this view seem far from convincing. Nevertheless, if it is admitted that the fresh-water beds of southwest Idaho, to be described hereafter, which have furnished specimens[2] of *Latia dalli*, *Melania taylori*, and *Lithasia antiqua*, belong to the Truckee group, then it is reasonable to suppose that the beds along Powder River, Old Emigrant road, and those on the eastern slope of Blue Mountains, Union County, all investigated by Condon[3] and found to contain *Lithasia antiqua* and a large *Vivipara*, may be true representatives of this group.

Ticholeptus beds.—These beds are known to exist in the John Day basin from the notes and collections of J. L. Wortman. They are said[4] to rest upon John Day beds along Cottonwood Creek and contain the following species: *Protohippus* sp., *Hippotherium seversum*, *H. sinclairi*, *H. occidentale*, *Anchitherium ultimum*, *Dicotyles condoni*, *Protolabis transmontanus*, *Merycochœrus obliquidens*, and *Blastomeryx borealis*.

"Considerable interest attaches to the discovery of an *Anchitherium* and of a *Merycochœrus* at this locality, as these genera ally the epoch to the John Day period, while *Hippotherium*, *Dicotyles*, and *Protolabis* are Loup Fork genera."[5] *Blastomeryx borealis* is the only species in common with this and the Deep River, Mont., Ticholeptus bed.[6]

PLIOCENE LAKE BEDS.

The so-called "Idaho group" of Cope probably extends into eastern Oregon somewhat as represented on the accompanying map. The statements of King regarding the outlines of his Shoshone Lake in this district are exceedingly vague; but Cope states[7] definitely that, of the four species of *Cottus* that have been found in the Idaho beds, one at least (*C. divaricatus*) and probably two others (*C. hypoceras* and *pontifex*) were from Willow Creek, Oregon. These beds, as will be seen

[1] U. S. Geol. Explor. 40th Parallel, 1878, vol. 1, p. 423.
[2] Proc. U. S. Nat. Mus., 1882, vol. 5, pp. 99–102, pl. V.
[3] Information furnished Mr. Dall by Prof. Condon. See discussion of this group under Idaho.
[4] Am. Nat., 1886, vol. 20, p. 367.
[5] Am. Nat., 1886, vol. 20, p. 368.
[6] Ibid., p. 369.
[7] Proc. Phila. Acad. Nat. Sci., 1883, pp. 162–164.

under "Idaho," are considered by Cope to be of lower or medial Pliocene age.

There is, however, another lake deposit of Oregon which this author regards as "very probably the contemporary of that of the Pliocene lake of Idaho."[1] Its locality is not given, but it is said to contain the following remains: *Canis* sp., *Elephas* or *Mastodon*, *Holomeniscus* or *Auchenia*, *Aphelops* sp., *Hippotherium relictum*, and *Equus* sp.[2] "The interest of the list consists in the fact that it represents for the first time a fauna which 'includes the large true horses and llamas and the three-toed horses and *Aphelops* rhinoceros. The latter forms belong to the Loup Fork horizon and the former to the Pliocene, and they have not been found hitherto in association in the Rocky Mountain region."[3]

Another lake bed, of more recent date, is that known as the "Fossil lake" or "Lone yard" situated about 40 miles east of Silver Lake. It forms a slight depression embracing perhaps 20 acres.[4] "The depth of the formation is unknown, butit is probably not great. It consists, first, of loose sand above, which is moved and piled into dunes by the wind; second, of a soft clay bed a few inches in thickness; third, of a bed of sand of one or two feet in depth; then a bed of clay mixed with sand of unknown depth. The middle bed of sand is fossiliferous."[5] Whitened shells of *Carinifex newberryi* Lea, as well as obsidian implements of various degrees of workmanship, are strewn abundantly over the surface. Similar implements are represented by Cope as "mingled in the same deposit in undistinguishable relation" with the fossil remains of this place. They are in some instances covered by a deposit of volcanic sand and ashes to a depth of from 15 to 20 feet.[6]

General discussion of the Equus beds.—The numerous vertebrate remains in the lake basin just described are regarded by Cope as constituting a typical *Equus* fauna. Therefore a general review of the history and fluctuation of opinion regarding these beds may properly be given in this place.

The term Equus beds was first used to denote a subdivision of the geologic scale by Prof. Marsh in an address read before the American Association for the Advancement of Science in 1877. No attempt was then made to give the geographical distribution of these beds; nor, in fact, was much more information imparted than that "our Pliocene forms essentially a continuous series, although the upper beds may be distinguished from the lower by the presence of a true *Equus* and some other existing genera." On the plate accompanying the author's edition of this address the Pliocene is subdivided into *Pliohippus* and

[1] Am. Nat., 1889, vol. 23, p. 254.

[2] Ibid., p. 253.

[3] Ibid., p. 254. They are, however, associated in the Peace Creek beds of Florida. Cope described several Pliocene species from Oregon, collected by Sternberg, in Proc. Am. Philos. Soc., 1877, vol. 17, pp. 230, 231. No definite localities are given.

[4] Am. Nat., 1889, vol. 23, p. 979.

[5] U. S. Geol. Surv. Terr., 1884, vol. 3, book 1, p. 19.

[6] Am. Nat., 1878, vol. 12, p. 126.

Equus beds, the latter being characterized by the genera *Equus*, *Tapirus*, and *Elephas*. Since that time these beds have been recognized in Washington, Oregon, Idaho, California, Nebraska, Kansas, and Texas at such localities and under such conditions as will be found given under these several states.[1]

According to Cope the fauna of these beds is characterized by the presence of *Glyptodontidæ* (Mexico), *Megatheriidæ*, *Eschatiidæ;* extinct genera, *Holomeniscus*, *Mastodon* (Mexico), *Smilodon* (Texas); extinct species, *Elephas primigenius; Equus*, four species; *Lutra*, *Cervus*, etc.; recent species of *Thomomys*, *Arvicola*, *Castor*, *Canis*,*?* *Homo*. Absence of *Cosoryx*, *Oreodontidæ*, *Protolabiidæ*, *Raiidæ*, *Cobitidæ*, *Mylocyprinus*, and the fishes of the Idaho beds in general, *Castoroides* and *Amblyrhiza*.

Much difference of opinion has already arisen regarding their age. Marsh, we have seen, first referred them to the upper Pliocene; in this he has been followed by Cope, King, and others, the first of whom remarks:

As a conclusion of the comparison of the American *Equus* beds in general with those of Europe, it may be stated that the number of identical genera is so large that we may not hesitate to parallelize them as stratigraphically the same. On the other hand the agreement with the South American Pampean formations is so marked in some respects as to induce us to believe that the distinction is geographic rather than stratigraphic. Believing that the Pampean formation contains too large a per cent of extinct genera to be properly regarded, as it has been, as post-Pliocene or Quaternary, its characters, both essentially and as a result of the comparison which I have been able to make, refer it properly to the Pliocene. It appears, then, that the term Pliocene or Subappenine is applicable to the horizon of this fauna in Europe and North and South America.[2]

G. K. Gilbert,[3] however, in Monograph No. 1, U. S. Geological Survey, on Lake Bonneville, devotes one chapter to a discussion of the "Age of the Equus Fauna" and endeavors to show that it is late Pleistocene. The essential points of the arguments he employs to reach this result may be thus briefly summarized:

(1) The three genera mentioned by Marsh, viz, *Equus*, *Tapirus*, and *Elephas*, are all credited to the post-Tertiaries, while none are credited to the lower Pliocene. "The characterization thus fails to separate the Equus fauna from the Pleistocene."

(2) The post-Tertiary age of the Lahontan beds being well established it necessarily follows that Christmas Lake Equus beds are of this age, since (*a*) the physical history of each has been the same and (*b*) they contain several vertebrate and invertebrate species in common.

(3) "The abandoned lake shores of Christmas valley and of the Lahontan basin, the lacustrine plains below them, and the correlated glacial moraines are all of youthful habit, as youthful as the parallel roads of Glen Roy and other surface features marking the wane of glaciation in Scotland."

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[1] See, also, Cope: Rept. U. S. Geol. Surv. Terr., 1884, vol. 3, book 1, p. 19.
[2] Bull. U. S. Geol. Surv. Terr., 1879, vol. 5, p. 48.
[3] Op. cit., pp. 393–402.

(4) By comparing the Christmas Lake fauna with European standards, it is found that its age falls between the upper Pliocene of the Arno valley and the middle of the Pleistocene of Great Britain. Hence this evidence alone might indicate an *early* Pleistocene age for this fauna; it is, however, outweighed by the foregoing considerations.

Dalles group.—Above the Loup Fork beds of the John Day basin, there is a lava outflow which has furnished the materials for a late lacustrine formation, which contains many vegetable remains.[1] The material is coarse and sometimes gravelly, and is found on the Columbia River and probably also in the interior basin. Prof. Condon calls this the Dalles group.[2] It is in turn overlain by the beds of the second great volcanic outflow. The exact horizon of this group has not been determined. It may be synchronous with the "Equus beds."

IDAHO.

TRUCKEE GROUP.

In Vol. II, Paleontology of California, Gabb figures and describes[3] two species of fresh water Tertiary mollusks from "deposits on Snake River, Idaho territory, on the road from Fort Boise to the Owyhee mining country." These species, *Melania taylori* Gabb, and *Lithasia antiqua* Gabb, were said to be associated with a small bivalve, perhaps a species of *Sphærium*, too poorly preserved to admit of description.

Meek described a *Sphærium? idahoensis* from "Castle Creek" in the Proceedings of the Philadelphia Academy of Sciences in 1870 (vol. 22, p. 57) repeating the same and adding two figures in 1877.[4] This is given as a Tertiary species of the Fossil Hill, Nevada, horizon. To these species of southwestern Idaho, Dr. White[5] added one more in 1882, viz, *Latia dallii*, which is said to have come from "50 miles below Salmon Falls, Snake River," and was associated with *Melania taylori* and *Lithasia antiqua.*

Much confusion has already arisen concerning the horizon of these molluscan forms. This may be stated briefly as follows: In 1870 Meek[6] correlated certain deposits on Castle Creek, Idaho, with others at Fossil Hill, Nevada, by identifying "*Sphærium? idahoense*" from both localities. King having applied the name Truckee group to the beds containing this species at Fossil Hill,[7] would presumably include the Castle Creek beds in the same group; at least he has been quoted[8] as doing so. Dr. White goes still further and states that Gabb's two species evidently come from this same geological horizon, hence they all belong to the Truckee Miocene.

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[1] Am. Jour. Sci., 1879, 3d ser., vol. 18, p. 408.
[2] Am. Nat., 1880, vol. 14, p. 458.
[3] Op. cit., p. 13, pl. 2, figs. 21, 22.
[4] U. S. Geol. Explor. Exped. 40th Parallel, vol. 4; pt. 1, p. 183, pl. 16, figs. 1, 1*a*.
[5] Proc. U. S. Nat. Mus., 1882., vol. 5, p. 100, pl. v, figs. 17–20.
[6] Proc. Phila. Ac. Nat. Sci., 1870, p. 57. Notice that Meek here gives other fossils from "Idaho territory." This should read Nevada. See vol. 4, U. S. Geol. Surv. Terr., "Ornithology and Paleontology."
[7] U. S. Geol. Surv. Terr., 1878, vol. 1, p. 420.
[8] Dr. C. A. White: Proc. U. S. Nat. Mus., 1882, vol. 5, p. 99.

From Castle Creek and other localities in southwestern Idaho, Cope[1] has described numerous fish remains, referring them all to his "Idaho group, or "beds," which he regards as of lower or middle Pliocene age.[2] To this same group he refers Meek's molluscan species from this creek and from Fossil Hill, as well as Leidy's *Mastodon mirificus* and *Equus excelsus*[3] from Sinker Creek, Idaho. Accordingly Truckee group (King) and Idaho group (Cope) become synonyms. If so, in judging by Cope's determination of the age of the latter, the Truckee group must be of Pliocene age. Something of the kind has been suggested by Cope,[4] though for this he gives Dr. White as authority.

The fossiliferous deposits here referred to are of limited geographic extent, as may be seen by consulting the accompanying map. Igneous rocks are met with on all sides. King calls special attention to the fact that in southwestern Idaho "there are two sets of Pliocene strata, separated by basaltic eruptions.[5] He states, moreover, that—

> Sections obtained along the plains between the Owyhee Mountains and Snake River show that a considerable portion of the beds of the valley, which consist chiefly of white sands and marls carrying numerous well defined Pliocene forms, were overlaid by large accumulations of basaltic flow, and that subsequently a second period of lacustrine deposition took place, likewise characterized by Pliocene forms, the latter representing a more advanced stage of development and more recent type than those beneath the basalt.

SALT LAKE GROUP.

By looking at maps 2, 4, and 5 accompanying Hayden's Twelfth Report[6] it will be seen that certain deposits exposed along the borders of Malade, Cache, Port Neuf, Upper Port Neuf, and Bear Lake valleys have been assigned an upper Tertiary age and have been termed the "Salt Lake group."[7]

It seems indeed possible, if not probable, that these various beds, which are made up of clays, sands, marls, limestone, and shales,[8] may have been deposited in outliers of the great Shoshone Lake of King,[9] and, if so, they are synchronous with the Humboldt group of that author.

This so-called Salt Lake group has yielded few fossils in this part of the state. In Utah, however, near "The Gates," Peale has recorded numerous genera of fresh-water mollusca, *Limnæa*, *Valvata*, *Planorbis*, *Sphærium*, *Bythinella*, *Physa*, *Vivipara*,[10] etc.; but these furnish no definite clue as to the age of the group.

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[1] Proc. Phila. Acad. Nat. Sci., 1883, pp. 153–166.
[2] Amer. Nat., 1889, p. 254.
[3] Proc. Phila. Acad. Nat. Sci., 1870, p. 67, and 1883, p. 166.
[4] Am. Nat., 1877, 456, et in litt.
[5] U. S. Geol. Surv. 40th Parallel, 1878, vol. 1, p. 440.
[6] Maps and Panoramas: Twelfth Annual Report of U. S. Geol. and Geog. Survey of the Territories, 1878.
[7] Fourth An. Rept. U. S. Geol. and Geog. Survey Terr., 1870, p. 169.
[8] Eleventh Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1877, pp. 604–605.
[9] U. S. Geol. Explor., 40th Par., 1878, vol. 1, p. 456.
[10] Eleventh Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1877, pp. 604–605.

The *Vivipara*, however, if correctly named, is of much interest, owing to the fact that it is not known west of the Rockies alive. Its occurrence in various places in central and eastern Oregon is referred to in the discussion of that state.

This group is sometimes overlain by Quaternary sedimentary deposits, as by the Cache group in the valley of that name,[1] but not unfrequently it is capped by a bed of basalt as along the low range of hills that border the east side of the great Snake River basin, especially from Port Neuf Canyon northward.[2]

The beds of this group are generally somewhat inclined, though generally at a low angle, rarely exceeding 10°, and always in the same direction as the inclination of the underlying formations.[3]

MONTANA.

NEOCENE LAKE BEDS.

Passing from Idaho, over the "divide" into Montana, beds of Neocene lacustrine materials are found well developed in the valley of Red Rock Creek, one of the head branches of the Jefferson fork of Missouri River. These beds are often several hundred feet in thickness, and consist for the most part of a

light gray marl, with concretionary masses, and a sort of pudding stone.[4] In these concretions are often inclosed masses of basalt, which occur here and there all over the country. While we have the evidence of a period of effusion subsequent to the deposition of these lake beds, from the fact that the basalt lies over them, we see by these isolated masses frequently that there were other periods either before or during the Pliocene. At one locality I found in these lake deposits the fossil remains of a species of *Anchitherium*[5] and a land snail (*Helix*). The inclination of these modern beds is west 5°.

Fort Ellis beds.—In the vicinity of Fort Ellis Peale describes[6] bluffs composed of "Pliocene" sandstones, marls, and conglomerates.

The strata are for the most part horizontal, although inclined sometimes at a very small angle, which is never more than 5°. The height of these bluffs above the level of the creek is 175 feet. They are remnants of Pliocene formations that once spread over the entire valley of the Gallatin and formed the bottom of the vast lake that spread over what are now the valleys of the Jefferson, Madison, and Gallatin rivers, reaching to the junction of the three streams. * * * Each of the rivers has cut deeply into these Pliocene rocks, and their valleys are the results of the erosion that has taken place since the draining of the ancient lake.

The "Pliocene" sandstone and marls of the Yellowstone valley are capped by basaltic plateaus.

Deep Creek beds.—Still farther to the east, along Deep Creek, exist

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1 Eleventh Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1877, p. 603.

2 Fifth Ann. Rept. U. S. Geol. and Geog. Survey, Terr., 1871, p. 25.

3 For a description of certain volcanic ash deposits in this part of the State, termed "Pliocene sandstone," see Am. Jour. Sci., 3d ser., 1886, vol. 32, pp. 199-204.

4 Hayden, 5th Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1871, p. 33.

5 *Anchitherium agreste* Leidy. Found in indurated, gray, arenaceous marl, compared with Miocene forms from Dakota and Oregon. Leidy, U. S. Geol. Surv. Terr., 1873, vol. 1, pp. 251-252. Ibid., p. 323, "Miocene?"

6 Sixth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1873, pp. 112-113.

remarkable deposits of both "Miocene" and "Pliocene" ages. These were brought to light by the explorations of Grinnell[1] and Dana, who describe them as follows:

The Tertiary beds found here consist for the most part of homogeneous cream-colored clays, so hard as to be with difficulty cut with a knife. The beds are horizontal and rest uncomformably upon the upturned yellow and red slates below. The clays of which they are formed resemble closely those found in the Miocene beds at Scotts Bluffs, near the North Platte River in Wyoming. The deposits at Camp Baker have been extensively denuded and nowhere reach any very great thickness. At a point about 3 miles southeast of the post, some bluffs were noticed where the Miocene beds attained a thickness of 200 feet, and these were capped by 50 feet of Pliocene clays, both beds containing characteristic fossils. * * *

It seems probable that in Pliocene time at least the Baker Lake may have extended north to the Missouri River, and perhaps up that stream to the Three Forks, thus connecting it with the lake which existed near Fort Ellis.

In 1877 Prof. Cope[2] sent his assistant, Mr. Isåac, to collect fossil remains from this basin. The results were satisfactory. A considerable number of species was obtained. Of these *Pithecistes brevifacies*, *Brachymeryx feliceps*, *Cyclopidius simus*, *C. heterodon*, and *Blastomeryx borealis* were described by Cope in 1877[3], while a complete faunal list was given nine years later[4], which includes the following species:

Mastodon proavus Cope.
Protohippus sejunctus Cope.
Merycochœrus montanus Cope.
Merychyus zygomaticus Cope.
pariogonus Cope.
Cyclopidius simus Cope.
Cyclopidius emydinus Cope.
Pithecistes brevifacies Cope.
decedens Cope.
heterodon Cope.
Procamelus vel *Protolabis* sp.
Blastomeryx borealis Cope.

The horizon represented by this old lake formation is that of the Ticholeptus beds of Cope, and is by this author correlated with a somewhat similar deposit on "Cottonwood Creek," Oregon, though but one species, *Blastomeryx borealis*, is found at both localities, "a fact which indicates some important difference in the horizon, either topographically or epochal."[5]

NORTH DAKOTA.

WHITE RIVER BEDS.

Our present knowledge of the existence, characteristics, and distribution of Neocene deposits in this State is limited to the following letter from Prof. E. D. Cope, read before the American Philosophical Society, September 21, 1883,[6] dated Sully Springs, Dakota, September 7, 1883:

I have the pleasure to announce to you that I have within the last week discovered the locality of a new lake of the White River epoch, at a point in this Territory nearly 200 miles northwest of the nearest boundary of the deposit of this age hitherto known. The beds, which are unmistakably of the White River formation, consist of greenish

[1] Am. Jour. Sci., 3d ser., vol. 11, pp. 126-128.
[2] U. S. Geol. Surv. Terr., 1884, vol. 3, book 1, p. XXVI.
[3] Proc. Am. Philos. Soc., 1877-'78, vol. 17, pp. 219-223.
[4] Cope. Proc. Am. Philos. Soc., 1885-'86, vol. 23, p. 359.
[5] Cope, Am. Nat., 1886, vol. 20, p. 369.
[6] Proc. Am. Philo. Soc., 1883, vol. 21, pp. 216-217.

sandstone and sand beds of a combined thickness of about 100 feet. These rest upon white calcareous clay, rocks, and marls of a total thickness of 100 feet. These probably also belong to the White River epoch, but contain no fossils. Below this deposit is a third bed of drab clay, which swells and cracks on exposure to weather, which rests on a thick bed of white and gray sand, more or less mixed with gravel. This bed, with the overlying clay, probably belongs to the Laramie period, as the beds lower in the series certainly do.

The deposit as observed does not extend over 10 miles in north and south diameter. The east and west extent was not determined.

The fossils, which indicate clearly the age of the formation, are the following:

Pisces:	
Rhineastes, sp. nov; *Aminurus*, sp. nov	2
Lacertilia:	
sp. indet	1
Testudinata:	
Trionyx sp; *Trionyx* sp; *Stylemys* sp	3
Rodentia:	
Castor sp	1
Carnivora:	
Galecynus gregarius; *Hoplophoneus* sp; ? *Hoplophoneus* sp	3
Perissodactyla:	
Aceratherium sp; *Aceratherium* sp; *Anchitherium* sp	3
Artiodactyla:	
Elotherium ramosum; *Hyopotamus* sp; *Oreodon* sp; *Oreodon* sp; *Oreodon* sp; *Leptomeryx* sp; *Hypertragulus* sp	7
Total species	20

Interesting features of the above catalogue are: The absence of *Hyracodon* and *Poebrotherium*, so abundant in the beds of this age elsewhere; the presence of fishes, not hitherto detected in them; and the presence of the genus of tortoises, *Trionyx*. The latter genus has not hitherto been found in our western lacustrine beds of later than Eocene age, while they are abundant in our modern rivers. This discovery partially bridges the interval. The same is true of the fishes mentioned, which represent the order *Nematognathi*.

SOUTH DAKOTA.

WHITE RIVER GROUP.

During early Miocene or Oligocene times the triangular area formed by the Cheyenne and Missouri rivers and the Nebraska State line was occupied by the northern limb of a vast fresh water lake that extended southward and westward into Nebraska, Colorado, and Wyoming. To this sheet of water King has applied the name of Sioux Lake,[1] and has

[1] U. S. Geol. Ex. 40th Parallel, 1878, vol. 1, p. 451.

endeavored to demonstrate its contemporaneity with the "Pah-Ute" lake west of the Rockies. Its sedimentary formations now form the well known White River group, so strikingly displayed in the "Mauvaises Terres,"[1] and from which such vast quantities of vertebrate remains have been obtained.

The subdivision of this group into "beds," and the determination of the geographical distribution of each, has been done almost exclusively by Dr. F. V. Hayden. His generalized section,[2] constructed in 1857, must still be considered our most reliable source of information regarding the general stratigraphy of this region. Accordingly, that portion of it which relates to the Tertiary series is here given in full.

Vertical section, showing the order of superposition of the different beds of the Bad Lands of White River, so far as determined.

		Subdivisions.	Localities.	
MIOCENE TERTIARY.	Bed H.	Gray and greenish gray sandstone, varying from a very compact structure to a conglomerate.	Bijou Hills, Medicine Hills, Eagle Nest hills.	20 feet.
	Bed G.	Yellowish gray grit, passing down into a yellow and light yellow argillo-calcareous marl, with numerous calcareous concretions and much crystalline material, like sulphate of baryta. Fossils: *Hipparion*, *Merychippus*, *Steneofiber*, etc.	Bijou Hills, Medicine Hills, Eagle Nest Hills, and numerous localities on south side of White River; also at the head of Teton River.	50 feet.
	Bed F.	Grayish and light gray rather coarse sandstone, with much sulphate of alumina (?) disseminated through it.	Along White River valley on the south side.	20 feet.
	Bed E.	Yellowish and flesh-colored indurated argillo-calcareous bed, with tough argillo-calcareous concretions containing *Testudo*, *Hipparion*, *Steneofiber*, *Oreodon*, *Rhinoceros*, etc.	Seen along the White River valley on the south side.	30 feet.
	Bed D.	Yellow and light yellow calcareous marl, with argillo-calcareous concretions and slabs of siliceous limestone, containing well preserved fresh-water shells.	On the south side of White River. Seen in its greatest thickness at Pianos Spring.	40 feet.
	Bed C.	Light gray siliceous grit, sometimes forming a compact fine-grained sandstone.	Seen on both sides of White River; also at Ash Grove Spring.	20 feet.
	Bed B.	A reddish, flesh-colored, argillo-calcareous, indurated material, passing down into a gray clay, containing concretionary sandstone, sometimes an aggregate of angular grains of quartz, underlaid by a flesh-colored argillo-calcareous indurated stratum containing a profusion of mammalian and chelonian remains. Turtle and Oreodon bed.	Revealed on both sides of White river and throughout the main body of the Bad Lands.	80 feet.
	Bed A.	Light gray calcareous grit, passing down into a stratum composed of an aggregate of rather coarse granular quartz, underlain by an ash-colored argillaceous indurated bed with a greenish tinge. Titanotherium bed.	Best developed at the entrance of the basin from Bear Creek. Seen also in the channel of White River.	50 feet.
Cretaceous system.				

[1] For a vivid description of this region see Owen's Geol. Surv. Minn., Wis., etc., 1852, pp. 196–197.
[2] Proc. Acad. Nat. Sci. Phila., 1857, p. 153.

The White River group includes but the first four "beds" of this section,[1] while bed E, and those above it, belong to the Loup Fork group, to be noticed hereafter.

The manner in which these beds are exposed along Sage and Bear creeks, tributaries of the Cheyenne, as well as along White River in the vicinity of Wounded Knee Creek, is clearly stated in the itinerary of Hayden's journey[2] from Bear Peak to Fort Randall, on the Missouri.

Much detailed information is given regarding the two lower beds of his group, which, it will be observed, must necessitate slight modifications in the thickness given to these beds in the general section.

Exposures about 15 miles above the mouth of Bear Creek, on the left side of the Cheyenne, present the following strata:[3]

		Ft.	*In.*
Titanotherium bed.	1. Light gray indurated clay	6	
	2. Seams of gray sandstone	1	6
	3. Ash-colored plastic clay with a greenish tinge, and a pinkish band of fine grit at the base	30	

Between the Cheyenne and White rivers both Titanotherium and Oreodon beds are exposed. The following section[4] shows their main characteristics:

		Ft.	*In.*
Bed	1. Flesh-colored marl	10	
	2. Bluish laminated clay with a yellowish tinge	2	
	3. Flesh-colored indurated marl	25	
Bed	4. Light gray indurated argillaceous grit, forming conglomerate of nodules of clay	4-6	
Oreodon bed	5. Flesh-colored indurated grit	20	
	6. Bluish argillaceous grit		10
	7. Flesh-colored marl	4	
	8. Argillaceous grit		6-12
	9. Flesh-colored marl	30	
Titanotherium bed.	10. A light gray calcareous grit passing down into an ash-colored clay, with micaceous and siliceous sandstone at base tinged with a purplish hue	80-100	
	11. Cretaceous beds Nos. 5 and 4.		

Still farther southward the White River beds gradually disappear beneath the overlying Loup Fork deposits, showing in many instances that the upper surface of the former must have been extensively eroded before the deposition of the latter.[5]

No attempt will be made in this place to discuss or even to mention by species, genus, or family the vast assemblage of animals which have left the record of their existence in the mud of this bygone lake. For information on this subject the reader should refer to the following works of Dr. Leidy: "Description of the Remains of Extinct Mam-

[1] U. S. Geol. Surv. Terr., 1884, vol. 3, Tertiary Vertebrata, p. 14.
[2] Trans. Am. Phil. Soc., new series, 1863, vol. 12, pp. 29-33.
[3] Ibid., p. 29.
[4] Ibid., p. 31.
[5] Trans. Am. Phil. Soc., 1863, new series, vol. 12, p. 33, and Jour. Acad. Nat. Sci. Phila., 1869, 2nd series, vol. 7, p. 12.

malia and Chelonia, from Nebraska Territory,"[1] "The Ancient Fauna of Nebraska, or a Description of Remains of Extinct Mammalia and Chelonia from the Mauvaises Terres of Nebraska," and "The Extinct Mammalian Fauna of Dakota and Nebraska."[2]

Though these beds are so well developed and so well characterized by numerous fossil remains, geologists and paleontologists alike have assigned them to different horizons in the Tertiary series. In the earlier publications of Leidy & Owen,[3] they were known as Eocene beds or deposits; later the unanimous verdict was that these same beds are more properly classed as Miocene;[4] still later Cope reversed this upward tendency, showing that several forms were closely allied to the so-called Oligocene[5] forms of Europe; and lastly Scott maintains that some "newly discovered forms strongly confirm the view that the White River beds correspond to the Lower Oligocene of Europe. They largely increase the number of known correspondences between the White River formation on the one hand and the Uinta and Bridger on the other."[6]

LOUP FORK GROUP.

The geographical distribution and lithological characters of the various beds of this group are briefly stated in Hayden's generalized section given on p. 291. It will receive little attention here, since its greatest development and most interesting features are displayed farther south in Nebraska. Yet there are a few outliers of this group some distance east from the typical Mauvaises Terres that must be noticed in this place, viz, Bijou Hills. Concerning them Hayden[7] remarks:

In the summer of 1853 I ascended one of these hills nearest the river in company with my friend Mr. Meek, and from a denuded portion near the summit we obtained several fragments of jaws and teeth belonging to two new species of mammals, which have been described by Dr. Leidy as *Hipparion speciosum* and *Merycadus necatus*. In the autumn of 1856 I discovered on the denuded summits of the same hills *Hipparion occidentalis* and two new genera, *Leptarcus primus*, an animal allied to the racoon, and *Merychippus insignis*, a remarkable new genus of ruminant horse. These remains have all been described by Dr. Leidy in the proceedings of the Philadelphia Academy.

The summits of these hills are capped with a bed of bluish gray, compact rock, quite variable in its character. Sometimes it is very fine, not unlike a metamorphic rock; again it is composed of an aggregation of particles of granular quartz, inter-

[1] Owen's Geological Survey of Minn., etc., 1852, pp, 535–572.

[2] Smithsonian Contr. to Knowl., 1854, vol. 6, Art. 7. Jour. Acad. Nat. Sci., Phila., 1869, 2d ser. vol. 7. Marsh has also described several new species from the Mauvaise Terres. See Am. Jour. Sci., 1874, 3d ser., vol, 7, p. 534; 1875, vol, 9, p. 240; 1887, vol. 34, pp, 328, 330, 331, 1890, vol. 39, pp. 523, 524; 1890, vol. 40, p. 179; 1891, vol. 12, p. 81. Scott and Osborn give no definite localities to the forms they describe or discuss from the White River group. Bull. Mus. Com, Zool., Harv. Coll., 1890, vol. 20, No. 3.

[3] Owen's Geol. Surv. Minn., etc., 1852, pp. 199, 539, and Smithsonian Contr. to Knowl., vol. 6, art. 7.

[4] F. V. Hayden: Proc. Phila. Acad. Nat. Sci., 1857, p. 153, and Trans. Amer. Phil. Soc., new series, 1863, vol. 12, p. 105.

[5] Amer. Nat., 1887, vol. 21, p. 456.

[6] Princeton Col. Bull., Nov., 1890, vol. 2, pt. 4, p. 75.

[7] Proc. Acad. Nat. Sci. Phil., 1857, p. 157.

spersed with a few small water worn pebbles; then a coarse gray somewhat friable sandstone. Farther into the interior, capping the summit of the long hill, this rock may be seen in places 20 to 30 feet in thickness. The calcareous grits and marls underneath may be subdivided in descending thus:

First. Yellowish gray grit, with compact fine calcareous concretions.

Second. Yellowish white calcareous marl, containing great quantities of the comminuted fragments of bones.

Third. Compact whitish calcareous clay, with a few vertebrate remains and concreting limestone. The aggregate thickness of these beds I could not determine, as the sides of the hill were for the most part covered with a surface deposit of considerable thickness, sustaining a good growth of vegetation.

NEBRASKA.

TERTIARIES OF WHITE AND NIOBRARA RIVERS.

Stratigraphy.—Under South Dakota we have given Dr. Hayden's section of the Loup Fork and White River groups as they are exposed along White River and in that state generally. For convenience in reference we here insert the same author's "vertical section showing the order of superposition of the different beds of the Tertiary basin of White and Niobrara rivers."[1]

		Subdivisions.	Localities.	Estimated thickness.
POST-PLIOCENE.		Yellow siliceous marl, similar in its character to the loess of the Rhine, passing down into variagated indurated clays and brown-yellow fine grits; contains remains of extinct quadrupeds, mingled with those identical with recent ones; also a few mollusca, mostly identical with recent species so far as determined.	Most fully developed along the Missouri River, from the mouth of the Niobrara to St. Joseph; also in the Platte Valley and on the Loup Fork.	300 to 500 feet.
PLIOCENE.	Bed F.	First, dark gray or brown sand, loose, incoherent, with remains of mastodon elephant, etc.; second, sand and gravel incoherent; third, yellowish white grit, with many calcareous, arenaceous concretions; fourth, gray sand, with a greenish tinge; contains the greater part of the organic remains; fifth, deep yellowish red arenaceous marl; sixth, yellowish gray grit, sometimes quite calcareous, with numerous layers of concretionary limestone from 2 to 6 inches in thickness, containing fresh water and land shells, *Succinea*, *Limnea*, *Paludina*, *Helix*, etc., closely allied and perhaps identical with living species; also much wood of coniferous character.	Covers a very large area on Loup Fork from the mouth of North Branch to the source of Loup Fork; also in the Platte Valley. Most fully developed on the Niobrara River, extending from the mouth of Turtle River 300 miles up the Niobrara. Also on Bijou Hills and Medicine Hills. Thinly represented in the valley of White River.	300 to 400 feet.
MIOCENE.	Bed E.	Usually a coarse grained sandstone, sometimes heavy bedded and compact; sometimes loose and incoherent; varies much in different localities. Forms immense masses of conglomerate; also contains layers of tabular limestone with indistinct organic remains; very few mammalian remains detected, and those in a fragmentary condition. Passes gradually into the bed below.	Most fully developed along the upper portion of Niobrara River and in the region around Fort Laramie. Seen also on the White River and on Grindstone Hills.	180 to 200 feet.
	Bed D.	A dull, reddish brown, indurated grit, with many layers of silico-calcareous concretions, sometimes forming a heavy-bedded, fine-grained sandstone; contains comparatively few organic remains.	Niobrara and Platte rivers; well developed in the region of Fort Laramie; also in the valley of White River. Conspicuous and composing the main part of the dividing ridge between White and Niobrara rivers.	350 to 400 feet.

[1] Proc. Phila. Acad. Nat. Sci., 1858, p. 148.

		Subdivisions.	Localities.	Estimated thickness.
MIOCENE.	Bed C.	Very fine yellow calcareous sand, not differing very materially from bed D, with numerous layers of concretions and rarely organic remains passing down into a variegated bed consisting of alternate layers of dark brown clay and light gray calcareous grit forming bands, of which I counted twenty-seven at one locality, varying from 1 inch to 2 feet in thickness.	White River, Bear Creek, Ash Grove Spring, head of Cheyenne River. Most conspicuous near White River.	50 to 80 feet.
	Turtle and Oreodon bed B.	A deep flesh-colored argillo-calcareous indurated grit; the outside, when weathered, has the appearance of a plastic clay. Passes down into a gray clay with layers of sandstone, overlaid by a flesh-colored argillo-calcareous stratum, containing a profusion of mammalian and chelonian remains. Turtle and Oreodon bed.	Old Womans Creek, a fork of Cheyenne River; also on the head of the South Fork of the Cheyenne; most conspicuous on Sage and Bear creeks and at Ash Grove Spring. Well developed in numerous localities in the valley of White River.	80 to 100 feet.
	Titanotherium bed A.	Light gray fine sand, with more or less calcareous matter, passing down into an ash-colored plastic clay, with large quantities of quartz grains disseminated through it, sometimes forming aggregated masses like quartzose sandstone cemented with plaster; then an ash-colored clay with a greenish tinge, underlaid at base by a light gray and ferruginous siliceous sand and gravel with pinkish bands. Immense quantities of silex in the form of seams all through the beds. Titanotherium bed.	Old Woman's Creek; also in many localities along the valley of the South Fork of Cheyenne. Best development on Sage and Bear creeks. Seen at several localities in the valley of the White River.	80 to 100 feet.
CRETACEOUS.	Nos. 4 and 5.	Cretaceous beds 5 and 4, with their usual lithological characters and fossils.	Exposed underneath the Tertiary beds on the South Fork of Cheyenne and its southern branches, also in the White River Valley near its source.	

Concerning the characteristics and distribution of the beds mentioned in the above table Hayden[1] gives the following itinerary notes:

Ascending the Loup Fork, the first indication we observed of this formation was near the old Pawnee village, about 8 miles above the mouth of Beaver Creek. Here we found, near the bed of the river, large masses of pebbly conglomerate, cemented with a calcareous grit, which undoubtedly belongs to bed C of the vertical section. The distant hills on either side of the river are covered with a considerable thickness of Pliocene and post-Pliocene beds.

Near the mouth of North Branch the following section of the strata in descending order was observed:

	Feet.
(*d*) Yellowish brown laminated argillaceous grit; effervesces briskly with muriatic acid.	
(*c*) Similar to the bed above, but of deeper color, more compact, containing a greater per cent of clay, with numerous calcareous concretions disseminated through it	70–100
(*b*) Light brown clay filled with whitish particles like magnesia	70
(*a*) Gray coarse sand forming a heavy bedded sandstone reaches to the water's edge	30

In the upper beds of the above local section fragments of mammalian and chelonian remains were found, and all but the lower bed, which is bed E of the vertical

[1] Proc. Phila. Acad. Nat. Sci., 1858, pp. 150–152.

section, are Pliocene. Lieut. Warren explored the North Branch 30 miles above its mouth, and met with a similar series of beds, containing the same organic remains. Above the mouth of North Branch, bed "a" of the local section appears in the form of large ledges, of light gray arenaceous limestone, filled with silicified tubes like the stems of plants and seeds resembling cherry-stones. On the distant hills, when exposed by erosion, I found numerous fragments of bones and teeth of *Hipparion*, *Cervus*, etc.

About longitude 99° we enter the desolate region of the sand hills. I measured the height of these hills at one locality and found them to be 230 feet above the bed of Loup Fork, and composed of Pliocene beds as a base, then a thin bed of post-Pliocene marl overlaid by a great thickness of loose incoherent sand and gravel derived from the erosion of the different Tertiary beds. The whole country from the head of Loup Fork presents a similar character, consisting of movable sand hills, the true Tertiary beds being being very seldom exposed. On the South Branch the streams cut through the following Pliocene strata:

	Feet.
(*c*) Yellowish brown grit containing *Mastodon mirificus* (Leidy).	
(*b*) White chalky stratum, charged with fresh-water and land shells of the genera *Helix*, *Planorbis*, *Limnea*, etc., probably identical with recent species	3
(*a*) Heavy bedded gray sandstone	8–10

From the head of Loup Fork to the Niobrara River the whole country is covered with this superficial deposit of sand, which is blown by the wind into ridges and high conical hills, rendering traveling quite difficult. On reaching the Niobrara, we find bed E quite well developed; also a full series of Pliocene beds filled with Mammalian remains. Passing up the Niobrara about 50 miles the Pliocene strata gradually disappear, and the whole country is occupied by the upper Miocene beds E and D. A butte near this point affords a fine detailed section of the gray sandstone bed E, which measured from the base with a pocket level I found to be 166 feet in height. It is composed mostly of gray, coarse grit, sometimes quite incoherent, containing many layers of concretionary sandstone. On the summit is a thin bed of shelving limestone, similar to that containing organic remains at Pinau's spring, though probably not holding the same geological position. Indistinct traces of fresh-water shells and numerous remains of fish scales, vertebrates, etc., were visible in the tabular masses. It seems to form the upper portion of bed E, and to vary much in its character in different localities. It presents every variety, from a translucent chalcedony to a fine grained sandstone or compact limestone, and furnishes those chalcedonic masses which meet the eye of the traveler so often and have the appearance of erratic blocks. Farther from the river, and holding a higher position than the summit of the Butte, are thin beds of yellow and yellowish gray calcareous grit, undoubtedly of Pliocene age, containing numerous fragments of teeth and finely preserved bones of the mastodon and elephant. As we pass up the river the gray sandstone, bed E, presents a great variety of lithological characters. Sometimes it forms a coarse conglomerate; then an aggregate of grains of quartz cemented by calcareous matter.

About 60 miles above the point where we struck the Niobrara, bed D, of the vertical section, is revealed to the water's edge. The dip of the strata toward the east gradually brings this bed to view quite conspicuously. It is composed of flesh-colored calcareous grit, and the eroded material of this bed gives to the country a dull reddish yellow tint. It also contains many layers of silico-calcareous concretions forming large ledges which break into irregular masses on exposure. The more incoherent material has much the color and appearance of that composing the Turtle bed at Bear Creek, but contains much less clay. It does not differ materially from its equivalent in the White River valley, of which Eagle Nest Butte forms a part.

These notes embody the greater part of all that is known concerning the stratigraphic geology of the Tertiary in Nebraska. The limited area along Lodge Pole Creek in extreme western Nebraska has been reported upon by Cope,[1] as stated under Colorado, while bed D, referred to above, has been studied by Mr. R. S. Hill.[2] Numerous articles have, to be sure, appeared in various reports and periodicals, giving in some instances fairly definite information regarding localities where vertebrate remains have been found, but this is still insufficient to form a basis for stratigraphic generalizations.

The geological maps of Hayden, Hitchcock, and McGee represent all the Tertiaries of Nebraska by one tint, since the areal distribution of the various subdivisions has not been determined. The same method must be followed in the map accompanying this report.

White River group.—The White River group as first defined[3] included beds A–E of the above section, while the Loup Fork group included only a bed F; the former was estimated to have a thickness of "1,000 feet or more," while the latter was given as "300 to 400 feet."

LOUP FORK GROUP.

The taxonomy and general features of the White River group have already been given under South Dakota, where its typical development is attained. Like features of the Loup Fork group will for a similar reason be now presented. Bed F (Hayden, 1858, or "Loup River beds," Meek and Hayden, 1861) was formerly regarded as "Pliocene Tertiary," not only on account of the unconformity between its strata and those of the supposed Miocene below, but also because its fauna was found to be "specifically distinct from, yet intermediate between that of the Miocene and our present period."[4]

This view was unchallenged until 1873, when Cope[5] wrote:

> The Loup Fork beds, from the greater proportion of the existing genera which they contain, display a resemblance to the European Pliocene, but they differ strikingly in the greater number of horses and camels which they contain. The smaller percentage of existing genera in the Loup Fork beds, with the presence of an oreodont (*Merychyus*), indicates that these also should be placed anterior to the Pliocene of France.

Later, in 1875[6] he found "that the facies of the fauna of this horizon throughout the West, including as it does *Amphicyon*, *Dicrocerus*, *Hippotherium*, *Aceratherium*, *Mastodon* allied to *M. angustidens*, etc., more nearly resembles the upper Miocene of Europe than the Pliocene of that continent." Marsh,[7] however, that same year, concluded "that

[1] Bull. U. S. Geol. and Geog. Surv. Terr., No. 1, 1874, pp. 10 et seq.
[2] Am. Nat., 1880, vol. 14, p. 141.
[3] Proc. Acad. Nat. Sci., Phila., 1861, vol. 13, p. 433.
[4] Proc. Phila. Acad. Nat. Sci., 1858, p. 157. See also Proc. Phila. Acad. Nat. Sci., 1861, p. 435.
[5] U. S. Geol. and Geog. Surv., Colo., 1873, p. 462.
[6] Proc. Phila. Acad. Nat. Sci., 1875, p. 257.
[7] Am. Jour. Sci., 3d ser., 1875, vol. 9, p. 51.

most of the upper beds (D and E), 500 feet at least in thickness, which were called Miocene by Prof. Hayden," should, from their fossil contents, be regarded as Pliocene. Cope,[1] in 1876, gave a list of Loup Fork genera, showing their stratigraphic position in Europe. This confirmed his views already expressed. In 1879 he instituted a comparison of Loup Fork genera on the one hand and Falunian and Oeningian on the other. The conclusion reached by so doing was "the facies of the Loup Fork horizon is then a compound of that of the Falunian and Oeningian or Middle and Upper Miocene."[2] In the same article he subdivides the Loup Fork group formation into two divisions on paleontological grounds, under the names of Ticholeptus and Procamelus beds. The former name was first applied to certain deposits already described on Deep River, Montana, which were recognized as having more affinity to the White River group than does the "True Loup Fork."

The same subdivisions obtain in vol. 3 (1884) of the Final Reports of Hayden's Survey. It is there observed that bed D of Hayden's section is the Nebraskan representative of the Ticholeptus bed.[3] In a brief article in the American Naturalist (1886) entitled "The vertebrate fauna of the Ticholeptus Beds," Prof. Cope states that the horizon represented "is intermediate in all respects between the Middle and Upper Miocene formations of the West, as represented by the John Day and Loup Fork beds."[4] The same idea is carried out in his paper[5] entitled "The Mesozoic and Cænozoic Realms of the Interior of North America," where the Ticholeptus division of the Miocene is given equal taxonomic importance with the White River or Loup Fork, though its greater affinities to the latter are clearly pointed out.

Prof. Marsh, as we have seen, in 1875 included the greater part of beds D and E of Hayden's section in the Pliocene, i. e., in the Loup Fork or Niobrara formation. By referring to the various papers of this author, cited below, it will be seen that he, although making no special attempt to maintain his position, cites all Loup Fork or Niobrara species as from a Pliocene horizon. Indeed, in a letter dated March 11, 1891, he writes: "The Loup Fork or Niobrara group should be classified as Pliocene and not Miocene."

Profs. Scott and Osborne, in Bull. Mus. Comp. Zool., 1890, vol. 20, No. 3, p. 65, refer the "Loup Fork mammals" to the "Upper Miocene."

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[1] U. S. Geograph. Surv. W. 100th Mer., 1877, vol. 4, pt. 2, p. 364.
[2] U. S. Geol. and Geog. Surv. Terr., Bull. 5, No. 1, 1879, pp. 46-47.
[3] Op. cit., p. 18.
[4] Vol. 20, p. 367.
[5] Am. Nat., 1887, vol. 21, p. 455.

The conclusions of the foregoing discussion may be represented diagrammatically as follows:

<table>
<tr><th colspan="5">Miocene.</th><th>Pliocene.</th><th rowspan="2">Hayden's section of 1858.</th></tr>
<tr><th>Bed A.</th><th>Bed B.</th><th>Bed C.</th><th>Bed D.</th><th>Bed E.</th><th>Bed F.</th></tr>
<tr><td colspan="5">White River Miocene</td><td>Loup River Pliocene.</td><td>Meek and Hayden, 1861.</td></tr>
<tr><td colspan="3">White River Miocene</td><td colspan="3">Niobrara or Loup Fork Pliocene</td><td>Marsh, 1875.</td></tr>
<tr><td colspan="5">White River Miocene</td><td>Loup Fork Miocene?</td><td>Cope, 1873.</td></tr>
<tr><td colspan="3">White River Miocene (Oligocene)</td><td colspan="3">Loup Fork Miocene</td><td>Cope, 1884.</td></tr>
<tr><td colspan="3">White River Miocene (Oligocene)</td><td>Ticholeptus Miocene.</td><td colspan="2">Loup Fork Miocene</td><td>Cope, 1887.</td></tr>
<tr><td colspan="3">White River Lower Oligocene)</td><td colspan="3">Loup Fork Miocene</td><td>Scott and Osborn, 1890.</td></tr>
</table>

It seems unnecessary in this place to go into details regarding the genesis of this group. It, like the White River, John Day, Green River, or most of the Tertiary formations of the "interior," resulted from successive sedimentation in an extensive sheet of fresh water. To this, King has given the name "Cheyenne Lake."[1] Its great area has been commented upon by Hayden, King,[2] and Marsh.[3] though most of their personal observations were made to the north of Indian Territory or even Kansas. The labors of R. T. Hill[4] in Texas and Indian Territory have demonstrated what before was but hypothetical, viz, that "Cheyenne Lake" (or whatever name one may choose to call it) extended southward from South Dakota well into the State of Texas. Authors of geological maps embracing this part of the country have as yet been too conservative with their "Neocene" tints. In fact, the area of this particular basin ought nearly to be doubled.[4]

PLIOCENE—EQUUS BEDS.

The Pliocene formation (Equus beds), as understood by Cope, has not yet been properly discriminated from the underlying Loup Fork Miocene within the boundaries of the State. The faunas of the two "have probably been confounded." This is the conclusion arrived at by Cope from a process of reasoning entirely analogous to that used in this essay in determining that both Miocene and Pliocene marine forms are present in the Upper Tertiaries of South Carolina, because the two have since their original deposition been intermingled, and not because the two were contemporary or represent a transition from one epoch to another. In Oregon and extreme southwest Texas he finds the Equus beds, or Pliocene fauna, pure and simple, while in Colorado and New Mexico the Loup Fork fauna presents no Equus-bed features.

[1] U. S. Geol. Explor. 40th parallel, 1878, vol. 1, p. 455.

[2] The Equus beds (Pliocene of Cope) are apparently classified by King as deposits of his "Cheyenne Lake."

[3] Am. Jour. Sci., 1875, 3d ser., vol. 9, p. 52.

[4] Am. Nat., 1891, vol. 25, p. 49.

PALEONTOLOGY.

The first important paper on the paleontology of this State was that of Dr. Leidy in the proceedings of the Philadelphia Academy of Natural Sciences for 1858, entitled "Notice of Remains of Extinct Vertebrata, from the valley of the Niobrara River, collected during the exploring expedition of 1857, in Nebraska, under the command of Lieut. G. W. Warren, Top. Eng., by Dr. F. V. Hayden, geologist of the expedition."

In this paper he described twenty-three new mammalian forms, and determined the identity of four more, with species already described from the Bijou Hills horizon of South Dakota. The same author's memoir on the extinct mammalian fauna of Dakota and Nebraska, published in volume 7 of the Journal of the Philadelphia Academy of Natural Sciences, 1869, sets forth clearly all that was known regarding the paleontology of this class of animals from this State up to that date.[1]

Since then Marsh[2], Cope,[3] Scott and Osborn,[4] and Leidy[5] have occasionally described new forms from this State, most of which are from near Loup Fork and Niobrara rivers, though the avoidance of mention of definite localities is extremely noticeable.

KANSAS.

In the year 1861, Prof. Newberry[6] described the "Tertiary basin of the Arkansas" as it appears along a section from "Pawnee Fork to crossing of Cimarron" and suggested its probable stratigraphic continuity with similar beds in Nebraska.

In 1876 Mudge[7] described the lithological features of this formation in the western part of the State, and determined its thickness on Prairie Dog Creek, Norton County, to be 400 feet. Two years later he mapped[8] the same and estimated its total thickness to be not less than 1,500 feet.

Cope, Marsh, Scott, and Osborn have from time to time described or identified Loup Fork vertebrate remains from various localities within this State, especially from Norton and Phillips counties.

Robert Hay has recently published two important reports which include discussions of the Tertiary geology of Kansas. The first may be found in the Sixth Biennial Report of the Kansas State Board of Agriculture, 1889, entitled "Northwest Kansas; Its Topography, Geology, Climate, and Resources."

[1] For a general idea of the vegetation of the Loup Fork and White River groups, see "Sketches of the Physical Geography and Geology of Nebraska," 1880, pp. 225, 241, 242. Samuel Aughey.

[2] Am. Jour. Sci., 3d ser., 1871, vol. 2, pp. 41, 121, 124. Ibid., 3d ser., 1874, vol. 7, pp. 251, 252, 253. Ibid., 3d ser., 1875, vol. 9, pp. 246. Ibid., 3d ser., 1877, vol. 14, pp. 251, 252, 254. Ibid., 3d ser., 1887, vol. 34, p. 326.

[3] See "Paleontological Bulletins" Nos. 14, 15, and 16; no definite localities given. Also, Bull. U. S. Geol. Surv. Terr., 1881, vol. 5, No. 1, p. 176. Ibid., 1881, vol. 5, No. 2, pp. 370-389. American Naturalist, 1890, vol. 24, pp. 950, 951, 1067. Ibid., 1891, vol. 25, p. 48.

[4] Bull. Mus. Comp. Zool. Harvard Coll., 1890, vol. 20, No. 3.

[5] U. S. Geol. Surv. Terr., 1873, vol. 1, pp. 227, 252, 260.

[6] Ives' Colorado Expl. Exped., pt. 3, Geol. Rep., p. 109.

[7] Bull. U. S. Geol. and Geog. Surv. Terr., vol. 2, pp. 212-213.

[8] First Bienn. Rep. Kansas Board of Agric., 1878, p. 47.

The Tertiary group is here divided into "Miocene grit" which "is considered to be the Loup Fork of Nebraska," and the "Pliocene marl" which is "probably identifiable" with the Equus beds.

Contrary to the observations of Mudge, Hay finds that the Tertiary beds have a decidedly eastern dip. Moreover, the total thickness of these beds along a section from Glasco to the Colorado line he represents as being not over 500 feet.

The second report by Hay constitutes Bulletin 57 of the U. S. Geological Survey, 1890—"A Geological Reconnaissance in Southwestern Kansas." In this report he says:

Two apparently distinct formations of Tertiary age have been found in all parts of the region explored. Occurring in isolated patches in the eastern part of the area, they are more largely developed as we proceed westward, where they are of such thickness and so related to the previous erosion as to completely hide all other formations from view. Feeling sure of the identity of these formations with similar deposits in northwestern Kansas, I am inclined to use the nomenclature of Prof. Cope, and call these respectively Loup Fork (Miocene) and the Equus beds (Pliocene). But having regard to the extensive area over which the beds are developed and the comparative infrequency of fossils in the latter formation, I deem it best to designate them by purely provisional names and leave others to fix them more specifically when they have been examined over the whole region of the Great Plains and their subdivisions made out. These Tertiary formations then we name in ascending order: (*a*) The Tertiary grit; (*b*) The Tertiary marl.

The Tertiary grit.—The first named division is made up of a mortar-like substance, composed of lime and sand which frequently incloses pebbles of quartz, feldspar, diorite, greenstone, etc., and sometimes contains fine siliceous volcanic matter. Again, the limy matter almost disappears and a coarse, pebbly conglomerate is found. This is stratigraphically above the limy beds. The under surface of the Tertiary grit is very irregular owing to the unevenness of the Permian, Jura-Trias, and Cretaceous surfaces upon which it has been laid down. For its geographical distribution, see map accompanying Hay's report.

The Tertiary marl is arenaceous, argillaceous, and calcareous in texture, and is in most cases readily distinguishable from the mortar grit and the loess. Its color is very uniform. It is a buff marl everywhere.

This formation rests upon the eroded surfaces of the Permian, Jura-Trias, Cretaceous, and Tertiary grit.

It forms the dead level of the high prairie between the great rivers, thinning off toward their valleys, but following the slope of the tributary dales. This thickening on the high prairie is manifest in almost every county—Barber, Pratt, Edwards, Meade, Ford, Hamilton, Seward, Scott, Graham, Norton—from Indian Territory to the Nebraska line. Wells pierce it in most of these counties over 100 feet, and in Meade County and in Graham from 140 to 180 feet, before the grit is reached.

For its areal distribution see map accompanying Hay's report.

Mudge[1] and Hay[2] mention the occurrence of mastodon, rhinoceros, turtle, and other bones in beds of the Loup Fork horizon. The former, however, mentions having found a three-toed horse in a deposit but 10

[1] Bull. U. S. Geol. Surv. Terr., vol. 2, p. 213.
[2] Bull. U. S. Geol. Surv., No. 57, 1890, p. 34.

feet above the Cretaceous, in Ellis County, which may, in his opinion, denote a lower horizon for that locality. The occurrence of *Limnophysa caperata* is noted by Hay from near Kiowa Creek. The new vertebrate species from this horizon have been described mainly by Profs. Cope,[1] Marsh,[2] Scott, and Osborn.[3]

INDIAN TERRITORY.

That Neocene beds exist in the northwestern prolongation of this Territory might readily be inferred from their distribution in adjacent parts of Kansas, New Mexico, and Texas. This inference is placed beyond cavil by the observations of Prof. J. S. Newberry, made in 1859.[4] He says:[5]

The geology of the region lying between the Enchanted Spring and Cottonwood Spring is similar throughout. The rocky basis of the country is formed by the lower Cretaceous sandstone, covered here and there with patches of white tufaceous Tertiary limestone.

A section at Cedar Spring shows the following strata:

		Feet.
(*a*) *Tertiary:*	1. White, chalky, tufaceous limestone, with hard, gray, compact bands	15
	2. Cream-colored, spongy, tufaceous limestone (similar to that on the Arkansas and Cimarron)	40
(*b*) *Cretaceous:*	1. Yellow fine-grained sandstone, etc.	

From Cedar Spring to McNees Creek the road passes over a high prairie underlain by Tertiary limestones. At McNee's Creek the Tertiary rocks are cut through and the Cretaceous series freely opened. No fossils were found here, but the rock is generally similar to that at Cedar Spring.

NEW MEXICO.

Galisteo group.—In New Mexico, the sedimentary Neocene formations may be classed in two groups, viz, the Galisteo group and the Santa Fe marls. The former term was, in a slightly modified form, applied by Dr. Hayden in 1869 to a series of sandstones outcropping along a creek by that name in the central part of the Territory. They were then regarded by him as of "Middle Tertiary"[6] age; later he correlated them with the Wasatch Eocene,[7] while Prof. Cope found them to be Cretaceous.[8] The observations of J. J. Stevenson show that two very different deposits may be referred to in Hayden's original description of this group. The one found on the south side of the creek he regards as Laramie,[9] while

[1] Bull. U. S. Geol. Surv. Terr., 1878, vol. 4, pp. 382–385, 392. Proc. Am. Philos. Soc., 1877–'78, vol. 17, pp. 224–225. (Am. Nat., 1880, vol. 14, p. 141). Am. Nat., 1886, vol. 20, p. 1045. Am. Nat., 1887, vol. 21, p. 1020.

[2] Am. Jour. Sci., 3d ser., 1887, vol. 34, p. 325.

[3] Bull. Mus. Comp. Zool., 1890, vol. 20, No. 3, p. 70.

[4] Exploring Expedition from Santa Fe to the Junction of Green and Grand Rivers, 1859. Macomb. (Published 1876.) Geology by Prof. Newberry.

[5] Op. cit., pp. 30, 31.

[6] Prelim. Field Rep. U. S. Geol. Surv., Colo. and N. Mex., 1869, p. 90.

[7] Am. Nat., 1878; vol. 12, p. 831.

[8] Proc. Phila. Acad. Nat. Sci., 1875, p. 360.

[9] U. S. Geog. Surv. W. 100th Mer.; Suppl. 1881, vol. 3, p. 159.

the other, lying to the north is of much later origin.[1] This author, accordingly, restricts the use of the term Galisteo group to the latter or newer deposits. A typical development of the same may be seen on Galisteo Creek, as follows:[2]

	Feet.
Trachyte breccia	150
Soft light gray sandstone	40

For some distance along the northern banks of this creek both these subdivisions are well exposed. Their areal distribution is represented on sheet 3, accompanying U. S. Geog. Surv. W. 100th Mer., Suppl., 1881, vol. III.

According to Stevenson, this group "can not be older than early Miocene or newer than early Pliocene."[3] It is seen to rest unconformably on the Dakota group; it was undisturbed by the trachytic outbursts which "caused frightful contortions of the Laramie beds."[1] Upon it lie the Santa Fe beds unconformably. It "certainly antedates the great flow of basalt."[3]

The Santa Fe marls were named and described at some length by Hayden in 1869.[4] He characterizes them as "mostly of a light cream color, sometimes rusty yellow, and sometimes yellowish white, with layers of sandstones varying in texture from a very fine aggregate of quartz to a moderately coarse pudding stone." They reach a great thickness north of Santa Fe in the Rio Grande Valley, from 1,200 to 1,500 feet,[5] and have a tendency to weather into the monumental and castellate forms of a Mauvaise Terre. Their areal distribution in this valley may be seen on sheet 3 of the work already referred to.

To the east of Rio Grande Valley, similar beds were long since observed by Dr. Newberry, "lying along the eastern bases of the mountains," and "filling depressions or excavations in the surfaces on which they were deposited."[6] Stevenson says: "This tufaceous limestone," which he refers to the Santa Fe group, occurs in many small patches at many localities south and east from the mountainous area. Evidently it is very thick in the Pecos Basin near the village of Pecos, and it was observed also on Vaca Creek at Las Colonias. Small patches were seen near Las Vegas, and an extended area lies between the Canadian hills and the Mora Canyon, reaching westward to beyond Fort Union. Fragmentary exhibitions were seen much farther north."[7]

The great development of these marls to the south and west of Santa Fe was first pointed out by Cope in 1883. He writes[8] as follows:

In descending the Rio Grande, beds appear on the west side of the river which strongly resemble those of Santa Fe. They extend along the eastern base of the

[1] U. S. Geog. Surv. W. 100th Mer.; Suppl. 1881, vol. 3, p. 161.
[2] Ibid., p. 159.
[3] Ibid., p. 162.
[4] Prelim. Rep. U. S. Geol. Surv., W. 100th Mer., 1869, p. 66.
[5] Prelim. Rep. U. S. Geol. Surv., Colo. and N. Mex., 1869, p. 69.
[6] Expl. Exped., Santa Fe, Junc. Green and Grand Rivers, 1859, p. 52.
[7] U. S. Geog. Surv. W. 100th Mer., Suppl. vol. 3, 1881, p. 163.
[8] Proc. Am. Philos. Soc., vol. 21, pp. 308–309.

Magdalene Mountains, and as far south as Socorro, in considerable extent and thickness. South of Socorro they appear, but less extensively. The eastern part of the plain which lies between the Rio Grande and Mimbres Mountains is composed of beds of this age where cut by the grade of the Atchison, Topeka and Santa Fe Railroad, west of Hatch Station. West of the Mimbres Mountains the valley of the river of the same name is filled with débris of the bed of eruptive outflow which covered the country as far as traversed by the railroad from Deming to Silver City. Its age I could not ascertain.

A great display of Loup Fork formation is seen in the drainage basins of the heads of the Gila River. In traveling westward from Silver City, its beds first appear in the Valley of Mangus Creek, which enters the Gila from the east. Crossing the Gila, the mail route to the west passes through the valley of Duck Creek, which flows eastward into the river. Though bounded by eruptive hills and mountains and their outflows, the valley was once filled with Loup Fork beds, which have been extensively eroded, the principal exposures being on the north side of the valley, forming the foothills of the Mogollon Range. On the divide between the waters of the Gila and San Francisco rivers, the formation rises in bluffs of 300 feet elevation. The descent into the valley of the San Francisco brings to light a still greater depth of this deposit. The valley which extends from the canyon which incloses the river south from the mouth of Dry Creek to the Tulerosa Mountains on the north, and between the Mogollons on the east and the San Francisco Range on the west, was once filled with the deposits of a Loup Fork lake. This mass has been reduced by the erosive action of the San Francisco and its drainage to a greater or less extent, as it has been protected by basaltic outflows or not. When so protected the river flows through comparatively narrow canyons. Where the outflow is wanting, the valley of the river is wider, and the Loup Fork formations remain as wide grassy mesas, which extend to the feet of the mountain ranges.

As early as 1861 Newberry[1] expressed himself as being "inclined" to refer "the white tufaceous limestones of the Rio Grande Valley" to the same horizon as those of the Arkansas River basin. Hayden in 1869 says,[2] referring to his Santa Fé marls:

They are doubtless of the age of Upper Tertiary and synchronous with the upper beds of the White River group as seen along the North and South Forks of the Platte and near Cheyenne.

In 1874 the horizon of this formation was definitely established by Cope,[3] who found them to contain well known and characteristic Loup Fork vertebrate remains.

For information upon the paleontology of this group the reader should consult:

Leidy, Proc. Phila. Acad. Nat. Sci., 1872, p. 142.
Cope, Proc. Phila. Acad. Nat. Sci., 1874, pp. 147-152, 221-223.
Ann. Rep. Chief of Engineers, 1874, pt. 2, pp. 603-607.
Ann. Rep. Chief of Engineers, 1875, pt. 2, pp. 988-996.
Proc. Phila. Acad. Nat. Sci., 1875, pp. 256-258, 261, 262, 271.
Proc. Phila. Acad. Nat. Sci., 1876, p. 144.
U. S. Geog. Surv. W. 100th Mer., 1877, vol. 4, Paleont., pp. 20, 365.
Proc. Am. Philos. Soc., 1883, vol. 21, p. 309.
Proc. Phila. Acad. Nat. Sci., 1883, p. 301.

[1] Ives's Rep. on Col. Riv. of West, 1861, pt. 3, Geology, p. 109.
[2] Prelim. Rep. U. S. Geol. Surv. Col. and N. Mex., 1869, p. 90.
[3] Ann. Rep. Chief of Engineers for 1874, Appendix FF, p. 127.

COLORADO.

Formations of post-Eocene Tertiary age, so extensively developed on the Great Plains east of the Rockies, as well as in the Great Basin to the west, are found only in patches of limited dimensions within the boundaries of this State. Of these, some have been referred to this section of the geological scale from the evidence afforded by their fossil contents, while others are only provisionally so referred from supposed stratigraphic relations or lithological resemblance to deposits of known horizon. The former class is mainly confined to such areas as were occupied by Sioux and Cheyenne lakes as defined by King, while the latter includes the Monument Creek group in part, and the comparatively recent sedimentary deposits of the "parks" in the central and north central part of the State.

LOUP FORK AND WHITE RIVER GROUPS.

The watershed between Lodge Pole Creek and South Platte River presents not only surface accumulations and Laramie beds, but also deposits known from their fossil contents to belong to the Loup Fork and White River groups. These were traversed by Hayden in 1869 while en route from Cheyenne to Denver; but his notes[1] on the same are very meager. Their fossil contents and true stratigraphic relations were first brought to light by Prof. Marsh,[2] who in 1870 traced them from Little Crow Creek, past Chalk Bluffs, northward into Wyoming, collecting in the meantime characteristic Mauvaises Terres or White River fossils. In 1873 Prof. Cope visited this region, worked out the stratigraphy with considerable detail, and made extensive collections of vertebrate remains. His generalized section extending from Chalk Bluffs southward along Horse Tail Creek is given as follows:[3]

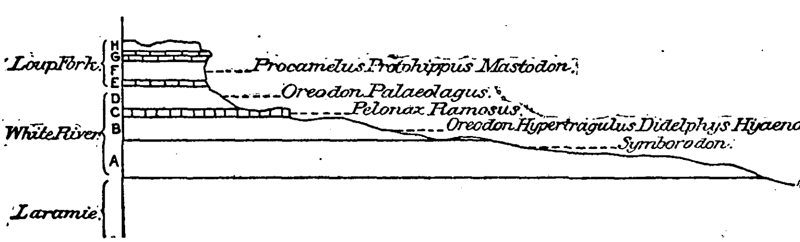

FIG. 43.—Section in eastern Colorado. (After Cope.)

Bed A is a white, calcareous, soft clay rock, breaking into angular fragments. Bed B has a similar mineral character, frequently with a red color of different obscure shades. Bed C is a sandstone of varying persistence. Bed D is a white, argillaceous rock like that of bed A. These four beds constitute the White River group as here represented, which, according to Cope, has at this place a thickness of several hun-

[1] 3d Ann. Rep. U. S. Geol. Surv. Terr., 1869, pp. 11–16.
[2] Am. Jour. Sci., 3d ser., 1870, vol. 1, p. 292.
[3] Rep. U. S. Geol. Surv. Terr., 1884, vol. 3, "Tertiary Vertebrata," p. 16.

dred feet. Above, and including beds E, F, G, H, is the Loup Fork group, which consists of alternating hard and soft layers of sandstone. Its thickness is given by Cope as not over 75 feet, of which the softer beds are the lower and vary in depth from 1 foot to 20. The superior strata are either sandstone conglomerate or a coarse sand of varying thickness, the former of which contains white pebbles and rolled mammalian remains.

Between the White River and Laramie groups there is but little angular unconformity,[1] while the line of demarkation between the White River and Loup Fork groups[2] is mainly determined upon paleontological evidence.

The sum total of the Tertiary strata here represented is, according to King,[3] about 700 feet, of which the "Miocene" includes the lower 300 feet,[4] while the "Pliocene" includes [5] the remaining 300 or 400 feet.

For information regarding the vertebrate paleontology of this region the following articles and reports by Prof. Cope should be consulted:

Third Notice of Extinct Vertebrata from the Tertiary of the Plains. Paleont. Bull. No. 16, August, 1873.

Synopsis of New Vertebrata from the Tertiary of Colorado, October, 1873. Printed as an advance extract from the 7th Ann. Rep. U. S. Geol. Surv., in which, however, it failed to appear.

Report on the Stratigraphy and Pliocene Vertebrate Paleontology of Northern Colorado. U. S. Geol. Surv. Terr., Bull. No. 1, 1874.

Report on the Vertebrate Paleontology of Colorado. 7th Ann. Rep. U. S. Geol. Surv. Terr., 1873, chapter 4, pp. 461–533.[6]

Tertiary marl.—Passing now in a southeasterly direction to the headwaters and tributaries of Republican River, Loup Fork beds, and those of more recent deposition are found well displayed as represented on the map. South of these in turn, the so-called "Tertiary marl," whose distribution in southern and southwestern Kansas Mr. Hay[7] has recently determined, doubtless passes across the state line and extends some distance up the Arkansas Valley[8] and over the broad plains on both sides; as yet, however, its distribution is wholly unknown.

PLIOCENE BEDS.

The Pliocene deposits of limited geographical extent southwest of Pueblo, according to Hills[9]—

Have their greatest development on the southern slope of the divide separating the drainage of the Muddy Branch of the Huerfano from Grape Creek and Wet

[1] King, Ex. 40th, Par., 1877, vol. 1, p. 409.

[2] Ibid., p. 426.

[3] Explor. 40th Par., 1877, vol 1, p. 410.

[4] Ibid., p. 411.

[5] Ibid., p. 426.

[6] The Princeton expedition of 1882 made a collection at Chalk Bluffs. Among the material so collected Scott discovered a new species of *Didelphys* (*D. pygmæa*). See Am. Jour. Sci., 3d ser., 1884, vol. 27, pp. 442–443.

[7] This is in accordance with Newberry's observations made in 1859 (Geol. Rep. Explor. Exped. from Santa Fe to Junction of Grand and Green rivers, 1859; pub. 1876, p. 25.)

[8] Robert Hay: Bull. No. 57, U. S. Geol. Surv., 1890.

[9] Proc. Colo. Sci. Soc., 1888, vol. 3, pt. 1, p. 161.

Mountain Valley. The maximum thickness of the beds was estimated to be between 700 and 800 feet. Loosely aggregated coarse conglomerates and sandstones predominate in the lower half of the series, and fawn or buff colored compact marls, sometimes sandy, in the upper half. The basal conglomerates are distinguished from the conglomerates of the Eocene in being composed of much coarser material and in containing a greater number of eruptive pebbles and small bowlders representing varieties common to the more recent eruptive outflows. One prominent bed of conglomerate situated some distance above the base of the series contains cleavable calcite as a cementing material. This bed is exposed on the south side of the divide near the Gradner and Silver Cliff Road.

The Pliocene exposures have but a limited geographical extent in the section of the country examined, being mostly confined to the vicinity of the Grape Creek divide and to small isolated areas of the basal conglomerate occurring in the neighborhood of Greaser Creek and Poison Canyon. A remnant was also observed resting on the eroded surface of the Colorado shales as far east as the southern of the two black buttes near Silver Mountain.

The deposits were traced northeasterly to the head of Cottonwood Canyon, and branches of Williams Creek north of Promontory Bluffs, and for a short distance southwest of Muddy Creek, but toward the northwest, or in the direction of Wet Mountain Valley, they soon disappear under accumulations of heavy glacial drift. This takes place near the top of the divide referred to, where the greatest thickness of Pliocene strata is developed, indicating that the beds underlie the valley for a considerable distance in the direction of Grape Creek and Silver Cliff. The inclination is observed nowhere more than a few feet in the hundred, less generally than the slope of the land surface in the Huerfano Valley. A nonconformity of about 33° exists between the basal conglomerate and the upturned Eocene on Poison Canyon and Greaser Creek, but elsewhere the points of contact with the Eocene are not exposed. Great nonconformity with the Colorado was observed on the southwest side of Muddy Creek.

Between Muddy and Turkey creeks there exists[1] detached deposits of volcanic ash consisting of flat? angular particles of glass, which rest directly on the marls of the Huerfano beds, and from the vertebrate remains found in them are evidently of Pliocene age. They are usually overlaid by beds of coarse sand clay, and in a few places by ancient deposits of travertine partly consolidated into limestone. The ash beds probably belong at the base of the series of marls and conglomerates exposed near the Grape Creek-Muddy Divide.

The search for mammalian remains in the deposits referred to the Pliocene age has met with the best success in the ash beds, from which have been taken a number of bones, including teeth and portions of the jaws of horses and camels, probably belonging to the Upper Pliocene.

Arkansas Park.—Between the Sawatch and Park ranges there is a broad valley along the upper Arkansas, to which the name Arkansas Park is sometimes applied. It was visited in 1869 by Dr. Hayden, who described its more recent geological formations as follows:

On the west side of the Arkansas Valley the recent Tertiary beds run up to and overlap the margins of the mountains. They are composed mostly of fine sands, arenaceous clays, and pudding stones, cream-colored arenaceous clays, and rusty-yellow marls, fine sand predominating. These beds weather into peculiar architectural forms somewhat like the "Bad Lands" of Dakota. Indeed, they are very nearly the same as the Santa Fe marls, and were doubtless cotemporaneous and dip at the same angle, 3° to 5°, a little west of north. The tops of the hills have all been planed down as if smoothed with a roller. I have called this group the Arkansas marls.

[1] Proc. Colo. Sci. Soc. 1889, pp. 220, 221.

They occupy the entire valley of the Arkansas. This valley is about 40 miles in length, and on an average about 5 to 10 miles in width. It might properly be called a park, for it is completely surrounded by mountains.[1]

In a later report[2] we learn that the upper end of this valley or park is about 5 miles below the mining town of Granite, and that terraces have been formed on both sides, showing the former existence of a lake in which were deposited from 800 to 1,200 feet of fine sediments during the Pliocene age.

Peale says:[3]

Above this valley the river is in a canyon or rather a canyon-like valley, until we get above Twin Lakes, when we have another valley reaching almost to the head of the stream. It is about 16 to 20 miles in length, and about 10 miles in width at the lower end. The whole valley, as far as could be determined, is underlaid by granite. At the lower end, back of Weston's ranch, in the terraces, there are modern Tertiary deposits, soft conglomerate sandstones.

Middle Park lake beds.—The lake deposits of Middle Park have thus been described by Marvin[4]:

After the Lignite there is a geological break, the beds next following being of far more recent age. These occur nowhere at the higher elevations, but occupy all the lower basins. In these and following the streams they usually form broad, low terraces, often much cut by the lateral streams into isolated pieces or long, even-topped tongues running out from the valley sides. Near the borders of these areas these beds often plainly show that their material was derived from the adjacent rock, often being of coarse granitic or schistose débris, or débris of the lignitic sandstone worked over; more frequently they are of finer sands and of characteristic marls of exceedingly white color. They are usually found resting on the Archean rocks, as along the Lower Grand, or on the softer shales of the Cretaceous, which, in former times, as now, afforded the weakest lines for erosion to work at most successfully, and which, therefore, occupy nearly all the lower areas. Along such lines, then, the streams cutting through these terraced beds constantly expose beneath them the more or less upturned edges of the Middle Cretaceous beds. They show a thickness of probably not over 300 feet at any point, though their vertical range seems to reach to or above 1,000 feet. A few dips of 10°, possibly 15°, were observed in them in the eastern portion of the park. Unfortunately no fossils were found in these beds, leaving a satisfactory determination of their age impossible, though they are undoubtedly very late, or, perhaps, post-Tertiary.

Concerning these deposits, Hayden remarks[5] that they are undoubtedly contemporaneous with the Arkansas and Santa Fé marls.

North Park lake beds.—In North Park Hague found extensive lake deposits lying in general nearly horizontally and rarely inclined at a higher angle than 4°.

They lie unconformably upon the lower rocks, resting in places against every formation from the Archean to the top of the Colorado group, and are seen in an undisturbed condition, resting against the basalts. They extend over the entire Park basin, giving it the level, prairie-like aspect which it presents from all the

[1] 3d Ann. Rept. U. S. Geol. Surv. Terr., 1869, p. 77.
[2] 7th Ann. Rept. U. S. Geol. Surv. Terr., 1873, pp. 48, 49, 50.
[3] Ibid., p. 240.
[4] Ibid., p. 157.
[5] 3d Ann. Rep. U. S. Geol. Surv. Terr., 1869, p. 186.

higher elevations. Through these beds the many streams of the Platte drainage have worn their present channels, leaving everywhere long, bench-like ridges with steep sides, which, though offering numerous good exposures, appear in no case to have cut deeply into underlying strata, thus making any determination of their thickness uncertain.

Within the park they probably do not exceed a few hundred feet. Lithologically, these deposits possess a somewhat local character, the material of which the uppermost beds are formed being derived exclusively from the relatively narrow limits hemmed in by the park walls, rendering any comparison with other basins almost impossible, although they present certain features like the Niobrara Pliocene beds east of the Laramie hills.

So far as known to us, neither vertebrate nor invertebrate forms have as yet been obtained from these deposits, so that paleontological evidence, so desirable in determining the age of Tertiary basins, is still wanting for the North Park deposits. It is quite probable that there may be found included within the Park two distinct Tertiary series. Some observations were made at the time of our explorations, which would tend in this direction, showing a lower set of unconformable beds, which, however, reach the surface in only a few localities, the greater part of the area being covered with more recent deposits. From the difficulty of sharply defining the two horizons of these beds, they have been given a local name, the North Park Tertiary, and a distinct designation upon the geological map. Partly from the general appearance of the strata, and in part from their relation to the basaltic rocks, they have been regarded provisionally as of late Pliocene age.[1]

MONUMENT CREEK GROUP.

There is still another series of deposits that must be considered before leaving this state. We refer to the Monument Creek group of Hayden. Its geographical distribution is shown on map 11 of "Maps and Panoramas" accompanying the 12th Annual Report of the U. S. Geological Survey of the Territories, as well as on the map accompanying this report. Hayden encountered this group in 1869 while on his way from Denver southward, and described it substantially as follows[2]:

About 5 miles south of Platte Cañon one meets with a series of variegated beds of sand and arenaceous clays, nearly horizontal, resting on the upturned edges of the older rocks. These beds form the northern edge of an extensive Tertiary basin of comparatively modern date, either late Miocene or Pliocene. From the point of their first appearance to about 5 miles north of Colorado City, these beds jut up against the foot-hills of the mountains, inclining at a small angle, never more than 8 degrees, and entirely concealing all the older sedimentary rocks. Far to the eastward stretches this Tertiary divide, giving rise to a large number of streams, as Cherry Creek, Running Water, Kiowa, Bijou, and other creeks. Through this basin flows Monument Creek, which has become so celebrated for its unique scenery.

The beds of this formation are of various colors—red, yellow, and white—and of various degrees of texture, from coarse pudding-stones to very fine-grained sands and sandstones. There is very little lime in the entire series of beds. There is much ferruginous matter in all the beds, to some of which it gives a rusty brown color. Along the mountain slopes the rocks are mostly coarse pudding-stones, the water-worn pebbles varying in size from a grain of quartz to a mass several inches in diameter. But eastward from the mountains the sediments become finer and finer until the coarse pudding-stones disappear. Lignite is sometimes found in the fine argillaceous beds.

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[1] U. S. Geol. Expl. 40th Par., 2, 1877, pp. 127-128.

[2] See 3d. Ann. Rept. U. S. Geol. Surv. Terr., pp. 139-142.

In Monument Park, there are a great number of columns standing thickly over the surface, each surmounted with a cap of harder material. The shaft of the column is usually thick at the base, rising up 10 or 20 feet, tapering to the cap, composed of a coarse aggregate of quartz grains, small pebbles all water worn, very loosely held together with rather coarse sand cement. The cap is a deep rust color, composed of sand cemented with oxide of iron, and by its greater hardness has resisted more effectually the eroding agencies.

At a late period of geological history, dikes or protrusions of igneous material flowed over the Monument Creek sandstones in broad sheets or beds; and broad table-topped buttes or mesas, 100 to 150 feet high, now indicate the extent of later erosion.

In his report for 1869, Hayden referred this group to the Miocene Tertiary, on account of its modern appearance and its position with reference to the granites, but in 1873 he was inclined to regard it as possibly belonging to the upper division of the Lignitic series, since it contains seams of "impure coal, with deciduous leaves, some of which are identical with species occurring in the Lignitic strata from New Mexico to the Upper Missouri. Indeed, the general aspect of the rocks in this region is much like the Lignitic group on the Yellowstone and Missouri rivers near their junction and in the vicinity."[1]

On this question Cope remarks:[2]

The age of the Monument Creek formation in relation to the other Tertiaries not having been definitely determined, I sought for vertebrate fossils. The most characteristic one which I procured was a hind leg and foot of an Artiodactyle of the *Oreodon* type, which indicated conclusively that the formation is newer than the Eocene. From the same neighborhood and stratum, as I have every reason for believing, the fragment of the *Megaceratops coloradoensis* was obtained. This fossil is equally conclusive against the Pliocene age of the formation, so that it may be referred to the Miocene until further discoveries enable us to be more exact.

WYOMING.

The various beds or formations of this State that have usually been assigned a post-Eocene Tertiary age may be enumerated as follows: Neozoic eruptives (partim) of the Yellowstone Park region; Sweetwater Pliocene; Wyoming conglomerate; and the White River and Niobrara Tertiary of the extreme southeastern part of the State.

CENOZOIC ERUPTIVES.

These have been described under the name of "volcanic Tertiary" with considerable detail by W. H. Holmes.[3] Its geographical distribution is shown on map 6 of "Maps and Panoramas" accompanying the last mentioned annual report.

The materials that enter into its composition are for the most part fragmentary volcanic products, which have been apparently redistributed by water, and now form breccias, conglomerates, and sandstones.[4]

[1] 7th Ann. Rep. U. S. Geol. Surv. Terr., 1873, p. 33.

[2] Ibid., p. 430.

[3] In vol. 5, Bull. U. S. Geol. and Geog. Surv., and in part 2, of the Twelfth Annual Report of the same survey.

[4] Bull. U. S. Geol. and Geog. Surv., 1879, No. 1, vol. 5, p. 125.

These reach their maximum development in the valley of the "East Fork," where they rest upon the unevenly eroded surfaces of the paleozoic and granitic rocks and present a total thickness of 5,500 feet. They are preeminently characterized throughout by the enormous quantities of silicified wood they contain. Leaves and small twigs are by no means so abundant as stumps and logs, but at least two localities have yielded determinable leaves, and by these Lesquereux has determined their horizon as Eocene and Lower Pliocene or Upper Miocene respectively.[1] By inspecting the map just referred to, it will be seen that the Eocene beds are limited to narrow strips along the Yellowstone River in the vicinity of Elk Creek, while the post-Eocene deposits are much more widely distributed. The conglomerate material of the latter is frequently interstratified with sheets of basalt, while the rhyolitic outflows are, stratigraphically speaking, above the whole.

SWEETWATER PLIOCENE.

In Central Wyoming, the beds of the Sweetwater group have been extensively scooped out or eroded, and upon them have been deposited marls and sands of Pliocene age.[2] "Near the base * * * we find a very loosely aggregated sandstone, almost partaking of the character of a conglomerate. It is light gray and yellowish, easily decomposing." Above this follows a succession of light marls and indurated clays. Usually these are either very light yellow or white, but pink and greenish beds are not wanting. Toward the eastern terminus of the group, the strata become highly siliceous. These beds are nearly horizontal; along their northern border they participate in the southward dip of the Sweetwater group,[3] amounting from 1° to 4°.

The geographical distribution of these "Pliocene" deposits may be seen by consulting maps 3 and 11 of "Maps and Panoramas" accompanying the Twelfth Report of the U. S. Geological and Geographical Survey of the Territories. Endlich estimates their maximum thickness as from 700 to 900 feet.[4] They are probably of Loup Fork horizon, as shown by their lithological characters, their horizontality, and their vertebrate remains.

A small collection of fossils was obtained by Hayden's expedition of 1870, on Sweetwater River, 18 miles west of Devils Gate, Wyoming. Upon these Dr. Leidy reports[5] and finds them "Nearly related with those from the Pliocene Tertiary sands of the Niobrara River," and, "without doubt, of a much more recent date than those of the Bridger beds."

Farther to the west, and "within the narrow depression between the subsidiary Prozoic Range and the western base of the Wind River

[1] Bull. U. S. Geol. and Geog. Surv., 1879, No. 1, vol. 5, pp. 126, 128.
[2] Fourth Ann. Rep. U. S. Geol. and Geog. Surv. Terr., 1870, p. 29.
[3] 11th Ann. Rep. U. S. Geol. and Geog. Surv. Terr., 1877, p. 112.
[4] Ibid., p. 113.
[5] U. S. Geol. Surv. Terr., vol. 1, pp. 198–209.

Mountains," there is a local depression filled with loose white and yellowish clays and marls. Their thickness has been estimated at about 300 feet, and they have been regarded as synchronous with the Pliocene of Sweetwater River, although no fossils except a *Pupa* have been found in them.[1]

WYOMING CONGLOMERATE.

Concerning this formation Endlich remarks:

This term has been used by Emmons and Hague to designate the widespread conglomeritic accumulations of drift which may be assigned to the Pliocene period. It is entirely structureless and composed of most varying material. Essentially it may be regarded as the product of all the formations existing within a given area. During the last era of extensive inundations it was deposited at the most convenient localities. Along the entire northern slope of the Sweetwater and Seminole hills we find enormous deposits of this material. No structure whatever can be observed there, and the whole forms merely a huge cover of erratic bowlders. Their size varies somewhat, but does not reach any considerable dimensions. We find the narrow gullies running down from the hillsides cut into this conglomerate, and the tops of the ridges are covered by it for some distance. Its presence is so marked a feature in this region that it can not be overlooked. With regard to its age, I consider the period of deposition as synchronous with that of the younger portions of the Pliocene marls and shales. It is found near the edges of the ancient lake, and was probably carried there by the waters draining into the former. It must not be mistaken for the glacial drift which occurs in the same region. The relative positions alone of these two deposits will easily determine their character.[2]

This same conglomerate occurs in the limited Pliocene valley west of South Pass. In fact "it is scattered to a greater or less extent all over the country, which has been subjected to extensive erosion."[3]

WHITE RIVER GROUP.

Cenozoic beds in the extreme southeastern part of the State.—Referring to this area, Dr. Hayden remarks:

That portion of Wyoming east of the Laramie range and south of the line of the Union Pacific Railroad is entirely covered with the upper beds of the White River Tertiary basin. The valley of the Lodge Pole, Crow Creek, and Chugwater show the formations of this basin very distinctly from mouth to source. The Union Pacific Railroad ascends the eastern slope of the Laramie range on a sort of bench of this formation, which seems to be unusually developed, and to extend without much interruption up to the very margin of the mountains, sometimes concealing all the rocks of intermediate age and resting on the syenites.

About 20 miles south of Cheyenne these beds disappear entirely along the western flank of the mountains, and the lignite Tertiary beds are exposed to view.[4]

Again:

The geological formations immediately underlying Cheyenne are of Tertiary age, probably Pliocene or very late Miocene. The beds have been slightly disturbed by the upheaval of the mountain range, but their position in relation to the older Ter-

[1] 11th Ann. Rep. U. S. Geol. and Geog. Surv. Terr., 1877, pp. 132–133.
[2] Ibid., pp. 113–114.
[3] Ibid., p. 133.
[4] U. S. Geol. and Geog. Surv. Terr., 1869, vol. 3, p. 11.

tiary beds shows their deposition to have been of late date. They are found deposited in the valleys and sometimes high on the mountain sides, and it is very seldom that they dip at an angle of more than 5°. These beds can be traced far northward to the Black Hills of Dakota, a distance of 350 miles, and they are thus shown probably to be the upper beds or most recent formation of the White River Tertiary.[1]

UTAH.

There are two series of deposits within this territory which for reasons elsewhere given have been referred to the Neocene division of the Tertiary. They are (1) the Humboldt group of King, which includes the Salt Lake group of Hayden, and (2) the Wyoming conglomerate.

THE HUMBOLDT GROUP.

This is well displayed in Weber, Ogden, and Cache valleys east of Great Salt Lake, and in the Terrace and Raft River mountains to the west. In Weber Valley it was that Hayden[2] first studied this formation and found it to consist of light colored sands, sandstones, and marls, reaching in thickness from 800 to 1,200 feet.

The corresponding deposits of Ogden Valley "have been referred to the Humboldt Pliocene, although it should be stated that they are too far removed from well defined Humboldt formations to trace any direct connection, and paleontological evidence is yet too meager to throw any important light on the question."[3]

Beds in Cache Valley, supposed to be of this age, have been described by Hayden,[4] Bradley,[5] Hague,[6] Peale,[7] and others. The central portion of the valley is occupied by Quaternary deposits, termed by Peale the Cache Valley group, while the older beds crop out around the borders. The latter are accredited by Bradley with a dip of 25° in some instances. Hague says: "They are found to have been considerably uplifted, showing angles of dip of 10° and 15°." These figures, it will be observed, indicate a considerably greater amount of dip than is usually shown in the sedimentary "Pliocene" deposits of the West.

The maximum thickness of these beds is not less than 350 feet.[8]

At one locality, Mendon, some of the sandy layers contain vast numbers of *Limnæa*, *Physa*, *Vivipara*, and *Helix;* at the "Gates" the limestones and shales contain *Limnæa*, *Valvata*, *Planorbis*, *Sphærium*.[9] These fossils, however, are of little value for determining the age of the strata in which they are entombed. The determination rests wholly upon lithologic and stratigraphic criteria.

[1] U. S. Geol. and Geog. Surv. Terr., 1869, vol. 3, p. 11.
[2] Prelim. Rep. U. S. Geol. Surv. Col. and N. Mex., 1869, p. 92.
[3] U. S. Geol. Explor. 40th Par., vol. 2, Descriptive Geology, 1877, p. 418.
[4] U. S. Geol. Surv. Terr., 5th Ann. Rep., 1871, pp. 19–22.
[5] U. S. Geol. Surv. Terr., 6th Ann. Rep., 1872, p. 199.
[6] U. S. Geol. Explor. 40th Par., vol. 2, Descriptive Geology, 1877, pp. 406, 417.
[7] U. S. Geol. Surv. Terr., 11th Ann. Rep., 1877, p. 603.
[8] U. S. Geol. Explor. 40th Par., vol. 2, Desc. Geol., 1877, p. 417.
[9] U. S. Geol. Surv. Terr., 11th Ann. Rep., 1877, pp. 604–605.

On both eastern and western slopes of Terrace Mountain there is a broad canyon, filled to some extent with beds that "resemble the fine sands, reddish gravels, and marls which form the Humboldt Pliocene beds of eastern Nevada, and have been referred to the same horizon."[1]

The western slopes of Raft River Mountains "are covered high up on the flanks by heavy white beds, sloping gently toward the center of the valley, composed of fine white pumiceous sands, loose sandstones, fine conglomerates, which have been referred to the horizon of the Humboldt Pliocene, from their general resemblance to these beds as developed in the valley of the Upper Humboldt."[2]

THE WYOMING CONGLOMERATE.

The Wyoming conglomerate may be seen along both flanks of the Uinta range, forming the cap-rock of minor elevations, such as Ti Ra-Kava and Concrete plateaus and Black Tail Mountain.[3] It is often 100,[4] 200, or even 300[5] feet in thickness, is composed wholly of local materials, and is devoid of organic remains.[6]

(See this formation under Wyoming.)

NEVADA.

The post-Eocene Tertiary geology of this State is known chiefly from the reports of the U. S. Geological Exploration of the fortieth parallel. The various deposits here referred to which are found scattered about in widely different localities are treated in these reports as having been laid down in two great sheets of fresh water, one of Miocene, the other of Pliocene age, to which King has applied the names Pah-Ute and Shoshone lakes. To the deposits of the former this author gives the name "Truckee group;" to those of the latter, "Humboldt group."

TRUCKEE GROUP.

Numerous references have already been made in our discussions of adjacent States to deposits supposed to form a part of the group. King says:[7]

> The rocks of the group are limited on the east, within the boundaries of our exploration, by the one hundred and seventeenth meridian, and on the west by the abrupt wall of the Sierra Nevada. Northward they extend through Oregon and pass into Washington Territory, having their greatest development on Crooked River, the John Day, and the Malheur. South of our work they are all well known in the valley of the Walker River, but beyond that southward I am not aware of their having been observed.

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[1] U. S. Geol. Explor. 40th Par., vol. 2, 1877, p. 427.
[2] Ibid, p. 429.
[3] See Maps II and III of Atlas accompanying King's Reports.
[4] U. S. Geol. Explor. 40th Par., vol. 2, Descr. Geol., 1877, p. 247.
[5] Ibid., p. 290.
[6] Ibid., p. 248.
[7] U. S. Geol. Explor. 40th Par., vol. 1, Syst. Geol., 1878, p. 413.

For details regarding their distribution in Nevada, reference should be made to the reports of King, Hague, and Emmons, also to the accompanying atlas.

In King's report on the Systematic Geology (p. 415), he says:

The most important and characteristic development of this series within our limits is at the Kawsoh Mountains and along the southern extremity of Montezuma Range. The northern and eastern portion of the Kawsoh Mountains and the valley which lies north of them, separating the broken detached group of hills from the end of Montezuma Range, together offer a section of about 2,300 feet of Miocene beds, noting from the top as follows:

1. The upper 1,200 feet consists entirely of drab mauve gray, pale buff, and white stratified trachyte tuff, intermixed with more or less detrital material. The beds are characterized by rapid changes of color and texture, are of very variable coarseness, and have a prevailing amount of glassy fragments, as if an enormous amount of the material were the glassy scoria and rapilli of violent and long continued trachytic eruption. At intervals are beds of pure gray sand, with a few seams of slightly marly clay. The microscope shows that this entire series is made up of angular and subangular fragments, many of them excessively small. There are some singular chalcedonic strata, one to two feet thick, of which the lower stratum plane is exceedingly rough, resting upon the trachytic tuff and including a great many minute fragments of the volcanic material, the upper surfaces being rudely botryoidal, the protuberances reaching the size of an egg. Toward the lower edge of this great series of trachytic tuffs, the upper limits of which are nowhere seen, the proportion of their detrital material—quartz and feldspar sand—becomes rapidly greater until the tuff is underlaid by:

	Feet.
2. Coarse, sandy grits, gray and yellow fragments, partially rounded, partially angular, with a slight proportion of calcitic material.........	250
3. Saccharoidal limestone, rich in fresh-water mollusks[1]................	60
4. Marly grits, yellow and drab, rather coarse..........................	40
5. Fine-grained friable buff and gray sandstone, having a peculiarly sharp gritty feel	70
6. Variable gray sandstones..	100
7. A marly grit	50 or 60
8. White and yellow infusorial silica	200 to 250
9. Palagonite tuff, base never seen ....(maximum exposure) ..	250

Intermediate between the times of deposition of the two fresh-water groups already referred to, or perhaps synchronous in part with the earlier portion of the latter, there were enormous outpourings of the rhyolitic materials in the area under consideration. The older, or Truckee group, was accordingly often much disturbed by volcanic and orographic phenomena, and its layers are often inclined 10°, 20°, or even 30° from the horizontal.

Concerning the age of this group, King[2] says:

No vertebrate remains have been found upon the area of Map V, except a single rhinoceros tooth[3] from the grits of the Kawsoh Mountains, a species which has been pronounced to be probably Miocene. The fresh-water mollusca of the saccharoidal

[1] *Sphærium rugosum* Meek, *Sphærium? idahoense* Meek, *Anyclus undulatus* Meek, *Carinifex (Vorticifex) binneyi* Meek, *C. (V.) tryoni* Meek, *Melania? subsculptilis?* Meek, *M. sculptilis* Meek (= *M. taylori* Gabb). U. S. Geol. Surv. 40th, vol. 4, pt. 1, pp. 182–196. First published in Proc. Phila. Acad. Nat. Sci., 1870, pp. 56–60.

[2] Systematic Geology, 1878, p. 423-424.

[3] *R. pacificus* probably, King, p. 455.

limestone of Fossil Hill would not alone afford sufficient data for referring this series to the Miocene, although Prof. Meek, independently of any other reason, made this assignment. The main reason for classing the whole group as Miocene is, that farther north in Oregon upon John Day, Des Chutes, and Crooked rivers, Prof. Meek's researches have brought to light an immense formation computed by him to be 3,000 or 4,000 feet thick, containing numerous vertebrate remains of clearly Miocene type. These Oregon beds are all in inclined positions, earlier than basaltic eruptions, and the main material of this whole series, as I have determined by microscopic studies, is of stratified trachytic pumices, tuffs, and hyaline sands. The Oregon Miocene is apparently the direct northern continuation of the Nevada formation. Besides the parallelism between the two series, is the fact of an overlying unconformable Pliocene in each case. The mollusks from Fossil Hill and the rhinoceros tooth distinctly refer the Nevada strata to the Miocene. The overlying Pliocenes and basalts are similar and of identical position in each case; and this, together with the identity of material and similarity of disturbed position, has led us finally to refer our Truckee group to the Miocene.[1]

Paleontology.—If we confine ourselves to the development of this group within the boundaries of Nevada, its paleontologic features can be given in few words. Besides the above-mentioned rhinoceros tooth and fresh-water mollusks, infusorial and vegetable remains have been noted in several localities. Just above the town of Reno, in Truckee valley, Hague finds in beds doubtfully referred to this group, "stems, leaves, and partially carbonized vegetable matter," which "are abundant in certain layers of shale." Coal seams have been observed north of the town of Verdi, and on Dog Creek, a short distance north of Crystal Peak.

Regarding the infusoria referred to in King's section, quoted above, Hague[2] says:

Under the microscope, even with a moderate power, these siliceous beds are seen to be made up of innumerable fragments of Diatomacea. Dr. C. G. Ehrenberg,[3] of Berlin, Prussia, to whom were sent a large number of specimens from this locality has described no less than thirty-three distinct organic forms, one of which may belong to the vegetable world. Of these forms, twelve have been classed as *Polygastrica* and twenty as *Phytolitharia*, the most abundant species being:

Gallionella granulata.
Gallionella sculpta.
Spongolithus acicularis.

Accompanying Dr. Ehrenberg's work is a plate giving the microscopic sections of the infusorial earth from this locality, together with others from the Truckee Valley, and Salt Lake Desert.

A similar deposit is noted about 2 miles south of Winnemucca Lake (p. 320).

HUMBOLDT GROUP.

This group, according to the geologists of the fortieth parallel, was deposited in "Shoshone Lake," whose existence was in part contemporaneous with, but mainly subsequent to, the period of rhyolite outflows,

[1] On p. 450 he correlates it with the White River group.
[2] Descriptive Geol., vol. 2, p. 768.
[3] Ueber die wachsende Kenntniss des unsichtbaren Lebens als felsbildende Bacillarien in California, p. 19, Berlin, 1870.

though often hidden under vast sheets of basalt. References will be found under Oregon, Washington, Idaho, and Utah of outlying portions of this formation, but it is in Humboldt Valley, Nevada, that it is typically developed and accordingly receives its name. King describes this region, as follows:

West of Humboldt and Tucubits ranges there is a long valley drained by Humboldt River and Huntington Creek. Throughout the length of this depression, over 100 miles, there is a nearly continuous exposure of horizontal Pliocene beds. It is difficult to decide what thickness of beds is exposed, since they are often buried by Quaternary, but there can not be less than 600 or 800 feet. In the middle of this valley the beds are horizontal, but on either side there is a dip of from 2° to 3°, which is probably the inclination of deposition. The foot-hills of the ranges on both sides are skirted by continuous belts of Tertiary, which are beveled off to the central valley. Streams have excavated broad depressions down these plains and the intervening spurs have been graded off, so that the whole valley country presents few abrupt exposures and those only along certain exceptionally sharp stream cuts. The most important of these are seen in the valley of the South Fork of the Humboldt, where 100 to 150 feet of sandstone cliffs flank the valley on either side. Here are found sands that are at times quite marly, associated with more or less coarse beds of grit, which nearer the mountains are entitled to be named conglomerate. There are a few calcareous clays, and some limited beds of true marly limestone. It is not surprising that this whole Pliocene exposure should have more or less calcareous material within its mass, since so large a portion of the surrounding mountain sides from which the material has been derived is of Paleozoic limestones.

The descriptions of this formation as it occurs at numerous other localities within the limits of the fortieth parallel survey will be found in volumes 1 and 2 of its reports.

Concerning the age of this group, King remarks:

At Bone Valley, which is drained by the waters of the North Fork of the Humboldt, a few vertebrate remains were found, including a jaw of *Protohippus perditus*, also a jaw of *Merychippus mirabilis*, and fragments of *Cosoryx*. These forms are of importance as proving the identity of the beds in which they were found with those of the Niobrara Pliocene east of the Rocky Mountains.

Cope evidently refers[1] these fossils to the Procamelus division of the Loup Fork (Niobrara) Miocene. Fossil remains are exceedingly rare in the formation within the boundaries of Nevada. They appear to be limited to the forms mentioned above, together with a few undetermined fresh-water mollusks.

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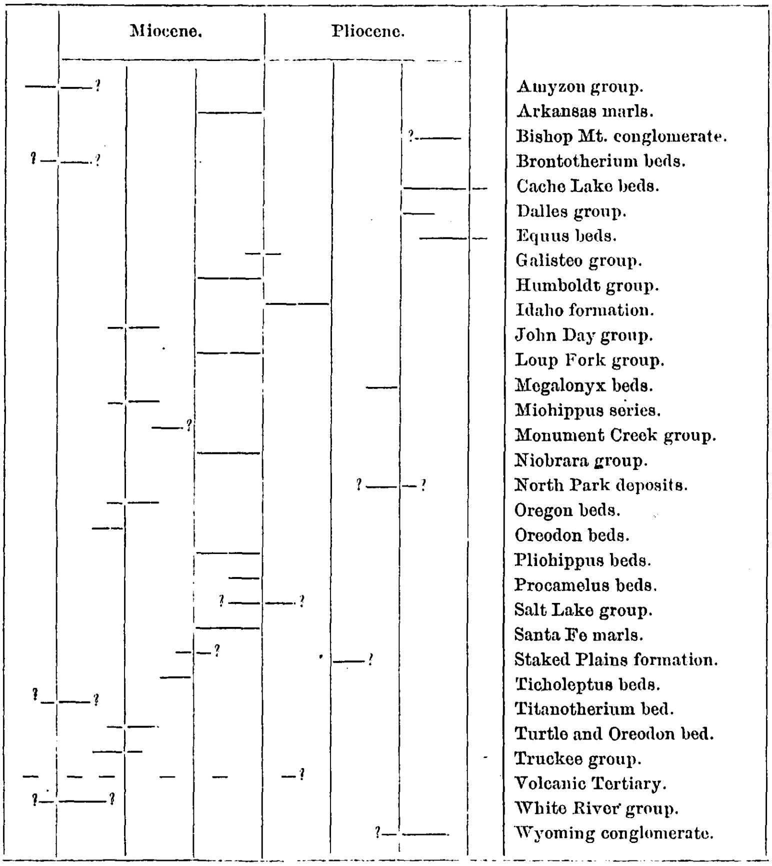
[1] U. S. Geol. Surv. Terr., 1884, vol. 3, p. 19.

Table showing the vertical range of the Neocene formations of the interior region.



NOTES ON THE MAP.

In view of the uncertainty in the determination of the age of many of the Neocene beds of the Great Interior region, it has seemed best to color them uniformly and leave to the future the task of assigning to each area its relative position in the geologic scale.

The small scale of the map renders it impracticable to discriminate the subdivisions of the Miocene by separate colors. The old Miocene area is mostly indicated on the map of Florida. Northeastward of Georgia the only area of this age which has been definitely recognized is that represented by the small patches of the Shiloh marls in southwestern New Jersey. The rest of the Atlantic Miocene, not perezonal in character, belongs to the Chesapeake group as far as yet identified.

The Eocene island of Florida is colored on account of the important relation it bears to the beds about it and to distinguish it from Pleistocene and other areas left uncolored. As the lake areas and swamps of Florida are undoubtedly Pliocene under their Pleistocene sands, the Okeefinokee Swamp is presumably of the same age, and there is reason to believe, as elsewhere shown, that this is also true of the Dismal Swamp of Virginia. These areas have therefore been mapped as Pliocene. Part of the marginal beds of sand, clay, etc., which border the Gulf Miocene on the south, are presumably Pliocene, as well as the central portion of the trough of the Mississippi Basin below the material which has been rearranged in Pleistocene times, and apart from the Appomattox formation. These are distinctively colored to distinguish them from the marine beds denoted by their fauna to be Pliocene. The peneplains of the valley of California and of the Willamette River, Oregon, are similarly treated.

On the Atlantic coast there are gaps in the vicinity of the great Carolinian ridge where the Neocene has been denuded, leaving only smaller or larger patches in the more depressed basins of the Eocene surface. These patches, often too small to be separately platted on a map of this scale, have been generalized for present purposes.

Submarine areas off Hatteras, Nantucket, and on Georges Banks, have been indicated by a circular spot in each case.

The Neocene of the Pacific coast has been indicated from the sources of information mentioned in the text. That of the State of Washington is mapped from the geological map of the Dominion of Canada, no published information other than that being available, especially for the portion west from Puget Sound. No attempt has been made to map the volcanic rocks possibly of Neocene age.

The Appomattox formation is mapped in two shades of color. One of these represents that portion of this formation which has been recognized by McGee as forming the top rock or surface material, and as such has been definitely mapped by him. In the northwestern part of the Gulf of Mississippi the beds of this formation have been denuded, making a gap in the perezonal line. Following the general relation of the known beds to the subjacent Eocene, the remainder of the Appomattox perezone has been carried hypothetically across Arkansas and Texas, in order to enable the eye to take in more fully the relations of the formation as a whole as at present understood.

A lighter shade indicates the extension under the sands of the Columbia formation of beds assigned by McGee to the Appomattox, though in southern Georgia and northern Florida this extension is represented as somewhat less than he would give it, since, theoretically, it would seem improbable that these beds should cover the Okeefinokee Basin, while the oxidized gravels and red clays of northern Florida may well have had another origin.

In the interior, Neocene beds, according to Cope, exist on the line separating the two Dakotas, where beds assigned by him to the White River horizon form a Neocene island separated by a gap of 200 miles from those of the same character to the south. As there are no data for the definite location of these beds geographically, they have been omitted on the map.

In the lower part of the Colorado Valley near the Gulf of California it is probable that Pliocene beds exist, but in the absence of definite information no attempt has been made to place them on the map. Throughout the map the presence of post-glacial or Pleistocene beds above the Neocene rocks has been ignored; the object being to show as fully as existing information would warrant the general distribution of the Neocene formations. If the presence of the superficial Pleistocene materials had been taken into account the underlying beds would have been practically hidden from view, except as almost invisible lines along the water courses or the shores.

CHAPTER VII.

LIST OF NAMES APPLIED TO CENOZOIC BEDS AND FORMATIONS OF THE UNITED STATES, EXCLUDING THE LARAMIE.[1]

ÆOLIAN SANDROCK.

Wind-blown character of contents. W. H. Dall, 1892;[2] this essay, pp. 153–155. Pleistocene of Florida.

ALACHUA CLAYS.

Alachua County, Florida. W. H. Dall, 1892; this essay, p. 127. Pliocene.

ALTAMAHA GRIT.

Altamaha River, southeast Georgia. W. H. Dall, 1892; this essay, p. 81. Older Miocene.

ALUM BLUFF BEDS.

Typically displayed in the upper part of the bluff at Alum Bluff, eastern bank of Appalachicola River, northwest Florida. W. H. Dall, 1892; this essay, p. 112. Miocene.

AMYZON BEDS.

Amyzon, generic name of a characteristic fish. E. D. Cope, May, 1879; Am. Nat., vol. 13, p. 332. Later Eocene or early Miocene.

Amyzon group. Cope; Am. Nat., June, 1880.

These beds were first described, though not named, by Cope in 1872; Proc. Am. Phil. Soc., 1872, p. 478.

APPOMATTOX FORMATION.

Appomattox, a river of Virginia, along which the formation is typically displayed. W. J. McGee, Feb., 1888; Am. Jour. Sci., 3rd ser., vol. 35, p. 125; "Later Tertiary age;" "Much nearer the age of the Columbia formation than that of the fossiliferous Miocene" (Ibid., p. 330); its age corresponds "at least roughly with the Pliocene." (Ibid., vol. 40, p. 33.) "Post-Pliocene"? Langdon (Ibid., vol. 40, p. 238).

See under Lafayette formation.

ARAPAHOE BEDS.

Arapahoe County, Colorado. George H. Eldridge, 1889; Am. Jour. Sci., 3rd ser., vol. 37, p. 282.[3]

Lowest Tertiary.

ARCADIA MARL.

Arcadia, De Soto County, Florida. W. H. Dall, 1892; this essay, p. 131. Older Pliocene.

ARKADELPHIA SHALE.

Arkadelphia, a town, Clarke County, Arkansas. Robert T. Hill, 1888; Rept. Ark. Geol. Surv., vol. 2, p. 53. Eocene.

ARKANSAS MARLS.

Arkansas River, Colorado. F. V. Hayden, 1869; Preliminary Field Report of the U. S. Geol. Surv. of Colorado and New Mexico, p. 77.

"Contemporaneous with the Santa Fe marls."

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[1] The names applied to Pleistocene beds in this essay are included.

[2] Date of publication. This and other names by W. H. Dall were proposed in 1891.

[3] See also Proc, Col. Sci. Soc.; 1888, vol. 3, part 1, p. 97. This publication, though apparently antedating the preceding, did not actually appear until some time after the former.—Whitman Cross.

ASHLEY BEDS.

Ashley River, South Carolina. M. Tuomey, 1848; Report on the Geology of South Carolina, p. 164. Eocene.

ASHLEY AND COOPER BEDS.

Ashley and Cooper rivers, South Carolina. M. Tuomey, 1848; Geology of South Carolina, pp. 162, 211. "Newest Eocene of the State."

ASTORIA GROUP.

Astoria, a town in Clatsop County, Oregon. W. H. Dall, 1892; this essay, p. 225. Miocene.

Includes the Astoria shales and sandstones, the Solen bed of Condon, the Crepidula bed of Dall, and the Nulato sandstone.

ASTORIA SANDSTONES.

Astoria, a town in Clatsop County, Oregon. W. H. Dall, 1892; this essay; p. 224. Miocene.

ASTORIA SHALES.

Astoria, a town in Clatsop County, Oregon. Thomas Condon; published by E. D. Cope from MS. notes of Prof. Condon, June, 1880; American Naturalist, vol. 14, p. 457. Miocene.

ASTRINGENT CLAY.

Astringent property of the clay. H. D. Rogers, 1836; Report of the Geol. Surv. of New Jersey, p. 26. Eocene.

ATLANTIC GROUP.

Lying along the Atlantic border. Otto Meyer, 1888; American Geologist, p. 93. Includes all the Tertiaries of the Atlantic slope.

ATURIA BED.

Aturia, a characteristic fossil. W. H. Dall, 1892; this essay, p. 224. Upper Eocene of Astoria, Oregon.

AURIFEROUS GRAVELS.

Gold-bearing gravels of the Sierra Nevada, California. J. D. Whitney, 1879; Mem. Mus. Com. Zool. at Harvard College, vol. 6, 1. Neozoic, culminating in the later Pliocene.

BASAL OR WILLS POINT CLAYS.

Basal, because "its position is the lowermost of the Eocene," and Wills Point, Texas, where the beds are well exposed. R. A. F. Penrose, jr., 1889; First Ann. Rep. Geol. Surv. Tex., 1890, p. 19. Lower Eocene.

BASHI SERIES.

Bashi Creek, Clarke County, Alabama, on which the series is typhically displayed. Smith and Johnson, 1887; U. S. Geol. Surv. Bull. No. 43, p. 43.

=Wood's Bluff series.

BELL'S LANDING SERIES.

Bell's Landing on Alabama River, Monroe County, Alabama. E. A. Smith and Lawrence Johnson, 1887. U. S. Geol. Surv. Bull. No. 43, p. 46. Lignitic Eocene.

=Tuscahoma series.

BINGEN SANDS.

Bingen, a village, Hempstead County, Arkansas. R. T. Hill, 1888; Ann. Rep. Ark. Geol. Surv., vol. 2, p. 56. Eocene.

BISHOP MOUNTAIN CONGLOMERATE.

Bishop Mountain, Sweetwater County, Wyoming. J. W. Powell, 1876; Geol. Uinta Mts., pp. 40–44. "Pliocene."

=Wyoming conglomerate.

BISON BEDS.

Bison, generic name of a characteristic fossil. O. C. Marsh, 1887; Am. Jour. Sci., 3d ser., vol. 34, p. 324. "Probably later Pliocene."

=Denver group, partim.—Cross.

The name has been canceled by Marsh (in lit.)

BITTER CREEK GROUP.

Bitter Creek, Wyoming. J. W. Powell, 1876; Geol. Uinta Mts., pp. 40, 45, 46. Eocene.

=Wasatch group; see p. 65.

Its upper part includes the Washiki group, p. 65.

BLACK BLUFF SERIES.

Black Bluff on Tombigbee River, Sumter County, Alabama. Smith and Johnson, 1887; U. S. Geol. Surv., Bull. No. 43, p. 61. Eocene.

To be known as the Sucarnochee series in a forthcoming report by Smith and Langdon.

=Buff sand, partim.

BLUFF LIGNITIC.

Bluffs along the Mississippi containing lignite. J. M. Safford, 1864; Am. Jour. Sci., 2d ser., vol. 37, p. 370. Provisional Tertiary?

Identified with Safford's Porter's Creek group by R. H. Loughridge; Jackson Purchase Region, Geol. Surv. Ky., 1888, p. 41.

BRANDON PERIOD.

Brandon, a town of Rutland County, Vermont. H. C. Lewis, 1880; Proc. Acad. Nat. Sci. Phila., vol. 32, p. 289. Oligocene?

BRIDGER GROUP.

Fort Bridger, Uinta County, Wyoming. F. V. Hayden, 1869; Preliminary Field Report of the U. S. Geol. Surv. of Colorado and New Mexico, p. 91. "Upper Tertiary." Eocene.

=Dinoceras beds.

BRONTOTHERIUM BEDS.

Brontotherium, generic name of a characteristic fossil. O. C. Marsh, 1877; Am. Jour. Sci., 3d ser., vol. 14, p. 354. "Lowest Miocene."

A subdivision of the White River group.

BROWN'S PARK GROUP.

Brown's park, northeastern Utah. J. W. Powell, 1876; Geol. of Uinta Mts., pp. 40, 44. Eocene.

=Uinta Group.—White.

BUFF SAND.

Buff color of the component sands. A. Winchell, 1856; Proc. Am. Assoc. Adv. Sci., vol. 10, p. 89. Lower Eocene.

See Black Bluff series.

BULLA STRIATA MARLS.

Bulla striata, characteristic fossil. W. H. Dall, 1892; this essay, p. 147, footnote. Pleistocene.

=Venus cancellata bed, partim, Heilprin.

BURRSTONE FORMATION.

Burrstone (Buhrstone), a rough siliceous rock characteristic of the formation. Charles Lyell, 1845; Quart. Jour. Geol. Soc., Lond., vol. 1, p. 435. Eocene.

Regarded by Lyell as newer than the White Limestone.

John Finch referred to the "Buhr-stone of Georgia" as early as 1823 (Am. Jour. Sci., vol. 7, p. 38), and Vanuxem used the term in 1827 (Jour. Acad. Nat. Sci., Phila., vol. 6, pt. 1, pp. 60, 66), but in each case the usage seems that of a common rather than a proper noun.

CACHE LAKE BEDS.

Cache Lake, Lake County, California. G. F. Becker, 1888; U. S. Geol. Surv., Monograph vol. 13, p. 219. Late Pliocene.

CALAMITE BEDS.

Calamites, characteristic fossil. Thos. Condon, by E. D. Cope, Am. Nat., June, 1880; vol. 14, p. 458. Eocene? of central Oregon.

CALCAIRE OSTRÉE.

Abundance of *Ostrea*. John Finch, 1823; Am. Jour. Sci., 1824, vol. 7, p. 39.

A name applied to portions of the Eocene of South Carolina and Georgia, but which may have included some of the lower Miocene of Florida. Conrad, as early as 1832, pointed out the fact that this formation has no real existence.

CALCAREOUS CLAIBORNE.

Calcareousness of the component strata; its fossils show its equivalency to the beds at Claiborne, Alabama. Eug. W. Hilgard, 1860; Agric. and Geol. Miss., p. 126. Middle Eocene.

CALOOSAHATCHIE BEDS.

Typically exposed on that river in Florida. W. H. Dall, 1887; Am. Jour. Sci., 3d ser., vol. 34, pp. 167, 169.

Includes the upper marine and fresh-water Pliocene of south Florida and South Carolina.

CAMDEN SERIES.

Camden, a town, Ouachita County, Arkansas. Robert T. Hill, 1888; Ann. Rep. Ark. Geol. Surv., vol. 2, p. 49. Eocene.

CAROLINIAN (Upper Atlantic Miocene).

Typically developed in North and South Carolina. Angelo Heilprin, 1882; Proc. Phila. Acad. Nat. Sci., 1882, p. 183. Upper Miocene.

CERITHIUM ROCK.

Abundance of the genus *Cerithium*. Angelo Heilprin, 1887. Trans. Wagner Free Inst. Sci., vol. 1, pp. 11, 123. Older Miocene of Florida.

CHATTAHOOCHE GROUP.

Chattahoochee, river and town, northwestern Florida. D. W. Langdon, 1889; Am. Jour. Sci., 3d ser., vol. 38, p. 324. Basal Miocene, as shown in this essay.

CHATTAHOOCHEE LIMESTONE.

Typical exposure on the Chattahooche River, northwestern Florida. W. H. Dall, 1892; this essay, pp. 106, 107. Older Miocene.

CHESAPEAKE FORMATION.

Typical exposures on the bay of that name. N. H. Darton, 1891; Bull. Geol. Soc. Am., vol. 2, p. 443. Includes the Miocene of Maryland and Virginia, and is the term stratigraphically equivalent to the expression "Yorktown Epoch" of Dana.

CHESAPEAKE GROUP.

Typically developed in the hydrographic basin of Chesapeake Bay. W. H. Dall, 1891; Geological Magazine for June, 1891, p. 287; this essay, p. 123.

Includes the Chesapeake formation of Darton and all other beds containing the same general fauna of the Atlantic and Gulf coasts of the United States.

CHICO-TEJON GROUP.

Chico, a town and creek in Butte County, California, and Tejon, a fort in Kern County, California. C. A. White, 1885; U. S. Geol. Surv., Bull. No. 15, p. 11. Cretaceo-Eocene.

CHIPOLA BEDS.

Typically exposed at Chipola River, Florida. W. H. Dall, 1892; this essay, p. 112. Older Miocene of Florida.

CHIPOLA MARL.

Typically displayed on Chipola River, northwestern Florida. W. H. Dall, 1892; this essay, p. 122. Older Miocene.

=Chipola formation of Frank Burns (MS. notes), 1890.

CLAIBORNE GROUP.

Claiborne, a town, Monroe County, Alabama. T. A. Conrad, January, 1855; Proc. Phila. Acad. Nat. Sci., vol. 7, p. 257. Eocene. "Claibornian," Heilprin; Proc. Acad. Nat. Sci. Phila., 1882, p. 184.

CLAYTON GROUP.

Clayton, Barbour County, Alabama. D. W. Langdon, July, 1891; Bull. Geol. Soc. Am., vol. 2, p. 594. Name applied to a phase of the Midway Eocene in eastern Alabama.

CLEVELAND COUNTY RED LANDS.

Red color of the soil in Cleveland County, Arkansas. Robert T. Hill, 1888; Ann. Rep. Ark. Geol. Surv., vol. 2, p. 58. Eocene.

CORAL LIMESTONE.

Characterized by fossil corals. Smith and Johnson, 1887; U. S. Geol. Surv., Bull. No. 43, p. 18. Uppermost Eocene of Salt Hill, Clarke County, Alabama.

CORYPHODON BEDS.

Coryphodon, name of a characteristic genus. O. C. Marsh, 1877; Am. Jour. Sci., 3d ser., vol. 14, p. 354. Lowest Eocene.

See Wasatch group.

CREPIDULA BED.

Crepidula, characteristic fossil. W. H. Dall, 1892; this essay, p. 255. Marine Miocene of Alaska.

CUCHARA BEDS.

Cuchara River, central Colorado. R. C. Hills, 1891; "Remarks on the classification of the Huerfano Eocene." Abstract from vol. 4, pt. 2, Proc. Colo. Scientific Soc., February, 1891. Lower Eocene.

DALLES GROUP.

"The Dalles," a town, Wasco County, Oregon. Thomas Condon; first published by E. D. Cope, from Condon's MS. notes, June, 1880; Proc. Am. Philos. Soc., vol. 19, p. 61. Pliocene. ?

= ? Equus beds.

DENVER GROUP.

Denver, Colorado. O. C. Marsh, 1887. Am. Jour. Sci., 3d ser., vol. 34, p. 324. Eocene? ("Probably late Pliocene."—O. C. M.) "D. Formation," Whitman Cross, Mining Industry, August 3, 1888, and Am. Jour. Sci., 3d ser., vol. 37, p. 261. "Eocene."

DE SOTO BEDS.

De Soto, a supposed Pliocene lake in Florida named for the Spanish explorer. W. H. Dall, 1892; this essay, p. 133. Pliocene.

Includes the lower marine Pliocene beds of Peace Creek and the Alachua clays.

DINOCERAS BEDS.

Dinoceras, generic name of a characteristic fossil. O. C. Marsh, 1877. Am. Jour. Sci., 3d ser., vol. 14, p. 354. Middle Eocene.

= Green River group and Bridger group.—Marsh, 1877.

= Bridger group.—Marsh, 1886.

DIPLACODON BEDS.

Diplacodon, generic name of a characteristic genus. O. C. Marsh, 1877. Am. Jour. Sci., 3d ser., vol. 14, p. 354. Uppermost Eocene.

= Uinta group.—Marsh.

ECPHORA BED.

Ecphora, a characteristic genus. W. H. Dall, 1892; this essay, p. 124. Newer Miocene of Alum Bluff, Chattahoochee River, Florida.

EOCENE.

ἠώς, Ionic form for Att. ἕως = Lat. *Aurora;* dawn, and καινός, ή, όν, Lat. *recens;* new, fresh, recent. Charles Lyell, 1833 (1832, lectures delivered at King's College, London). Principles of Geology, 1st ed., about p. 53 of vol. 3.

NOTE.—We have not had access to the volume itself; the above data are mainly derived from statements made in Lyell's Principles of Geology, ed. of 1834, vol. 1, pp. xiv, xv, and vol. 3, pp. 305, 306, and in Lea's Contributions to Geology, introd. p. 14. It should be noted that the conclusions and researches, which finally resulted in the classification for which the terms Eocene, Miocene, Pliocene, and post-Pliocene were framed, were the joint work of Lyell and G. P. Deshayes. See Bull. Soc. géol. de France, 1830, vol. 1, pp. 185–188.

EO-LIGNITIC.

ἠώς, dawn, and lignitic. Angelo Heilprin, 1881. Proc. Acad. Nat. Sci., Phila., 1881, p. 159, foot-note. Lower Eocene.

EQUUS BEDS.

Equus, a characteristic genus. O. C. Marsh, 1877. Am. Jour. Sci., 3d ser., vol. 14, p. 355. See also plate accompanying "Introduction and Succession of Vertebrate Life in America." Author's edition, 1877. Upper Pliocene. Pleistocene.—G. K. Gilbert, U. S. Geol. Surv., Mon. vol. 1, 1890, p. 393.

EVERGLADES LIMESTONE.

Rock forming about the margin and underlying the basin of the Everglades of Florida. W. H. Dall., 1891; this essay, p. 154. Pleistocene and recent.

FAYETTE BEDS.

Fayette, a county of Texas. R. A. F. Penrose, jr., 1889. First. Ann. Rep. Geol. Surv. Tex., 1890, p. 47, of Penrose's Rep. Equivalent at least in part to the Grand Gulf (Miocene).

FERRUGINOUS GRAVEL.

Character of the beds. W. H. Dall, 1892; this essay, p. 109. Older Miocene of Hawthorne beds of Florida and Georgia.

FLATWOODS CLAY.

Characteristic gray clay formation of the Flatwoods region; a level tract of land bordering the Cretaceous on the west, from Tippah to Kemper County, Mississippi. Eug. W. Hilgard, 1860. Agric. and Geol. Miss., pp. 110, 112, 113. Lowest Eocene.

FLORIDIAN SERIES.

Typically developed in the State of Florida. Angelo Heilprin, 1887. Trans. Wag. Free. Inst. Sci., vol. 1, p. 32. "The Pliocene series of the Caloosahatchie." Loc cit.

= Floridian group, partim, this essay, which includes in this group all the Pliocene beds of Florida.

FLORIDITE PHOSPHATIC ROCK.

Phosphate bearing; locality, Florida. E. T. Cox, 1890; Am. Nat., vol. 24, p. 1185. Eocene.

FORT UNION (OR GREAT LIGNITIC) GROUP.

Fort Union, western North Dakota. F. B. Meek and F. V. Hayden, 1861; Proc. Phila. Ac. Nat. Sci., 1861, vol. 13, p. 433. Eocene or Laramie.

GALISTEO GROUP.

Gallisteo (Galisteo) Creek, New Mexico. J. J. Stevenson, 1881; U. S. Geol. Surv. W. 100th Mer., vol. 3, Suppl., p. 159. "Miocene or early Pliocene."

GALLISTEO (SAND) GROUP.

Gallisteo Creek, New Mexico. F. V. Hayden, 1869; Prelim. Field Rep. U. S. Geol. Surv. Colo. and N. Mex. Third Ann. of Hayden's Surv., 1869, p. 40. "Middle Tertiary," p. 90. "Cretaceous," Cope, 1875; Proc. Phila. Ac. Nat. Sci., p. 360. "Wasatch Eocene," Hayden, 1878; Am. Nat., p. 83. "Laramie," (?) Stevenson, 1881; U. S. Geol. Surv. W. 100th Mer., p. 160 (Suppl. to vol. 3).

There seems to be some doubt as to what beds Hayden intended to apply this name. This may in part account for the various ages assigned to the group. See Galisteo group, Stevenson.

GAY HEAD SERIES.

Gay Head, a promotory on the extreme western end of the island of Marthas Vineyard, off Massachusetts. N. S. Shaler, 1888; U. S. Geol. Surv., 7th Ann. Rep., pp. 339, 340. Publ., 1888.

This, according to Shaler (in litt.), includes that portion of the Vineyard series shown at Gay Head; consequently we must regard it as in part Cretaceous and in part Upper Miocene, or Pliocene.

See Vineyard series.

GNATHODON BED.

Gnathodon, a characteristic genus. W. H. Dall, 1892; this essay, p. 164. Fossiliferous bed in Grand Gulf group, Mississippi.

GRAND GULF GROUP.

Grand Gulf, a village in Claiborne County, Mississippi. Eug. W. Hilgard, 1860; Rep. Agric. and Geol. ot Miss., pp. 108, 147. Miocene.

Sometimes called the Southern Lignitic group.

GRAND GULF SANDSTONE.

Grand Gulf, a village, Claiborne County, Mississippi, where the sandstone is is typically exposed. L. C. Wailes, 1854; Agric. of Miss., p. 216. Miocene.

This sandstone forms the most characteristic phase in the Grand Gulf group of Hilgard (q. v.).

GREAT CAROLINIAN BED [of marl].

Typically developed in South Carolina. Edmund Ruffin, 1843. Report on the Commencement and Progress of the Agric. Surv. of S. C., p. 7. Eocene.

GREEN RIVER GROUP.

Green River, southwest Wyoming. F. V. Hayden, 1869. Prelim. Field Rep. U. S. Geol. Surv. of Colo. and N. Mex., p. 90. Eocene.

Subdivided into Upper and Lower Green River groups by Powell. (Geol. Uinta Mts., 1876, pp. 40, 45, 46.)

See Dinoceras beds and Haliobatis beds.

GREEN SAND.

An expression used by A. Winchell to denote a supposed stratigraphic unit in the Alabama Eocene series. He would have it include beds that are now known to belong to the Claiborne group, as well as others that belong to the Lignitic series, maintaining in the meantime that they are all above the Buhrstone. The impossibilities of these conditions will be at once apparent by consulting the generalized sections in Bull. No. 43, U. S. Geol. Surv.; Proc. Am. A. A. Sci., 1856, vol. 10, p. 86.

GROUND ICE FORMATION.

Interstratified ice of Kotzebue Sound and northern Alaska. W. H. Dall, 1892; this essay, p. 260. Pliocene or early Pleistocene.

GULF GROUP.

Proximity to the Gulf of Mexico. Otto Myer, 1888. Am. Geologist, vol. 2, p. 89.

Includes all the Tertiaries of the Gulf States.

HATCHETIGBEE SERIES.

Hatchetigbee, a bluff on Tombigbee River, Washington County, Alabama. Smith and Johnson, 1887. U. S. Geol. Surv., Bull. No. 43, p. 39. Eocene.

HAWTHORNE BEDS.

Hawthorne, a village of Alachua County, Florida. W. H. Dall, 1892; this essay, p. 107. Basal Miocene.

HELIOBATIS BEDS.

Heliobatis, characteristic genus. O. C. Marsh, 1886. Mon. on Dinocerata, pp. 6-7. Middle Eocene.

=Green River beds.--Marsh.

HICKMAN GROUP. (Provisional.)

Hickman, a town, Fulton County, Kentucky. R. H. Loughridge, 1888. Geol. Surv. Ky. Jackson Purchase region (F), p. 37. Lowest Eocene.

HUERFANO BEDS.

Huerfano River, south central Colorado. R. C. Hills, 1888. Proc. Colo. Sci. Soc., vol. 3, pt. 1, 148. Eocene.

Huerfano series, Hills. "Remarks on the Classification of the Huerfano Eocene." Abstract from vol. 4., pt. 2, Colo. Sci. Soc., Feb. 1891.

HUMBOLDT GROUP.

Humboldt Valley, Nevada. Clarence King, 1876; Atlas accompanying U. S. Geol. Explor., 40th Par., 1876, map iii, western half. Vol. 1 of the report of the above expedition, p. 434; "Pliocene."

Probably Loup Fork Miocene.

Includes the Salt Lake group of Hayden.

IDAHO FORMATION.

Idaho, a State. E. D. Cope, 1883; Proc. Phila. Ac. Nat. Sci., 1883, p. 135; "earlier Pliocene."

=Idaho beds, Cope, Am. Nat., 1889, vol. 23, p. 354.

INFUSORIAL EARTH.

Stratum containing *Infusoria*. J. W. Bailey, 1850; Smithsonian Contr. to Knowledge, vol. 2, No. 8, p. 19; older Miocene of Tampa, Florida.

Recent observations make the infusorial character of this bed somewhat questionable.

INFUSORIAL STRATUM.

Stratum containing *Infusoria*. W. B. Rogers, 1840; Rep. of Prog. of the Geol. Surv. of Virginia for 1840; or, A Reprint of the Annual Reports and Other Papers on the Geology of the Virginias, 1884, p. 449; Miocene.

INTERMEDIATE YELLOW CLAYS AND SANDS.

Intermediate between the "northern" and "southern" Tertiary of Delaware. J. C. Booth, 1837–'38; Mem. Geol. Surv. Del., Senate ed., p. 49; Miocene?

JACKSON GROUP.

Jackson, a village, Hinds County, Mississippi. T. A. Conrad, 1855; Proc. Phila. Acad. Nat. Sci., vol. 7, p. 257; Upper Eocene.

"Jackson Tertiary;" see Wailes's Geol. Mississippi, 1854, pp. 274, 289.

"Jacksonian;" Heilprin, Proc. Phila. Acad. Nat. Sci., 1882, p. 184.

JACKSONVILLE LIMESTONE.

Jacksonville, a town, northeast Florida. W. H. Dall, 1892; this essay, p. 124; newer Miocene.

JOHN DAY GROUP.

John Day River, northern Oregon. O. C. Marsh, 1875; Am. Jour. Sci., 3d ser., vol. 9, p. 52; equivalent to the upper part of the White River (Miocene?) group.

It will be noticed that at the place referred to Marsh does not use the expression "John Day group," but "John Day basin."

?=Northern extension of the Truckee group.

KENAI GROUP.

Kenai peninsula, Alaska. W. H. Dall, 1892; this essay, p. 234; Miocene of paleobotanists, possibly Eocene.

KOWAK CLAYS.

Kowak River, northern Alaska. W. H. Dall, 1892; this essay, p. 265; Pliocene or Pleistocene.

LAFAYETTE FORMATION.

Lafayette County, Mississippi. Hilgard, Safford, and McGee, 1891; Am. Geologist, August, 1891, pp. 129-131; Pliocene.

The circumstances under which this name has come to be adopted instead of prior designations are set forth by the geologists concerned as follows: (Op. cit. pp. 129-131.)

"Orange sand, Lagrange, and Appomattox. The study lately bestowed upon the formations of the Southwestern States in connection with those of the North, and especially those of the Atlantic slope by McGee, seems to render a revision and redefinition of the above names desirable. The first two, Orange sand and Lagrange, were first applied in 1856, by Safford, to a series of beds in west Tennessee that bear a very close resemblance in general aspect; and in the mere reconnoissance then made by Safford of the region, were by him presumed to be of identical age. In a subsequent report (1869) Safford recognized the fact that a portion of the beds included by him in the above designation belonged to the Cretaceous; and he accordingly defines the 'Orange sand or Lagrange group' as being of Tertiary (probably Eocene) age.

"Meanwhile I had, in 1856, examined the portion of Mississippi adjacent to the Tennessee line, and in subsequent years up to 1860 the remainder of the State. I had found what I presumed to be Safford's Orange sand more widely developed in Mississippi than even in Tennessee, and found it overlying the latest recognized Tertiary beds—the Grand Gulf rocks. Accordingly I adopted Safford's name in my Mississippi report of 1860, in which the features of the formation are described in considerable detail; and for reasons there given the 'Orange sand' is assigned to the early Quaternary.

"The intervention of the war prevented any early conference between Safford and myself on the subject; and it was only in 1869 that I learned that Safford assigned his 'Orange sand' and 'Lagrange,' as a unit, to the Eocene age.

"During our subsequent correspondence it was developed that lignitiferous beds of unquestionably Eocene, exposed not far from Lagrange, Tenn., were included by Safford within his group. I therefore suggested to him that the latter name should be retained for the yellow and gray lignitiferous sands of the Eocene that immediately overlie the 'Flatwood' or 'Porter's Creek' beds, which themselves overlie directly, and almost conformably, the uppermost Cretaceous. The name of 'Orange sand,' on the other hand, it was agreed, should designate the higher series to which it is peculiarly appropriate. To this agreement we have since adhered, and have therein been followed by other western geologists.

"As stated in my Mississippi report of 1860, I had concluded from the descriptions of Tuomey and others that the Orange sand extended with more or less similarity of character at least to South Carolina, and probably along the Atlantic coast plain as far north as Washington.

"The excellent work carried out for some years past by McGee along the coastal plain of the Atlantic slope, while restricting somewhat the supposed northward extension of the formation, has shed much new light upon its general relations and regional modifications; and while the identity of the whole is unquestionable, and hence the prior designation (Orange sand) should stand in place of the name Appomattox applied by McGee to the Atlantic portion of the formation, yet the deviation of the former name from the accepted rule of forming such names from type localities, as well as a certain degree of confusion that has occurred in its actual use, seems to render a change advisable.

"At a late conference on the whole subject, participated in by Messrs. McGee, Joseph Le Conte, Loughridge, and myself, it was suggested that in view of the various objections to all the later names, that of 'Lafayette,' which the

LAFAYETTE FORMATION—continued.

formation had borne for several years in my early field notes (from the type localities in Lafayette County, Miss., where I first discriminated it from the Eocene sands), might appropriately be adopted, with the assent of Safford, as one of the parties to the former agreement. This having been secured, it would seem advisable that all unite upon the use hereafter of 'Lafayette' as the equivalent of the Orange sand (as understood by Safford and myself) of the Southwest and of the Appomattox as defined by McGee for the Atlantic and Southeastern States. Whatever differences of opinion may exist in regard to the genesis of the formation, or the assignment of particular local phases, will be more readily discussed and reconciled when a single name only is employed by all.

"E. W. HILGARD.

"BERKLEY, CAL., *June 15, 1891.*"

"The above paper was sent to me previous to publication for examination, and, if acceptable, for my approval. Prof. Hilgard has given the correct history of the names 'Orange sand' and 'Lagrange,' and, in the prospect of harmonizing views all around, thereby facilitating the study of the beds concerned, I heartily concur in the conclusion reached by him in conference with the gentlemen mentioned above. It is pleasant to know that in important points a satisfactory understanding now exists.

"JAS. M. SAFFORD.

"NASHVILLE, TENN., *June 22, 1891.*"

LAGRANGE GROUP, or ORANGE SAND.

Lagrange, a village, Fayette County, Tennessee. J. M. Safford, 1864; Am. Jour. Sci., 2d ser., vol. 37, p. 369.

Regarded then as Eocene; now considered by McGee as belonging to the Appomattox (Pliocene) formation.

See under Lafayette formation.

LIGNITIC, or LIGNITE GROUP.

Terms used loosely in American geology to denote—

(1) Portions or the whole of the so-called Laramie group.

(2) That portion of the Eocene of the Gulf states which lies beneath the Buhrstone formation; the Eo-lignitic of Heilprin, Northern Lignite of Hilgard, Bluff Lignitic of Safford.

LOUP FORK BEDS.

Loup Fork of Platte River, central Nebraska. F. V. Hayden and F. B. Meek, 1861; Proc. Phila. Acad. Nat. Sci., vol. 13, pp. 433, 435. "Pliocene." Miocene according to Cope.

= Loup Fork group. F. V. Hayden, 1863; Am. Jour. Sci., 2d ser., vol. 33, p. 312.

MANSFIELD GROUP.

Mansfield, a town, De Soto Parish, Louisiana. Eug. W. Hilgard, 1869; "Prelim. Rept. Geol. Reconn. La.," De Bow's Review, Sept., 1869, p. 9; also Am. Jour. Sci., Nov., 1869.

Regarded at first as intermediate in age between the Jackson and Vicksburg Eocene; more recently (Hopkin's 2d Ann. Rept. Geol. La., p. 8, and Hilgard's "Suppl. and Final Rept. Geol. Reconn. La.," pp. 40, 41) shown to be a subdivision of the Jackson.

MANTI BEDS.

Manti, name of a valley and town in eastern Utah. E. D. Cope, 1880; Am. Nat., vol. 14, p. 304. Middle Eocene, probably equivalent to the Green River shales.

MALARYNDIAN (or Lower Atlantic Miocene).

Typically developed in Maryland. Angelo Heilprin, 1882; Proc. Phila. Acad. Nat. Sci., 1882, p. 183. "Lower Miocene."

MEGALONYX BEDS.

Megalonyx, name of a characteristic genus. E. D. Cope, 1879; Bull. U. S. Geol. Surv. Terr., vol. 5, pt. 1, p. 48. Later Pliocene or Pleistocene.

MIDWAY SERIES.

Midway, a plantation and landing on Alabama River, Wilcox County, Alabama. Smith and Johnson, 1887; U. S. Geol. Surv. Bull. No. 43, p. 62. Lowest Eocene.

MILIOLITE LIMESTONE.

From the various Miliolite foraminifera it contains. Angelo Heilprin, 1887; Trans. Wagner Free Inst. Sci., vol. 1, p. 4. Upper Eocene, or "Oligocene" of Florida.

MIOCENE.

μείων (irreg. comp. of μικρός), less, and καινός, recens, new. Charles Lyell, 1833 (lectures at King's College, May or June, 1832); Principles of Geology, 1st ed., vol. 3, (about) p. 53.

See Eocene.

MIOHIPPUS SERIES.

Miohippus, a characteristic genus. O. C. Marsh, 1877; Am. Jour. Sci., 3d ser., vol. 14, p. 355. Miocene.

This term has priority over all others in designation of a certain series of deposits in Oregon now known commonly by the term John Day beds or group. The expression "John Day basin" was coined by Marsh in 1875, but this basin includes Loup Fork beds as well. The name Truckee group was in print as early as 1875, but the correlation of the Oregon deposits with those of the typical locality of this group is, in a measure, open to criticism. Cope's name, "Oregon beds," was applied in 1879.

MISSISSIPPI CLAYS.

Developed in the basin of Mississippi River. W. H. Dall, 1892; this essay, p. 157. Miocene of Grand Gulf perezone.

MONUMENT CREEK GROUP.

Monument Creek, Central Colorado. F. V. Hayden, 1869; Prelim. Field Rept. U. S. Geol. Surv. Colo. and N. Mex., pp. 39, 40. Miocene, probably. (See Rept. U. S. Geol. Surv. Terr., 1873, p. 430.)

MYTILUS BED.

Mytilus condoni, characteristic fossil. W. H. Dall, 1892; this essay, p. 228. Pliocene of Shoalwater Bay, Washington.

NAHEOLA AND MATTHEWS LANDING SERIES.

Naheola, a post-office and landing on Tombigbee River, Marengo County, Alabama; and Matthews Landing on Alabama River, Wilcox County, Alabama. Smith and Johnson, 1887; U. S. Geol. Surv. Bull. No. 43, p. 57. Eocene.

NANAFALIA SERIES.

Nanafalia, name of a village in Marengo County; also a landing and bluff on Tombigbee River, Alabama. Smith and Johnson, 1887. U. S. Geol. Surv. Bull., No. 43, p. 51. Eocene.

NASHAQUITSA SERIES.

Nashaquitsa Cliffs, southwest part of Martha's Vineyard, Massachusetts. N. S. Shaler, 1888; U. S. Geol. Surv., 7th Ann. Rept., p. 343. "Pliocene, probably."

=Weyquosque series—Shaler.

NAUSHON SERIES.

Naushon, name of an island between Martha's Vineyard and the mainland. N. S. Shaler, 1888; U. S. Geol. Surv., 7th Ann. Rept., p. 342, Pl. xx. Late Pliocene or Quaternary.

NIOBRARA GROUP.

Niobrara River, northern Nebraska. F. V. Hayden, 1870; U. S. Geol. Surv. Terr., 4th Ann. Rept., p. 170. Formerly regarded as Pliocene; according to Cope, Miocene. "Niobrara basin," Marsh, Am. Jour. Sci., 1875, 3d ser., vol. 9, p. 52.

= Loup Fork group.

NORTHERN LIGNITIC.

Containing lignite, and lying north of the marine Tertiary in Mississippi. Eug. W. Hilgard, 1860. Agric. and Geol. Miss., p. 110. Lower Eocene. Eo-lignitic of Heilprin.

NORTHERN TERTIARY.

Northern portion of the Tertiary in Delaware. James C. Booth, 1837–'38; Memoir Geol. Surv. Del. Senate edition, p. 48.

NORTH PARK DEPOSITS.

North Park, northern Colorado. A. Hague, 1877; U. S. Geol. Exp. 40th Par., vol. 2, "Descriptive Geology," p. 128; also Map 1 of Atlas accompanying the report of this exploration. 1876.

Dr. C. A. White informs us that this sheet was printed in advance of the Atlas and was distributed as early as November, 1875.

Pliocene?

NULATO SANDSTONE.

Nulato, village on the Yukon River, Alaska. W. H. Dall, 1892; this essay, p. 247 Miocene.

NUMMULITIC BEDS.

Prevalence of Nummulites. W. H. Dall, 1892; this essay, p. 103.

Include the foraminiferal phases of the uppermost part of the Vicksburg group in Florida as well as the deposits of floridite, which have resulted from their modification in the presence of phosphoric acid.

NUMMULITIC LIMESTONE.

Abundance of a supposed Nummulite (*Orbitoides mantelli*). Samuel G. Morton, 1834. Synop. Organ. Rem. Cret. Group, p. 22.

Then supposed to be Upper Cretaceous. Shown by Lyell in 1846 to be Upper Eocene. In 1847, when Lyell, through the aid of his friend, Mr. Forbes, found that the so-called *Nummulites mantelli* should be referred to the genus. *Orbitoides*, he immediately adopted the term "Orbitolite limestone" for this deposit. See Am. Jour. Sci., 1847, 2d ser., vol. 4, p. 189.

The term "Nummulitic limestone" has been applied by Heilprin to an Upper Eocene bed of Florida, characterized by *Nummulites willcoxii*. See Trans. Wagner Free Inst. Sci., 1887, vol. 1, p. 4.

OCALA GROUP.

Typical locality at Ocala, Florida. W. H. Dall, 1892; this essay, p. 331.

Includes the various foraminiferal limestones in which the Floridian and Georgian Eocene culminates, above the typical Orbitoides limestone.

OCALA LIMESTONE.

Typically developed at Ocala, Florida. W. H. Dall, 1892; this essay, p. 103. Eocene or "Oligocene."

"Ocala nummulitic bed," Dall, Trans. Wagner Free Inst. Sci., 1890, vol. 3, p. 9.

Nummulitic limestone of Heilprin, *non* Morton.

OCHEESEE BEDS.

Typically developed at Ocheesee, Jackson County, Florida. W. H. Dall, 1892; this essay, p. 105. Older Miocene.

ORANGE SAND GROUP.

Orange color of its component sands. James M. Safford, 1856. Geol. Reconn. Tenn., 1st Bienn. Rep., p. 161.

This name Safford here applies to the "Cretaceous system" of Tennessee. In an article in the Am. Jour. Sci., 2d sér., vol. 37, and in his "Geology of Tennessee," 1869, the same term is used to designate the medial portion of the Tertiary series of this State. Finally in 1876 (See Elem. Geol., by Safford and Killebrew) the term is applied to the lowest member of the post-Tertiary.

For Hilgard's application of the same. See Agric. and Geol. Miss., 1860. He considers it Quaternary.

McGee includes the greater part of Hilgard's "Orange sand" in his "Appomatox formation;" Am. Jour. Sci., July, 1890, 3d ser. vol. 40. See Lafayette formation.

As used in this essay the Orange sand refers solely to the red Pliocene sands of the Appomattox formation.

ORBITOIDES LIMESTONE.

Abundance of *Orbitoides mantelli*. M. Tuomey, 1850. 1st Bienn. Rep. Geol. Ala., pp. 154–157. Eocene.

See Nummulitic limestone.

ORBITOLITE LIMESTONE.

Abundance of *Orbitoides mantelli*. Charles Lyell, 1847. Am. Jour. Sci., 1847, 2d ser., vol. 4, p. 189. Upper Eocene. Vicksburg group, partim.

See Nummulitic limestone. This bed has also been called Orbitoides rock, Heilprin; Proc. Phila. Ac. Nat. Sci., 1881, p. 155; Orbitoitic, Heilprin, Proc. Phila. Ac. Nat. Sci., 1882, p. 184. Orbitoides limestone, Tuomey, 1st Bienn. Rep. Geol. Ala.

ORBITOLITE LIMESTONE.

Abundance of *Orbitolites floridanus* (Con.) Heilprin. Angelo Heilprin, 1887. Trans. Wag. Free Inst. Sci., vol. 1, pp. 4, 12. Lower Miocene.

This name is used by Heilprin, loc. cit., to distinguish "a type of foraminiferal rock" and not as the name of a formation or a stratigraphic unit.

=Tampa limestone, q. v.

OREGON BEDS.

Oregon, a State. E. D. Cope, 1879. U. S. Geol. Surv. Terr. Bull., vol. 5, No. 1, p. 50. Miocene.

This name was withdrawn by its author in 1884 (Bull. 3, U. S. Geol. Surv. Terr., p. 16) because King's name "Truckee group" was supposed to include the same deposits.

=John Day group.

See Miohippus series.

OREODON BEDS.

Oreodon, name of a characteristic genus. F. V. Hayden, 1862. Trans. Am. Phil. Soc., 2d ser., vol. 12, pt. 1, p. 31. Miocene, or perhaps Oligocene.

A subdivision of the White River group.

ORTHAULAX BED.

Prevalence of the genus *Orthaulax*. W. H. Dall, 1892; this essay, p. 113. Older Miocene of Florida.

The bed has also been known colloquially as the Tampa silex bed; see Dall, Trans. Wag. Free Inst. Sci., 1890, vol. 3, p. 47.

OYSTER MARL.

Abundance of the genus *Ostrea* in the marl along Peace Creek, Florida. W. H. Dall, 1892; this essay, p. 132 Lower Pliocene.

PAMUNKEY FORMATION.

Typically exposed on the river of that name in Virginia. N. H. Darton, 1891. Bull. Geol. Soc. Am., vol. 2, p. 439.

Includes the Eocene beds of Virginia and Maryland, and is the equivalent of the Eocene of Rogers and Conrad.

PATUXENT BEDS.

Typically exposed on the Patuxent River, Maryland. W. H. Dall, 1892; this essay p. 157.

Provisional term, to include the lower Chesapeake Miocene if the latter prove divisible.

PEACE CREEK BONE BED.

Vertebrate remains near Peace Creek, Florida. W. H. Dall, 1892; this essay, p. 130. Older Pliocene.

PERNA BEDS.

Prevalence of the genus *Perna*. Angelo Heilprin (colloquial?) 1884. Jour. Acad. Nat. Sci., 2d ser., vol. 9, p. 13. Older Chesapeake Miocene of Patuxent River, near Benedict, Maryland.

PLANORBIS ROCK.

Planorbis, an abundant and characteristic genus contained in it. W. H. Dall, 1892; this essay, p. 143. Uppermost Pliocene bed of Florida.

PLIOCENE.

πλείων (comp. of πολύς, many) more; and καινός, recens, new. Charles Lyell, 1833. Principles of geology, 1st ed., vol. 3 (about), p. 53.

In a course of lectures delivered at King's College, London, during May and June, 1832, Lyell communicated to the public his views on the Tertiary formations, and accordingly the names Eocene, Miocene, and Pliocene may have been published in some scientific periodicals during the same year.

See Eocene.

PLIOHIPPUS BEDS.

Pliohippus, a characteristic genus. O. C. Marsh, 1877. "Introduction and Succession of Vertebrate Life." Plate. Author's edition, 1877. "Lower Pliocene."—Marsh. Upper Miocene.—Cope.

POISON CANYON SERIES.

Poison Canyon, along Poison Creek. South central Colorado. R. C. Hills, 1888. Proc. Colo. Sci. Soc., vol. 3, pt. 1, p. 152. Eocene. (Applied to the lithological sequence of the Huerfano Eocene in Poison Canyon.")

Poison Canyon beds, Hills, 1891; "Remarks on the classification of the Huerfano Eocene." Abstract from Proc. Colo. Sci. Soc., vol. 4, pt. 2.

PORTERS CREEK GROUP.

Porters Creek, Hardeman County, Tennessee. Jas. M. Safford, 1864. Am. Jour. Sci., 2d ser., vol. 37, p. 368. Lower Eocene.

In their Elementary Geology of Tennessee, 1876, Safford and Killebrew substitute for this name that of Hilgard, i. e., Flatwoods sands or group.

Shown by Loughridge to be stratigraphically continuous with Safford's "Bluff lignite." See Geol. Surv. Ky., Jackson Purchase Region (F), 1888, p. 41.

PROCAMELUS BEDS.

Procamelus, characteristic genus. E. D. Cope, 1879. U. S. Geol. Surv. Terr. Bull., vol. 5, pt. 1, pp. 50–52. Upper portion of the Loup Fork "Miocene."

PUGET GROUP.

Puget Sound, Washington. C. A. White, 1888. Am. Jour. Sci., 3d ser., vol. 37, p. 443. Eocene or Laramie.

RED BLUFF GROUP.

Red Bluff, a railway station, Wayne County, Mississippi. Eug. W. Hilgard, 1860. Agric. and Geol. Miss., 1860, pp. 135–6. Eocene. Probably includes Conrad's "Shell Bluff group."

RED HILLS.

Color of the formation in South Carolina. Colloquial expression locally in use for the area covered by the red Buhrstone formation, and in the geological works of Tuomey and subsequent writers; but, perhaps, never explicitly assigned a definition in systematic stratigraphy. Upper Claiborne Eocene of South Carolina.

SALT LAKE GROUP.

Salt Lake, Utah. F. V. Hayden, 1869. Prelim. Field. Rep. U. S. Geol. Surv. Colo. and N. Mex., p. 92. "Pliocene." Miocene of Cope.?

= Humboldt group of King (partim), see Hayden's 7th Ann. Rep., 1877, p. 640.

SAND HILLS.

Composition of the formation in South Carolina.

A local expression occasionally used by geologists treating of the region, indicating the area where the country rock is composed of white siliceous Buhrstone in contradistinction to the red Buhrstone.

Lower Claibornian Eocene.

SAN FRANCISCO GROUP.

San Francisco, city and county of California. J. S. Newberry, 1857; Pac. R. R. Rept., vol. 6, pt. 2, p. 11. Miocene, for the most part.

SANTA FÉ MARLS.

Santa Fé, a town in New Mexico. F. V. Hayden, 1869. Prelim. Field. Rep. U. S. Geol. Surv. Col. and N. Mex., p. 66. "Modern Tertiary," p. 72.

Shown in Cope's report to Wheeler, 1874, to be a member of the Loup Fork division of the Miocene.

SANTEE BEDS.

Santee River, South Carolina. M. Tuomey, 1848. Rep. on Geol. of S. C., p. 156. Eocene.

SHELL BLUFF GROUP.

Shell Bluff, bluff on Savannah River, Georgia. T. A. Conrad, 1866. Am. Jour. Sci., 2d ser. vol. 41, p. 96. Upper Eocene.

The meager grounds upon which this so-called group was founded are clearly pointed out by Eug. W. Hilgard in an article in the Am. Jour. Sci., 2d ser., vol. 42, pp. 68–70. Its characteristic phase, as exhibited in the State of Mississippi, doubtless falls into Hilgard's Red bluff group, q. vid.

SHILOH MARLS.

Shiloh, a hamlet of Cumberland County, New Jersey. W. H. Dall, 1892; this essay, p. 40. Older Miocene of New Jersey.

SILICEOUS CLAIBORNE.

Siliceous character of the rocks in contrast with the calcareous Claiborne beds above. Eug. W. Hilgard, 1860. Agric. and Geol. Miss., p. 123. Eocene.

On page 226 of vol. 20, Am. Assoc. Adv. Sci., 1871, Hilgard accepts the term "Buhrstone" of Lyell and Tuomey for his "Siliceous Claiborne." See also explanation of the accompanying map opposite page 222 of that article.

SOLEN BEDS.

Prevalence of the genus *Solen*. Thomas Condon; first published by Cope from MS notes of Dr. Condon. Am. Nat., 1880, vol. 14, p. 457. Upper Miocene of Oregon, Condon.

SOPCHOPPY LIMESTONE.

Sopchoppy, a village, Wakulla County, Florida. W. H. Dall, 1892; this essay, p. 119. Older Miocene.

STAKED PLAINS FORMATION.

Staked Plains, Llano Estacado, northwestern Texas. R. T. Hill, 1889. Proc. Am. Assoc. Adv. Sci., vol. 38, p. 243. "Later Tertiary or early Quaternary." Tertiary, Hill; Amer. Geol., Feb., 1890.

ST. MARY'S BEDS.

Typically exposed on St. Mary's River, Maryland. W. H. Dall, 1892; this essay, p. 157.

Provisional term for the upper Chesapeake Miocene if the latter prove divisible.

ST. STEPHEN'S GROUP.

St. Stephen's Bluff, Washington County, Alabama. T. A. Conrad, 1855; Proc. Phila. Acad. Nat. Sci., vol. 7, p. 257. Upper Eocene.

SOUTHERN LIGNITIC GROUP—Grand Gulf group.

Hilgard writes (in litt.): "I have always used Grand Gulf group as the final equivalent of the designation first adopted in my field notes, viz, Southern Lignitic. The latter designation has hardly been used enough to entitle it to more than mere mention, and it is misleading because of the lignitic facies of the Port Hudson beds of the Gulf border."

SOUTHERN TERTIARY.

Southern portion of the Tertiary in Delaware. J. C. Booth, 1837-'38; Memoir Geol. Surv. Del., Senate edition, p. 49.

SUMTER BEDS.

Sumter, name of a town and county of South Carolina. M. Tuomey, 1848; Geol. Surv. S. C., p. 178. "Pliocene;" probably a mixture of both Miocene and Pliocene.

Sumter epoch, Dana; Manual of Geology, 1862, pp. 506-511. This term as used by Dana seems to have been intended as an equivalent in the nomenclature of American stratigraphy for the term Pliocene Period.

SWEETWATER GROUP.

Sweetwater River, south central Wyoming. F. V. Hayden, 1870. 4th Ann. Rep. U. S. Geol. Surv. Terr., 1871, p. 29. Eocene, probably.

TAMPA BEDS.

Typically exposed about Tampa, Florida. W. H. Dall, 1892; this essay, p. 112. Miocene.

Include the cherty beds of Hillsboro River and Tampa limestone.

TAMPA FORMATION.

Typically exposed at Tampa, Florida. L. C. Johnson, 1888; Am. Jour. Sci., 3d ser., vol. 36, p. 235. Miocene (at least in part. There is serious doubt as to whether the "formation" as defined is a stratigraphic unit.)

=Tampa limestone, Dall (partim).

TAMPA GROUP.

Typically exposed at Tampa, Florida. W. H. Dall, 1892; this essay, p. 112. Older Miocene, between the Chattahoochee and Chesapeake groups.

TAMPA LIMESTONE.

Typically exposed at Tampa, Florida. Heilprin (colloquially), 1887; Trans. Wagner Free Inst. Sci., vol. 1, p. 52. Dall (specifically), 1891; this essay, p. 117. Older Miocene.

Tampa Silex beds. Dall, Trans. Wag. Free Inst. Sci., 1890, vol. 3, p. 47.

See Orthaulax bed.

TEJON GROUP.

Fort Tejon, Kern County, California. W. M. Gabb, 1869; Geol. Surv. Cal., Pal., vol. 2, pp. xii-xiii. Eocene.

On the pages above referred to it is stated that Gabb read a paper before the National Academy of Sciences at Northampton, Massachusetts, in August [1868], wherein the above-mentioned group was defined.

TICHOLEPTUS BEDS.

Ticholeptus, name of a characteristic genus. E. D. Cope, 1879; Bull. U. S. Geol. Surv. Terr., vol. 5, pt. 1, pp. 50-52.

"Intermediate in all respects between the Middle and Upper Miocene formations of the West, as represented by the John Day and Loup Fork beds."—Cope, Am. Nat., 1886, vol. 20, p. 367.

TIMBER BELT OR SABINE RIVER BEDS.

Timber belt, a term applied to a certain wooded belt in Texas, and Sabine River, Texas. R. A. F. Penrose, jr., 1889; 1st Ann. Rep. Geol. Surv. Tex., 1890; p. 22 of Penrose's Report. Eocene.

TITANOTHERIUM BED.

Titanotherium, name of characteristic genus. F. V. Hayden, 1857. Proc. Phila. Acad. Nat. Sci., 1857, p. 120. Oligocene.

The lowest bed of the White River group.

TRUCKEE GROUP.

Truckee Mountains and River, Nevada. Clarence King, 1875; western half, map 1 of atlas accompanying the Repts. U. S. Geol. Explor., 40th Par. See also vol. 1 of these reports, pp. 412, 424.

Supposed by King and others to be of the same age as the John Day or Oregon beds in Oregon, and also the same as a part or the whole of the White River group east of the Rocky Mountains.

TURRITELLA MARL.

Turritella, a characteristic genus. W. H. Dall, 1892; this essay, p. 147. Pliocene of the Caloosahatchie, Florida.

TURTLE AND OREODON BEDS.

Abundance of turtle and *Oreodon* remains. F. V. Hayden, 1858; Proc. Phila. Acad. Nat. Sci., 1858, p. 150. Subdivision of the White River Miocene (Oligocene?.)

TUSCAHOMA SERIES.

Tuscahoma Landing, Choctaw County, Alabama. D. W. Langdon, July, 1891; Bull. Geol. Soc. Am., vol. 2, p. 596.

Lignitic Eocene.

UINTA GROUP.

Unita Mountains, Utah. Clarence King, 1876; atlas accompanying the 40th Par. Rept., 1876. Upper Eocene.

In 1871 Marsh (Am. Jour. Sci., 3d ser., vol. 1, p. 196) uses the term "Uintah basin" for the depression in which this group was deposited.

Brown's Park group, Powell.—White.

Diplacodon beds, Marsh.—Marsh.

UNGA CONGLOMERATE.

Unga Island, Shumagin Islands, Alaska. W. H. Dall, 1892; this essay, p. 234. Upper beds of the Kenai group, early Miocene or latest Eocene.

VENUS CANCELLATA BED.

Prevalence of this species in the bed. Angelo Heilprin, 1887; Trans. Wag. Free Inst. Sci., vol. 1, pp. 31, 32. "Post-Pliocene" of south Florida.

The bed to which this name was first applied has been proved to be late Pliocene; and to Pliocene beds of this character Dall has restricted the name, reserving for the similar Pleistocene beds the name of Bulla striata marls (q. vid.).

VENUS CANCELLATA BED.

Venus cancellata, a predominant species. W. H. Dall, 1892; this essay, p. 147, footnote. Upper Pliocene.

Venus Cancellata bed of Heilprin (partim).

VERMETUS ROCK.

Formed by the agency of that mollusk on the coast of Florida. W. H. Dall, 1892; this essay, pp. 153, 157. Pleistocene and recent "Worm rock" of the residents of Florida.

VERMILION CREEK GROUP.

Vermilion Creek, northwestern Colorado. Clarence King, 1875; Map 1, western half, of atlas accompanying the 40th Par. Reports. Eocene.

This particular sheet, Dr. White informs us, was printed in advance of the atlas above mentioned, and a copy was sent him in November, 1875. See Wasatch group of Hayden.

VICKSBURG GROUP.

Vicksburg, a city of Warren County, Mississippi. T. A. Conrad, 1846; Am. Jour. Sci., 2d ser., vol. 2, p. 124. Upper Eocene.

Otto Meyer divides this group into "Higher Vicksburgian, Middle Vicksburgian, and Lower Vicksburgian." Am. Jour. Sci., 1885, 3d ser., vol. 30, p. 71.

As used in this essay the term comprehends both the "Jackson" and "Vicksburg" groups of Conrad, and is the equivalent of the "White Limestone" as used by Smith and Johnson.

VINEYARD SERIES (or Marthas Vineyard series).

Martha's Vineyard, an island off the southern coast of Massachusetts. N. S. Shaler, 1888; U. S. Geol. Surv., 7th Ann. Rept., p. 303. "Later Miocene or Pliocene," p. 332. Now known to include both Tertiary and Cretaceous beds.

VIRGINIAN (Middle Atlantic Miocene).

State of Virginia, in which the representative beds are well developed. Angelo Heilprin, 1882; Proc. Phila. Acad. Nat. Sci., 1882, p. 183; "Middle Miocene."

VOLCANIC TERTIARY.

Volcanic origin of the material. F. H. Bradley, 1872; map of the source of Snake River; accompanying Hayden's Ann. Rep. for 1872, publ. 1873.

WALDO FORMATION.

Waldo, a village, Alachua County, Florida. L. C. Johnson, 1888; Am. Jour. Sci., 3d ser., vol. 36, p. 234. Miocene.

As defined by Johnson this includes old Miocene phosphatic rock, forming one phase of the Hawthorne beds, with newer or Chesapeake Miocene limestone analogous to the Jacksonville limestone of Florida. The typical locality near Waldo belongs in the latter category.

WASATCH GROUP.

Wasatch Mountains, Utah. F. V. Hayden, 1869; Prelim. Field Rep. U. S. Geol. Surv. Colo. and N. Mex., p. 91. Eocene. (See Cope; Proc. Am. Philos. Soc., Feb., 1872.)

=Vermilion Creek group, King, }
=Bitter Creek group, Powell, } according to Dr. C. A. White.
=Washakee group, Hayden, }
=Coryphodon beds, Marsh.

WASHAKEE GROUP.

Washakee (Washakie) station, Sweetwater County, Wyoming. F. V. Hayden, 1869; Prelim. Field Rept. U. S. Geol. Surv. Col. and N. Mex., p. 90. Eocene.

See Wasatch group.

WEYQUOSQUE SERIES.

Weyquosque Cliffs, in southwestern part of Martha's Vineyard. N. S. Shaler, 1888; U. S. Geol. Surv., 7th Ann. Rep., p. 320, and plate opposite p. 308. "Probably Pliocene."—Shaler.

WHITE BEACH SANDROCK.

White Beach, locality on Little Sarasota Bay, in western Manatee County, Florida. W. H. Dall, 1892; this essay, p. 114. Older Miocene.

WHITE LIMESTONE.

Character and color of its component material. Charles Lyell, 1845; Quart. Jour. Geol. Soc. Lond., vol. 1, p. 429. Eocene of South Carolina.

White limestone, Tuomey; 1st Biennl. Rept. Geol. Ala., 1850, p. 154.

Also in frequent use colloquially as an equivalent for the "Jackson group" limestone.

White limestone, Smith and Johnson; U. S. Geol. Surv. Bull. No. 43, 1887, p. 19, equals the Upper Eocene of Alabama, or the "Vicksburg group" of this essay.

WHITE RIVER GROUP.

White River, southern South Dakota. F. B. Meek and F. V. Hayden, 1861. Proc. Phila. Acad. Nat. Sci., vol. 18, pp. 443, 434.

Regarded by Leidy as Eocene in 1852 (see Leidy's Memoir in Owen's Geol. Surv. Minn., Iowa, Wisconsin, pp. 539–572), but upon paleontologic as well as stratigraphic evidence Leidy, Meek, and Hayden conclude that this group should be referred to the Miocene.(Proc. Phila. Acad. Nat. Sci., 1857, p. 120). Later Cope (Am. Nat., vol. 18, p. 686) refers the same to the Oligocene; likewise Scott (Princeton Coll. Bull., 1890, vol. 2, No. 4, p. 75).

WHITE SAND.

Prevalent color of the beds in Florida. W. H. Dall, 1891. This essay, p. 156. Upper Pleistocene or recent.

WILLOW CREEK BEDS.

Willow Creek, central Colorado. Geo. H. Eldridge, 1888. "Mining Industry" of Denver, July 13, 1888. (See Am. Jour. Sci., 1889, 3d. ser., vol. 37, p. 263.)

Mr. Eldridge finding this name preoccupied, substitutes for it "Arapahoe Beds," q. vid.

WIND RIVER GROUP.

Wind River, northwest Wyoming. Meek and Hayden, 1861; Proc. Phila. Acad. Nat. Sci., vol. 13, p. 447. Eocene.

In the American Naturalist, 1878, vol 12, p. 831, Hayden states that he named and described this group in detail in 1859. Thus far we have failed to find this early description.

=Wasatch group. Hayden, Am. Nat., 1878, vol. 12, p. 831.

WOODS BLUFF OR BASHI SERIES.

Woods Bluff, a river bluff, Clarke County, Alabama; Bashi Creek, Clarke County, Alabama, Smith and Johnson, 1887; U. S. Geol. Surv. Bull. No. 43, p. 43. Eocene.

WYOMING CONGLOMERATE.

Typically developed in the State of Wyoming. Clarence King, 1875. Atlas sheet No. 1, western half, U. S. Geol. Explor. 40th Par. "Pliocene."

YELLOW CLAYS OF THE APPOQUINIMINK HUNDRED.

Appoquinimink Hundred, name given to a certain district in the State of Delaware. Jas. C. Booth, 1837–8. Memoir Geol. Surv. Del., Senate ed., p. 49, "Tertiary."

YELLOW SAND.

Color of the formation. W. H. Dall, 1891. This essay, p. 154. Late Pliocene or early Pleistocene of Florida.

YORKTOWN EPOCH.

Yorktown, York County, Virginia. J. D. Dana, 1862. Dana's Manual of Geology, 1st ed., pp. 506–511.

This term appears to have been used by Dana to indicate in American geological nomenclature the period of time occupied in the deposition of the Miocene and not as a stratigraphic term. Similarly the American Pliocene was deposited during the epoch called by Dana the Sumter epoch.

INDEX.

C.

D.

E.

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