GEOLOGICAL REPORT

OF THE

EXPLORATION

OF THE

YELLOWSTONE AND MISSOURI RIVERS

BY

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UNDER THE DIRECTION OF

CAPTAIN (NOW LIEUT. COL. AND BREVET BRIG. GEN.) W. F. RAYNOLDS,
CORPS OF ENGINEERS,

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PHILADELPHIA, *March* 1, 1867.

SIR: I have the honor to present herewith my report on the geology of the routes traversed by you in your expedition of 1859 and 1860 to explore the headwaters of the Missouri and Yellowstone rivers. Dr. Hine's report of Lieutenant Maynadier's route is also appended.

Very respectfully, your obedient servant,

F. V. HAYDEN,
Geologist to the Expedition.

Col. WM. F. RAYNOLDS, *U. S. Eng'rs U. S. A.,*
In charge of Expedition to headwaters Missouri and Yellowstone rivers.

HISTORICAL INTRODUCTION.

In presenting what may be regarded as a final official report upon the geology of the great region drained by the Missouri river and its tributaries, it may be well to give a sort of historical resumé of the labors of other explorers that have preceded me. While my own labors, which have extended over a series of years, indeed from the spring of 1853 to the autumn of 1866, more or less, have brought out the greater part of the definite scientific results, I do not wish to pass by the valuable labors of those frontier men who were not as well prepared to develop the continuous geological structure over large areas.

The first reliable explorers who added anything of value to the scientific knowledge of the upper Missouri district, were those enterprising travelers, Lewis and Clarke, who made an expedition up the Missouri river and across the mountains to the Pacific ocean and back, during the years 1804, 1805, and 1806. Considering the period when this expedition was undertaken and the grand results brought out by their report, it may justly be regarded the first expedition ever made on this continent. The descriptive portion of their journal is excellent, indeed almost unsurpassed for beauty and accuracy, but they seemed to have no definite idea of the geological age of the country examined by them. Still they gave so accurate descriptions of the general physical features of the bluffs, coal-beds, &c., that their report has proved an excellent guide to subsequent explorers. They often mention beds of "stone-coal," (lignite,) different strata of sands, sandstones, clays, &c., yet do not suggest any idea of the age of these deposits. A small collection of cretaceous fossils obtained by these travelers, enabled Dr. Morton to show the existence of the cretaceous formations on the upper Missouri.* In 1832 Prince Maximilian, of Neuwied, passed up the Missouri river, and the results of his travels were embodied in one of the most magnificently illustrated works in our country. The illustrations have the merit not only of great artistic skill, but also of most remarkable accuracy. The sketches were all taken from nature, and present a very true and vivid picture of the country, as well as of its aboriginal inhabitants. He mentions the occurrence, in numerous localities, of sands, clays, and lignites, and also observes that he collected *ammonites*, *baculites*, and other cretaceous fossils, all along the river from the source of the Missouri to the Big Sioux.

This statement led Von Buch to observe that "this great river

* Synopsis of the Organic Remains of the Cretaceous Groups of the United States, &c. By S. G. Morton. Philadelphia: 1834.

(Missouri) flows uninterruptedly from the foot of the Rocky mountains through strata of chalk, at least as far as the mouth of Sioux river. This is the result of the accounts and collections of Prince Neuwied, and of the report of the celebrated astronomer Nicollet."*

Nothing very definite was ascertained, however, respecting the geology of the country by this expedition, except to confirm the fact of the existence of a cretaceous formation on the upper Missouri, indications of which had already been determined from the collections of Lewis and Clarke. He also obtained a fine specimen of the remains of a saurian animal, characterizing the cretaceous period which was described by Goldfuss as *Mosasaurus Maximilian*, fragments of which were in the collection of Lewis and Clarke.

The next important expedition into that country was made in 1839, by the distinguished geographer Nicollet. He ascended the Missouri no farther than Fort Pierre, in latitude 44° 23′, yet from his observations the first reliable information was obtained in regard to the extent and interest of the cretaceous rocks in that region. He collected a good many cretaceous fossils at different points along the river, especially at the Great Bend, all of which were described by Conrad and Morton in the Proceedings of the Academy of Natural Sciences of Philadelphia.

Although he passed rapidly through the country, he formed a tolerably accurate idea of its geology, and gave in his report a vertical section of the rocks. He seems to have had no knowledge of No. 2, and represented two of the subdivisions of No. 3 as distinct formations. He says that at or near the mouth of the Big Sioux he saw a carboniferous limestone, and as no rocks but those of the Dakota group occur there, he was mistaken. As he did not go above Fort Pierre he did not see anything of No. 5, though he obtained some of its characteristic fossils, which may have been presented to him by members of the American Fur Company.

It seems somewhat remarkable that so many travelers should wander over this region during a period of so many years, and yet throw so little definite light over its geology. A few facts have been gathered here and there sufficient for our home geologists to draw a few inferences, but nothing that would extend our geological knowledge over large areas.

Mr. Edward Harris, who accompanied Mr. Audubon to the mouth of the Yellowstone in 1843, was instructed by the Academy of Natural Sciences at Philadelphia to make some observations on the geology of that unknown region. His communication to the Academy on his return was very interesting, and contained many important facts, and from his notes and collections the committee were able to arrive at still more important conclusions. The committee, consisting of Professors Rogers, Morton and Johnson, reported that they found incontestable proofs of a fresh-water formation in that region. From one locality Mr. Harris obtained a specimen of "brown ferruginous rock, containing three or four

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* Silliman's Journal, September, 1850.

species of fresh-water univalve shells of the genera *lymnea*, *planorbis*, &c. One of the species of *planorbis*, it is conjectured, may be a form extinct, but the mutilated condition of the specimen prohibits a positive opinion. This bed of clay also contains leaves of deciduous trees, bearing a close resemblance to those of the beech." It will be seen at a glance that these remarks, indefinite as they are, refer to the presence of the great lignite basin on the upper Missouri. I have seen in the collections of the Academy of Natural Sciences two or three fragments of rock which have been baked by the ignition of the lignite beds, bearing upon them quite distinct impressions of dicotyledonous leaves.

At various times specimens of mammalian remains were brought in by gentlemen connected with the American Fur Company, indicating the existence of an interesting deposit on White river; the first account of which was published by Dr. H. A. Prout, of St. Louis, in the American Journal of Science, 1847.

In 1849 Dr. John Evans, one of the assistants in the geological survey of the Chippewa land district, under the direction of Dr. D. D. Owen, was sent by that gentleman on an expedition to the Mauvaises Terres of White river. He there secured a fine collection of mammalian and chelonian remains which were investigated by Dr. Leidy, of Philadelphia. He also collected many interesting cretaceous fossils which were described by Dr. Owen, and published in his final report in 1852. Dr. Evans's observations, embracing a section of the Bad Lands, together with a description of their physical features, were also published in this report.

In the following year Mr. Thaddeus A. Culbertson visited the upper Missouri country under the auspices of the Smithsonian Institution, during which expedition he collected some interesting vertebrate remains from the White river formations. He also ascended the Missouri on the fur company's boat to a point above Fort Union, noting the character of the surface of the country, and the occurrence of lignite beds at various localities. It will be seen, however, on examining his report, that he collected no specimens, and gave no definite idea of the age of these formations.

In the spring of 1853, Dr. Evans again visited this country incidentally while on his way to Oregon Territory, in the geological survey of which he was engaged, under the patronage of the general government. During this expedition he made another extensive collection of vertebrate remains, and some fresh-water mollusca at the Bad Lands of White river, as well as some cretaceous fossils from Sage creek. The mammalian remains of this expedition were also studied by Dr. Leidy, and the invertebrate fossils by Drs. Evans and Shumard, and published in the proceedings of the Academy of Natural Sciences at Philadelphia, and the Academy of Sciences of St. Louis.

At the same time, (1853,) Mr. F. B. Meek and the writer were employed by Professor James Hall, of Albany, New York, to visit the Bad Lands of White river, for the purpose of making a collection of the cretaceous and tertiary fossils of that region. Many interesting and important facts were obtained during the expedition in regard to the geological structure of the country from Fort Pierre to Council Bluffs, which formed the basis of a paper read by Professor Hall before the American Association for the Advancement of Science, at the Providence meeting in the summer of 1855. The mammalian remains collected during this trip were placed in the hands of Dr. Leidy for examination, and the new species of cretaceous fossils were investigated by Messrs. Hall and Meek in an interesting memoir published in the transactions of the American Academy of Arts and Sciences at Boston. A brief, vertical section accompanied this memoir, showing the order of the superposition of the different cretaceous beds. In the spring of 1854, subsequent to all these expeditions, the writer visited the upper Missouri country and spent two years traversing various portions, a portion of which time he was aided by Colonel A. J. Vaughan, Indian agent, and afterwards by Mr. Alexander Culbertson, and other gentlemen of the American Fur Company. During this expedition the writer traversed the Missouri river to Fort Benton, and the Yellowstone to the mouth of the Big Horn river, also considerable portions of the Bad Lands of White river, and other districts not immediately bordering upon the Missouri.

The vertebrate remains collected by the writer during the various expeditions to that country, commencing with the spring of 1853, and ending with the autumn of 1860, as may be seen by reference to the various papers by Professor Leidy, in the proceedings of the academy, embrace a larger number of species than all those previously known from that country, many of which belong to new and remarkable genera.

Large collections of mollusca were also obtained from the cretaceous and tertiary formations, which have since been published by Mr. Meek and the writer, with remarks on the geology of different portions of the country, in several memoirs read before the Academy of Natural Sciences at Philadelphia. The writer accompanied the expeditions under the command of General G. K. Warren, and every facility was afforded by that intelligent and most able officer for carrying out his geological and natural history operations.

A portion of the above historical remarks were taken from a memoir by the writer, entitled "The Geology and Natural History of the Upper Missouri," published in the transactions of the American Philosophical Society, at Philadelphia, in 1862. It was my object to point out to the readers of this report some of the pioneers whose labors have done much toward calling the attention of the world to this great west. How much of definite knowledge they gave to the world in regard to the geology and natural history of this great region, I leave to the careful student of history to decide. The different books and memoirs in regard to this country, which have been published during a period of over 50 years, are accessible to any earnest, thorough student. Any man who regards the permanency or endurance of his own reputation, will not ignore any of these frontier men who made their early explorations under circumstances of great danger and hardship; and yet, two official State geological reports of Kansas, and one railroad geological report of southeastern Nebraska, have been recently published in which all former explorations are entirely ignored, and one not acquainted with geological literature would infer that the authors of these reports had studied the geological structure of Kansas and Nebraska for the first time, while not one of the reports contains anything important that had not been published years before. If we make a comparison of geological maps, it will be seen at a glance that the first one that makes any pretensions to accuracy was prepared by me and published in the proceedings of the Academy of Natural Sciences, May, 1857.* This map contains my own personal examinations of that region up to that date. If a comparison be made between my map and those of Professors Marcou and Rogers, neither of whom ever visited that portion of the west, it will be seen at once that there are few points in common. I would also say that the geological map of the country west of the Mississippi, published by Professor James Hall, without date, in General Emory's Mexican Boundary Report, was not prepared until after mine was published. Connected with my geological map is a section of the different formations from the mouth of the Platte to Fort Benton. In June of 1858 I published, in the proceedings of the academy at Philadelphia, a second edition of my geological map, with such additional information as I had obtained during the year 1857 as geologist to the expedition to the Black Hills, under command of Lieutenant G. K. Warren, topographical engineers, United States army. Again, a third geological map was published in the Transactions of the American Philosophical Society of Philadelphia, in 1862, to accompany a memoir "on the geology and natural history of the upper Missouri." The map which accompanies this report contains all the information that we have additional, secured during a period of two years' exploration by the expedition to the headwaters of the Missouri and Yellowstone, under the command of Colonel William F. Raynolds, United States engineers. The details of the geology, especially in the vicinity of the mountain ranges, are approximately correct. I have now personally explored the greater portion of Kansas, Nebraska, Dakota, Montana, Idaho, and Colorado, and I do not think that future examinations will essentially change the published results, though a more detailed State survey may modify them to some extent.

During the summer of 1866 I made a very successful tour to the Bad Lands of White river, passing up the Niobrara river to the mouth of Rapid river, then to the head of Little White river, examining some portions of that great tertiary basin not before seen by me. Several new species of vertebrate remains were found, which are now in the possession of Dr. Leidy for examination.

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* *Notes explanatory of* a map and section illustrating the geological structure of the country bordering on the Missouri river, &c., May, 1857.

CHAPTER I.

SKETCH OF PHYSICAL GEOGRAPHY OF THE MISSOURI VALLEY—AVERAGE GRADE OF ASCENT FROM MISSISSIPPI TO THE BASE OF THE ROCKY MOUNTAINS—BLACK HILLS—LARAMIE RANGE—BIG HORN AND WIND RIVER MOUNTAINS—DIFFERENT GEOLOGICAL FORMATIONS OF WHICH THEY ARE COMPOSED—MISSOURI RIVER AND ITS TRIBUTARIES—YELLOWSTONE, BIG HORN, TONGUE, AND POWDER RIVERS—MUSCLE SHELL, LITTLE MISSOURI, BIG KNIFE, HEART, CANNON BALL, GRAND, MOREAU, AND BIG CHYENNE RIVERS—WHITE RIVER, NIOBRARA, PLATTE, MILK, WHITE EARTH, JAMES, VERMILION AND BIG SIOUX RIVERS.

The physical geography of the Missouri valley will be spoken of in this chapter, or so far as it relates to the geology, and will more fully explain the geological chart.

Nearly all the vast area west of the Mississippi may be divided into mountain and prairie, for very soon after passing westward from Leavenworth there is very little timber to be seen except that which skirts the streams. This consists mostly of cottonwood. A few low oaks or pines I found on the dry hills, and here and there an elm or ash. The whole surface is undulating; ridge on ridge and hill on hill as far as the eye can reach. This combination of mountain and prairie may be said to comprise what is generally known as the Rocky Mountain region. As we proceed westward we find that the ascent is gradual, at first not more than one foot per mile, gradually increasing until we approach the mountain elevations where the grade of ascent becomes 40 to 50 feet per mile. If we examine in their order some of the barometric profiles which have been made along the line of the routes explored for the Pacific railroad, we can readily ascertain the gradual ascent toward the mountain elevations.

Leaving St. Louis westward, we gradually ascend, passing over a prairie country for the most part, for the distance of nearly 800 miles, and when we have reached an elevation of 6,000 feet we come abruptly to the lofty, rugged peaks which compose the various series of elevated ridges. Examining the general map of the country west of the Mississippi, published by the War Department, we observe that the immediate Rocky Mountain region is not composed of merely a single lofty, upheaved ridge extending across the continent, but a vast series of ridges or ranges, which, taken singly, do not seem to have any definite trend, but when viewed in the aggregate extend across the map in a direction nearly northwest and southeast, forming a zone or belt 500 to 1,000 miles in width from east to west. From longitude 96° westward to the foot of the mountain ridges the country traversed exhibits the true typical prairie; no timber being found to any extent, except that which skirts the streams. From thence to the Pacific coast we have what may be called the true mountain portion, which is composed of a vast number of ridges of elevation, interspersed with beautiful valleys, many of which are remarkable for their fertility. Some of the valleys are quite large and surrounded by the mountain ridges as by gigantic walls.

If we examine the barometrical profile constructed by Governor Stevens, from St. Paul, Minnesota, to the foot of the mountains westward, we find that the former locality is 828 feet above the sea level. Near the mouth of the Yellowstone, 670 miles to the westward, we find that the elevation is 2,010 feet above the sea, and that we have made a gradual, almost imperceptible ascent in that distance of 1,172 feet, or an average of nearly two feet to the mile. As we approach the base of the mountain ridges the ascent continues to increase, and when we reach the valley of Dearborn river, 448 miles further west, we ascertain that this locality is 4,091 feet above the sea level, and that in that distance of 448 miles we have ascended 2,081 feet, or nearly five feet to the mile. The valley of Dearborn river is just at the foot of the mountains, and to that point the country traversed belongs to the true type of the western prairie.

Again, if we examine the profile commencing at Council Bluffs on the Missouri river we find the elevation at that point to be 1,327 feet above the sea level. Thence proceeding westward to the sources of Lodge Pole creek, at the base of the Laramie range of mountains, we have made an ascent, while thus passing over the prairie region, of nearly 5,000 feet. We thus see that in the distance of 550 miles we have reached an elevation of 3,000 feet higher than our starting point by an ascent of five feet to the mile.

Again, glancing at the profile extending from Fort Leavenworth westward, we observe that at the Missouri river the elevation is 904 feet above the sea. At the base of the Laramie range of mountains 659 miles west, the elevation is 6,716 feet. To illustrate the increased rapidity of ascent as we approach the vicinity of the upland ridges, we see that the elevation at the forks of the Platte is 3,000 feet above the sea, making an ascent from the Missouri river to this point, a distance of 413 miles, of 2,096 feet, or about five feet to the mile. From the forks of the Platte to the foot of the Laramie mountains, a distance of 413 miles, we find an increased elevation of 3,716 miles, or 15 feet to the mile. After reaching the base of the elevated ridges, the ascent is more or less abrupt, sometimes rising to the height of 3,000 to 6,000 feet above the open prairie country around.

We might continue our remarks in regard to the profiles still further southward with similar results, but we have said enough to indicate the beautiful unity in the physical development of the western portion of our continent. We have shown that the whole country west of the Mississippi to the Pacific may be regarded as a vast plateau, and that it was gradually elevated until the crust of the more central portions was strained to its utmost tension, and that it then burst and along here evolved the lofty ranges which, taken collectively, now pass under the name of the Rocky mountains.

So far as my own observations have extended there appear to be two types of mountain elevations, namely: those elevations which have a granite nucleus and form long continuous lines of fracture, with far less irregularity of outline, and those ranges which are composed of erupted rocks which are very rugged in their outline and irregular in their trend. The Black Hill, the most eastern outlier of the main mountain range, presents an excellent illustration of the first type. Very little was known of these mountains until they were explored in the summer of 1857, by an expedition placed by the War Department under the command of Lieutenant G. K. Warren, United States army, to which expedition the writer was attached as geologist and naturalist. A preliminary report of this results of this exploration was presented to the War Department under the title of "Explorations in Nebraska and Dakota in the years 1855, 1856 and 1857."

The Black Hills lie between the 43d and 45th degrees of latitude and the 103d and 105th parallels of longitude, and occupy an area about 100 miles in length and 60 in breadth. According to Lieutenant Warren the shape of the mass is elliptical and the major axis trends about 20° west of north. The base of these hills is about 2,500 to 3,000 feet above the sea, and the highest peaks 6,700 feet. The whole range is clasped, as it were, by the north and south branches of the Big Shyenne river, the most important stream in this region. The north branch passes along the northern side of the range, receiving very many of its tributaries and most of its waters from it, but takes its rise far to the westward of the range, near the source of Powder river, in the "divide" between the waters of the Yellowstone and those of the Missouri.

The South Fork also rises in the same divide, flowing along the southern base of the range, and also receives numerous tributaries which have their sources in it. These two main branches unite about 30 miles east of the Black Hills, forming the Big Shyenne, which empties into the Missouri about 60 miles above Fort Pierre. The Moreau, Grand, Cannon Ball, and other rivers flowing into the Missouri north of the Shyenne and south of the Yellowstone, rise in a high tertiary divide north of the Black Hills, and are for the greater part of the season quite shallow and sometimes nearly dry, but the Little Missouri derives a portion of its waters from the Black Hills through a number of small branches which flow from the northwestern slope.

We thus see that the Black Hills do not give rise directly to any important stream, if we except the Little Missouri, a few branches of which flow from springs near the base of the hills, but afford a comparatively small supply of water from that source.

We will now allude for a moment to what we believe to be the economical value of the timber in the Black Hills to the people now rapidly settling Dakota Territory. As we have previously remarked in this chapter, these hills occupy an area about 100 miles in length and about 60 in breadth, or 6,000 square miles. I think it is safe to say that at least one-third of this area, or about 2,000 square miles, is covered with excellent pine timber, or 1,280,000 acres. Now the next question arises, how is this timber to be made available? As I have before remarked, the two forks of the Shyenne river, as it were, clasp the Black Hills, the two branches passing along close to the northern and southern borders of the hills. Last four to six months of the year these streams are quite high. The logs could be cut and transported to the sides of these streams during the dry season, and when the streams are high in the spring of the year they could be taken down into the Missouri river with a good degree of safety and ease. At least, that is my impression. In a report made to Lieutenant G. K. Warren, March 15, 1856, I made use of the following language in reference to this matter: "The Black Hills which appear in the distance, and derive their name from their dark and gloomy appearance, contain an inexhaustible quantity of the finest timber, mostly pine, which will doubtless remain undisturbed for many years to come. I will, however, propose a plan for obtaining this timber and rendering it useful to future settlers; though I do it with some hesitation, lest it may seem visionary. The left fork of the Shyenne passes through the northern portion of the Black Hills, and even there is a considerable stream, from 30 to 50 yards wide. In the spring the river is much swollen, and the current exceedingly rapid, and the timber, if cut and hauled to the banks of the river, might be floated down into the Missouri with considerable safety and ease." At the time the above was written I had seen but little of the Black Hills, and nothing was known of the geography of the forks of the Shyenne.

The geological structure of the Black Hills may be mentioned briefly in this connection. The nucleus or central portion is composed of red feldspathic granite, with a series of metamorphic slates and schists superimposed, and thence upon each side of the axis of elevation the various fossiliferous formations of this region follow in their order to the summits of the cretaceous, the whole inclining against the granitoid rocks at a greater or less angle. There seems to be no unconformability in the fossiliferous rocks, from the Potsdam inclusive to the top of the cretaceous. From these facts we draw the inference that, prior to the elevation of the Black Hills, which must have occurred after the deposition of the cretaceous rocks, all these formations presented an unbroken continuity over the whole area occupied by these mountains. This is an important conclusion, and we shall hereafter see its application to other ranges, and also to the Rocky Mountain range taken in the aggregate.

Proceeding in a southwest direction from the Black Hills, we find that there are ample proofs of the connection of these hills with the Laramie mountains through a low anti-clinal which can be followed for many miles. It is sometimes concealed by the recent tertiary beds, but it reappears at different points. By the Laramie mountains we designate those eastern ranges which extend from the Red Buttes southward to the Arkansas. This range, when examined in detail, is composed of a large number of smaller ranges, all, as far as I have observed, of the true granitic type. The trend of the whole group is very nearly north and south, northward as far as Fort Laramie, where they make an abrupt flexure around to the west and northwest, and gradually cease or die out at the Red Buttes. From this point, westward and northward, there is a space of from 20 to 40 miles in width destitute of mountain elevations, though the strata exhibit evidences of dislocation or crust movements.

Geologically the Laramie range is also composed of a granitoid nucleus, with the fossiliferous formations, silurian, carboniferous, red arenaceous beds, (triassic,) jurassic, cretaceous, and in many places lignite tertiary, inclining from each side of a central axis at various angles. It is from these mountains that the numerous branches of the Platte have their sources, extending a distance of nearly 400 miles. From the observations which I have made in this range, it seems to me that the conclusion is plain that all the above-named rocks, in a nearly or quite horizontal position, were continuous over the whole area at present occupied by it some time during the tertiary period.

The most important outlier of the Rocky mountains, on the eastern slope, is the Big Horn range, which, though somewhat irregular in the shape of its mass, has a general trend nearly northwest and southeast. It occupies an area about 180 miles in length and 50 in breadth. Near latitude 43½° and longitude 102° the line of fracture seems to have partially died out, as it were, toward the south or southeast, and to have made a gradual flexure around to the west, the whole range soon losing its granitoid character, and becoming entirely composed of mere modern eruptive rocks. The eruptive portion continues westward until it joins on to the Wind River range, near the sources of Wind river. At the southern end of the Big Horn mountains we can trace a single low anticlinal across the prairie connecting these mountains with the Laramie range at the Red Buttes, on the North Platte. We also know, by the position of the sedimentary beds upheaved along the mountains, that these mountains also form a connection with the Wind River range by the gradual flexure westward of the eruptive rocks. The central portion of these mountains is also composed of granite and granitoid rocks, *with the same series of* fossiliferous formations, inclining at various angles from each side of the axis of elevation, as are seen around the Black Hills and along the Laramie mountains. Some of the more lofty peaks are from 8,000 to 12,000 feet above the sea, and are covered with perpetual snow. We think that the evidence is quite conclusive that, up to the time of the accumulation of a large portion of the lignite tertiary beds, all these formations, from the silurian to the true lignite strata inclusive, were in a horizontal position, extending continuously over the whole area occupied by the mountains; but, as they were slowly elevated, the central portions were removed by the erosive action of water. The eruptive portion which unites the Big Horn range with the Wind River mountains is exceedingly picturesque, presenting the appearance of a connected series of basaltic cones, and so rugged and inaccessible are they that the persevering trappers have never been able to penetrate them in their hunting explorations.

Like the Black Hills, the Big Horn range does not give rise to many important sub-hydrographical basins. The largest stream in this region, and one which gives name to the mountains, rises in the Wind River range, passes through the Big Horn mountains, and unites with the Yellowstone about 70 miles to the southward. Before reaching the mountains it takes the name of Wind river, and assumes the name of Big Horn after emerging from them. This range, however, constitutes quite an important feeder to the Yellowstone. Powder river, which rises in this range by numerous branches, drains a large area, mostly lignite tertiary, and pours a considerable volume of water into the Yellowstone, near longitude 105½° and latitude 46½°. Tongue river is the next most important stream which, though not draining so great an area as Powder river, empties into the Yellowstone a much larger volume of water.

The Medicine Bow and Sweetwater mountains appear to be of the same character, for the most part; but on the east side of the Sweetwater river the evidence of igneous action is shown on a large scale. The ancient volcanic material would seem to have been elevated to a great height in but a partially fluid condition, and then to have gradually cooled, affecting to a greater or less extent the fossiliferous strata in contact.

Near the junction of the Popo Agie with Wind river, we come in full view of the Wind River mountains, which form the dividing crest of the continent. The streams on the one side flowing into the Atlantic, and those on the other into the Pacific. This range is also composed, to a large extent, of red and gray feldspathic granite, with the fossiliferous rocks inclining high upon its sides. After passing the sources of Wind river, the mountains appear to be composed entirely of eruptive rocks. Even the Three Tetons, which raise their summits 11,000 feet above the ocean level, are formed of very compact basaltic rock. The Wasatch and Green River ranges, where we observed them, have the same igneous origin, and the mountains all along the sources of the different branches of the Columbia exhibit these rocks in their full force. In Pierre's Hole, Jackson's Hole, and other valleys surrounded by upheaved ridges, these ancient volcanic rocks seem to have been poured out over the country, and to have cooled in layers, giving to vast thicknesses of the rocks the appearance of stratified beds.

The mountains about the sources of the Missouri and Yellowstone rivers are of eruptive origin, and in the valley of the Madison fork of the Missouri are vertical walls of these ancient volcanic rocks 1,000 to 1,500 feet in height, exhibiting the appearance of stratified deposits, dipping at a considerable angle. As we pass down the Madison we find some beds of feldspathic rocks and mica and clay slates beneath the eruptive layers, dipping at the same angle. After passing the divide below the Three Forks of the Missouri, we see a number of partially detached ranges, which appear to be of the same igneous character. In the Belt, Highwood mountains, and indeed all along the eastern slope in this region, we find continual evidence of the outpouring of the fluid material in the form of surface beds or in layers thrust between the fossiliferous strata. These igneous beds thin out rapidly as we recede from the point of effusion. A large number of these centers of protrusion may be seen along the slope of the mountains west of the Judith range. The erupted material sometimes presents a vertical wall 300 feet high, then suddenly thins out and disappears. The Judith, Bear's Paw, and Little Rocky mountains seem to be composed for the most part of granite and other rocks, with igneous protrusions here and there. I had supposed, from the observations made in my former explorations, that the central portions of our mountain ranges are composed of feldspathic granite, and to a certain extent this is true of the more eastern outliers, but the observations during this expedition have convinced me that these rocks, which I have classed as eruptive, compose by far the greater portion of the mountain masses of the west.

In this connection I have thought it best to remark more systematically in regard to the principal rivers that drain this immense area of country. The Missouri river and its tributaries forms one of the largest as well as most important hydrographical basins in America. It drains an area of nearly or quite 1,000,000 square miles. Taking its rise in the loftiest portion of the Rocky mountains, near latitude 44°, longitude 113°, it flows northward in three principal branches, Madison, Gallatin, and Jefferson forks, to their junction, and then proceeds onward until it emerges from the gate of the mountains, a distance of nearly 200 miles; it then bends to the westward, flowing in this direction to the entrance of White Earth river, a distance of nearly 500 miles; it then gradually bends southward and southwestward to its junction with the Mississippi, a distance of 1,500 to 2,000 miles. The branches which form the sources of the Missouri rise in the central portions of the Rocky mountain range, flowing through granitic, basaltic, and the older sedimentary rocks until it emerges from the gate of the mountains, when the triassic and jurassic are shown. The falls of the Missouri, extending for a distance of 20 or 30 miles, cut their way through a great thickness of compact triassic rocks. Below the falls the channel makes its way through the soft yielding clays and sands of the cretaceous beds for about 250 miles, with the exception of the Judith tertiary basin, which is about 40 miles in length. The cretaceous beds continue extending nearly to the mouth of Milk river, where the lignite tertiary formations commence. These are also composed of sands, marls, and clays, as the character of the valley will show. The river flows through these tertiary rocks to the mouth of Heart river below Fort Union, a distance of nearly 250 miles, where the cretaceous rocks come to the surface again. These latter rocks extend nearly to Council Bluffs, a distance of over 500 miles. I have estimated the distances in a straight line as nearly as possible. Just above Council Bluffs the coal measure limestones commence, and the valley of the Missouri gradually becomes more restricted, though it is of moderate width even below the mouth of the Kansas.

The Yellowstone river is by far the largest branch of the Missouri, and for 400 miles from its mouth up it seems to be as large as the Missouri itself from Fort Union to Fort Pierre. It is navigable for large steamers during the spring and early summer for 300 to 400 miles above its junction with the Missouri. This river also takes its rise in the main divide of the Rocky mountains, near latitude 44½° and longitude 110°, in a lake, as some suppose, called Yellowstone lake, which is about 60 miles long and 10 to 20 wide. Its channel is formed in rocks similar to that of the Missouri, about 400 miles of its course passing through lignite tertiary beds. The character of its valley is very similar to that of the Missouri. Most of the important branches of this river I have alluded to in the preceding portion of this chapter. Tongue and Powder rivers, which are quite long branches, have their origin in the Big Horn mountains, their channels cutting through the different rocks that surround the Big Horn range. Tongue river is nearly 150 miles in length, and flows for the most part through the soft yielding rocks of the lignite tertiary. Powder river is from 250 to 300 miles in length, and also flows nearly all its course through the same tertiary beds as Tongue river.

Passing below Fort Union we observe on the right side of the Missouri river several large rivers, as Little Missouri, Big Knife, Heart, Cannon Ball, Grand, Moreau, and Big Shyenne. The Little Missouri receives a small portion of its waters from the Black Hills, but most of its branches have their origin in the prairie. The Big Shyenne, though receiving most of its waters from the Black Hills, takes its rise far west of the hills in the tertiary beds; but after flowing past the Black Hills wears its channel through the cretaceous beds of Nos. 4 and 5 of the section. The other rivers mentioned above take their rise in the legnite tertiary beds, near the eastern base of the Black Hills, and flow through lignite tertiary rocks until very near or quite to their junction with the Missouri.

The Teton river takes its origin in the northwestern river of the White River tertiary, runs nearly east, for the most part through formations Nos. 4 and 5 of the cretaceous period. It drains an area about 100 miles in length and 30 to 50 miles in width. The next most prominent stream is White River, which is noted for its relations to the Bad Lands, and giving name to one of the most remarkable tertiary deposits in the world. It takes its rise in the prairie near latitude 42½° and longitude 104°; flows for a time in a northeast direction, then bends around so as to enter the Missouri a little south of east near latitude 43° 41′ and longitude 99½°. Nearly its entire course is through the White River tertiary beds, and for the greater part of the year its waters are so full of sediment that they are quite unfit for use. When they stand for a time a thick scum accumulates on the surface which has much the color and consistency of cream. The water itself looks much like very turbid lime-water and is very astringent to the taste. It has generally a wide open valley, tolerably well wooded, and abounding in fine grass, and has always been a favorite resort for the Indians. The road between Forts Laramie and Pierre passes along the valley for a considerable distance, through some of the most picturesque scenery in the west. It has numerous branches, but the only one of importance is called the South Fork, and is nearly as large and long as the main stream. It drains an area about 250 miles in length and 40 to 60 in breadth.

The Niobrara river is the next most important stream, and as the area drained by this stream has been the subject of much interest to the inhabitants of Nebraska and Dakota, I take the liberty of quoting the minute and excellent description of Lieutenant Warren:* "The Niobrara being a stream heretofore unknown, and one in which the people of

* Letter to Hon. G. W. Jones, relative to his explorations of Nebraska Territory, January, 1858.

Nebraska feel much interest, I shall describe it in detail. The area occupied by the Niobrara is about 450 miles in length from east to west, and from 40 to 60 miles in width from north to south."

The next sub-hydrographical basin, and perhaps in many respects the most important one in the Missouri valley, is that of the Platte, which empties into the Missouri river near latitude 41° 3′ 24″. Its valley forms a natural grade for a railroad to the foot of the mountains, and already one has been constructed from Omaha City, 305 miles, and before this report will be given to the world, it will doubtless be completed to the foot of the mountains.

The Platte river takes its rise in the Laramie range, and flows for the greater part of its course through the more recent beds of the tertiary deposits. The area drained by this river must be at least 600 miles from east to west, and 80 to 150 from north to south. Although a wide stream, 1,000 yards or more, the water is so shallow and the channel so shifting that it can never be rendered navigable even for Mackanaw boats. Even the fur traders have never been able to rely for the transportation of their furs and skins.

On the left or north side of the Missouri there are comparatively few branches, the principal of which are Milk, White Earth, James, Vermilion, and Big Sioux. The three last named rise in the far north and flow through a much more rocky region and over a stony bed, and their waters as they pour them into the Missouri contain far less sediment then any of the others. Indeed, most of the rivers previously described flow through a more or less barren country, with a thirsty atmosphere and a still more thirsty soil, and on their way to the Missouri they lose nearly or quite all their waters. Many of these long rivers, as Grand, Cannon Ball, and Shyenne, in the autumn frequently become so dry as to cease to be running streams, while perhaps 100 miles above their mouths if in the vicinity of some mountain, there is a full supply of water. The Muscleshell river is a fine example. Toward the source of this river it is a fine running stream; in the dry season it is lost almost entirely before reaching the Missouri. Much more might be said in this connection, but enough has been written to enable the reader to comprehend to some extent the vast geographical area drained by the Missouri river and its tributaries.

CHAPTER II.

SYSTEM OF GEOLOGICAL FORMATIONS IN THE NORTHWEST.

GRANITE, AZOIC AND ERUPTIVE ROCKS—LOWER SILURIAN POTSDAM SANDSTONE—CARBONIFEROUS ROCKS, TRIASSIC AND JURASSIC—CRETACEOUS ROCKS, LOWER SERIES—GENERAL SECTION OF THE CRETACEOUS ROCKS OF THE NORTHWEST—DAKOTA GROUP—FORT BENTON GROUP—NIOBRARA DIVISION—RELATIONS OF THE LOWER CRETACEOUS SERIES OF THE NORTHWEST TO SUBDIVISIONS AT FOREIGN LOCALITIES—UPPER CRETACEOUS SERIES OF THE NORTHWEST—FORT PIERRE GROUP—FOX HILL BEDS—RELATIONS OF THE UPPER CRETACEOUS SERIES OF THE NORTHWEST TO EUROPEAN DIVISIONS—TERTIARY ROCKS—GENERAL SECTION OF THE TERTIARY ROCKS OF THE NORTHWEST—FORT UNION OR GREAT LIGNITE GROUP—WIND RIVER DEPOSITS—WHITE RIVER GROUP—LOUP RIVER BEDS.

The observations which have already been made in regard to the geology of the northwest, have served to fix upon a permanent basis the various geological formations that exist there. In order that the succeeding chapters may be better understood, I have thought it best to introduce in this chapter the brief descriptions of the different geological divisions, from a paper prepared for the Academy of Natural Sciences at Philadelphia, and published in December, 1861, by Mr. F. B. Meek and the writer, soon after my return from the west as geologist to the exploring expedition to the head-waters of the Missouri and Yellowstone rivers, under the command of Captain William F. Raynolds, topographical engineer. In a subsequent portion of this report, under the head of general geology, I shall give a more detailed account of each of the divisions named, with lists of the fossils known to be found in each. The object of this chapter is to render the narrative portion of the report more intelligible. The rocks observed in the northwest belong to the different geological periods in the following order:

I. Granite, stratified azoic, and eruptive rocks.
II. Potsdam sandstone, (silurian.)
III. Carboniferous rocks, including Peruvian.
IV. Triassic or red arenaceous deposits.
V. Jurassic beds.
VI. Cretaceous with its divisions.
VII. Tertiary deposits.
VIII. The various superficial deposits.

It will be sufficient to remark here that the first division forms the nucleus of the various mountain chains. By granite or granitoid I mean those unstratified crystalline rocks which hold a lower position than any of the stratified deposits, and for the most part possess a uniform character, forming the central portions of the larger mountains; by stratified azoic, a series of non-fossiliferous stratified beds, apparently sedimentary between the granite and Potsdam sandstone; and by eruptive rocks, those which have been melted by volcanic heat and brought to the surface in a more or less fluid condition at various periods. The carboniferous rocks form a belt or zone around all the mountain elevations—as also the red arenaceous deposits, or triassic beds. Although the evidence is not perfect, it is generally understood among geologists that these *red beds are of* triassic age.

LOWER SILURIAN (PRIMORDIAL) ROCKS.

In March, 1858, we announced in a paper read before the academy, that we had identified fossils of the age of the Potsdam sandstone among the collections brought by Lieutenant Warren's expeditions from the Black Hills, Nebraska. Previous to that time no organic remains of that age had been recognized, either from there or from the Rocky Mountain ranges further west. The specimens then identified by us were collected by one of the writers, (Dr. H.) who acted as geologist of Lieutenant Warren's expedition. They consist of *Lingula prima*, *L. antiqua*, and an *obolella* with fragments of a *trilobite* of primordial type, similar to some of those occurring in rocks of that age in Wisconsin. In the following pages of this paper we give descriptions of apparently the same *trilobite* mentioned above, and of a small *pteropod?* of the genus *puginuculus*, from the primordial or Potsdam sandstone at a locality near the head of Powder river on Big Horn mountains, a part of the Rocky Mountain range, near latitude 43° 30′ north, longitude 108° west. These fossils were collected by one of the writers, (Dr. Hayden, who acted as geologist of Captain Raynolds's expedition,) from a brownish, somewhat laminated, sandstone, also containing a *lingula* apparently identical with *L. antiqua*, but smaller than the average size of that shell. At this and other localities along the Rocky mountains, west of the Black Hills, as well as the latter, this rock was seen resting either directly upon granitic masses, or ancient upheaved metamorphic slates. At the Black Hills it is usually only from 50 to 80 feet in thickness, but in the Big Horn mountains it sometimes attains a thickness of 200 feet. Up to this time we have no positive evidence of the existence of any of the usually succeeding silurian and devonian rocks, throughout all this region, north of the South Pass, latitude 42° 31′ north, longitude 109° west. From the latter locality we have identified specimens of *Halysites catenulata* and a few other fossils probably of upper silurian age.* North of this, however, so far as we know, the primordial sandstones are directly succeeded by heavy deposits of carboniferous age, of arenaceous and more or less pure limestone. Surmounting the latter, there were also seen occasional local beds of magnesian limestones of the same age, and containing some of the same fossils as those referred by us and others in eastern Kansas to the Peruvian epoch. As it is our purpose, however, to confine our remarks more particularly to the strata from which the fossils described in this paper were obtained, we pass on to the

JURASSIC ROCKS.

In a paper already referred to, (published by us in the March number of the proceedings for 1858,) we announced that we had identified jurassic types of fossils among the collections brought in from the Black Hills by Lieutenant Warren's expedition. So far as we know, these were the first true jurassic fossils ever identified from the region of the Rocky mountains. In April, 1860, one of the writers, (F. B. M.,) and Mr. Henry Engelmann, recognized some of the same species along with a few new forms, in the collections brought by Captain Simpson's expedition, from equivalent beds at Red Buttes on the North Platte, and from near Uintah and Weber river in Utah.†

The specimens of this age, collected during Captain Raynolds's expeditions, are, in part, from near the head of Wind River valley, in the Rocky mountains, latitude 43° 30′ north, longitude 110° west, and

* *Transactions American Philosophical Society*, March 4, 1859, page 137.

† *See Proceedings of the Academy*, April, 1860, page 129.

rom Big Horn mountains, latitude 43° 30′ north, longitude 108° west. At both of these localities, at the Black Hills, and at the Red Buttes, n the North Platte, as well as at the other localities already mentioned n Utah, the rocks containing these jurassic fossils consist of a series of rayish, ash-colored and red argillo-calcareous, more or less gritty, strata, vith beds of soft dark-brown and reddish sandstones. These beds reserve a remarkable uniformity of character taken as a group, wherver they have been seen, and need never be confounded with the cretaeous or tertiary rocks so widely distributed over the northwestern erritories, even where no fossils are to be found. They are usually only een as we approach the mountains, near which they rise from beneath he cretaceous strata.

The organic remains found in these series present, both individually nd as a group, very close affinities to those in the jurassic epoch in the Old World; so close indeed, that in some instances, after the most careful omparisons with figures and descriptions, we are left in doubt whether hey should be regarded as distinct species, or as varieties of well known European jurassic forms. Among those so very closely allied to foreign urassic species may be mentioned an *ammonite* we have described under he name of *A. cordiformis*, which we now regard as probably identical vith *A. cordatus*, of Sowerby; a *gryphæa* we have only been able to disinguish as a variety from *G. calciola*, Quenstedt; a *pecten*, scarcely disinguishable from *P. lens*, Sowerby; a *modiola*, very closely allied to *M. ancellata*, of Goldfuss; a *belemnite*, agreeing very nearly with *B. excentricus*, Blainville, &c.

At the same time that the fossils of this group of strata are generally so closely analogous to known jurassic species of the Old World, they are all clearly distinct from any of those found in our cretaceous rocks above. In short, their jurassic age is as susceptible of demonstration, both upon stratigraphical and palæontological evidence, as that of succeeding rocks above them, or any part of the green sands of New Jersey, belong to the cretaceous epoch. The facts, likewise, nearly all, as we have mentioned on former occasions, point to the conclusion that they hold a rather low position in the jurassic system. At nearly all the localities already mentioned, where these well-marked jurassic rocks occur, there is, at their base, a more or less extensive series of brick-red strata, consisting of fine-grained areno-argillaceous material, with local intercalated beds of gypsum. These red strata seem to be nearly always destitute of organic remains, but from their position we have been inclined to regard them as probably of triassic age. During Captain Raynolds's expedition, however, some fossiliferous seams were found near their base, probably 300 feet below the horizon of the beds containing so many jurassic fossils. Among these we recognize one *Lingula brevirostra*, and *Monotis curta*, Hall, sp., both of which are common in the beds containing the jurassic fossils at the Black Hills. From this fact we are inclined to think that at least a large part of the red, gypsum-bearing strata of this region should also be included in the jurassic system. These beds augment greatly in thickness as we go southward, and, as Dr. Newberry and others have shown, similar if not equivalent strata are developed on a grand scale in New Mexico. Whether this vast series of red beds in the southwest belongs to the jurassic or triassic epoch, or whether they represent both in part, are questions it would be wandering from our subject to attempt to discuss here.

CRETACEOUS ROCKS, (LOWER SERIES.)

In our paper of March, 1858, already cited, we mentioned having recognized fresh or brackish-water shells in Lieutenant Warren's collections from the southwest base of the Black Hills, obtained, apparently, from the base of the cretaceous series of that region. These fossils consist of a *unio*, a small *planorbis*, and fragments of some small univalves like *paludina*, all of which were found associated with im perfect specimens of *ostrea*. The beds containing these fossils present a somewhat mixed character, being composed in part of light-gray clays and purple argillo-calcareous seams. The fresh-water shells were found in the latter hard seams, which sometimes assume nearly the aspect and composition of a true limestone. This formation rests directly upon the jurassic strata, and seems to pass beneath the older cretaceous beds.* Among Captain Raynolds's collections, now before us, from the head of Wind River valley, we also recognize, from a precisely similar bed, fragments of a *unio*, with great numbers of a *melania*, and a beautiful little *neritella*, which, although completely mineralized, retains its original zigzag bands of dark and light colors.†

The bed containing these fossils here, like that at the Black Hills, rests directly upon the jurassic strata, and appears to dip beneath the cretaceous, while its fossils are in exactly the same state of preservation as those collected at the Black Hills. As it differs at both these localities in its lithological characters, from all of the well-defined tertiary beds of the northwest, and its fossils are not only clearly distinct from the known tertiary forms of that region, but all present a more ancient aspect, we are still inclined to think it really holds a position near the lower part of the cretaceous series of that region. Until this can be determined, however, upon stratigraphical evidence, we do not feel warranted in assigning this formation a place in the general section of the cretaceous rocks of the northwest, since it may prove to be of tertiary, or even possibly of jurassic age. For, as all palæontologists are aware, the remains of fresh-water mollusca cannot be relied upon in determining the age of strata, excepting where they happen to be specifically identical with forms known to occur elsewhere in well-established horizons. This arises from the fact that they are very similar in rocks of all ages in which they are known to occur, or, at least, that they do not present peculiar distinctive features in different formations in so marked a degree as marine shells.

Since the first publication of a general section of Nebraska cretaceous rocks, based upon observations made by us in 1853, while on an expedition for Professor Hall, and subsequently published by him and one of the writers, (F. B. M.,) in the Memoirs of the American Academy of Arts and Sciences,‡ our knowledge of the range and thickness of these rocks, as well as of their relation to each other, and to cretaceous beds elsewhere, has been much extended. We have also been able, from the collections subsequently brought in by various expeditions from localities scattered over wide areas, not merely to add largely to the number of species previously known to be embraced in the cretaceous fauna of this region, but we have also extended our knowledge of their geographical distribution and vertical range. Consequently we have now

*At the time we published these facts we were led, by the discovery here of fresh-water shells, in such a position, to think that some estuary deposits of doubtful age, near the mouth of Judith river, on the Missouri, from which Dr. Leidy had described some saurian remains resembling Wealden types, might be older than tertiary. Later examinations, however, have demonstrated that the Judith beds contain an entirely different group of fossils from those found in the rock under consideration, and that they are really of tertiary age, and hold a position at the base of the great lignite series of the northwest.

†*Descriptions of the latter* two fossils are given in another part of this paper.

‡*December, 1861. Mem.* Am. Acad. Arts and Sci., Boston, vol. 5, N. S., p. 381.

he means of constructing a section of these rocks that will give a more lear and accurate idea of the relative importance and thickness of the ubdivisions, as well as their relations to each other, and of each to the vhole. Hitherto, in all the sections of these rocks published, the sub- livisions have been designated merely by the numbers 1, 2, 3, 4, and 5. Experience has taught us that inconvenience and confusion are apt to arise from the use of this kind of a nomenclature, because these larger groups are constantly liable to be confounded with unimportant sub- livisions of local sections, to which it is almost indispensably necessary o apply numbers. This being the case, we propose to designate each of these formations by a distinct name, retaining, however, opposite each name, the same number formerly used for each group. In select- ng names we have preferred those derived from localities to such as night be suggested by the lithological or palæontological characters of he different rocks; because however appropriate such a name as "inoceramus bed," or "silicious group," may be for a formation at a given ocality, it will generally be found inapplicable if we attempt to trace he rock over areas of any great extent.

Our names have also been selected from localities where the particular formation named is known to be well developed and readily recognizable.

In accordance with these views we present the following section:

General section of the cretaceous rocks of Nebraska.

	Divisions and subdivisions.		Localities.	Estimated thickness.	
				Feet.	
Upper series.	Fox Hills beds. Formation No. 5.	Gray, ferruginous, and yellowish sandstone, and arenaceous clays, containing *Belemintella bulbosa, Nautilus Dekayi, Ammonites placenta, A. lobatus, Scaphites Conradi, S. Nicolletti, Baculites grandis, Busycon Bairdi, Fusus Culbertson, F. Newberryi, Aporrhais Americana pseudo-buccinum, Nebrascensis, Mactra Warrenana, Cardium subquadratum*, and a great number of other molluscous fossils, together with bones of *Mosasaurus Missouriensis*, &c.	Fox hills, near Moreau river, near Long lake, above Fort Pierre, along base Big Horn mountains, and on North and South Platte rivers.	500	(Senonien, D'Orbigny.)
	Fort Pierre group. Formation No. 4.	Dark gray and bluish plastic clays, containing, near the upper part, *Nautilus Dekayi, Ammonites placenta, Baculites ovatus, B. compressus, Scaphites nodosus, Dentalium gracile, Crassatella Evansi, Cucullæa Nebrascensis, Inoceramus Sagensis, I. Nebrascensis, I. Vanuxeuir*, bones of *Mosasaurus Missouriensis*, &c.	Sage creek, Shyenne river, and on White River above the Mauvaises Terres.	700	*Eq.* upper or white chalk and Maestricht beds.
		Middle zone nearly barren of fossils	Fort Pierre and out to Bad Lands, down the Missouri, on the high country, to Great Bend.		
		Lower fossiliferous zone, containing *Ammonites complexus, Baculites ovatus, B. compressus, Helioceras Mortoni, H. tortum, H. umbrilicatum, H. cochleatum, Ptychoseras Mortoni, Fusus vinculum, Anisomyon borealis, Amauropsis paludiniformis, Inoceramus sublævis, I. tenuirlineatus*, bones of *Mosasaurus Missouriensis*, &c.	Great Bend of the Missouri, below Fort Pierre.		
		Dark bed of very fine unctuous clay, containing much carbonaceous matter, with veins and seams of gypsum, masses of sulphuret iron, and numerous small *scales, fishes, local, filling depressions in the bed below.*	Near Bijou hill, on the Missouri.		

General section of the cretaceous rocks of Nebraska—Continued.

		Divisions and subdivisions.	Localities.	Estimated thickness.	
				Feet.	
Lower series.	Niobrara division. Formation No. 3.	Lead-gray calcareous marl, weathering to a yellowish or whitish chalky appearance above, containing large scales and other remains of fishes, and numerous species of *Ostrea congesta* attached to fragments of *Inoceramus*. Passing down into light yellowish and whitish limestone, containing great numbers of *Inoceramus problematicus*, *I. pseudo-mytiloides*, *I. aviculoides*, and *Ostrea congesta*, fish scales, &c.	Bluffs along the Missouri, below the Great Bend, to the vicinity of Big Sioux river; also below there on the tops of the hills.	200	
	Fort Benton group. Formation No. 2.	Dark-gray laminated clays, sometimes alternating near the upper part with seams and layers of soft gray and light-colored limestone, *Inoceramus problematicus*, *I. tenuirostratus*, *I. latus*, *I. fragilis*, *Ostrea congesta*, *Venilia Mortoni*, *Pholadomya papyracea*, *Ammonites Mullani*, *A. percarinatus*, *A. vespertinus*, **Scaphites Warreni*, *S. larvæformis*, *S. ventricosus*, *S. vermiformis*, *Nautilus elegans* (?), &c.	Extensively developed near Fort Benton, on the upper Missouri; also along the latter from ten miles above James river to Big Sioux river, and along the eastern slope of the Rocky mountains as well as at the Black Hills.	800	Eq. lower or gray chalk (and upper gray sandstone) of British geologists. *Turonien* and *cenomanien* (?) of D'Orbigny.
	Dakota group. Formation No. 1.	Yellowish, reddish, and occasionally white sandstone, with, at places, alternations of various colored clays and beds and seams of impure lignite; also silicified wood and great numbers of leaves of the higher types of dicotyledonous trees, with casts of *Pharella*(?) *Dakotensis*, *Axinaea Siouxensis*, and *Cyprina arenarea*.	Hills back of the town of Dakota; also extensively developed in the surrounding country, in Dakota county, below the mouth of Big Sioux river, thence extending southward into northeastern Kansas and beyond.	400	

Geologists will understand that we do not regard the several rocks to which we have applied the names Dakota group, Fort Benton group, &c., as being always separately and individually recognizable at widely distant parts of the world, nor even in all cases throughout North America. They are merely convenient subdivisions, presenting more or less marked lithological and paleontological peculiarities, due to physical agencies that were probably in some instances comparatively local in their action; though in other cases we have been able to identify the equivalents of some of them, as we have shown on former occasions in New Jersey, Alabama and New Mexico.† When we wish to draw parallels between these rocks and those of the cretaceous system of the Old World, how-

* This is *A. Texanus* of Roemer. It is on the authority of Mr. Gabb that it is here regarded as identical with *A. vespertinus* of Morton. We should never have suspected this from Dr. Morton's figure, but Mr. Gabb assures us that after a careful examination of Dr. Morton's specimen, he can see no difference.

† *See Proceed. Acad. Nat. Sci. Phila.*, Nov., 1856, and May, 1857.

ever, we find it necessary to group them together, so far as our present knowledge extends, into two, or at any rate not more than three, principal series.

Dakota group.—Although we still retain this as a distinct rock, our present impression is that it is probably only a subdivision or member of the Fort Benton group. Still, until more fossils can be obtained from it in the region of the typical localities, the question whether or not it should rank as a distinct formation must remain an open one. That it is at least as old as the Fort Benton group, however, is clearly demonstrated by its position beneath some two hundred feet of that rock near the mouth of Big Sioux river, where the latter formation is seen to pass beneath the Niobrara division.

This order of superposition is also known to prevail throughout a considerable area in northeastern Kansas and southeastern Nebraska, as may be seen at hundreds of localities where all the strata lie in a nearly horizontal position.

That this rock cannot be referred to any older epoch than the cretaceous, is also equally clear from the modern affinities of numerous fossil leaves embedded in it. Among these remains Dr. Newberry and Professor Heer have identified the genera *Populus*, *Salix*, *Almus*, *Platanus*, *Liriodendron*, &c., &c.* The few animal remains yet found in it are merely casts of shells referable to the genera *Pharella*, *Axinæa*, *Mactra*, *and Cyprina.*

Along the Missouri, in the region of the mouth of Big Sioux river and below, this rock consists mainly of yellowish and reddish sandstones, in rather thick beds, interstratified, however, at places with beds of yellow and ash-colored clays and impure lignite. In this region it is generally quite distinct from the Fort Pierre group above, but farther south, in Kansas, the two rocks seem to be less distinct, while at the Black Hills and along the Rocky mountains west of these the whole appears to be represented at places by a series of alternating sandstones and clays.

Below the mouth of Big Sioux river this formation is seen at some localities resting directly upon the limestones of the coal measures; but in northeastern Kansas it usually reposes on a series of reddish and various-colored clays, probably of jurassic age.

Near the Black Hills, and along the Rocky mountains west of there, apparently representative beds were usually seen to be immediately underlaid by well-marked jurassic strata, excepting at the localities where the brackish-water deposits already mentioned appear to intervene between them and the jurassic.† This rock has not yet been satisfactorily recognized on the upper Missouri, though there is a similar formation near the mouth of Judith river, and below there, which we have sometimes thought may possibly represent it; until we can know more, however, in regard to the relations of the Judith river bed to the other rocks of the series in that region, and have an opportunity to examine more of its fossils, it would be unsafe to refer it to the Dakota group. The fossils collected from the sandstone here alluded to, near the Judith river, belong to the genus *Inoceramus*, *Tancredia*, *Mactra*, *Baculites*, &c., all of which are distinct from the species yet obtained from any of the known horizons elsewhere.

In our paper of May, 1857, we pointed out that the Dakota group (which we then designated as formation No. 1) is represented in New Jersey and Alabama by a series of more or less arenaceous clays and

* Proceed. Acad. Dec., 1858; Am. Journ. Sci., new ser., vol. 27, 1859; also March, 1860.
† This brackish-water bed we think probably belongs to the formations under consideration.

sandstones, with lignite and leaves of dicotyledonous trees.* Since that time Dr. Newberry has traced it from near the Arkansas river, in Kansas, by the remains of its characteristic flora, far in to New Mexico, where he found it surmounted by a great thickness of well-marked cretaceous rocks.† Dr. Shumard also thinks he can recognize it in Texas, at the base of the cretaceous series of that State.‡

Fort Benton group.—This formation usually consists of dark gray laminated clays, with thin, lighter-colored arenaceous partings, and layers and beds of sandstone. Towards the upper part, near its connection with the Niobrara division above, it sometimes includes intercalated layers of gray limestone, in all respects similar to the lower portion of the overlying rock, while at some other places its upper portion passes into a dark shale. It seems to attain its greatest thickness in the vicinity of Fort Benton, where the entire hills, eight or nine hundred feet in height, appear to be composed of it. Until we can have more exact information, however, in regard to the range of the organic remains, through this great thickness of strata, we must have some doubts in regard to whether there may not also be some representation here of the Dakota group.

This seems to be the more probable when we bear in mind that the rock under consideration becomes, as already stated, blended with the latter formation further south at the Black Hills and along the Rocky mountains west of them.

The Fort Benton group has a wide geographical extension in the country west of the Mississippi, though neither it nor the succeeding rock above appears to have any well defined representatives as a distinct formation in Alabama, New Jersey, and other States east of the Mississippi, as was pointed out by us in May, 1857.§

The highest northern locality at which we have any knowledge of its existence is on the north branch of the Saskatchewan, some thirty or forty miles west of Fort à la Corne near latitude 54 north, where Professor Hind discovered specimens which were referred by one of us (F. B. M.) to this horizon.‖ We had also previously referred to the same position some specimens discovered by Professor S. I. Dawson, at a locality 250 miles west of Fort Garry, on the Assiniboine river.¶

It is known to occur in northeastern Kansas, as well as in Arkansas; and in 1857 we pointed out that it is probably represented by one of the beds in Mr. Marcou's section of Pyramid mountain, in the far southwest. Dr. Newberry's investigations, in connection with Lieutenant Ives's expedition, seem to show that it is extensively developed in New Mexico, though it appears there to be generally blended with the Niobrara division, the two forming together the middle division of his section of the cretaceous, of New Mexico, which attains a thickness of

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* Proc. Acad. Nat. Sci., Phila., March, 1857, p. 117.

†American Journal Sci., sec. ser., vol. 29, p. 208, March, 1860.

‡ See an important paper on the Geology of Texas, by Dr. B. F. Shumard, in Trans. St. Louis Acad. Sci., vol. 1, p. 582. It is a source of much regret to those interested in the progress of geological science in this country that circumstances have prevented this able geologist from completing the survey of Texas.

§ We have sometimes suspected that the bed in New Jersey containing *Venilia Conradi*, *Scaphites hippocrepis*, and *Pholadomya occidentalis*, Morton, might belong to this horizon, from the analogy of these species to some of our far western Fort Benton group forms, but we have been assured that they occur in New Jersey, mingled with other species only found in our upper cretaceous beds of Nebraska.

‖ See Professor Hind's report on Saskatchewan and Assiniboine, Expl. Ex., p. 179, Toronto, 1859.

¶ See Professor Dawson's report on explorations of the country between Lake Superior and the Red River settlements, p, 18, Toronto, 1859.

from 1,200 to 1,500 feet. Dr. Shumard has also identified it in Texas, where it is apparently quite thin.*

All the facts show that this rock thins out, both in the south and at the north, in an easterly direction, its greatest thickness being at Fort Benton and along the mountains south of there, and in New Mexico, while on the Missouri, between James and Big Sioux rivers, it is only about 100 feet in thickness; and Dr. Shumard gives 50 feet as its thickness in his Texas section.

This formation contains a number of interesting organic remains, some of which are known to have a wide geographical range, and, as may be seen by the foregoing section, also pass up into the succeeding rock above. We also have reason to believe that several of them likewise occur further south in the formation below, thus apparently linking together, as already suggested, these three rocks as subordinate members of one great series. At any rate, the fossils described by Dr. Shumard from the "marly clay, or Red River group" of his Texas section, which, we think, he has correctly placed on a parallel with our Dakota group, (No. 1, of former sections,) are both individually and as a group apparently very closely allied to forms occurring in the formation under consideration in Nebraska. For instance, his *Inoceramus capulus* is scarcely distinguishable, as he has suggested, from our *I. umbonatus;* and, we think it probable, his *Ammonites Graysonensis* is not distinct from *A. percarinatus*, Hall and Meek. Again, his *Scaphites, vermiculus* is allied to our *S. larvæformis.*

Niobrara division.—The typical localities of this rock are along the Missouri, near the mouth of Niobrara river, where it forms perpendicular cliffs, from 90 to 100 feet in height. In this region it consists mainly of lead-gray, richly calcareous marl, which, where long exposed, assumes a light buff or whitish color, and presents much the appearance of true chalk. Below it passes into more compact beds of soft bluish gray limestone. It is first seen in descending the Missouri, a short distance below the Great Bend, where it rises by a gentle dip from beneath the succeeding formation, (the Fort Pierre group.) Further down the river it is seen to rise higher and higher, and gradually assumes the character of a surface rock, not far below the mouth of Niobrara river. When much exposed to the action of the weather, here and on Little Blue river, near the northern boundary of Kansas, it becomes a rather hard whitish limestone. This formation can be traced by exposures in northeastern Kansas, near Little Blue and Smoky Hill rivers, through Arkansas, into Texas and New Mexico.

In 1857 we pointed out that it is represented by the upper beds of Mr. Marcon's Pyramid mountain section; and Dr. Shumard has placed the "Washita limestone" and "indurated gray marl" of his Texas section on a parallel with it and two of the same beds in Mr. Marcon's section.

At the Black Hills this rock sometimes presents its normal appearance, but generally there, as well as along the Rocky mountains further west, it is scarcely distinguishable lithologically from the formation below. The fossils hitherto found in it in Nebraska are *Ostrea congesta, Inoceramus problematicus, I. aviculoides,* and a small *baculite*, together with large scales of fishes; all, excepting the fish scales, being identical with species found in the strata beneath. *Inoceramus problematicus*, or at least a form scarcely distinguishable from that species, and *Ostrea congesta*, occur in it almost everywhere that it has been met with.

In Texas, Dr. Shumard found in the bed he places on a parallel with

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* Transactions St. Louis Academy of Sciences, vol. 1, p. 583.

this formation, *Holaster simplex*, *Epiaster elegans*, *Cidaris hemigranosus*, *Gryphœa Pitchen*, (common variety, and *G. Tucumcarii*,) *G. sinuata*, Marcon, (not Sowerby,) *Ostrea subovata*, (*O. Marshii*, Marcon,) *O. carinata*, *O. quadriplicata*, *Janira Texana*, *J. Wrightii*, *Inoceramus problematicus*, *Pachymya Austinensis*, *Lima crenulicosta*, *Terebratula Wacoensis*, *Turrilites Brazoensis*, *Ammonites Texanus*, *A. Brazœnsis*, *Hamites Fremonti*, and *Nautilus Texanus*.

Relations of the lower cretaceous series of Nebraska to subdivisions at foreign localities.

Having now considered in the order of their succession the several rocks embraced in the lower series of the Nebraska cretaceous deposits, and endeavored, as far as our present means of investigating the subject enable us to do, to trace out their relations to the cretaceous beds of other parts of this country, it will be interesting to see how nearly their synchronism with known horizons in the cretaceous system of the old world can be traced out. With this view we have carefully compared with European forms all the fossils in the several Nebraska collections from these rocks, including those most recently obtained, to which the new species described in this paper belong. These comparisons have satisfied us that the formations under consideration—that is, the Niobrara division, Fort Benton group, and the Dakota group—represent together the lower or gray chalk, and probably the upper green sand of British geologists, (*turonien* and *cenomanien* of D'Orbigny.) We had in 1856 identified the gray chalk species, *Inoceramus problematicus*, in the Niobrara division, (No. 3 of former sections,) and suggested that this rock, probably, holds a position at about the horizon of the lower chalk of the Old World.* More recently, we had likewise mentioned that we regarded *Ammonites percarinatus*, Hall and Meek, as being, probably, identical with the well-known lower chalk species *A. Woolgari*, of Mantell.† These facts however, had not so forcibly attracted our attention until we commenced the investigation of the collections containing the new species described in this paper.

The evidence upon which we have placed these rocks on a parallel with the lower or gray chalk of British geologists will be more clearly understood by consulting the following list of species from them, which are either identical with, or so closely allied to, species found in that position in the Old World, as to be safely regarded, we think, as contemporaneous representative forms:

Found in the lower series of Nebraska—European lower chalk species:

Ammonites vespertinus, Mort., represents *A. Rhotomagensis*, Defr., and other lower chalk species.

A. percarinatus, H. and M., probably identical with *A. Woolgari* of Mantell.

Scaphites Warreni, M. and H., scarcely distinct from *S. æqualis*, Sowerby.

S. larvæformis, M. and H., same type as *S. æqualis*, Sowerby.

Nautilus elegans var. can scarcely be distinct from *N. elegans*, Sowerby.

Inoceramus latus ? appears to be the same as *I. latus* of Mantell.

Inoceramus problematicus,‡ cannot be distinguished from *I. problematicus*, Schlot, sp.

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* Proceedings Academy Natural Sciences, Philadelphia, November, 1856, p. 267.

† Proceedings Academy Natural Sciences, Philadelphia, October, 1860, p. 419. Mr. Gabb has also suggested in a note to p. 129 of his Synopsis Cretaceous Fossils, that the rocks under consideration may represent the lower chalk of England.

‡ *This species is said* to also occur in the upper green sand of Europe.

Inoceramus problematicus is most frequently met with in the Niobrara ivision, but is also sometimes found in the Fort Benton group; all the thers are generally peculiar to the latter rock in Nebraska. *Inocera-us latus*, *Ammonites vespertinus*, and a species very closely allied to *'autilus elegans*, are found in Texas in beds apparently representing the iobrara division. Other species from our lower series of Nebraska, milar to lower chalk forms of the Old World, might be mentioned, but ıe foregoing list includes the most striking examples. We may, how-ver, state that, with a few doubtful exceptions, nearly all the other pecies yet known in the lower series of Nebraska cretaceous rocks resent much nearer affinities to lower chalk forms than to species olding a higher position in the cretaceous of the Old World. The most nportant exception to this rule we have met with is *Inoceramus umbo-atus*, which is evidently closely allied to *I. involutus* of Sowerby, from ıe upper or white chalk. There still remains, however, some doubt in egard to the position of this fossil in the Nebraska formations, no speci-ıens of it having yet been collected *in situ* by any person familiar ith the order of succession of the Nebraska rocks.

UPPER CRETACEOUS SERIES OF NEBRASKA.

Fort Pierre group.—In the foregoing review of the lower series of ebraska cretaceous rocks, it has been shown that the subdivisions ften shade into each other lithologically, and that at least the upper wo members are so intimately related by the range and affinities of ıeir organic remains as to indicate that they are merely subordinate ırmations of one great series, or primary division of the cretaceous ystem. There seems to be no horizon at which we can, upon paleon-ological principles, draw a sharp line separating the beds below from ıose above, until we ascend to the top of the Niobrara division. In rossing this line, however, we not only generally observe a marked thological change, but so far as our present knowledge extends, we ıeet with the remains of an entirely different group of animals. It is ue, nearly or quite all the genera seen in the beds below are still bserved, along with many others in the strata above this horizon, but ıe species yet found in these upper formations in Nebraska, at least, re all distinct from those hitherto found in the lower series. We are ware that further investigations may possibly show closer relations etween the organic remains of the upper and lower series of these ocks in this region than have been hitherto discovered. Yet, when it borne in mind that our conclusions are based upon a careful study nd comparison of extensive collections from numerous localities, scat-ered over a great area of country, it will be readily understood how ery improbable it is that future explorations will materially modify hese results.

At the base of the Fort Pierre group, the inferior member of the upper eries of Nebraska cretaceous rocks, there is, at some localities along he Missouri below the Great Bend, a local bed, ten to thirty feet in hickness, composed of very dark, unctuous clay, containing great num-ers of small scales of fishes, much iron pyrites and carbonaceous matter, ith crystals, veins and seams of sulphate of lime. The bed usually ccupies depressions in the previously eroded upper surface of the for-ıation beneath. With the exception of the local deposit just mentioned, he Fort Pierre group consists of a vast accumulation of fine gray and ark-colored clays in moderately distinct layers, but never presents a aminated or slaty structure like the Fort Benton group. When wet, these clays are soft and plastic, but in drying they often crack and crumble so as to obliterate the marks of deposition in vertical exposures. This formation composes all the hills on both sides of the Missouri at Fort Pierre, and much of the country between there and the Bad Lands. It also forms the bluffs along the river below Fort Pierre to the Great Bend, just below which the Niobrara division rises above the level of the Missouri. From the Great Bend down to the mouth of Niobrara river, the country is made up of these two formations, which rise with the general inclination of all the rocks in this region, so that the Fort Pierre group finally runs out in the form of outliers on the tops of the hills below the mouth of the Niobrara river. Above Fort Pierre it gradually sinks beneath the Fox Hills group, in the region of Shyenne and Moreau rivers, but continues to be seen in the bluffs of the Missouri and other streams for some distance beyond.

On the upper Missouri this formation comes to the surface again, and forms much of the country in the region of Milk and Muscleshell rivers. It is also known to extend far up into the British possessions—some of its fossils having been discovered on the Saskatchewan by an expedition sent out by the Canadian government, in 1858, under the direction of Prof. S. J. Dawson.* Several of the characteristic fossils of this formation were also discovered, in 1858, on the south branch of the Saskatchewan, as well as on the Assiniboine and Little Souris rivers, by another Canadian government expedition under the charge of Prof. Henry Y. Hind.†

This formation is also known to be well developed at the Black Hills and along the Rocky mountains west of there in Nebraska, and extends southward at least as far as the region of Pike's Peak. It also exists in Texas, though it probably only occurs as thin local patches in the country between the Rocky mountains and the Mississippi south of Nebraska. We had pointed out its probable existence in Texas in 1856;‡ and Dr. Shumard has, as we think, correctly placed on a parallel with it the "Austin Limestone" and "Fish-bed" of his section of the Texas cretaceous rocks.§ The Fort Pierre group is also known to be represented on the western borders of North America, or more properly on Vancouver island, as well as on Lucia islands in the gulf of Georgia.‖ Coming eastward we find it again represented in New Jersey, and extending thence through into Alabama and other southern States. As long back as 1834, Dr. Morton had suggested in his Synopsis of Organic Remains, p. 25, that the beds at the Great Bend of the Missouri are probably on a parallel with the green sand of New Jersey. The identity of a few of the Nebraska cretaceous fossils with New Jersey species, was also pointed out by Prof. Hall and one of the writers (F. B. M.) in a paper published in the Memoirs of the American Academy of Arts and Sciences, vol. 5, N. S., p. 406, 1854; though too little was then known in regard to the range of fossils in the Nebraska beds to warrant any attempt at drawing parallels between subdivisions.

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* See Report Exploration of the Country between Lake Superior and the Red River Settlement, Toronto, 1859, page 18.

† For figures and descriptions of these fossils, see a paper by one of the writers in Professor Hind's Report of the Saskatchewan and Assiniboine Expedition, page 182. Toronto, 1859.

‡ See note appended to the extra copies distributed by us of a paper read before the academy in November, 1856.

§ Observations on the Cretaceous Strata of Texas, by B. F. Shumard, M. D., State Geologist. Trans. St. Louis Acad. Sci., vol. 1, page 583.

‖ See paper by F. B. Meek, describing cretaceous fossils from Vancouver island, in Trans. Albany Institute, read December, 1856. Also another paper by same in Proceed. Acad. *Nat. Sci.*, Phila. for October, 1861, on the Collections of N. W. Boundary Survey.

In November, 1856, after we had ascertained with some degree of accuracy the position and range of particular species in the Nebraska series, and had learned from the New Jersey reports and from Professor Cook the range of the same forms in New Jersey, we remarked that "the occurrence of several of the more common and characteristic fossils of the upper two Nebraska formations, (Fort Pierre group and Fox Hill beds,) such as *Ammonites placenta*, *Scaphites Conradi*, *Baculites ovatus*, *Nautilus Dekayi*," in the first and second green sand-beds, and the intervening ferruginous stratum in New Jersey, as well as in the "rotten limestone" of Alabama, clearly indicates the synchronism of these deposits, notwithstanding their widely separated geographical positions.* In May, 1857, we also submitted to the academy another paper in which we discussed more at length the relations of the Nebraska cretaceous rocks to those of New Jersey and other States, giving at the same time for comparison a section of the cretaceous strata of Alabama, furnished by Professor Winchell, another of those in northeastern Kansas by Mr. Hawn, and a third of the same in New Jersey compiled from the reports of Professor Ketchell and Professor Cook.†

As the last mentioned section of the New Jersey rocks will aid in the clear understanding of remarks and comparisons in other portions of this paper, we reproduce it below as originally published by us in the paper last above cited. The reader will understand that by formations No. 1, No. 4, and No. 5, of Nebraska, in the right hand column, we referred to the Dakota group, the Fort Pierre group, and the Fox Hills beds of this paper; the intermediate No. 2 and No. 3 (Fort Benton group and Niobrara division) being probably wanting in New Jersey.

New Jersey section compiled from the reports of that State.

a.	3d bed. G. sand.	Green sand ....60 ft. The sand between the second and third beds has usually been found with beach sand, which it closely resembles ....45 or 50 ft.	Tertiary.
b.	2d bed. G. sand.	Yellow limestone .... Green sand, *Scaphites Conradi*, *Baculites ovatus*, *Ammonites placenta*, 45 or 50 ft.	No. 5. Nebraska.
c.		Sand much colored with oxide of iron, and when sufficiently firm is found almost full of the impression of shells, *Belemnites mucronatus* † ....65 or 70 ft.	Represents No. 4. Nebraska.
d.	1st bed. G. sand.	Green sand, *Nautilus Dekayi*, *Baculites ovatus*, *Belemnites mucronatus*,‡ and bones of *Mosasaurus* ....50 ft.	
e.		Dark clays with "occasional streaks and irregular spots of green sand," *Ammonites placenta*, *Baculites ovatus*, &c ....130 ft.	
f.		Dark blue, ash colored, and whitish clays and micaceous sand, with thin seams of coal. Great quantities of sulphuret of iron. "Fossil wood is found in some of the layers in large quantities, and some very distinct impressions of net-veined leaves were examined in the clay at French's landing." ....130 ft. or more.	Represents No. 1, of Nebraska section.

* Proceed. Acad. Nat. Sci. Phila., November, 1856, p. 267.
† Proceed. Acad. Nat. Sci. Phila., May, 1857, p. 117.
‡ *Beleminitella mucronata.*

In an able and lucid article by Professor Hall, on the distribution of the cretaceous rocks of America, and their relations at distantly separated localities, published in the American Journal of Science, July, 1857, it will be seen he has arrived at nearly the same conclusions in regard to the Nebraska and New Jersey beds. He likewise draws the same parallels in an elaborate article in the first volume of the Report on the United States and Mexican Boundary Survey, published during the summer of 1858.*

The Fort Pierre group generally abounds in fossils in Nebraska, though they are not equally distributed through the whole formation, there being an upper and a lower fossiliferous zone, while a considerable thickness of the middle beds usually contain few organic remains. Its fossils are generally found in a fine state of preservation—the nacre of many of the shells being as brilliant as when the animals were living. In this latter respect they present a marked contrast with the dull appearance of those from the formations below.

In most cases they are found enveloped in very hard, dark argillo-calcareous concretions, from a few inches to several feet in diameter. Those occurring in the lower fossiliferous zone, at the base, are: *Mosasaurus Missouriensis*, *Callianassa Danæ*, *Ammonites complexus*, *Baculites ovatus* and *B. compressus*, *Hilicoceras Mortoni*, *H. cochleatum*, *H. tortum*, *H. umbilicatum*, *Fusus viniculum*, *F. Shumardi*, *Buccinum constrictum*, *Amauropsis paludinæformis*, *Anisomyon borealis*, *Inoceramus sublævis*, *I. incurous*, &c.

In the upper fossiliferous zone, organic remains are more abundant than in the lower. The following list contains the names of many of those usually found at this horizon, viz: Bones of *Mosasaurus Missouriensis*, with *Nautilus Dekayi*, *Ammonites placenta*, *Scaphites nodosus*, *S. Nicolletii*, *Baculites ovatus*, *B. compressus*, *Aptychus Cheyennensis*, *Fusus subturritus*, *F.* (?) *tenurlineatus*, *Gladius* (?) *Cheyennensis*, *Margarita*, *Nebrascensis*, *Dentalium gracile*, *Tectura occidentalis*, *Anisomyon patelliformis*, *A. alveolus*, *Bulla Nebrascensis*,† *Xylophaga elegantula*, *Corbulamella gregarea*, *Cardium rarum*, *Lucina occidentalis*, *Crassatella Evansi*, *Modiola Meekii*, *Inoceramus convexus*, *I. Mortoni*, *I. Nebrascensis*, *I. Sagensis*, *I. Vanuxemi*, &c. Several of these fossils pass up into the formation above.

Fox Hills beds.—This formation is generally more arenaceous than the Fort Pierre group, and also differs in presenting a more yellowish or ferruginous tinge. Towards the base it consists of sandy clays, but as we ascend to the higher beds we find the arenaceous matter increasing, so that at some places the whole passes into a sandstone. It is not separated by any strongly defined line of demarcation from the formation below, the change from the fine clays of the latter to the more sandy material above being usually very gradual. Nor are these two formations distinguished by any abrupt change in the organic remains, since several of the fossils occurring in the upper beds of the Fort Pierre group pass up into the Fox Hills beds, while at some localities we find a complete mingling in the same bed of the forms usually found at these two horizons. Indeed, we might with almost equal propriety, on paleontological principles, carry the line separating these two formations down so as to include the upper fossiliferous zone of the Fort

* This volume of the Mexican Boundary Report bears the date of 1857 on the title page, but it was not actually published until the summer of 1858. See American Journal of Science and Arts for July, 1859, p. 149.

† This species we had named *B. occidentalis*, in our papers of March, 1856. As that name had previously been used for a recent species of this genus by A. Adams, it becomes necessary to give our shell another name, and we now propose to call it *B. Nebrascensis*.

Pierre group, as we have defined it the formation above. All the facts, however, so far as our present information goes—taking into consideration the change in the sediments at or near where we have placed the line between these two rocks—seem to mark this as about the horizon where we find evidences of the greatest break in the continuity of physical conditions.

The formation under consideration is most distinctly marked at Fox Hills, between Shyenne and Moreau rivers, above Fort Pierre; and it also extends across upon the opposite side of the Missouri, in the region of Long lake. It likewise immediately underlies the tertiary bone beds of the *Mauvaises Terres* at Sage creek and other places in the vicinity of White river, but is not very fossiliferous, so far as known, in that region. At a single locality on the Yellowstone river, about 150 miles from its mouth, there is a low exposure having the lithological characters of the Fort Pierre group, but containing a complete mingling of the fossils usually found in the upper part of that rock, with those generally occurring in this. On the upper Missouri, in the region of Muscleshell and Milk rivers, the Fox Hills beds do not seem to be very well defined as a distinct rock. A few specimens, however, apparently from this horizon, were collected by Professor Hind's exploring expedition in the British Possessions, on the south branch of the Saskatchewan; and what is a little remarkable, they occur in a green sand matrix much like that in New Jersey, excepting that it is more indurated.

At the Black Hills, and along the Rocky mountains west of there, the Fox Hills beds are generally well developed. They also occur at Deer creek on the North Platte, and along the mountains southward, at least to the region of Pike's Peak. South of this they have not yet been certainly identified as a distinct rock. As already stated, we had pointed out, in November, 1856, and in May, 1857, that this rock is represented by the upper portion of the cretaceous beds in New Jersey, (the beds *b*, *c*, *d*, and *e* of the section on page 21 of this chapter, and by the rotten limestone of Alabama. The intimate relations between the Fox Hills beds and the Fort Pierre group, already mentioned, make it necessary, when we undertake to trace out the relations between our cretaceous rocks and those of the Old World, to view these two formations together as one series. Their synchronism with particular portions of the cretaceous system, at British and other foreign localities, will also be more clearly understood by keeping in view, as a half-way ground, their representative beds in New Jersey, which certainly contain a few foreign species. The evidence of the equivalence of our upper cretaceous series of Nebraska with the upper four divisions of the cretaceous in New Jersey, *b*, *c*, *d*, and *e* of the section on page 21 of this chapter, (which we must also take collectively, when we wish to compare them with particular horizons of the cretaceous abroad,) will be more clearly understood by consulting the following list of species common to the New Jersey and Nebraska upper cretaceous series:

New Jersey species.	Position in Nebraska upper series.
Mosasaurus Missouriensis	Ranges through the whole upper series.
Nautilus Dekayi	Upper zone Ft. P. g. and in F. H. beds.
Scaphites Conradi	Fox Hills beds.
Ammonites placenta	Upper zone Ft. P. g. and F. H. beds.
A. complexus	Lower zone Fort Pierre group.
A. lobatus	Fox Hills beds.
Baculites ovatus	Ranges all through Fort Pierre group.
*Amauropsis paludinæformis**	Lower zone Fort Pierre group.

* *This species has been identified in New Jersey by Dr. Isaac Lea.*

We have reason to believe several other species are common to the upper series in Nebraska and New Jersey, but we only include in this list those about which there can be no doubt. A list of the closely allied representative species at these distant localities would, if accompanied by figures, still more clearly illustrate the synchronism of the rocks under consideration.

RELATIONS OF THE UPPER CRETACEOUS SERIES OF NEBRASKA TO EUROPEAN DIVISIONS.

Before expressing any opinion in regard to the parallelism of our upper cretaceous series of Nebraska with particular portions of the cretaceous of the Old World, it is proper that we should give a brief statement of the views of others on this point, as well as in relation to the age of equivalent beds in New Jersey, and in the States further south. As is now well known, the cretaceous strata of New Jersey were first referred to that epoch by the lamented Professor Lardner Vanuxem, who did not, however, attempt to trace out close parallels between particular beds of the New Jersey strata and their exact equivalents in the Old World. Dr. Morton, to whom we are indebted for figures and descriptions of a large number of the New Jersey fossils, regarded these rocks and their equivalents in Nebraska and the southern States as mainly representatives of the upper green sand, or chalk marl of Europe. It should not be forgotten, however, that he considered what he had previously called the "middle division," that is, the upper calcareous stratum in New Jersey, contemporaneous with the European white chalk.*

Sir Charles Lyell expresses the opinion that the fossils of the New Jersey cretaceous beds "on the whole, agree most nearly with those of the upper European series from the Maestricht beds to the gault inclusive."†

Professor Henry D. Rogers, with his usual sagacity in such matters, remarks in his able report on the geology of New Jersey, that he does not regard the green sands of that State "in the strict sense of the word, as the equivalents of the green sand formation, so called, of Europe."‡

In his *Cours Elémentaire de Paléontologie*, Alcide D'Orbigny refers the fossiliferous cretaceous beds in New Jersey, and those in Nebraska, Arkansas, Texas, Alabama, &c., all to his *senonien*, the equivalent of the white or upper chalk and Maestricht beds.§

Professor F. J. Pictet, in his "*Traité de Paléontologie*," also refers most if not all of the New Jersey cretaceous species to the age of the white chalk of Europe. In an interesting paper read by Dr. Isaac Lea before the academy in December, 1858, he likewise seems to favor the conclusion that the cretaceous green sands of New Jersey represent the *senonien* of D'Orbigny, but suggests some reasons for that they may possibly belong a little lower in the series.‖

From a careful review of the whole subject, and an attentive study of extensive collections from the various formations of Nebraska, we are led to adopt D'Orbigny's views, so far as regards our upper cretaceous series of that region, and their equivalents in New Jersey and the States further south. That is to say, we regard these rocks as synchronous with the upper or white chalk, and Maestricht beds of Europe, (*senonien* of D'Orbigny.) We differ with him, however, in regard to the parallelism of

* Journal Academy of Natural Sciences, vol. 3, new series, page 217, 1841.
† Manual, page 224.
‡ Report on the geology of New Jersey, page 178, 1845.
§ Cours Elémentaire de Paléontologie, pages 671 and 672, vol. 2, 1852.
‖ *Proceedings of the* Academy of Natural Sciences, Philadelphia, December, 1858.

our lower series of Nebraska; or more properly, we differ with him in referring equivalent beds in Arkansas and further south to his *senonien*, for it is probable he had never seen any fossils from this lower series in Nebraska.

The evidence in favor of the conclusion we have adopted in regard to the synchronism of our upper series of cretaceous rocks in Nebraska with the white chalk and Maestricht beds of Europe, is both of a stratigraphical and paleontological nature. The stratigraphical evidence is that it holds, west of the Mississippi, a position above an older series, containing as we have shown, a group of organic remains corresponding in their affinities, and in several instances, as we think, agreeing specifically with lower chalk forms in the Old World. The paleontological evidence is, first, that many of its fossils belong to genera, which, according to Pictet, D'Orbigny, and others, are not known in Europe below the white chalk, nor even in some instances, below the oldest tertiary. Secondly, that several of the forms occurring in these beds in Nebraska are also found in equivalent beds in New Jersey and farther south, associated with well-known European upper chalk and Maestricht bed species; while they are all specifically distinct, so far as known, from those found in the lower series in Nebraska. The following is a list of the genera found in the upper series in Nebraska, and equivalent strata in New Jersey, Alabama, and some other States in the south; which, according to trustworthy authorities, are not known to range below the horizon of the white chalk, and a few of them not even below the oldest tertiary at foreign localities.*

Names of genera.	Position in Nebraska.	Localities in the States.	Position in Europe.
Mosasaurus	Fort Pierre group and Fox Hills beds.	New Jersey and Alabama.	White chalk and Maestricht beds.
Saurocephalus	....	New Jersey	White chalk.
Callianassa	Base Fort Pierre group	New Jersey	White chalk.
Pleurotoma	Fort Pierre group, upper part, and Fox Hills beds.	....	White chalk and Maestricht beds
Busycon	Fox Hills beds	....	....
Pseudo-buccinum	Fox Hills beds	....	....
Fasciolaria	Fox Hills beds	Tennessee	Maestricht beds.
Cypræa	....	Alabama	White chalk.
Xylophaga	Fox Hills beds	....	....
Pulvenites	....	Mississippi	White chalk.
Cassidulus	....	Ala. and Miss	White chalk.

Of this list of eleven genera, the following three, viz: *busycon*, *pseudobuccinum*, and *xylophaga*, have not yet, we believe, been found in the Old World so low as the cretaceous; while the genus *fasciolaria* is there said to extend no lower than the very latest member of the cretaceous, (the *danien* of D'Orbigny,) above the Maestricht beds.

The following seven of these genera, viz: *callianassa*, *busycon*, *pleurotoma*, *fasciolaria*, *cypræa*, *xylophaga*, and *cassidulus*, pass into the tertiary, and are represented in our present seas; while the genus *pseudo-buccinum* will probably be also found in the tertiary, since we know at least one species of it still living.† At the same time that we are already

*A few other genera might probably be added, but we have given what we consider the best authenticated examples.

† *P. ampullaceum, (Bullia ampulacea* of Middendorf,) from the Great Schantar island.

aware of the occurrence of eleven or more genera in our upper series of American cretaceous rocks not known to have been found below the horizon of the upper chalk in Europe, we can remember only three that have been identified in this upper series which are supposed not to range above the lower chalk of the Old World. These are *caprinello*, *goniomya*, and *macrăbacia*.* Of each of the latter two genera we certainly know one species in our Fox Hills beds; but the occurrence of the first in our upper series is very doubtful, since it has only been identified from a single imperfect specimen, that will probably be found to belong to some other group.

In addition to the general upward tendency, so to speak, of the genera in this upper series, both in Nebraska and farther eastward, we would also remark that a few of the forms found in our Fox Hills beds, particularly of the *gasteropoda*, present such close specific affinities to tertiary shells that we would have doubted the propriety of referring them to the cretaceous epoch were it not for the fact that we find them associated in the same bed with *baculites*, *ammonites*, *scaphites*, and other cretaceous genera and species.

Although we have not been fully able to satisfy ourselves that any of the species yet known from the upper cretaceous series of Nebraska are certainly identical with upper chalk forms in the Old World, many of them are undoubtedly closely allied representatives, and we think the following will probably prove to be common to this horizon in Nebraska and Europe, viz: *Nautilus Dekayi*, *Scaphites Conradi*, *Baculites anceps*, and *Gryphæa versicularis*. At any rate *Nautilus Dekayi* is closely related to some foreign forms, and is supposed by D'Orbigny to occur in the upper chalk of Europe. *Scaphites Conradi* also seems scarcely distinguishable from an upper chalk found in Germany, described by Roemer under the name of *S. pulcherimus*, and we find in our Fox Hills beds a *baculite* we cannot distinguish from a Texas shell referred by Dr. F. Roemer to *B. anceps* of Lamarck. We would remark, however, that if D'Orbigny's figures of Lamarck's species represent the sutures accurately, the American form will probably prove to be only an allied representative species. In addition to the above we likewise find a *gryphæa* in our Fort Pierre group, which presents close relations to *G. vesicularis*, if it is not indeed that species.

When we come to the equivalent rocks further eastward, however, in New Jersey, and at localities in Alabama and other southern States, we are no longer compelled, as previously stated, to rely upon doubtfully identical or closely allied representative species, for we there find a number of our Nebraska forms associated with some seven or eight well-known European upper chalk species. So far as we have been able to ascertain, the following list embraces the species known to be common to the New Jersey and Alabama rocks alluded to, and the upper chalk and Maestricht beds of the Old World:

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* We are aware the genus *belemnites* is not known to extend up into the upper chalk in Europe, and that Dr. Morton described a *B. ambiguus* from New Jersey. Dr. Leidy, however, has decided that it is a spine of a fish.

Names.	American localities.	Foreign localities and position.
Saurocephalus lanciformis..	New Jersey	England, white chalk.
Lamna acuminata	New Jersey......	England, white chalk.
Belemnitella mucronata	N. Jersey, Ala., &c...	England, France, &c., white chalk and Maestricht beds.
Neithea Mortoni...........	N. Jersey, Ala., &c...	France, white chalk.
Ostrea larva...............	N. J., Tenn., Ala., &c.	England, France, &c., white chalk and Maestricht beds.
Gryphœa vesicularis*......	N. J., Tenn., Ala., &c.	England, France, &c., white chalk and Maestricht beds.
Nucleolites crucifer	New Jersey	France, white chalk.

It is true we have in this upper series in Nebraska, and further east, a few forms allied to lower chalk and upper green sand species, and we have regarded two of these, at least, as probably identical with foreign species of that age. That is, we had supposed our *Cucullœa Shumardi* probably identical with the green sand species, *C. fibrosa* of Sowerby, and a small *micrabacia* from our Fox Hills beds probably identical with *M. coronula*, Goldfuss, sp., from the same horizon. Later comparisons, however, have led us to regard the latter as a distinct species, and although we have not yet been able to find characters by which our *Cucullœa Shumardi* can be distinguished from the figures and descriptions of Sowerby's species we have seen, it is quite probable that a careful comparison of a series of good specimens would bring to light constant differences of specific importance. Should these, however, and several others we have from time to time compared with green sand and lower chalk species, really prove to be undistinguishable from them, still the weight of evidence would, on the whole, be strongly in favor of the conclusion that these rocks are certainly of the age of the upper chalk and Maestricht beds.

From all the foregoing facts it may be seen, first, that the only strongly marked paleontological break in the Nebraska cretaceous section, so far as we now know, is that dividing the Nebraska division from the Fort Pierre group.

Secondly, that all the Nebraska cretaceous beds below this line included in our section, as well as the bed *f* of the New Jersey section, on page 21 of this chapter, represent the lower, or gray chalk, are probably the upper green sand of the Old World.†

Thirdly, that all the Nebraska beds between this strongly marked line, near the middle of the section, and the tertiary, as well as the beds *b*, *c*, *d*, and *e* of the New Jersey section, belong to the horizon of the upper or white chalk, and Maestricht beds of Europe.

TERTIARY ROCKS.

It would extend these remarks beyond the limits assigned them to attempt any detailed account of the tertiary rocks of Nebraska, or to discuss at length the questions respecting their relations to those of the Atlantic coast, or of the Old World. We must, therefore, limit our-

* This species is supposed by some to occur also in the upper green sand and the lower or gray chalk, but the form occurring in these lower positions is regarded by other authorities as a distinct species.

† By this remark we do not mean to express the opinion that cretaceous strata older than the upper green sand of Europe *may* not exist, and yet be discovered in Nebraska and New Jersey.

selves here to a few brief statements of leading facts, and leave all details for another occasion. In the first place we would remark that no strictly marine tertiary deposits have yet been discovered in all the Rocky Mountain region of Nebraska, nor, so far as we know, in any other portion of Nebraska, Kansas, or Utah. Throughout all this great central area of the continent, wherever the oldest tertiary deposits have been seen they give evidence of fresh and brackish-water origin; and where observed resting upon the most recent cretaceous beds, the two have been found conformable and sometimes blended together, so as to render it difficult to draw a line between them in the absence of organic remains. All the facts indicate a gradual change from the marine conditions of the cretaceous,—at first to brackish, and then to the fresh-water conditions of the tertiary. The predominance of *gasteropoda* and *lamellibranchiata*, and the comparative paucity of types usually considered characteristic of deeper water deposits, as well as the coarser nature of the sediments near the end of the cretaceous epoch in this region, indicate that the waters were growing more shallow as the land on the east encroached on the sea, and islands were rising where the Rocky mountains now stand, while the close of the cretaceous period seems to have been attended by the gradual elevation of large areas of country here above the ocean level. This, and other contemporaneous changes of physical conditions, caused the total destruction of the whole cretaceous fauna. After this, extensive tracts of country in the region of the Rocky mountains, and east of there in Nebraska and other northwestern Territories, were occupied by bays, inlets, estuaries, &c., of brackish water, inhabited by mollusca of the genera *ostrea*, *onio*, *pisidium*, *corbicula*, *potamomya*, *melania*, *melampus*, *vivipara*, &c., all of tertiary types. As the gradual elevation of the country continued, the salt and brackish waters receded and gave place to lakes and other bodies of fresh water, in which most of the tertiary rocks of the northwest were deposited; so that in all, excepting the earliest tertiary beds of this region, we find only the remains of strictly fresh-water and terrestrial animals.

The passage from the brackish to the fresh-water beds in the oldest member of the tertiary of this region seems not to be marked by any material alteration in the nature of the sediments. Nor have we, so far as is yet known, any reasons for believing that any climatic or other important physical changes beyond the slow rising of the land and the consequent recession of the salt and brackish water, took place during the deposition of the whole of the oldest member of the tertiary here, since we find a considerable proportion of the species of fresh-water mollusca ranging through this whole lower member. The principal difference between the fossils of its upper and lower beds consist in the gradual disappearance of strictly brackish-water types as we ascend from the inferior strata. The entire series of Nebraska tertiary rocks consists of three or four groups, three of which, at least, (and probably four,) evidently belong to separate and distinct epochs. They usually occur in isolated basins, but have, with one exception, all been seen in such connection as to leave no doubts in regard to their order of superposition. Their prevailing lithological characters, estimated maximum of thickness, and order of succession will be seen in the section given following:

General section of the tertiary rocks of Nebraska.

Names.	Subdivisions.	Thickness.	Localities.	Foreign equivalents.
Loup river beds.	Fine loose sand, with some layers of limestone; contains bones of *canis, felis, castor, equus, mastodon, testudo*, &c., some of which are scarcely distinguishable from living species. Also *helix, Physa succinea*, probably of recent species. All fresh water and land types.	*Feet.* 300 to 400	On Loup fork of Platte river, extending north to Niobrara river and south to an unknown distance beyond the Platte.	Pliocene.
White river group.	White and light drab clays, with some beds of sandstone and local layers of limestone. Fossils: *Oreodon, titanotherium, chæropotamus, rhinoceros, anchitherium, hyænonodon, machairodus, trionyx, testudo, helix, planorbis, limnæa*, petrified wood, &c. All extinct. No brackish-water or marine remains.	1,000 or more.	Bad Lands of White river, under the Loup River beds, on Niobrara, and across the country to the Platte.	Miocene.
Wind river deposits	Light gray and ash-colored sandstones, with more or less argillaceous layers. Fossils: fragments of *trionyx, testudo*, with large *helix, vivapara*, petrified wood, &c. No marine or brackish-water types.	1,500 to 2,000	Wind River valley; also west of Wind River mountains.	?
Fort Union or great lignite group.	Beds of clay and sand, with round ferruginous concretions, and numerous beds, seams, and local deposits of lignite, great numbers of dycotyledonous leaves, stems, &c., of the genera *platanus, acer, ulmus, populus*, &c., with very large leaves of true fan palms. Also *helix, melania, vivipara, corbicula, unio, ostrea, potamomya*, and scales of *lepidotus*, with bones of *trionyx, emys, compsemys, crocodilus*, &c.	2,000 or more.	Occupies the whole country around Fort Union, extending north into the British possessions to unknown distances; also southward to Fort Clark. Seen under the White River group on North Platte river above Ft. Laramie. Also on west side of Wind River mountains.	Eocene (?).

The Fort Union or Great Lignite group occupies extensive areas of country in Nebraska, and has been seen beneath the White River group at several distant localities. It was evidently deposited in large bodies of water, which were at first brackish, and then gradually became fresh. The great numbers of fossil leaves and numerous beds of lignite contained in it clearly show that the shores of these ancient estuaries, lakes, &c., in which this formation was deposited, supported dense forests of large trees and a growth of other vegetation far exceeding in luxuriance any thing now met with in these latitudes. Indeed, the presence of true fan palms of large size, and the remains of the genus *crocodilus*, as well as the affinities of the mollusca found in these beds, to southern forms, all point rather to the existence here of a tropical than a temperate climate during their deposition.

In regard to the relations of this formation to known horizons in the tertiary of the Old World, we feel scarcely prepared to express a very decided opinion. The difficulty in the way of drawing inferences bearing on this point from the remains of mollusca found in these beds is, that they, being fresh and brackish water types, bear little or no analogy to those of the tertiaries of the States bordering on the Atlantic; nor are any of them, so far as known, specifically identical with foreign forms. When we bear in mind, however, the fact that wherever this formation has been seen in contact with the latest cretaceous beds, the two have been found to be conformable, however great the upheavals and distortions may be, while at the junction there seems to be a complete mingling of sediments, one is strongly impressed with the probability that no important member of either system is wanting between them. This view is also rendered more probable by the fact that the formation under consideration is known to hold a position beneath the White River group, which is characterized by the remains of an entirely different fauna, clearly of miocene age. Again, the recurrence in this lower group of remains of the genus *lepidotus*, which is, we believe, in Europe unknown above the eocene, while the other vertebrate remains found associated with it have been compared by the distinguished comparative anatomist, Professor Leidy, with types even older than the tertiary, are facts strengthening the impression that this Fort Union lignite group probably represents the eocene of Europe.

It should not be forgotten, however, that an extensive and beautiful series of fossil plants from this formation, although not yet thoroughly investigated, have been thought by Dr. Newberry to be most analogous to miocene types. Yet, even if this formation should prove to be of eocene age, this would only be in accordance with what is now known in regard to the earlier introduction of particular types of plants in the cretaceous system of this country than in that of the Old World.

As the Wind River deposits have not yet been seen in contact with any well-marked beds of the other tertiary formations of this region, and few fossils have yet been found in them, their position in the series remains doubtful. It is therefore only provisionally that we have placed this formation between the Fort Union and White River groups in the foregoing section. It may possibly belong to the horizon of one of these rocks, or even represent them both in part, or, what is more probable, it may occupy an intermediate chronological position. The only fossils yet found in this formation are fragments of *tryonix* and *testudo*, together with the shells of two species of *helix* and a cast of a *vivipara*. One of these *helices* is more like *H. Leidyi* from the White River group than any of the other species yet known from any of these rocks, while the other is a very large depressed species of southern type, quite unlike any of those hitherto found in any of the other Nebraska rocks. The *vivipara* seems to be undistinguishable from our *V. trochiformis* from the Fort Benton group; though, as it is a mere cast, it cannot be identified with positive certainty with that shell. No marine or brackish-water fossils have been found in these beds.

The White River group is the formation that has furnished the extensive and interesting collections of vertebrate remains which have been so ably investigated by Professor Leidy. It occupies a considerable area in the region of White river, and is seen beneath the succeeding formation on the Niobrara and Platte rivers. Its position above the Fort Union or Great Lignite group has also been clearly and satisfactorily determined. This formation is mainly composed of a series of *whitish indurated* clays, which have been worn and cut by the streams, rains, and other atmospheric agencies, into numerous deep valleys and ravines, so as to leave various peaks, isolated columns, towers, &c., presenting, as seen from a distance, exactly the appearance of the ruins of an ancient city. The difficulty the traveller meets with in finding his way through this interminable labyrinth had caused the Indians to call it, in their own language, the Bad Grounds; hence, the French name, Mauvaises Terres, applied by the Canadian voyageurs in the employ of the fur companies. The vertebrate remains found in these beds belong to the genera *oreodon*, *agriochærus*, *pœbrotherium*, *leptomeryx*, *leptanchereia*, *protomeryx*, *merycodus*, *titanotherium*, *leptochærus*, *hyracodon*, *entelodon*, *palæochæous*, *rhinoceros*, *steneofiber*, *machairodus*, *anchitherium*, *hyopotamus*, *hyænodon*, *ischyromys*, *palæolagus*, and *eumys*, *testudo*, &c. The affinities of these fossils, as has been shown by Professor Leidy, clearly establish the miocene age of this formation. Comparatively few invertebrate remains have yet been found in the White River group. They consist of one species of *helix*, one or two of *limnæa*, a small *physa*, two or three small species of *planorbis*, &c. No fossil leaves, nor beds of lignite, have been met with in it; and all the animal remains, as may be seen from the foregoing list, are terrestrial and fresh-water types.

The Loup River beds consist mainly of incoherent materials, and were evidently deposited after the upper surface of the White River group had been worn into ravines and other depressions. It occupies much of the surface of the country in the region of the Loup fork of Platte river, and extending far south of the latter stream. The vertebrate remains described by Professor Leidy from it belong to the genera *megalomeryx*, *procamelus*, *cervus*, *rhinoceros*, *mastodon*, *elephas*, *hipparion*, *merychippus*, *equus*, *castor*, *felis*, *canis*, *testudo*, &c., many of which are very closely allied to recent species. A few shells of the genera *helix*, *physa*, &c., apparently identical with living species, have also been found in these beds. All the species of vertebrate and other remains yet found in them are distinct from those occurring in the White River group and beds below, and they have not yet afforded any brackish or marine types of any kind. When we take into consideration the position of this formation above the well-marked miocene White River group and the relations of its organic remains to pliocene and recent species, there is little room for doubting the correctness of its reference to the horizon of the pliocene of Europe.

CHAPTER III.

NARRATIVE—INTRODUCTION—CARBONIFEROUS ROCKS OF LOWER MISSOURI—PLATTE VALLEY AND ELKHORN—RELATIONS OF DAKOTA GROUP WITH CARBONIFEROUS ROCKS—DAKOTA GROUP, OR CRETACEOUS FORMATION NO. 1—ITS EXTENT—VEGETABLE REMAINS—SECTIONS OF BLUFFS—FORT BENTON GROUP, OR NO. 2—NIOBRARA DIVISION, OR NO. 3—ITS CHALKY CHARACTER—GEOLOGY NEAR YANKTON—DURION'S HILLS—FOSSILS OF NO. 3—DESCRIPTION OF SUPERFICIAL DEPOSITS—TERRACES—ALLUVIAL BOTTOMS—SUPERFICIAL DEPOSITS NEAR SIOUX CITY.

The following chapters form the narrative portion of this report. I hope that the details will not prove tedious; but in order that my geological map may be better understood, I thought it best to give the geology of our route from point to point substantially as I note it in my journal in the field. It was impossible, therefore, to avoid some repetition, and the same fault will occur in the latter portion of this report when treating of the general geology of that region.

It will also be seen how wonderfully simple is the geological structure of all this western country when once a key is secured to the different formations. It will also be observed that there is a great similarity in different portions—that when one district has been carefully studied it forms a key to the whole.

The narrative portion begins with a short notice of the carboniferous rocks on the lower Missouri.

CARBONIFEROUS ROCKS.

These rocks are well exposed along the Missouri river from the southern line of Kansas to the mouth of the Platte. Here more recent formations begin to overlap them, and they gradually disappear beneath the water-level of the river in the vicinity of De Soto, about 30 miles above Omaha City. Following up the valley of the Platte we find these coal-measure limestones dipping gently toward the northwest, so as to pass beneath the water-level of that river, near the mouth of the Elkhorn. Prior to reaching the latter locality, the ferruginous sandstones of cretaceous formation, No. 1, overlap the limestones, and at Elkhorn they occupy the whole country. We can thus see that a comparatively small area of the already-settled portion of Nebraska is underlaid by rocks of this age; and the next inquiry that naturally arises is, of what economical value are they to the country? In a former report I attempted to show that they belonged to the age of the upper carboniferous, and consequently above the true coal-beds, and that, though the seams of this useful mineral may be found in various localities, I suspect no workable beds will ever be discovered. In order that a bed of coal may be regarded as workable, there should be at least two or three feet of pure coal. The limestones form an excellent material for building purposes and for converting into lime, and several quarries have already been opened for that purpose and for converting into lime, with complete success.

By reference to the geological map it will be seen that but a small area in the southeastern portion of Nebraska is occupied by this formation; that at De Soto, on the Missouri, it gives place to the cretaceous sandstones, passing beneath the water-level; that it also disappears in the *Platte valley near* the mouth of the Elkhorn river. From thence to the mountains, the carboniferous rocks are not again seen until revealed along the margins of the mountain ranges.

Cretaceous beds, No. 1.—At De Soto, on the Missouri, and at the mouth of the Elkhorn, the Dakota group begins to attain considerable thickness and to underlie the country. Even near to Omaha City some remnants of it can be seen overlapping the carboniferous rocks. The rocks of this division of the cretaceous period are mostly of a concretionary character, and are quite variable in lithological structure at different localities. Near Blackbird Hill there is an irregular bed of bluish siliceous rock, very hard and compact, surrounded above and below by a loosely-aggregated micaceous, slightly calcareous sandstone, the whole containing an abundance of quite well preserved vegetable remains. Above this point the rocks soon change into an entirely loose friable sandstone, with layers of indurated clay and grits, and one bed of very impure lignite. Oblique laminæ, ripple-markings, and all the indications of shallow water and shore deposits, are abundant everywhere.

Near Iowa creek we pass some bluffs cut by the river, about 80 feet in height, which seem to be composed of a blending of cretaceous formations Nos. 1 and 2.

Section descending:

3. Laminated marl, (No. 3, cretaceous,) 60 feet.
2. Laminated black, plastic clay, but containing much iron and calcareous concretions, (No. 2,) 30 feet.
1. Ferruginous clay, alternating with layers of black, plastic clay, passing down into ferruginous sandstone, 10 feet.

The hills are covered with a fair growth of timber, though the trees on the uplands diminish in height as we ascend the river.

The next cut bluffs are on the Nebraska side of the Missouri, and are about 150 feet high. Here the lower portion of No. 3 is very compact, and of a bluish black or dark ash color, seeming to indicate a transition from No. 2 to No. 3. No. 3 is exposed here, with a thickness of about 100 feet, overlaid by 50 to 80 feet of yellow marl. No. 2 is seen not more than six feet above the water-level. Although in some localities a hard stratum of marly limestone seems to form a line of demarkation between Nos. 2 and 3, yet in other places the ore passes by imperceptible gradations into the other, and we also know that there is an intermingling of organic remains. At this point the lower part of No. 3 has been quarried to considerable extent and converted into lime.

Again, near the mouth of the Vermilion river are cut, by the Missouri, revealing Nos. 2 and 3, as before mentioned—

Section descending:

3. Yellow marl, a recent deposit, 40 feet.
2. Gray and rust-colored, chalky marl, (No. 3,) 30 feet.
1. Black, plastic clay, (No. 2,) 50 feet.

The bluffs opposite the mouth of James river are composed almost entirely of No. 3. No. 2 has passed beneath the water level and will not be seen again until we reach the vicinity of some of the mountain elevations.

Just above the Yankton village, a few hundred yards, the river again cuts the hills, forming a series of bluffs, which show the complete lithological character of No. 3, overlaid by a large deposit of yellow marl.

The bank upon which the village is located is about 30 feet above the river, and is composed entirely of a yellow calcareous and argillaceous material of recent date. This recent deposit is quite well developed along the Missouri in this district, and seems to fill up the irregularities of the surface of the cretaceous rocks. The next series of bluffs are opposite Durion's Hills. The base of No. 3 is quite compact bluish gray inside, but the top portion is a soft yellow chalk-like marl. Below Durion's Hills continuously for two or three miles we have the following section.

2. Yellow marl, a recent deposit.
1. Yellow marl of No. 3 passing down into gray marl more compact, but crumbling on exposure to the atmosphere.

About a fourth of a mile above Smutty Bear's village we see a fine exposure of No. 3 presenting a mural front of 150 feet in height and revealing in the greatest abundance a small species of oyster, (*Ostrea congesta, Conrad,*) and remains of fishes. At the mouth of the Niobrara we observe a fine exposure of No. 3 in a long series of conical bluff hills, capped with the dark laminated clays of No. 4. These bluffs are eroded by water so that they present the appearance of a series of cones split from apex to base. The recent deposits are very largely developed in the region which we now have under consideration. I do not intend in the narrative part of my report to do more than to state the facts which I have collected along the routes, leaving the generalizations and conclusions for subsequent chapters. The most important and most largely developed recent formation in this region is the yellow marl deposit, which covers to a great extent the State of Missouri and the eastern portions of Kansas and Nebraska. In an economical point of view also it is of the highest interest, as it underlies and forms a portion of the richest soils of the west. There are also the loose gravel deposits, the bottoms of the streams, and a quite important erratic block deposits, which has left its trace to a greater or less extent over the whole prairie country east of the Rocky mountains. Along the Missouri river, as well as the tributaries, are alluvial bottoms of greater or less width, the soil of which is of the greatest fertility, composed of a mingling of all the different formations in the west and containing a vast amount of vegetable matter. These bottoms sustain an annual growth of the most luxuriant vegetation, and upon them is found by far the greater part of the timber of the west. They vary in width from one to twenty miles. From Omaha City to the mouth of James river along the Missouri, the bottoms are of remarkable width, reminding one of the former existence of a great lake, while the hills that border these bottoms on either side are composed, to a great extent, of yellow marl. Another interesting feature, which we hope to allude to again, is the river terraces, which are more or less conspicuous everywhere in the valleys of all the streams flowing from the eastern slope.

At Glasgow, Missouri, the yellow marl deposit exhibits itself more conspicuously than at any other point observed by me thus far up the river. It here forms quite steep hills, with a somewhat irregular outline, 200 to 250 feet in height, with a color rather darker than usual, probably due to the presence of more vegetable matter. The bottoms seem to widen and are covered with a dense growth of cottonwood trees. On the high hills beyond are various kinds of timber in abundance, and the soil is of remarkable fertility, being well adapted to the growth of hemp and tobacco. The bottoms of the Missouri, composed of loose material, are constantly exposed to the erosive action of the current, and are liable at any time to be carried down the river and reformed at some other locality.

The immediate bottoms of the river, though constantly changing, present some interesting vertical sections, showing the alternate strata of clay and sand, and often reminding one of the tertiary deposits high up on the Missouri. Just above Atchison, Kansas, I took the following sections of what may be called the first terrace.

3. Fine gray arenaceous grit.
2. Alternate seams of indurated brown clay with gray sand, 4 to 6 feet.
1. Fine gray arenaceous marl, 4 to 6 feet.

The above sections would not represent the strata in different localities, for there is no uniformity in their character, but it will show the general character of the first terrace. Upon this bottom are trees of the largest size, platanus, cottonwood, ash, oak, &c.

From thence to Omaha City the bottoms are quite wide, the yellow marl hills visible in the distance on either side. Near Bellevue we find the following section of the valley:

4. Carboniferous limestones, shown where the river cuts the hills.
3. Hills of yellow marl, 150 feet thick.
2. Bottom prairie, very fertile soil.
1. Alluvial sand, forming the borders of the river and the islands.

The prairie bottom on the opposite side of the river extends about four miles to the hills, with a rise of not more than 20 or 30 feet, and through the summer and autumn is clothed with a luxuriant growth of weeds and coarse grass.

The alluvial bottoms or first terrace from Omaha City to Florence, on the right side of the Missouri, is very broad, covered with willows and a few cottonwoods. This terrace overflows often, and is undoubtedly the result of forces now in operation. There is now visible the deposit of last year, forming a stratum three inches in thickness. The second terraces are composed of loose fine sand at the base, as if deposited under the same circumstances as our islands and sandbars, with layers of clay, marl, and vegetable mold in distinct strata to the surface.

Near Florence the marl hills are well developed, and the bottom prairie is cross-sectioned by the Missouri, showing a thickness of 15 feet of vegetable mold. We can here also see the relative age of the two deposits. A large portion of the upper part of the section shown by the river at this point seems to be an unstratified homogeneous yellow marl, while lower down it becomes distinctly stratified and alternating with indurated clay. Opposite Florence, presenting their usual steep sides and denuded in many places, the marl hills approach within a quarter of a mile of the river, and continue for several miles, when they make a flexure toward the interior, and then commence the wide bottoms, which are continuous with one or two exceptions; thence to James river, a distance of nearly 150 miles.

The alluvial bottoms or first terraces occupy about one-fifth of the lowland, and it is upon this that the current manifests for the most part its vibrating power from side to side. It is upon this terrace that the greater part of the timber is found, which occupies about one-fourth of its area. The second terrace forms the true bottom prairie, which never overflows, except in seasons of the highest waters, probably not oftener than once in 20 or 30 years, though the vast quantities of recent shells, driftwood, and other vegetable matter distributed over this bottom, show that such an occurrence does sometimes take place.

The third terrace is considerably elevated above the river and is never overflowed, and is the one upon which most of the little towns are located.

These terraces vary much in width, and in their outline resemble the high hills. The hills, which border the whole valley, vary from 500 to 700 feet in height above the water level of the Missouri.

Superficial deposits near Sioux City.

Near Sioux City the river cuts the bluffs, exposing a very great thickness of yellow marl, and affording fine sections for examination, also near James river, where its connection with the cretaceous rocks is well shown.

So much are the topographical features of the surface determined by the character of the underlying geological formations, that it becomes a matter worthy of note. The prairie country may be well described as undulating or rolling, that is, in the form of a succession of hills; but over that portion which is underlaid by the carboniferous rocks the hills have quite steep slopes, and they gradually become less so as we approach the loose, friable sandstone rocks of cretaceous No. 1. After passing Omaha City, we may wander over the prairie upland westward for many miles over a quite undulating plain, clothed with a thick growth of grass, but an exposure of rock is seldom or never seen. All along the Elkhorn, from mouth to source, no rocks of value for economical purposes were observed, but the whole surface presents a gentle wave-like undulating appearance with scarcely a shrub to be seen. Through such a country the valleys of the streams are very broad, and the immediate channels are often quite deep and so miry as to render crossing very difficult and in many places next to impossible.

These gentle slopes prevail throughout the country, underlaid by formations Nos. 1 and 2, but in No. 3, while less abrupt than in the carboniferous districts, they seem to yield less readily to atmospheric and aqueous agencies.

CHAPTER IV.

From Niobrara to Fort Pierre — The cretaceous formations along the Missouri—The pliocene beds of the Niobrara—Recent deposits near Bonhomme island—Character of the country near Fort Randall—Terraces at Great Bend of the Missouri—The "Chain of Rocks"—Boulders and superficial deposits.

FROM NIOBRARA RIVER TO FORT PIERRE.

From the mouth of the Niobrara to Fort Pierre we have, in their order, formations Nos. 3 and 4, quite well exposed. Formation No. 3 continues to the foot of the Great Bend of the Missouri, where, by a gentle dip, it passes from sight beneath the water-level. No. 4 first makes its appearance as a continuous formation near the mouth of the Niobrara, though it is seen in isolated patches as low down the river as the Big Sioux. From the mouth of the Niobrara No. 3 is shown only in the valleys of streams, and does not give the surface features to the country.

I will now proceed to give such local details of this formation as I was able to secure in our rapid transit from point to point.

About 30 miles above the mouth of the Niobrara, on the left bank of the Missouri, are a series of bluffs, extending about eight or ten miles, presenting the same conical appearance before mentioned. No. 3 is here quite compact, with its usual lithological characters—a bluish gray marl internally, and when weathered changing to a yellow ferruginous chalk-like marl, capped with the black clays of No. 4.

The surface outline of No. 3 would be very rugged were it not for a superficial deposit of water-worn pebbles and yellow marl, which fills up all the irregularities. Between Nos. 3 and 4 is a local bed of black, plastic clay which has hitherto held a somewhat doubtful position, and has usually been joined to No. 3. I am now satisfied that the line of separation should be drawn below the plastic clay, on physical as well as paleontological grounds. We have long known that no fossils passed from one formation to the other, not a single species having yet been found common to the two beds. There are many localities showing the irregular outline of No. 3, which proves clearly that the sequence of the formation was broken, and that the surface of No. 3 was exposed to the erosive action of water. The black, plastic clay seems also to be somewhat carbonaceous, for it has ignited in many places, baking the laminated clays of No. 4, and changing them to a brick-red color. The largest development of the plastic clay is shown just below the mouth of White river, where it is 15 feet thick. For many miles along the Missouri in this region, No. 3 is sometimes 50 or 60 feet thick, then again not more than 20 feet exposed above the water's edge.

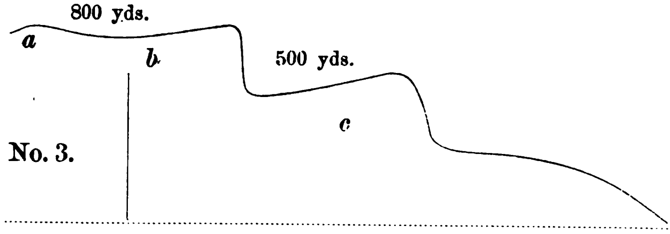
On both sides of the Missouri river are numerous remnants of the pliocene beds of the Niobrara, showing the vast extent of surface over which this lake must have extended. The most conspicuous monuments which now remain are the Bijou Hills and Medicine Buttes, which are, without doubt, of the same age with the Loup River beds or pliocene territory. All over the prairie country on the east side of the Missouri are there isolated patches of pliocene beds of greater or less thickness, showing the enormous extent of the denudation.

In the vicinity of the Niobrara the surface of the country bears a cheerful appearance, indicative of tolerable fertility at least. The soil is quite good and the vegetation is usually of medium growth. From thence it becomes less and less luxuriant as we ascend the river, and before reaching the Great Bend the bare, blackened hills underlaid by No. 4 give a dark and desolate appearance to the country. Most of the vegetation is peculiar to the arid soil, but the saline character of No. 4 renders it quite favorable to the growth of chenopadiaceous plants, which are very abundant.

The recent deposits are scarcely less interesting than in our last chapter, though the yellow marl has gradually ceased to be a prominent formation, and the erratic block-deposit assumes a marked character, and forms a quite conspicuous feature.

Near Bonhomme island is a remarkable bluff, 50 feet high, entirely composed of material eroded from No. 4, which I have classed with the yellow-marl deposits, as of the same age. It presents distinct lines of stratification, and is undoubtedly about the age of the high bench or third terrace, which I have already described.

Near Fort Randall, on the left bank of the Missouri, we find the following outline of the surface. *a* = Nos. 3 and 4; *b* = 2d terrace; *c* = 3d terrace. The first terrace varies in width from a few feet to



several miles. The second terrace is a dark, stratified, indurated clay, and of older date than the first. In this are many seams of worn pebble-stones, and it is composed, to a large extent, of the eroded materials of No. 4. One point in this series is 60 feet in height, with here and there irregular seams of pebbles and broken rocks from the formations in the vicinity. The outline of the surface of these second-terrace hills is like that of the high hills bordering the valley, on a smaller scale. This terrace is sometimes 150 feet above the river.

The hills around Fort Randall present a very irregular outline, and in many cases with very abrupt slopes and covered with a surface deposit of rocks or boulders. These rocks are more or less water-worn, and represent all the formations in the vicinity of the mountains, including every variety of granite, metamorphic azoic rocks, carboniferous and other limestones. They seem to be far more abundant on the east side of the Missouri, and it is quite probable that the same influences which scattered these erratic rocks so profusely over the surface of the country aided to form its surface irregularities also. Again, in the Great Bend we have quite conspicuous examples of the pebble deposit. At the foot of the Great Bend is a long series of bluffs which present the following section:

3. Fine, light gray sand, passing down into indurated, stratified clay, 4 to 6 feet.
2. Compact, ferruginous conglomerate, composed of pebbles of various sizes, cemented with a ferruginous sand, 6 to 8 feet.

1. Formation No. 3, 30 feet above water's edge. The conglomerate is sometimes as much as 15 feet in thickness, and the well water-worn pebbles are seldom more than two inches in diameter, mostly quite small.

At the point of land which extends into the Great Bend on right bank a broad terrace four miles in width is formed, and varies from 30 to 60 feet in height above the river. The bluffs show an extremely fine development of the drift. Occasionally formation No. 4 is seen just above the water's edge. The drift, which is composed of small, water-worn pebbles, cemented in some cases with ferruginous sand, is 20 to 30 feet thick with from 5 to 20 feet of fine, light yellow, ferruginous sand on the surface. On the opposite side is a terrace also, gently ascending to the foot of the main ridge, and is composed of indurated clay, and is perhaps more recent than the drift, or at least overlies it.

In the Great Bend a small stream empties into the Missouri, called the Chain of Rocks, from the fact that at its mouth, extending nearly across the Missouri, the bed of the latter river is paved with large, water-worn, erratic boulders of the same character as those so thickly scattered over the surface of this region. On the west side of the Missouri river are quite numerous boulders, but it is only on the east side that they assume importance as a surface deposit. So abundant are these stray rocks in this region that they will supply what would otherwise be a very great deficiency for economical purposes. The cretaceous formations afford no rocks suitable for building purposes, while the limestones distributed among the boulders will yield a good supply of lime. Some of the granite rocks are quite angular, as if but little worn, and they are generally sunk not more than from two to six inches below the surface.

CHAPTER V.

Fort Pierre to the Black Hills—Geology around Fort Pierre—Terraces—Sombre look of the country—Plumb creek—Valley of the Shyenne river—Cretaceous beds on Cherry creek—Lignite tertiary beds—Bear peak—Cañons in the Black Hills—Gypsum beds—Jurassic rocks—Siliceous limestones—"Cotes Bruleés" or Burnt Hills of the Canadian voyageurs—Source of Little Missouri—Walls on Fortification creek—General character of the Black Hills.

FORT PIERRE TO THE BLACK HILLS.

Fort Pierre is located in latitude 44° 24′ north and longitude 23° 27′ west from Washington. It is situated on one of the broad level bottoms of the Missouri which are so common along its borders, where it flows through the loose materials which compose the cretaceous and tertiary rocks. The distance from the channel of the river to the bluffs westward is from three-fourths of a mile to a mile, while on the opposite side the hills are cross-sectioned as it were, presenting a perpendicular front 200 to 300 feet in height. They then slope back a considerable distance until the highest point is from 800 to 1,000 feet above the bed of the river. These hills are composed entirely of the black plastic clays of the Fort Pierre group, or No. 4, though nearly destitute of organic remains. Now and then a fragment of a baculite, ammonite, or inoceramus is seen, and along the Teton river a few bones of the mosasaurus have been discovered, but there is very little in this region to attract the attention of the geologist. The fort is built upon the second terrace from the water, and the bottom there rises very gently back to the bluffs, where the ascent is abrupt to the summits that overlook the broad prairie westward.

From this point our westwardly course across the pathless prairie commenced. Leaving Fort Pierre we passed over the high cretaceous hills which border the Missouri toward the northern portion of the Black Hills. The whole region is underlaid by cretaceous formation No. 4, while scattered over the surface here and there are a few erratic rocks. The timber appears only along the streams, and there it occurs only in small quantities, mostly cottonwood. The Shyenne flows uninterruptedly from the base of the Black Hills to the Missouri river through No. 4, and on account of the yielding nature of these rocks its valley is quite broad, and the hills bordering it are so cut up by the erosive action of water that they present a most rugged aspect, and their dark color gives them a bleak and sombre appearance. Along the immediate margins of the streams are a few cottonwood trees, and on the hills a clump of stunted cedars is seen. Along the Shyenne river for the greater part of its course, although the exposures are very numerous, few fossils are detected; here and there a fragment of *Baculites ovatus* is seen. Near the mouths of Sage and Bear creeks the characteristic fossils of formations Nos. 4 and 5 are found in the greatest abundance and in a beautiful state of preservation, among which are *Scaphites Conradi*, *Ammonites lobatus*, *A. placenta*, *Baculites ovatus*, and many others. The clays of No. 4 are thoroughly impregnated with saline substances which render the water of the streams that flow through them quite purgative in their effects.

Near the mouth of Plum creek on the Shyenne our party camped for a night, which gave me an opportunity to examine the geology in some detail. The black plastic clays of No. 4 underlie the whole region. The hills that border the river as well as those that inclose the valleys of the tributaries are very much cut and broken by the erosive action of water forming an innumerable number of ravines. All over these hills in the neighborhood of the larger streams are strewed in great quantities well-worn rocks of various sizes, mostly quite small. The terraces also are well shown along Plum creek as well as the Shyenne. There is here a narrow terrace about two feet above the water at its usual stage, which is composed of sand and gravel and is always overflowed by high water. There is a second terrace elevated above the ordinary stages of water, on which the trees that margin the stream grow. This is never overflowed except when the river is unusually high. Beyond this is a third terrace elevated from 20 to 40 feet above the water of the river, and is usually from 100 yards to half a mile in width.

The difference between the high and low water mark of these streams is very great. Not fed by springs except at their sources, their rise is dependent upon the melting of the snow which accumulates during the winter in the numerous ravines, and as soon as the snow is melted they subside again to their former level. During the dry season of summer and autumn there is often no running water in these rivers. The Shyenne, however, which is fed by springs from the Black Hills, never ceases to be a running stream.

Leaving the valley of the Shyenne, we ascended to a high plateau, the most elevated terrace along the river, which is from 150 to 200 feet in height and from one-fourth to one-half a mile in width. In the rear it ascends gently back to the broken hills beyond, which are from 500 to 800 feet above the bed of the river. We can here see the leveling power of water on a larger scale than at any other point since leaving the Missouri. A surface formation of considerable thickness covers this upper terrace, which is composed of sand and gravel with numerous small water-worn rocks, as quartz, gneiss, schist, granite, &c., such as are found in the beds of the streams.

Passing beyond the influence of the Shyenne westward we begin to see traces of the ferruginous marls and grits of No. 5, with the characteristic fossils. Along the "divide" between the Shyenne river and Cherry creek, about 20 miles west of the valley of the former river, No. 5 is quite well developed, exhibiting its usual lithological characters with here and there remnants of beds which appear to belong to the lignite tertiary group. The surface of the country undergoes a marked change in its external appearance. The vegetation is more luxuriant, but we see abrupt hills and denuded places, some of which resemble the Bad Lands.

The more compact rocks are concretionary and lie in horizontal strata for the most part, but are themselves separated into thin laminæ and may be called laminated sandstone. As we proceed westward the lignite beds increase in thickness, and at a point about 30 miles west of the Shyenne they occupy the country, concealing from view the cretaceous rocks. The surface of the country presents a much more cheerful aspect; the vegetation is much improved and the water is quite pure and in running streams, as if it had its origin in springs. At this locality the following section of the beds was taken:

4. Gray, rather coarse calcareous sandstone, soft and friable, with thin layers of laminated clay and numerous seams of deep ferruginous matter, also nodules of sulphuret of iron; the harder portions of this bed turn a dull *rust color on* exposure, 25 feet.

3. Fine yellow calcareous grit, similar to the shell marl near Fort Clark, passing down into laminated clay with carbonaceous matter approaching lignite, 12 inches.
2. Fine, compact silicio-argillaceous layer with indistinct traces of vegetable remains, 8 inches.
1. Fine, ferruginous, sandy material with calcareous matter, 6 feet.

The loose friable portions seem to contain but a small quantity of calcareous matter, but the harder layers effervesce quite briskly.

About 15 miles north of the Shyenne I observed outlines of the White River group, and these beds seem to occupy an extensive area near the source of Cherry creek. They are composed of beds of light yellow marl with layers of whitish limestone containing fresh-water fossils of the genera *limnea*, *planorbis*, &c., of the same species as those occurring near Pinan's spring and in the White River valley. These beds rest directly upon the lignite strata, and thus show conclusively the relative age of the two deposits.

Near the source of Iroqua creek a section of the lignite beds is shown, exposing a seam of lignite, most of which is quite impure and of a brown chocolate color, but a small portion is a jet-black and quite pure. There are also numerous fragments of silicified wood.

On Iroqua creek No. 4 is largely shown, containing a large species of *inoceramus*, *Baculites ovatus*, *Tellina occidentalis*, *Scaphites Conradi*, *cardium*, &c. There is also a surface deposit of considerable thickness composed of drift material, water-worn boulders and pebbles, from the various formations in the vicinity, and especially from the Black Hills. Many of the rocks are of the same character as those composing Bear peak, Stone peak, &c.

On the evening of July 11 we camped at the base of Bear peak, on the northwest side. This peak is an isolated protrusion of basaltic rock, very compact, rising to the height of 1,500 feet above the prairie around and separated from the Black Hills by an intervening space of seven or eight miles. All around the peak the disturbed beds form annular ridges, receding from the central point like the waves of the sea. By the upheaval of this peak the sedimentary rocks are exposed down to the carboniferous limestones on the west side, while on the east and northeast the fossiliferous beds are almost entirely concealed by a superficial deposit of drift and marl which is covered with grass. The sides of this peak are covered with loose masses of rock, which with the steepness renders the ascent quite difficult. A few stinted pines cover the summit, but it is for the most part destitute of vegetation.

Proceeding southward from Bear peak toward the Black Hills, two miles distant, we reach exposures of beds which have been disturbed by the elevation of the main portion of the Black Hills, dipping from the central axis, and forming, with those inclining from Bear peak, a synclinal trough dip 30° to 40.°

5. Alternate beds of indurated light gray and dark brown clay, and ferruginous sandstone, with deep iron-rust colored layers of argillo-calcareous concretions; some of the sandstone is heavy-bedded and some in thin, loose layers; 30 feet.
4. Impure lignite, with a few thin, intercalated seams of purplish clay, 12 inches.
3. Bluish indurated calcareous marl, with concretions, containing numerous vegetable impressions, 2 feet.
2. Light gray and yellow variegated clays, 10 feet.
1. Reddish clay.

The rocks described in the above section belong to the cretaceous division, No. 1, or the Dakota group, as I suppose, and is given in this place to show the lithological characters of the lowest portion of the cretaceous as exposed around the Black Hills. Nowhere, however, do these rocks exhibit the typical character of No. 1 as shown along the Missouri in the vicinity of Big Sioux river or Blackbird Hill.

All along the base of the Black Hills, as well as along the valley of the north fork of the Shyenne, the black plastic clays of No. 2, or Fort Benton group are seen, presenting varied lithological characters, and inclining 4° to 20°. A portion of No. 2 is a laminated shale or slate, and the soil composed sustains isolated patches of stinted oaks. I also found in these beds of shale or slate quite abundant remains of fishes characteristic of No. 2.

In the Black Hills are numerous cañons, some of vast dimensions and picturesque character, formed by the numerous small streams which have their sources in springs. These flow down to the plain country to unite and form the larger rivers, as Shyenne, Little Missouri, White, &c., sometimes winding through fissures caused by the dislocated strata, or cutting their way directly through the lofty ridges of elevations, thus exposing upon each side high vertical walls, revealing very complete geological sections of the strata. In one of these cañons, which seem to have been formed by a rapid stream of water flowing along a fissure on the axis of an anticlinal, we have the following section of the beds descending:

1. Extensive slope, covered with immense blocks of sandstone, No. 1, 50 to 80 feet.

Jurassic:

2. Gray arenaceous laminated marl, with a few layers of friable sandstone, 50 feet.
3. Alternate layers of gray laminated sandy material with a reddish tinge, and beds of more or less laminated sandstone, 4 to 20 feet in thickness, the layers or laminæ varying in thickness from an eighth of an inch to four feet. The sandstone also has a reddish tinge, and is full of the casts of mytilus. There is also a red arenaceous bed 50 feet thick, 177 feet.

Triassic:

4. Red arenaceous bed, mostly slope covered with grass, but some denuded places show the character of the rock; seams of more or less pure gypsum interspersed; upper layer snowy gypsum, 200 to 250 feet.
5. Silicious limestone, a well-marked bed, forming vertical walls in the valleys of streams, which render the country almost impassable to travelers, 50 to 100 feet.

Red arenaceous deposits:

6. Slope occasionally exposed, formed of the red arenaceous material, 50 to 80 feet.
7. Loose brick-red earth and variegated sandstone, yellow, gray, and reddish, mostly heavy bedded, 300 feet.

On the summits of the hills are thick, irregular layers of sandstone, doubtless of the age of No. 1, with ripple markings, oblique laminæ, and waved surfaces, and not unfrequently the broad flat masses of calcareous sandstone, and covered with the trails of worms. The bed which I have before alluded to as siliceous limestone lies below a great thickness of the red deposits, and forms a conspicuous feature in the topography of the mountain slopes. It is usually seen in the more elevated portions of the ridge, sloping gently down toward the prairie below, and fitting itself with great flexibility to all the irregularities of the surface; but it is more conspicuous in the channels of the streams, where the extreme hardness of the rock has produced the vertical walls which form such impediments to travel. Testing this rock with sulphuric acid, it does not effervesce briskly, and though it contains a small portion of the carbonate of lime the sulphate of lime seems to form the larger constituent, and on that account I have called it the gypsiferous limestone; and it seems to be an invariable accompaniment of the gypsum-bearing red arenaceous deposits. It is for the most part very hard, almost crystalline, breaking into irregular fragments, and sometimes composed of thin laminæ instead of forming a compact heavy bedded mass. The sandstone which underlies it attains a thickness of from 400 to 1,000 feet. Its usual color is a light yellow, but it not unfrequently has a brick-red tinge, possibly colored from the red beds above. It may be called a calcareous sandstone, since it effervesces briskly with sulphuric acid. In the valley of Box Elder creek, the following section of the beds occurs, which may throw more light on the lithological character of the rocks in this region :

1. Gray arenaceous material capped with sandstone.
2. Yellow ferruginous sandstone, forming along the channels of streams a projecting, abrupt, escarpment-like wall, 10 feet.
3. Slope, covered with loose rocks. A few eroded spots show this bed to be composed of alternate layers of clay, laminated sandstone, and shaly, sandy material, mostly of a gray color, 15 feet.
4. Sandstone, like 2, separated into cubical masses, 4 to 6 feet.
5. Slope, lower portions very light-gray, fine, arenaceous marl, with alternate layers of gray sandstone, two to six feet thick, breaking into cubical blocks, 76 feet.

The valley in which the above section was taken is formed by the uplifting of the strata along the slopes of the Black Hills, and at this point extends west-southwest and east-northeast, averaging from half a mile to two miles in width. The hills on the north side of the valley are not high, but slope gently down to the Shyenne valley, while those on the south side are quite abrupt. The erosion of the upraised strata, to form the valley of Box Elder creek, reveals perpendicular walls of the red sandstone, which underlies the well-known jurassic rocks around the mountain elevations. Beds 2, 3, and 4 are undoubtedly of the age of cretaceous No. 1, as it is understood to exist in this region. These sandstones present most of the peculiarities which are observed in No. 1 at other localities, varying in color from gray, yellow, light ferruginous, to a deep iron-rust, containing a large per cent. of iron ore. Many of the slabs or flat layers of rock are covered with the trails of worms.

At another locality bed 5 of section is revealed, so as to show its character more fully:

1st. Alternate layers of sandstone, yellow and light-gray, arenaceous material, the light, brick-red grit, with layers of harder sandstone, passing up into yellow, indurated, sandy material; also with layers of sandstone; the beds or layers of sandstone being, for the most part, of a concretionary character, varying greatly in thickness within the space of one or two miles.

All along the immediate valley of the Shyenne, the country is occupied with the black, plastic clays of No. 2 or the Fort Benton group of the general section. Even on the north side of the river the influences of the elevating forces have affected the strata, and the hills or uplifted ridges are from 400 to 500 feet in height, the upper 300 feet presenting a light-gray appearance in the distance, unlike any rocks of this group before observed in the west. On a close examination, this light-gray color proved to be the result of exposure, for, on penetrating the layers, I found them to be composed of the dark, plastic, laminated clays which are characteristic of the Fort Benton group, with scales, vertebræ, and other remains of fishes.

Following up the north branch of the Shyenne toward the source of the Little Missouri, we passed over to No. 2 entirely. But few fossils were detected, but, after a diligent search among the ravines and cañons, I discovered fragments of *Inoceramus problematicus* and an *ostrea*, which proved, beyond a doubt, that the formation so largely developed along the Shyenne and the base of the Black Hills properly belongs to the age of No. 2.

The surface of the country along the Shyenne is exceedingly bleak and barren, though not entirely destitute of vegetation. The most abundant shrub, and one which covers the ground quite thickly in many places, grows from two to four feet in height, and is peculiar to these saline clays, is the *Artemisia trifida*. The surface has also a blackened or burnt appearance, and from this fact these hills, as also others of a similar character in other places, have been called by the Canadian voyageurs "Côtés Brulées," or "Burnt Hills." This appearance is undoubtedly due to the concretionary rocks containing much iron pyrites, which explodes when it comes in contact with the atmosphere. Fragments of the broken rocks cover the ground, and are very heavy, as if containing a large per cent. of iron, and are of a deep iron-rust or an iron-black color. The shales of No. 2, where exposed in a vertical section by the river, exhibit a glossy steel-gray color, and resemble somewhat in external appearance the shales of No. 4, or Fort Pierre beds, near the mouth of Grand river along the Missouri. The strata are slightly disturbed far to the north of the Shyenne and the several low ridges raised above their original position by the elevation of the Black Hills, and becoming lower and strata less disturbed in a northern direction, thus representing the dying-out of the elevatory influences. All along the margins of the hills bordering the river there appears to be little or no vegetable soil, yet a few oaks send their roots in among the layers of shale and draw a scanty subsistence, but seldom rising to a height of more than 10 or 15 feet.

Leaving the valley of the Shyenne, we proceeded westward across the upland prairie toward the sources of the Little Missouri, about 15 miles distant. Before reaching the first branch of the Little Missouri, I detected formations 4 and 5, with some of their characteristic fossils, as ammonites, baculites, fusus, &c. About 15 miles northeast of our road is a high, bald, white ridge, 300 to 500 feet in height above the surrounding country, called by the Indians the "White Hills." Their trend is about southeast and northwest, and they are composed of the lignite tertiary beds, and clothed with a thin growth of pines. This is a ridge left after erosion, and a sort of land marking the southern rim of the great lignite basin. In the same manner Slave, Slim Buttes, and Deer's Ears mark the southeastern shores.

In the vicinity of the Black Hills, as well as in several other localities, which will be alluded to hereafter in their proper places, are a series of doubtful beds, between the well-marked jurassic and the cretaceous. These rocks are quite variable in their character, sometimes composed, for the most part, of a loose material, clays and grits; again of compact concretionary sand or limestones. But few organic remains have as yet been found in these beds, although the most diligent search has been made, and those are quite uncharacteristic, so that their position remains in doubt. I have therefore ventured to call them beds of transition, or passage between the close of the jurassic period and the dawn of animal life in the cretaceous. The locality where the following section of these doubtful beds was taken is near the source of the Little Missouri, upon the northeastern side of the Black Hills.

1. Alternate layers of yellowish sandstone, in regular strata, and brown, indurated clay: first, sandstone, 6 feet, with a few thin partings of clay; second, yellowish brown indurated clay, 6 feet; third, alternate layers, 2 to 20 inches thick, of yellowish sandstone, with brown, indurated clay, 15 feet; fourth, brown indurated clay, 5 feet; fifth, alternate layers of yellow sandstone, 4 inches to 10 feet in thickness, with thin partings of brown and yellow indurated, calcareous, argillaceous grit, 30 feet.
2. Indurated, laminated clay, upper part light yellow, and lower dark ash-color, 4 feet.
3. Compact, fine, yellow sandstone, in regular layers, one-fourth of an inch to six inches in thickness, 5 feet.
4. Yellowish gray indurated, calcareous grit, with thin layers of ferruginous sand and clay stones, 5 feet.
5. Dark indurated, carbonaceous clay, passing up into a fine-grained, argillaceous grit, 4 to 6 feet.
6. Ferruginous, indurated, yellow, calcareous clay, 5 feet.
7. Ashen gray indurated clay, 10 feet.
8. Mostly light, brick-red, though somewhat variegated, indurated clay, 25 feet.
9. Dark indurated clay, with a seam or two of light gray indurated, calcareous grit, 26 feet.
10. Light gray indurated grit, upper part concretionary, 6 feet.
11. Ash-colored indurated, marly clay, with a greenish tinge.
12. Brick-red marl, with a purplish tint.

The top bed of the above is in some places nearly a brick-red color, as if it had been effected by heat, and some of the ferruginous layers in bed 4 have the upper surfaces covered with waved markings, indicating a shore deposit.

The Black Hills assume the form of an ellipse with a nucleus of granite and stratified azoic rocks with the sedimentary formations inclining in regular sequence outward. This form of upheaval is shown in the ridges, which are as mere annular circling round this axis and gradually diminishing in height, and the abrupt sides revealing fewer beds, and those of more recent age, until the ridges die out in the prairie. Beginning from the first ridge near the axis we have the Potsdam sandstone resting unconformably upon the stratified azoic rocks, presenting outcropping edges of the strata toward the axis, but sloping at a greater or less angle from it in all directions. We then have a valley of greater or less width, varying from a quarter of a mile to two or three miles, and a second ridge, exposing the carboniferous rocks in their full thickness and sometimes a part of the red arenaceous beds capping the summits. Again proceeding outward we come to a third ridge composed of red arenaceous deposits and jurassic rocks; then a fourth ridge with cretaceous formations Nos. 1 and 2, and a fifth ridge with many smaller ridges of the more recent cretaceous rocks, until all the influences of the elevating forces die out in the level prairie. I would not pretend to say that all these ridges assume the regularity that I have depicted above. Sometimes smaller local ridges are intercalated, and in the same ridges may be found quite a mixture of rocks, of different epochs, as Potsdam and carboniferous rocks in the same *ridge, and* carboniferous, red arenaceous deposits, and jurassic rocks, together. But the general law in regard to these ridges is as I have described.

The following notes are designed for the section below:

1. Nucleus of red feldspathic granite.
2. Azoic stratified rocks, gneiss, mica slates, schists, &c.
3. Potsdam sandstone, inclining 5° to 15°, sometimes uplifted in a very horizontal position, overlaid by carboniferous rocks.
4. Carboniferous rocks, mostly from 1,200 to 1,500 feet above the bed of the Shyenne—inclination from 20° to 50°. Distance from top of first ridge to top of second from one-half to three miles.
5. Red arenaceous and jurassic rocks, dipping from 20° to 40°. Distance from top of second ridge to third from half a mile to two miles, elevated 800 feet above the bed of the Shyenne.
6. Lower cretaceous rocks, dip 5° to 20°, sloping to the Shyenne. Distance from top of third to top of fourth ridge six miles.
7. Cretaceous formation No. 2, dip 3°. Distance from ridge to ridge two miles.
8. Cretaceous formations Nos. 2, 3, and 4, dip 2°. Distance three miles.

The trend of all these ridges seems to depend upon our position to the central axis.

CHAPTER VI.

From the Black Hills to the Yellowstone river—Geology of the country west of the Black Hills—Cretaceous and tertiary beds—Topographical features—Vertical sections of tertiary rocks—Powder river—Impressions of fossil plants—Tongue river—Silicified wood—Erosion—Cretaceous beds at the mouth of Big Horn river—Thickness of lignite beds at mouth of Rosebud.

FROM THE BLACK HILLS TO THE YELLOWSTONE RIVER.

After leaving the Black Hills we struck off in a northwesterly direction toward the valley of the Yellowstone. Nearly all the country is occupied by deposits of lignite tertiary age which are exceedingly variable in their character, precluding the possibility of giving continuous sections of the strata over large areas. I have, therefore, at the risk of seeming tedious and of repeating much, given many local sections and described the country in much detail, in order that I may present the facts upon which my generalizations will rest, directly or indirectly. It is true that there is a great apparent uniformity in the lithological characters of the lignite tertiary beds, and still the actual field observer will find that no two local sections, though taken at no great distance from each other, will be near enough alike to venture much in drawing a parallelism of the strata without organic remains. Even then it would require the slow and toilsome labor of years to unravel the complications, even if it were possible, for oftentimes we pass over large areas where not a trace of any organic remains can be found. The same species also seem to be distributed through all the beds which are adapted by their nature for the preservation of organic remains.

Leaving the Black Hills, therefore, near its northwestern base, we pass over a bed of No. 2, then Nos. 4 and 5, each of these beds revealing here and there a few of their characteristic fossils and all inclining from the axis of elevation. The cretaceous rocks are disposed in low ridges of elevation, dipping very gently toward the level plain country, and as we approach the level prairie we begin to see the overlapping edges of the lignite beds resting quite regularly upon the cretaceous rocks. I have estimated Nos. 4. and 5 at 250 feet in thickness at this locality.

Ascending the slope of the dividing ridge between Little Missouri and Powder rivers, we come into a full development of the tertiary beds, dipping gently at angles of 1° to 8° with indications of the cretaceous strata beneath. Far to the westward of the Black Hills also we can see the tertiary deposits continuously, and dipping at a small angle because so remote from the central cause of disturbance.

I have numbered the sections from this time onward in their order, 1, 2, 3, 4, &c., so that I may refer beds from one section to another when it is possible. The first section was taken after crossing the source of the Little Missouri and ascending the ridge, the base of which is 400 to 600 feet above the bed of the stream, the lower portion being composed of cretaceous strata.

Section 1.

4. Slope composed of gray arenaceous material, with thin beds 6 to 12 inches thick of ferruginous sandstone, 30 feet.

3. Gray and yellow ferruginous, heavy bedded friable sandstone, with the most irregular laminæ of deposit, indicating shallow water or shore deposition, also containing small seams of clay nodules and numerous small concretions of various kinds, some globular nodules containing iron, 20 to 28 feet.
2. A yellowish ferruginous indurated sand filled with black grains and particles of mica and traces of vegetable remains. There are also large numbers of roundish concretions projecting out of the beds, which turn a brown rusty drab color on exposure but internally are a dark gray sandstone with small nodules of bluish clay. These beds have a somewhat banded appearance from the fact that some strata are darker than others. There is a considerable quantity of silicified wood dispersed throughout this bed and some uncharacteristic bones, 100 feet.
1. Gray and bluish gray sandstone with some partings of bluish gray arenaceous shale. The sandstones vary much in thickness and not unfrequently in lithological characters. The upper part is a fine sand alternating with layers of sandstone more compact, 150 feet.

The above section is quite similar in its character to the lower beds of the lignite basin along the Moreau and Grand rivers, and on the northeast side of the Missouri near Long lake. It will be remembered that in these localities we have the eastern and northeastern rims of this basin, and the beds hold a similar position geologically. In some of the localities I noticed a yellow arenaceous bed resting upon well marked cretaceous rocks. This also occurs in other localities in the same position but is not permanent. The black hornblendic grains in bed 2, section 1, gives its external surface a dark brown color, and it contains bones and wood, &c., and is undoubtedly the same bed which is well developed in the localities above mentioned.

As we ascend the dividing ridges between the Little Missouri and Powder rivers, bed after bed of the tertiary comes in, so that when we reach the top of the ridge we stand upon a thickness of 300 or 400 feet of tertiary. Passing over this ridge we descend into the valley of the Dry Fork of Powder river, and the cretaceous rocks are seen in only a few localities in some of the deep cuts near the bed of the stream. A section from near the summit of the ridge will show the character of the beds at this point.

Section 2.

18. Dark brown indurated arenaceous marl, 6 feet.
17. Very impure indurated sandy lignite, some portions laminated, contains fragments of charcoal and much sulphuret of iron, 5 feet.
16. Differs from the bed below only in being a deep ferruginous yellow color, 15 feet.
15. Light gray and yellow ferruginous, arenaceous material, which, when exposed to the atmospheric agencies, disintegrates so that it is blown about by the winds. This bed is capped with a ledge of gray sandstone, 17 feet.
14. Very impure lignite, light, loose material, in a shaly or laminated form. A seam of light gray clay just above, 6 inches.
13. Dark gray indurated marl, 7 feet.
12. Impure lignite, with clay above and below as usual, 3 inches.
11. Light ferruginous, somewhat indurated argillaceous sand, 17 feet.
10. Dark, impure lignite, loose and light material, as if formed of dried vegetable matter from a peat bog. Just above and below a small seam of clay, 4 inches.

9. Ferruginous argillo-arenaceous material, 10 feet.
8. Dark brown and dull purplish brown lignite, impure, with thin seams of ashen gray clay above and below, 6 inches.
7. Yellow ferruginous sand and clay, 12 feet.
6. Impure lignite, like bed 10, 12 inches.
5. Gray and yellow ferruginous, fine-grained arenaceous material, with a few layers of concretionary calcareous sandstone, 39 feet.
4. Impure lignite and carbonaceous clay, of a dull brown color, some portions of the clay light gray; the whole filled with uncharacteristic fragments of vegetable remains, 3 feet.
3. Yellow ferruginous, arenaceous material, indurated with layers of gray concretionary sandstone, 78 feet.
2. Impure lignite and indurated carbonaceous clay, 4 feet.
1. Slopes down to bed of creek, but evidently composed of yellow and gray calcareous sands.

On another hill above the bed of sandstone which caps bed 15, section 2, is a repetition of the light gray and ferruginous yellow calcareous sands, with arenaceous concretions, about 20 feet exposed. At another locality lignite beds 12 and 14, section 2, become respectively 3 and 4 feet in thickness, but still impure, containing large quantities of selenite, and a yellow substance like sulphur. In some places where erosion has been quite extensive, we can see that the beds of sandstone, which project from the sides of the vertical cuts, do not extend into the bank but a few feet, while they may be continuous for a long distance. They are simply concretions and not permanent beds of sandstone. The figure will show the form of some of these sandstone layers. The ends show the layers of deposition.

The same variable character is seen throughout the tertiary formations everywhere. Sometimes we have a bed of hard rock, 30 to 50 feet in thickness, and at a few hundred yards distance it is changed into a loose arenaceous material, with very little coherence. We have seen from the sections already given, that the geological structure of the country is such that the surface would necessarily become very rugged by the erosive action of water and atmospheric agencies. The whole country along Powder river is of the character of Bad Lands, that is, almost entirely destitute of vegetation, the greater part entirely bare, the myriads of little streams in wet weather forming almost vertical cuts along the slopes of the streams, while on the uplands we have a continuous series of conical hills or sharp ridges, among which it is next to impossible to travel.

Section 3.—On the Dry Fork of Powder river.

7. Light gray and yellow ferruginous calcareous sand, 15 feet.
6. Eighteen inches impure lignite, passing down into clay and ferruginous calcareous sand, 7 feet.
5. Yellow and gray sand, like bed 7, 6 feet.
4. Impure lignite and clay, 2 feet.
3. Light gray arenaceous material, filled with numerous yellow and black particles, which give color to the bed, also irregular layers of laminated concretionary rock which is fine-grained and contains a small portion of calcareous matter. There is also much ferruginous material in the form of nodules of impure sulphuret of iron. The harder layers project out of the sandy beds and are from 1 to 4 feet in thickness. These concretionary layers are doubtless formed of *an irregular induration* of the arenaceous material, for the same layer

varies in thickness from 6 inches to several feet within a distance of a hundred yards.

2. Impure lignite under and overlaid by dark carbonaceous clay, 4 feet.

1. Slope down to the bed of the river composed of loose arenaceous material.

In bed 7, of section 3, on the opposite side of the river, I found a large palm leaf; also numerous impressions of dicotyledonous leaves. The above section was taken from a vertical cut made by the river. There is here a long irregular ascent of bad lands to the top of the hills, with the beds exposed mostly in the ravines. We have first, yellow and light gray marls, with more or less coarse-grained sandstone, 50 to 100 feet; then dull, reddish, impure lignite, 18 inches to two feet; ferruginous calcareous sand, 15 feet; impure lignite; dark-gray or brown indurated clay, 15 feet; yellow ferruginous, light-gray and ash-colored calcareous sand, 30 to 40 feet; quite pure black lignite, burned in some localities, 4 feet; passing up into 3 feet of dull, purplish, indurated clay, which also passes up into a 3-foot bed of fine yellow sand, 5 feet; impure lignite and clay passing up into the dark-brown indurated calcareous clay. Same horizon as bed 18, section 2. At another locality, still above this, we have a continuation of the beds upward over bed 18 a layer of lignite, sometimes quite impure and then again of unusual variety, ignited in many places, giving a red, brick-like appearance to the summits of the hills. Much selenite occurs in the bed.

Above this is a slope of 40 feet of yellow ferruginous, arenaceous material, with numerous brown ferruginous sandstone concretions, approaching a globular form.

On the left bank of Powder river, just above its junction with Dry Fork, I took the following section of a nearly vertical bluff:

Section 4.

22. Very ferruginous, yellow indurated marl capping the hills at this point, 25 feet exposed.

21. Seam, impure lignite and clay, 6 inches.

20. Indurated ferruginous arenaceous material, with occasional seams of clay, and one layer sandstone, 18 inches to—

19. Dark-brown indurated laminated clay, with vegetable matter, at the top 6 inches dull black lignite, 7 feet.

18. Deep yellow ferruginous marl, 2 feet.

17. Impure lignite, a portion is black, apparently not different from soft charcoal or charred wood, 12 inches.

16. Light gray and yellow ferruginous sand, rather homogeneous, presenting a vertical front—contains a small portion of calcareous matter, 10 feet.

15. Alternate beds of gray indurated sand and brown indurated clay with vegetable matter, 2½ feet impure lignite and carbonaceous clay, central portion black, with some tolerably pure seams, 18 feet.

14. Gray ferruginous sand, with small nodules of sulphret of iron disseminated through it, 6 feet.

13. Black lignite, 2 inches.

12. Yellow ferruginous marl, 8 feet.

11. Light gray indurated arenaceous marl, containing some ferruginous matter and singularly shaped iron rust colored concretions of sandstone, partially spherical, but usually broken in pieces on exposure. There appears to be but one compact layer, varying in thickness from 6

inches to four feet, sometimes massive or separated into thin laminæ, 18 feet.

10. Alternate seams of dark laminated lignite and deep ashen-gray indurated carbonaceous clay, fully charged with uncharacteristic vegetable remains, as stems, grasses, &c: 1st, 18 inches clay; 2d, 4 inches black lignite; 3d, 6 inches clay; 4th, 2 inches lignite; 5th, 2 feet clay; 6th, 5 inches impure laminated lignite; 7th, 2 feet indurated clay; 8th, 5 feet dark-brown arenaceous lignite, consisting of about two parts of rather fine gray sand, and the remainder vegetable matter.
9. Two feet of ferruginous, yellow arenaceous marl, passing up into a dark brown, indurated argillaceous sand, with small reddish iron rust concretions, 30 feet.
8. Impure lignite, 8 inches.
7. Yellow ferruginous arenaceous marl, 3 feet.
6. Lignite and clay, 6 inches.
5. Arenaceous clay, 3 feet.
4. Seam of impure lignite, 2 inches.
3. Light gray marl, 5 feet.
2. Lignite in layers, more or less pure, with seams of clay, 5 to 7 feet.
1. Fine-grained ferruginous arenaceous marl, with many grains of mica and hornblende, 30 feet above river bed.

The above section was taken from a fine exposure, and each bed measured with care, so that it may be regarded as an exhibition of the position and character of the strata at this locality. Bed 9 contains, in its lower portion, dark brown calcareous concretions and hard layers of clay, with vegetable impressions in great abundance, among which is a large species of *platanus*, *acer*, &c. Where the bluffs are washed by the river on either side we find beds of harder layers, sometimes from 12 to 18 inches in thickness, almost entirely composed of dicotyledonous leaves. Many of the arenaceous beds show oblique laminæ of deposit and other indications of shallow or turbulent waters and shore depositions.

Section 5.—Powder river, near our crossing.

27. Baked and melted earth, from the ignition of lignite beneath. The lignite bed must have been from two to four feet in thickness, but has been entirely consumed as far as the eye can reach, 32 feet.
26. Yellow arenaceous marl, like 21 and 23, containing some seams of impure lignite and clay, with numerous concretions, 62 feet.
25. Black lignite; sometimes a dull drab argillaceous lignite, 18 inches.
24. Ash-colored, light gray, and drab brown indurated clay, 6 feet.
23. Like 21, 17 feet.
22. Eighteen inches black lignite passing down into 18 inches drab brown carbonaceous clay; then 3 feet drak gray indurated clay; then 18 inches drab brown indurated clay; then 2 feet ash-colored indurated clay.
21. Deep yellow ferruginous arenaceous marl, with numerous ferruginous calcareous concretions, containing an abundance of vegetable impressions. These marls are very slightly coherent, 24 feet.
20. Carbonaceous clay and impure shaly lignite, 4 feet.
19. Yellow arenaceous marl, 6 feet.
18. Dark brown indurated arenaceous clay, with iron rust calcareous concretions, 15 feet.
17. Shaly argillaceous lignite, passing down into dull, drab brown, indurated carbonaceous clay, 4½ feet; then 6 inches dark carbonaceous *clay; then 8 inches* brown indurated clay, then 6 inches dark clay.

16. Dark gray indurated arenaceous clay, with several layers of dull, iron rust colored concretions, breaking in fragments on exposure, 24 feet.
15. Alternate seams of lignite and clay: 1st, 10 inches black, rather pure lignite; 2d, 18 inches dark gray indurated arenaceous clay; 3d, 6 inches drab brown shaly argillaceous lignite; 4th, 12 inches dark-brown indurated clay.
14. Dark brown indurated arenaceous clay, with some light yellowish bands, with ferruginous concretions, breaking into small fragments on exposure, 12 feet.
13. Dull, reddish brown, shaly argillaceous lignite, 2 feet.
12. Alternate bands of indurated brown clay and yellow arenaceous marl, with thin seams of laminated argillaceous chocolate-colored lignite. About the middle of this bed is a layer, 6 inches thick, for ferruginous calcareous concretions, breaking into fragments, 38 feet.
11. Lignite, mostly quite pure, sometimes argillaceous and laminated, of a chocolate color, 7 feet.
10. Yellow and dark gray indurated clay, with layers of shaly, impure lignite, ferruginous, 7 feet.
9. Gray, indurated, ferruginous arenaceous marl, 10 feet.
8. Lignite and dull, reddish drab clay; the middle portion, 6 to 10 inches, is sometimes clay and sometimes lignite; 18 inches to 2 feet.
7. Drab brown, indurated arenaceous marl; contains much vegetable matter, 3 feet.
6. Impure earthy lignite, chocolate color, 18 inches.
5. Yellow, yellowish brown, and gray arenaceous marl, 14 feet.
4. Dark carbonaceous clay and impure lignite, underlaid by 3 feet light gray indurated clay, 17 feet.
3. Yellow, ferruginous arenaceous marl, capped with a layer, 2 feet in thickness, of ferruginous arenaceous limestone, 27 feet.
2. Lignite more or less pure, some portions impure and laminated, containing clay, others black compact lignite. This bed of lignite is by far the best seen on the river, and has been ignited in many places. It is also underlaid by a thin seam of fine white clay, 10 feet.
1. Slope from thin bed, a half a mile, 150 feet above water level.

The upper yellow portion of the above section forms a well marked horizon in this region. No portion of the country yet seen exhibits the "Bad Lands" in so marked a manner. The entire surface is cut up into long high sharp ridges or conical hills to an enormous extent, and the different colored clays, marls, and lignites give to these hills a most unique banded appearance.

On the summits of the hills between Tongue river and Pumpkin creek we obtain a fine collection of fossil plants, among which was a species of *dombeyopsis*, and a beautiful impression of the leaf of an *ulmus*. In some sandstones drifted into the bed of Tongue river were large specimens of apparently the same species of platanus, closely allied to P. hercules, found lower down, below the mouth of Powder river on the Yellowstone. In the channel of a little stream that flows into Powder river from the dividing ridge between Powder and Tongue rivers, we have the following section of the strata, which I have presented from the fullness of detail with which it was taken. It will also enable us to draw some parallels in regard to the beds which may be important, and many lithological differences, not before seen, must be of interest.

Section 6.

12. Yellow ferruginous marl, passing down into a yellow friable ferruginous sand, with layers from two to four feet thick of coarse-grained sandstone, then light gray and yellow ferruginous arenaceous clay with thin laminæ of iron-rust colored sandstone. The laminæ of deposit in this bed, in the hard as well as more friable portion, are very irregular, sometimes forming curved lines, or inclining at angles varying from 5° to 25°. The sandstone contains many small fine-grained harder masses, which give it the appearance of a pudding stone.
11. Clay and impure lignite in alternate layers. 1st, impure lignite, gradually passing down into dark carbonaceous clay, 4 feet; 2d, a light ashen gray carbonaceous clay, passing down into a dark chocolate impure lignite, 2 feet, underlaid by 18 inches ash-colored indurated clay.
10. Dark brown indurated clay, portions arenaceous and calcareous, with layers of hard limestone dark rust brown inside, and deep iron rust yellow on the outside, breaking into pieces on exposure, with beautiful impressions of dicotyledonous leaves. There are also thicker layers of rather arenaceous yellow limestone fully charged with leaves, but the particles of sand are not sufficiently coherent to preserve the perfect impression. This bed also shows in the layers of deposit the vegetable dust which is accumulated with the sand—the sand being the heaviest sinks to the bottom, while the vegetable fragments are deposited on the surface of the laminæ, 150 feet.
9. A thin seam of ash-colore dindurated clay, passing down into chocolate-colored argillaceous lignite, portions quite pure, underlaid by yellowish brown indurated clay, 2 feet.
8. A light gray marl passing down into dark ash-colored indurated ferruginous clay, with small concretionary masses of very hard, fine, brittle limestone, interior dark brown, exterior iron rust color, with indistinct vegetable impression. All the thin layers of deposit have spread over their upper surfaces a fine vegetable material, such as is communicated and drifted by the little streams. Two small seams of this vegetable matter, each half an inch in thickness—sometimes a thin layer of clay is deposited one to three inches, 10 feet.
7. A thin seam, two inches of dark, impure lignite, underlaid by 18 inches light gray ferruginous marl, intersected with streaks of vegetable matter.
6. Four feet of reddish brown and dark ash-colored carbonaceous clay or shaly lignite, underlaid by 18 inches chocolate-colored indurated carbonaceous clay.
5. Yellow ferruginous marl with a hard layer of yellowish iron-rust colored concretionary limestone, containing abundant vegetable impressions, mostly indistinct. This bed forms a well marked horizon, and is traced over a large area.
4. A thin seam of over clay; then 18 inches black and chocolate colored lignite, with 18 inches dark brown under clay.
3. Drab indurated arenaceous clay, passing down into a fine arenaceous material underlaid by chocolate clay, 8 feet.
2. Two feet lignite, middle portion quite pure and black, but above and below the middle portion impure chocolate color, underlaid by about 6 feet of clay.
1. Yellow ferruginous arenaceous material with layers of laminated arenaceous limestone, the whole filled with globular masses of impure sulphuret of iron.

The channel of Tongue river often exposes quite high vertical sections of the strata and numerous beds of compact calcareous rock fully charged with the most beautiful impressions of leaves. I know of no portion of the west which promises so abundantly these vegetable fossils. Just below our crossing there is a vertical escarpment of sand and sandstone showing oblique laminæ of deposition. In this mural face of sandstone we see a seam of quite pure lignite 2 inches thick and 10 or 12 feet long arranged in the sandstone at an angle of 45°.

Near this point bed 2, section 6, is composed of very black lignite, quite pure, 5 feet in thickness. About 2 miles above the crossing on Tongue river we have the following section of the strata:

Section 7.

10. Yellow indurated marl with thick layers of fine calcareous concretions, 20 to 40 feet.
9. Yellow marl with some masses of concretionary sandstones, 15 feet.
8. Seam of black lignite, 8 inches.
7. Same as bed 8, 25 feet.
6. Lignite more or less pure. 1st, 4 inches of clay with roots passing through into a layer of sand beneath; 2d, 10 inches mostly dull black, rather pure lignite, with thin laminæ horizontally, but breaking vertically into cuboidal masses; some portions are of a shining black color containing large quantities of a yellow powder like sulphur, which gathers about the exterior surface of the fractured masses; also thin seams of selenite sometimes fibrous, which is also deposited about the exterior surface of the fractured portions; 3d, 3 inches of indurated chocolate clay, with rhomboidal crystals of selenite; 4th, 2 feet of dark brown carbonaceous clay with the fracture and character of indurated clay; 5th, 6 inches like 2d seam; 6th, 12 inches like 4th; 7th, 3 inches like 5th; 8th, 2 feet like 4th.

All the beds in this vicinity seem to have a vertical fracture like jointed rocks, which are somewhat irregular in their direction, but have a general direction northeast by southwest.

5. Alternate thin laminæ of clay and arenaceous material, very fine, light ashen gray colored, but still containing many nodules of the sulphuret of iron, 4 feet.
4. Two feet light ashen gray clay passing down into arenaceous material, which is intersected in every direction by small threads of vegetable matter, seldom more than one-fourth of an inch in diameter, like roots of trees or shrubs. These roots not only extend down into the sand beneath, but up into the chocolate clay, indicating that the materials which compose the bed of lignite probably grew upon the spot where the roots are now found.
3. Yellowish gray arenaceous marl with 2 or 3 thin seams of carbonaceous matter and numerous thin layers of clay, 5 feet.
2. Chocolate indurated clay, 4 inches, 3 inches pure and impure lignite, portions with a shining black fracture, and 4 inches of clay underneath.
1. Ashen gray indurated arenaceous clay with large layers of calcareous sandstone containing large specimens of *platanus*, 11 feet above the level of the river.

We examined with a good deal of care the bluff containing the small seams of lignite, (of which Mr. Schonborn made a sketch.) The layers of deposit are very irregular, and a seam 2 inches of lignite, 5 feet in length, *lower portion inclining* 10°, upper 15°. The material above and below is a yellowish gray sand with numerous deep yellow ferruginous bands, and just above the coal seam is a harder mass of rock which is concretionary; the laminæ running directly through it, but becoming less distinct in the harder portion. The lignite is a black, quite good lignite, and must have been formed by a deposit of vegetable matter upon a slope. It is not always the case that the harder concretionary layers preserve the laminæ continuous with the more friable material. A nucleus seems to be formed of gray fine-grained limestone, quite arenaceous whenever fractured, of an iron-rust color, with laminæ quite indistinct 12 to 18 inches in thickness; the surrounding distinct layers of light gray sandstone. The lines of deposit seem to pass through the harder nucleus of limestone. The harder arenaceous limestone appears like a kernel or pit around which the layers of sandstone were deposited, yet not with concentric coats. This concretionary layer extends horizontally about 40 feet without interruption, passing at each end into the yellow friable sand, which also corresponds in the laminæ deposit for a short distance further. This rock is full of rounded masses of sulphuret of iron. The central portions have the color and fracture of cast iron, and surrounding each ball in the bed is a coating of deep yellow sand. Inclination of laminæ 20°. The whole bed seems to be the same as bed 1, section 7. This bed at the base is everywhere filled with leaves of the genera *platanus*, *populus*, &c.

On the dividing ridge between Rosebud and Tongue river I saw an immense palm leaf, the ribs radiating each way from a common center, and then as they were revealed upon the surface of the rock measured 55 inches in length, and at least 10 inches had been broken of.

As we ascend this ridge we find the country exceedingly rough, gashed up by myriads of gullies, and covered with square conical hills 80 to 200 feet high. A bed of yellow marl forms the summit, then a layer of lignite which has frequently ignited and baked the superincumbent yellow marl, so that the high hills are covered with a bed 5 to 20 feet in thickness with a brick-red rock, many of them fused. Sometimes immense masses are cemented together in large blocks of nearly baked material. The melted material varies in character from a light vesicular to a hard compact rock. The hills are covered with pines to a greater or less extent, seldom over 2 feet in diameter, and 80 feet in height. Descending into the valley of the Rosebud we encounter the same rugged country, with indications of the burning out of the lignite beds and the fused and semi-fused material covering the hills, giving them a peculiar picturesque, reddened appearance. Numerous seams of lignite occur more or less pure, and in the intervening beds are plants and fruits, and also the same species of palm before mentioned.

Near the great lignite beds in this region we meet with large silicified stumps which look as though they might have belonged to trees two to four feet in diameter, standing apparently in the position in which they grew. They were in the clay which underlies the lignite beds. The main roots were distinct, and they were split into several portions from the summit of the stump. Near the summits of the hills are thick layers of rather coarse yellow sandstone, with a slight portion of calcareous matter which seems to be composed of leaves in an imperfect state of preservation. *Platanus* occur in great numbers. The rock breaks into thin layers, and its composition is such as to prevent the fossils from being obtained with any degree of perfection. There are no indications of these leaves having been entombed in the beds in turbulent waters. The stumps are in a drab clay beneath the lignite bed, which is here about four feet thick, and they seem to be standing where they grew though I hardly think it possible. The hollow portion, which seems to have decayed prior to the petrification, exhibits an appearance very similar to that before being buried in the earth, but now all the little interstices are filled up with crystalline silex. Descending to Ammel's Fork, we again see the yellow marl beds capping the summits of the hills. In the west we can see the Wolf Hills, an elevated range which has been lifted up by the internal forces which have upheaved the mountain chains. Being so far remote from the central source of power, it seems to have acted with comparative feebleness, forming simply one or two anticlinals and revealing only a portion of the cretaceous strata. The surface of the country around the western slope of the Wolf range has been very much worn by denudation, so that grassy slopes appear with here and there isolated knobs or pillars of sandstone. Most of these pillars are capped with layers, often three or four feet in thickness, of argillo-calcareous concretionary rock which contains plants, and seems to protect the underlying more friable portion from the rapid erosive action of atmospheric agencies. It is evidently the same sandstone so often mentioned before but with increased thickness, and reveals the same tendency to irregular laminæ and little layers of nodules. As we approach within five or six miles of the hills the country, though sloping gently into hill and valley, has a much more cheerful appearance. The hills are much more gently sloping, covered with a much thicker superficial deposit, and on the summits of the hills are immense masses of sandstone exposed by erosion, yet the ground is covered with grass all around. One of these isolated pillars is shown in the sketch below as the form merely of a cap about 12 feet high; the base, about two feet in diameter, gradually enlarging toward the middle, which is about ten feet in diameter, and of a hard concretionary character.

This range of hills exhibits undoubted evidence of upheaval, but so gradually does it seem to have taken place that the horizontality of the tertiary strata is scarcely disturbed. Many of the hills are elevated bodily in such a way that the beds are still horizontal. Although this range of hills exhibits undoubted evidence of upheaval, yet on the eastern side there are no rocks older than tertiary exposed. In the valley of Ammel's Fork, a little stream which takes its rise in the Wolf range, are some beds of a sort of siliceous limestone which contains many of the finest specimens of plants, with shells like *corbula*, the whole bed resembling the one containing plants at Red Springs, just above Fort Clark, on the Missouri river.

After leaving this point we pass over into the valley of the Yellowstone, about 30 miles below the mouth of the Big Horn river. All the intervening country is covered with tertiary beds exhibiting the peculiarities already so often mentioned. But about 30 miles below the mouth of the Big Horn, in the valley of a little stream emptying into the Yellowstone, I saw No. 4 quite well developed, 60 to 100 feet in thickness, with its usual calcareous concretions containing *inoceramus*. The lithological characters approach somewhat those of No. 4, and is, I think, the upper part of No. 4 passing up into No. 5. The strata at first incline toward the west at an angle of 45°, but further examination showed that this dip was local, and was due to land-slides. Deposited upon it was a considerable thickness of sand and pebbles, stratified in alternate layers, filling up the surface irregularities, the layers of deposit conforming to the dip of the cretaceous rocks. The hills as well as the beds of the streams are paved with the nearly rounded pebbles or boulders which seemed to have been derived from all the older rocks, but for the most part from the metamorphic and paleozoic rocks. These pebbles are seldom of large size, more commonly four to six inches in diameter, though sometimes 12 to 18 inches, and they increase in size as we approach the foot of the mountains. It is worthy of remark and a subject which I shall investigate more fully hereafter, that as we approach the cretaceous rocks the contour or surface becomes much smoother, the hills are covered with grass, gently sloping, and the bluffs are hardly half as high. There is here a deep reddish yellow sandstone resting upon the well-marked cretaceous rocks which I cannot positively affirm as belonging to the upper part of No. 5 or the lower bed of tertiary. I am inclined to think that the same bed is seen holding some position high up on the Missouri and along the southern rim of the lignite basin as it skirts the Black Hills.

Passing up the valley of the Yellowstone we see the gray sandstone tertiary which we have observed to cover the cretaceous nearly to the foot of the bluffs. The junction of the formations is quite well-marked on both sides of the river. For a considerable distance, both above and below Fort Sarpy, a bed of sandstone forms nearly vertical bluffs on both sides of the river which I find it difficult to locate. Nos. 4 and 5, composed of yellowish brown indurated clay, with concretions containing *Baculites ovatus*, *rostellaria*, &c., in great abundance, occur, passing up into a dark gray, coarse-grained sandstone, containing also *B. ovatus*, *aricula*, like *A. Nebrascensis*, and an *ostrea*, new species. This also passes up into a sandstone having a most ragged front, from atmospheric agencies and the difference in the consistency of the materials composing the bed. It is, in the main, a coarse-grained, friable, ferruginous, yellow sandstone, but containing vast numbers of concretions, some a reddish yellow arenaceous limestone, others sandstone; some nearly compact, with laminæ; others divided into thin layers, the harder portions projecting out beyond the friable ones. The harder layers lie in the vertical cut, usually from 5 to 30 feet long.

The layers are quite irregular in their horizontal fracture. The whole bed exhibits indications of having been deposited in moving waters. May it not be the transition-bed from the cretaceous to the tertiary epoch; the foreshadowing of the tertiary period? A few rare and indistinct bivalves are seen, evidently of marine origin.

The cretaceous beds in this region are evidently exposed by the elevation of the Wolf range and the denudation of the superincumbent tertiary strata, and the area continues to widen until we arrive within 10 miles of the mouth of the Big Horn, when a series of marls, clays, and sandstones, lower than the true lignite beds, make their appearance, and are shown in some localities to rest directly upon the cretaceous.

Section near the mouth of the Big Horn river.

4. Ferruginous sandstone, like that described yesterday, underlaid by local beds of impure lignite, containing casts of a large species of *unio* and bones of turtle, 100 to 150 feet.
3. Yellow, feruginous, indurated, arenaceous clay, variable in thickness, 10 to 20 feet.
2. Very impure lignite clay, consisting of alternate layers of chocolate, dark brown carbonaceous clays, and dark ferruginous clays, with two feet dark-brown under-clay, 14 feet.
1. Laminated clays and sands, forming a slope of 80 feet from the river-bed, capped with 22 feet of more or less arenaceous clays, with layers of shale sandstone, strata dipping 4°, direction 20° west of south.

In bed 1 of the last section some masses of calcareous sandstone, containing *melanias* and *cyclas*, were found; and from these facts I infer that these beds are the same as those occurring at the mouth of the Judith. There is a great thickness at this point of loose, friable, ferruginous, arenaceous clay, interstratified with thick beds of sandstone. Near the mouth of the Big Horn river I think that the evidence is clear that there are a series of beds corresponding in age with the Judith deposits. We have, first, Nos. 4 and 5, with their peculiar fossils, *lingula*, *aricula*, *baculites*, *scaphites*, &c., reaching about 20 feet above the water's edge. In most places the cretaceous rocks are concealed by the sliding over of the superincumbent tertiary beds. Above the cretaceous beds we have 500 to 600 feet alternate beds of yellow, gray, and dark drab, indurated, arenaceous clays, with yellow, ferruginous, heavy-bedded, rather coarse-grained, friable sandstone. Like many of the beds near the mouth of the Judith, these seem to have been lifted up nearly horizontal, so that the dip, in most instances, is scarcely perceptible. Just below the mouth of the Big Horn I counted twelve of these alternations, and many of arenaceous clay and sandstone; the former varying from 20 to 60 feet, the latter from 10 to 30 feet, in thickness. The layers of sandstone contain many argillo-calcareous concretions of an iron-rust color, which break into small fragments on exposure.

From the mouth of the Big Horn to the union of the Yellowstone with the Missouri, the lignite beds occupy the whole country, with the exception of the portion already described and a distance immediately on the river of about seven miles, called Shell Point. The lignite beds are well-developed, and at least 20 to 30 seams are shown, varying in purity and thickness from a few inches to seven feet.

Near the mouth of the Rosebud creek there is a lignite bed which is five feet in thickness. Three hundred yards above, it separates into two parts, two to two and one-half feet each, with six to eight feet of arenaceous clay between. Five hundred yards further, the two beds begin again to unite, there being about six inches chocolate clay between. The lignite is quite pure. The sandstone at the base of the bluffs seems to be the same as that seen on Tongue river.

Section.

5. Yellow and gray arenaceous marl, capping the hills, contains numerous silico-calcareous concretions, 25 feet exposed.
4. Yellowish drab, very ferruginous, indurated clay, portions arenaceous, 30 feet.
3. Alternate layers; first, light ash-colored clay, with a larger amount of sesquioxide of iron as coloring matter, containing small roots ramifying all through it, 2 feet. Two inches dark-chocolate carbonaceous clay; then one inch pure lignite; then six inches dark brown indurated clay. Third, four feet very pure lignite. All the lignite contains small crystals of selenite, and the fractured portions are coated with a dirty-white saline substance.
2. Yellow and dark ash-colored clay, in alternate layers, 20 feet.
1. Gray and yellowish gray arenaceous clay and sand, with large concretions of very hard calcareous sandstone; the same bed as the one affording so many plants on Tongue river.

From the Black Hills to the Yellowstone we find that the surface of the country is occupied by tertiary deposits which, yielding so readily to the erosive action of water and other atmospheric agencies, is gashed up into innumerable ravines which form the "Bad Lands," so well known in this portion of the west. Everywhere on the summits of the highest hills or in the valleys a superficial deposit of gravel or water-worn pebbles of various sizes is seen, though in the interior of the country no heavy deposits occur. Along the valley of the Yellowstone, however, the drift deposits are quite conspicuous, reaching a thickness at times of 50 to 150 feet, and arranged in alternations of yellowish brown marl and small pebble-stones, showing stratification and indications of having been deposited in very turbulent waters.

CHAPTER VII.

FROM MOUTH OF BIG HORN RIVER TO BIG HORN MOUNTAINS.

ESTUARY DEPOSITS AT THE MOUTH OF THE BIG HORN—TERTIARY BEDS—GEOLOGY OF THE LITTLE HORN—GORGE OF THE BIG HORN MOUNTAINS—DIFFERENT FORMATIONS ALONG THE BASE OF THE MOUNTAINS—POTSDAM SANDSTONE AND ITS FOSSILS—CARBONIFEROUS BELT—FRIASSIC OR RED BEDS—JURASSIC—CRETACEOUS ROCKS WITH FOSSILS—GYPSUM DEPOSITS—EROSION OF SANDSTONES—SECTION OF VARIOUS BELTS EXPOSED BY THE ELEVATION OF MOUNTAINS—ABUNDANCE OF JURASSIC FOSSILS—POWDER RIVER—POWDER RIVER CAÑON—WIND RIVER VALLEY—INDICATIONS OF PERMIAN ROCKS—VALLEY OF THE NORTH PLATTE.

The country around the mouth of the Big Horn is occupied with from 600 to 800 feet of estuary beds, passing up into true lignite strata. The latter are only seen as we ascend O'Fallon's creek. Crossing a high ridge which seems to be covered with a considerable thickness of loose drift, we descend the valley of Tullock's Fork, where the same beds before mentioned are exposed with a bed of lignite 4 feet in thickness, corresponding with that seen in so many localities, as on Tongue river and other places. On the Big Horn a few miles above its mouth, I found in a laminated bed a quantity of fresh-water shells, which appear to be identical with those occurring at the mouth of the Judith. They consist of two species of *cyclas*, several *paludinas*, a *unio* and several saurian teeth.

For about 15 miles above the mouth of the Big Horn we have the tertiary in full, with its rough, angular outlines, and then comes a marked change in the topographical features of the country. The cretaceous then make their appearance, and the inclination is such that within a mile from the point where they first appear 30 feet are exposed, and within 8 miles 150 feet, presenting all the characters of No. 4—the upper portion, being yellow ferruginous, may represent No. 5.

The waters of the Big Horn were so deep that I could not cross over from the right hand to the left, where the cretaceous rocks are most finely developed, yet a few fossils were found which fixed their position. As soon as the cretaceous rocks appear, the high tertiary ridge, which is clothed with pines to some extent, begins to diverge from the river on both sides of the valley and finally disappear.

Near the mouth of the Little Horn, there is a high cut bluff, which shows 60 to 80 feet of gray marl very much like No. 3 as seen on the Missouri, though of a darker color. The dark gray marl gradually passes down into the black plastic clays of No. 2. On the left side of the Big Horn river, for about 25 miles above its mouth, the bottom varies from 2 to 5 miles in width. After passing the mouth of the Little Horn the bottom becomes narrower, and about 7 miles above the Big Horn cuts the hills on the left bank and the bottom commences on the right, and the surface of the country is rugged in the extreme. At this point No. 2 is from 100 to 150 feet thick, with small *ammonites* and numerous small iron rust concretions. Though No. 2 is quite largely developed but few fossils occur. It continues in full development and with strata very nearly horizontal or inclining gently, until we reach the vicinity of the gorge or pass of the Big Horn, where within 200 yards the strata become suddenly nearly vertical. No. 1 seems to be quite thinly represented, if indeed it is seen at all, and then come the jurassic beds without any apparent unconformability.

Section at the gorge of the Big Horn.

1. Whitish sandstones.
2. Variegated arenaceous marls.
3. Sandstone with a reddish tinge.
4. Brick red arenaceous material.
5. Hard blue limestone, 50 to 100 feet thick. This gives character to the gorge—the dip or inclination of the first upheaval seems to be from 30° to 50°.

No. 2 extends in a long ridge up to the mountains trending nearly southeast and northwest, and strata dipping 1°. Trees grow on the sides of the mountains sloping 50°, but the fire had run over the ground killing all the pines. Skirting along the north side of the Big Horn mountains, I do not think the jurassic is more than half a mile in width and is merely an outcropping formation. Then come the carboniferous limestones, with the same fossils as seen in the Black Hills. The gorge of the Big Horn is also carboniferous, at least the lower strata. In the jurassic bed are layers of sandstone with *ostrea*, same as seen in the Black Hills, and the same beds are covered with the trails of worms. The lower portion of brick red bed contains large quantities of snowy gypsum. Although the brick red deposits contain all through the beds either crystalline or amorphous gypsum, yet it does not occur in such quantities as found in the Black Hills. These red beds appear to be quite heavy-bedded and arenaceous. Beyond the brick red bed, which reveals its upturned edges inclining at various angles from 5° to 50°, we have a valley of denudation covered with carboniferous limestones, extending with a gentle slope for about 6 miles, and is not far from 1,500 to 2,000 feet in height. Sometimes the carboniferous limestones are shown under the brick-red deposits, dipping at the same angle with it.

On the north side of the Big Horn we can see a high ridge of tertiary, about 15 miles distant, apparently approaching us. The intermediate space is occupied with cretaceous rocks of No. 2 mostly.

September 12.—The belt of jurassic to-day has been about 2 miles in width, and the whole deposit, including the red beds, is much thicker, 800 to 1,000 feet. The upper sandstone is about 50 feet in thickness, presenting in many places vertical walls; then comes a series of variegated areno-calcareous shales and sandstones, and in one of the beds of calcareous sandstone are immense quantities of a new species of ostrea. The latter part of our road led us over No. 5 cretaceous, containing *baculites*, &c. In a seam of ferruginous sandstone, 3 feet in thickness below, was black clay, and above dark yellow iron rust arenaceous clay. The ridge of tertiary is now near us.

September 13.—We traveled most of the day over the upper portion of No. 5, cretaceous clay, seldom cutting down into No. 4. The summits of the hills are covered with a rusty sandstone, which is sometimes in regular layers, but often in spherical concretionary rocks, like those seen no Cannon Ball river. Along the latter part of the road to-day No. 5 is much inclined, usually about 25°. A cut bank reveals the character of the bed, which seems to be composed of alternate thin layers of yellow and ash-colored clay, with yellow and ash-colored sandstone, containing concretions.

September 14.—We continue to pass near the foot of the mountains. No. 5 is elevated in ridges, inclining at an angle of 15°. We then pass over No. 2 southward, and No. 1, which is concealed by grassy slopes, to jurassic, to the gorge of Tongue river, which exhibits to us one of the most magnificent views yet seen. The main branch of Tongue river as it issues from the mountains is a swift running stream of pure crystal water, about 12 inches deep and 10 to 15 yards in width, and cuts its way through about 1,000 feet of light yellow limestone rock. The strata all dip at a large angle, but looking up the gorge they seem in most cases to be nearly horizontal. In the distance north about 15 miles, we have the summit of a ridge which appears to be a continuation of the Wolf range, and is undoubtedly of tertiary age, though upon the base of the southern side the cretaceous rocks must be exposed. This ridge is about 800 to 1,000 feet above the bed of the stream beneath, and the strata have felt but slightly, comparatively, the influences which have elevated the Big Horn mountains. This high tertiary ridge has undoubtedly been elevated to its present height by internal influences, but the tertiary as well as most of the intermediate cretaceous strata have not been much disturbed. It is not until we come into immediate proximity to the mountains that we see the full force of the upheaval, and then it commences quite abruptly, forming a series of nearly parallel ridges, trending nearly east and west, and dipping at angles varying from 30° to 60°. Toward the north, Tongue river with its various branches cuts through the ridge nearly at right angles, and taking a northeast course touches the tertiary beds within 25 miles.

The vallies and cañons that extend down from the mountains are very nearly northeast and southwest, forming to the sight, as we pass along the northern base, a series of upheaved ridges "*en échelon*" as it were, one after the other, the one more west passing beyond the one more east. Therefore the inclination of the strata are for the most part nearly northeast. The jurassic rocks to-day form a belt about two miles mide and are also thinly represented on the higher hills. The series of beds would stand thus: 1st, brick red bed, mostly compact calcareous sandstone, near the base a small quantity of gypsum; 1st ridge, dip 32°, height 50 feet. 2d ridge, 200 feet high, dip 35°, remainder of brick red bed, capped with about 15 feet compact brittle, bluish, cherty limestone. 3d, 20 feet, brick red grit. 4th, 5 feet, very light gray cherty argillaceous limestone, dip 21°; then comes a valley, showing you the southwest slope, about 150 feet of bluish ash-colored shaly arenaceous marl, cropping out in many places and dipping about 15°, capped with 15 to 20 feet of compact heavy-bedded arenaceous limestone. Beyond are grassy slopes, concealing the other rocks. About six miles on our course, the distance between the foot of the mountains and an outcropping upheaval of No. 5 is not more than two miles. The other cretaceous formations are concealed by grassy slopes, except in the cuts of the little streams. The jurassic is not more than from half a mile to a mile in width. The dip of the rocks, comprising No. 5, is about 15°, but not more than 50 feet above the water level. It is a ferruginous yellow friable sandstone, with numerous layers of rusty sandstone concretions, many of them spherical, the whole formation being lithologically very much like the upper part of No. 5, on Cannon Ball river. In the distance the ridge of tertiary bends down with the valley of Tongue river, then comes up again on the opposite side, so that we have patches of the tertiary within three miles of the base of the mountains, and it is even seen in the form of a ridge upheaval on the latter part of our road to-day, the strata inclining at an angle of 5°. The summits of the ridge present a beautiful red appearance from the burning out of lignite beds. There is a belt of country from the base of the mountains northward, which has been smoothed to a great extent by water, and all the hills are paved with fragments more or less worn of the rocks in the vicinity.

Traveling southward toward the mountains, we see on the cretaceous belt the drift rocks of that period with those of the formations to the south of it to the mountains. On the jurassic belt we see no cretaceous rocks, but a few jurassic carboniferous, with a few granitic, and so on. We can thus see that the influences which scattered these rocks over the country proceeded from the mountains. We have already stated the direction of the valleys; the ridges and the theory of upheaval will be developed in another portion of the report. I found to-day in the upper part of the jurassic, *Belemnites densus*, in the greatest abundance, associated with a new species of *ostrea*.

September 15.—There is a distance of two or three miles between the tertiary outliers and the foot of the mountains. The jurassic appears along the edge of the hills, but is not conspicuous. The cretaceous is also covered with a superficial deposit, but in the distance from 8 to 15 miles the tertiary beds are visible, with apparently horizontal strata. The lignite beds having been burnt out, give to the surface an unusual reddened burnt appearance.

September 16.—We have a great thickness of carboniferous limestone inclining from the axis of upheaval at angles from 30° to 60°. The lower portion is a bluish gray argillaceous limestone, composed of nodules of clay cemented with lime. This bed seems to be the lowest, and to be about 50 feet thick. That the azoic rocks exist to some extent is evident, for some fragments of schistose rocks occur. In the distance we can see the snow-clad peaks, which are composed of red feldspathic granite. Near the head of the most southern branch of Tongue river the distance in a straight line from the tertiary to the granite is not over five miles. For mapping purposes we may say about four miles of cretaceous rocks, which are mostly concealed by grass, a half a mile jurassic, and a half a mile carboniferous limestone; and although hitherto we have had 1,200 to 1,500 feet of carboniferous rocks, I would not think that they were here more than 400 or 500 feet. Near the head of Clear Fork of Powder river I noticed a considerable thickness of steel-gray rock, (*trap*, *hornblende*, &c.,) then a great thickness, 300 feet, of yellowish white cherty limestone, dipping at an angle of 30°. One bed still lower, 30 feet thick, was very vertical, 80° inclination. There was a most remarkable illustration of the drift to-day where the lower mountain ridges, which seem to be 1,500 feet high, are composed of water-worn, nearly rounded granite boulders, with the loose eroded or decomposed material of the granite rocks. Over the top of this deposit are about 10 feet of yellow marl. I do not think that the entire bulk of the hills is composed of this drift material, but a great thickness has been accumulated, concealing all the rocks beneath. Vast quantities of granitic and other rocks are strewed over the plains below. It is only at this point so far on our route that the granite rocks have made their appearance in the first series of upheaved ridges. The erosion to form the valley of Tongue river, with its numerous branches, causes the southeastern edge of the great lignite basin to curve very greatly toward the northwest. It then returns, forming a high divide between the hydrographic basin and Tongue river, and that of Powder river. As far as one can see, perhaps a distance of 30 miles, there is most abundant evidence of the burning out of the lignite beds. The thick bed of lignite which occurs on the Yellowstone seems to have spread over a great area of country and to have ignited to a great extent, giving to the surface of the country a picturesque appearance.

September 19.—Traveled to day $15\frac{7}{10}$ miles. On our left are numer-'us high hills, covered with large ledges of red-burnt rock, varying in haracter from a brick-like mass to a completely melted condition. 'here is a very large district on our left which exhibits indications of he burning out of the lignite beds. The indications of cretaceous and ırassic rocks have been exceedingly faint to-day. Jurassic is revealed 'erhaps one-fourth of a mile wide; the cretaceous is concealed by an nmense deposit of drift. The high ridges extend down from the base f the mountains 500 to 800 feet high, thickly covered with worn and ngular masses of granite, hornblende, limestone, and small masses of ·hite quartz. The tertiary extends up within a mile of the mountains, nd seems to be composed of fine arenaceous material, mingled with mall quartz pebbles. The arenaceous material is gray, and various hades of yellow, from a light to a deep ferruginous, with alternations f impure lignite. There is a great deal of wood in the lignite beds; ome in the form of large masses lying lengthwise in the beds, others olding a vertical position in the sandstone.

I think that these lignite beds, which are very impure, are formed by he drifting in of the wood. In some places this impure lignite bed is 8 eet thick. The tertiary beds are disturbed to some extent so that at ne place they incline at an angle of 5°. Lake Desmet is a beautiful lear sheet of water, about three miles long, and one-fourth to half a mile ı width, surrounded on all sides by tertiary hills, capped with large ıyers of burnt rock. The water is fresh, though but little vegetation urrounds it; but the shores are paved with small masses of the burnt ock.

September 20.—The high hills near the base of the mountains are ıostly tertiary; a few indications of cretaceous are seen, and the juras-ic, although in the form of a very narrow belt not more than half a ıile wide, is still visible. Our road is about ten miles from the base of he mountains, and nearly nine miles of it is occupied with tertiary eds. I measured three successive ridges within two miles of the foot f the mountains, and found that the strata inclined respectively 25°, 1°, 21°.

In many places the superficial deposits seem to conform to this dip. 'he southwest side of these ridges is very abrupt in its descent and the ortheast slopes gently, and on the southwest side immense quantities f rocks from the various formations in the mountains have been lodged, howing most clearly the direction from whence they came. Cretaceous [o. 5, in this region, consists of alternations of clay and fine marl, with ıyers of concretionary ferruginous calcareous sandstone inclining north-ast, nearly vertical, at an angle of 85°. A few shells were found in the arder masses, among which I notice *cyprina*, two species, a *natica*, a *llina*, an *inoceramus*, *baculites*, *rostellaria*, &c. The belt of No. 5, ·hich shows this manner of upheaval, is about three-quarters of a mile in ·idth. The tertiary strata dip 31°; again, further from the mountain's ıclination, 16°. Tertiary hills, 200 to 300 feet high, dip 10°, 22°; again 1°; still further 15°; again 25°.

September 21.—Soon after leaving camp, right side of the road, the rst ridge is composed of the sandstone of No. 5, 70 feet high; trend outheast and northwest; inclination northeast and southwest 18°. This dge is about three miles from the base of the mountain. Six hundred ards further toward the mountains is another ridge, parallel to the last,) feet high, and inclining 7°. These ridges contain, at various locali-es, remnants of the tertiary rocks, showing the intimate connection of :etaceous No. 5 with the lignite basin. The first high ridges of elevation have revealed the older rocks, the limestones having a general dip of 60°, while the granites are vertical, or nearly so. Near our camp of this morning the first high ridge of carboniferous limestones runs out, and a second more sloping ridge commences, covered with pines, the carboniferous limestones prevailing, and inclining 30° to 50°. To-day the red beds are more conspicuous, and the cretaceous rocks cover a belt of two or three miles. The influence of the elevation of the mountains extends from their base 10 to 15 miles, disturbing the tertiary beds to a greater or less extent, until it dies out in the plain country. The hills all around the mountains are covered with great quantities of limestones and buff magnesian limestones, also granite rocks, showing the powerful forces which have been in operation near the verge of our present period.

September 22.—The cretaceous is becoming more extensively developed, as also the jurassic. A large amount of drift material and marl, forming grassy slopes which extend entirely up to the high upheavals of the carboniferous limestone, but toward the close of our day's travel we find a change in the surface of the country, which leads us to the high mountains by lesser upheavals, and the indications of erosion are far less conspicuous.

September 24.—The cretaceous occupies a large area near the sources of Powder river, and is much disturbed, the strata of many of the ridges inclining 11°. We seem to come to the end, as it were, of the lofty ridges, and by the *en échelon* arrangement the mountains make an extensive flexure towards the west and southwest, and gradually die out to a great extent. The first high ridge outside of the granite nucleus is about 2,000 feet high, composed of carboniferous limestones which incline 50°. From this ridge, about two miles in a straight line to the top of the next ridge, which inclines 30°, is deeply cut by streams, forming cañons. The jurassic is well developed in the valley and along the base of the hills. The ridges gradually pass off and die out in the prairie toward Powder river. There is an intermediate ridge, composed of jurassic and most of the red arenaceous beds, commencing near the base of the first ridge and running parallel with the second, about 500 feet high at its loftiest portion, covered with pines, with a dip 25° to 30°. It commences near the head of Willow creek, and is not more than 30 feet high, but gradually growing higher and higher toward the southeast. This forms "Red Cañon pass." There are a great number of low intermediate local ridges, from 30 to 100 feet high, the strata inclining at various angles from 10° to 30°. The high ridge of carboniferous limestone is 500 feet high, the ridge of red earth 300 feet.

A section of the ridges commencing with the first ridge of sedimentary fossiliferous rocks near the granitic nucleus and proceeding outward at right angles with the trend would be as follows:

First ridge. Carboniferous lines and sandstone underlaid by Potsdam sandstone; height 1,000 feet; inclination 30°.

Second ridge. Lower part of red arenaceous bed; valley between first and second ridge two miles wide; inclination 24°; height 300 to 500 feet.

Third ridge. Lower part red bed, upper portion a brown calcareous sandstone in separate layers, probably the cherty limestone; valley 200 yards; inclination 19°; height 300 feet.

Fourth ridge. Brown sandstone at top and arenaceous shale at bottom; contains an abundance of *pentacrinus* and *ostrea;* valley 300 yards; height 200 feet; dip 14°.

Fifth ridge. Alternate layers of brown calcareous sandstone and ashen gray laminated marl; valley 600 yards; height 60 feet; inclination 11°.

Sixth ridge. Mostly sandstone; valley 100 yards; height 50 feet; inclination 10°; a sub-ridge.

Seventh ridge. Ashen gray laminated marl at base with calcareous sandstone at the summit, almost made up of *Ostrea avicula*, same as seen in the Black Hills, also a few *belemnites*, (*B. densus;*) valley 300 yards; height 60 feet; dip 10° to 11°.

Again we have a second description of the ridges:

First ridge. Carboniferous limestone; inclination 30°.

Second ridge. Two hundred and fifty feet of brick red arenaceous material with gypsum. This bed and the jurassic form a series of ridges extending eastward toward Pumpkin butte. The brick red bed occupies a belt about a half a mile wide here, but after passing this zone we have about 600 yards, forming three ridges in close succession, capped with from 10 to 15 feet of blue limestone.

Third ridge. Eighty to 100 feet light gray sandstone and shale; valley 500 yards; dip 11°.

Fourth ridge. Valley 800 yards; height 150 feet; dark gray argillaceous shale with thin layers of calcareous sandstone and spherical concretions; toward the summit a layer two inches thick, composed almost entirely of *Ostrea avicula* in an exceedingly comminuted state, capped with about 15 feet of calcareous grit in shelving layers; dip 11°.

Fifth ridge. A series of variegated beds, greenish, ash-color, iron rust, yellow ferruginous, light gray, deep purple, with three or four seams of very impure lignite—ascending, first, greenish marl; second, iron rust; third, yellow ferruginous; fourth, dark ashen gray; fifth, greenish ash; sixth, dark gray clay; seventh, dark impure lignite—these beds alternating with clay 18 inches to two feet each;—eighth, yellow ferruginous; ninth, light gray; the whole 100 feet; dip 14°.

Near the lignite we find a considerable quantity of silicified wood in a most perfect state of preservation, also fragments of bones. Are not these beds transitions from jurassic to cretaceous, or may they not represent some portion of No. 1? The sandstone on the summit of these beds is about 40 feet and the black plastic clays of No. 2 rest directly upon them.

Sixth ridge. Between the transition beds and the main ridge of No. 2 are the small intermediate ridges, but the main ridge is about 80 feet high, trending nearly north and south, composed of black plastic clay, passing up into light ash-colored shale, like that seen in the Shyenne river beyond the head of the Little Missouri; this also passes into a black plastic clay; dip 10°; valley half a mile wide with the two intermediate fragmentary ridges 40 feet high.

Seventh ridge. We have a valley half a mile wide, and a ridge 150 feet high, composed of Nos. 4 and 5, with a dip also of 11°.

Eighth ridge. Valley of Willow creek three-fourths of a mile wide to summit of last ridge; 200 feet, composed of tertiary, alternate beds of dark clay, sand, sandstone, and marls; dip 8°.

All the country about the immediate valley of Powder river seems to be cretaceous for a considerable distance from the foot of the mountains, and in the black plastic clays of what I must consider No. 2, I found *avicula*, *inoceramus*, and a *baculite*, all of undoubted cretaceous types. In passing up Red Cañon creek we find an immense development of jurassic with *belemnites*, *avicula*, *ostrea*, and a large species of *avicula*. The brick red bed here presents a mural front 250 to 300 feet high, the upper portion nearly horizontal, the lower part dipping 10°. There is the appearance of an anticlinal here but I do not think it is a true one. The strata are made to assume this appearance by the course of the creek through the upheaved ridges.

September 27.—We ascended the lofty ridge in which Powder river takes its rise. Over the surface of the ridge are traces of the brick red bed, but it is mostly composed of fine-grained, rather arenaceous, limestone, a calcareous sandstone, ferruginous, tinged with red. This sandstone is at least from 800 to 1,000 feet in thickness, and the little branches of Powder river wearing their way through it have formed immense cañons which are exceedingly picturesque in their character. Looking from this high ridge eastward we can see by the upheavals the outcropping edges of the different formations in their order, the red brick deposits, jurassic, cretaceous, and tertiary. We will here give a section outward, including the great ridges:

1. Eight hundred to 1,000 feet of calcareous sandstone with the strata at times elevated nearly horizontal or dipping 8°.
2. Brick red bed 450 feet thick, contains along Red Cañon creek a great many layers of gypsum from one inch to ten feet in thickness; also some thin layers of magnesian limestone and yellow calcareous arenaceous material. The gypsum is local, entirely absent in many places.
3. A blue magnesian limestone varying much in thickness; then a series of arenaceous laminated marls and heavy bedded sandstones of various colors, containing fossil shells 400 to 600 feet in thickness.
4. A series of variegated clays and marls 300 to 400 feet thick; the transition series.
5. Laminated plastic clays and alternate thin layers of sand and clay with heavy bedded sandstone, containing fossils of cretaceous forms, (No. 2,) 400 to 500 feet thick. I can see nothing that represents No. 3, but Nos. 4 and 5 with baculites, and in regular order the tertiary, all more or less disturbed.

Descending Powder river we find that the influences of the elevating power of the Big Horn mountains extends below the mouth of Pumpkin Butte creek 50 to 60 miles beyond the edge of the lignite tertiary. These influences are shown in the form of a regular series of ridges extending across the country, growing less and less conspicuous and the inclination diminishing as we recede from the focus of power.

The tertiary ridges incline from 15° to horizontal.

In ascending Powder river, on our way to the Platte, we made a careful examination of No. 2. It is barely possible that No. 1 is represented in this region, but I see nothing that indicates its typical form as shown near the Big Sioux on the Missouri; but the lower cretaceous is for the most part a black plastic clay, and it would seem to me that No. 1 has thinned out or has been merged into an increased development of No. 2. In the valley of Powder river we have 80 feet of shining shale, very much like that of No. 4 near the mouth of Grand river, resting upon the transition beds, passing up into a gray sandstone; then 300 feet of plastic clay, mostly an indurated clay slate with fish remains, passing up into a clay shale with a few seams of arenaceous material and a seam of impure lignite capped with yellowish gray sandstone 80 to 150 feet in thickness. These beds are sometimes very nearly horizontal, then again dipping 11°. They occupy a large area and form quite picturesque Bad Lands.

In Red Cañon creek, near its entrance into Powder river, we have a section as exposed of an anticlinal axis in ascending order:

1. Brick red arenaceous bed.
2. Yellow gray arenaceous marl, 50 feet.

3. Layers of yellowish calcareous sandstone, 15 feet.
4. Yellow calcareous marl with *belemnites*, 50 feet.
5. Alternations of limestone and marl, 20 feet.
6. Marl, 50 feet.
7. Yellowish-gray sandstone, 10 to 15 feet.
8. Variegated marls and sandstones, (transition,) 200 feet.
9. Plastic clays and shale of cretaceous, No. 2.

This series of beds from which the above section was taken assumes the form of an anticlinal by the waters of the Red Cañon creek, cutting through an upheaved ridge, the strata dipping each side from the cut; on the one side the strata dip from 6° to 10°, and on the other side 40° to 60°.

Again farther up the river, where the outcropping edges and the regularity of the upheavals are exhibited so finely, I took the detailed section with much care, and this, I hope, will confirm the order of sequence of the beds. At this point I begin with the red beds, and continue outward.

1. Red arenaceous material. There is a good deal of difference in the composition of the layers. The lower portions seem to be alternations of clay and sand, with layers of compact limestone, 150 feet.
2. Light gray, cherty magnesian sandstone in loose layers, 8 feet.
3. Brick red bed sandstone. Much of it would make good building material. The strata dip about 8°.
4. Red arenaceous laminated marl, passing up into a light gray ash-colored marl, 30 feet of each.
5. Arenaceous limestone in loose layers; contains great quantities of *pentacrinus*, very rarely *ostrea* and *avicula*, 25 feet.
6. Ash-colored arenaceous laminated marls, forming slopes in most instances; contains great quantities of *Belemnites densus*, *pecten avicula*, *mytilus*, *dentalium*, &c. In this bed is a hard layer, 3 feet thick, of arenaceous limestone, mostly composed of comminuted remains of fossils, and toward the summit 15 to 20 feet of fine-grained, heavy-bedded, light brown sandstone, in which I saw no fossils.
7. Yellowish brown arenaceous marl, forming slope 36 feet, capped with limestone 2 feet. This rock is concretionary, and is sometimes 10 feet or more in thickness.
8. A series, 200 feet in thickness, of variegated beds, which I have before mentioned as the transition series. It here contains silicified wood, impure lignite, and some uncharacteristic bones.
9. Resting directly upon bed 8 we have dark, plastic laminated clays of No. 2, with true cretaceous fossils.

At one locality the transition beds contained a bed of impure lignite 18 inches in thickness, and just beneath it were a quantity of vertebra. At the top was a thick bed of sandstone, which seems to indicate a physical change in the condition of this region. This rock presents every variety of character: a fine hard chert, an aggregation of grains of quartz cemented with yellow oxide of iron, a conglomerate of small water-worn pebbles, and fine-grained ferruginous sandstone. The whole presents the finest examples of false bedding, or oblique laminæ, inclining 60°. This marked change in the physical condition induces the belief that the upper portion of the transition series may be the break between the jurassic and cretaceous beds. The rounded hills at the left are composed of the black plastic clays of No. 2, while the river cuts the red beds and the carboniferous limestone.

Throughout the region where the red beds are exposed there is a considerable thickness of conglomerate of well water-worn pebbles, with the red earth and sesquioxide of iron. This bed is undoubtedly recent, and rests upon the worn edges of the brick red bed, conforming to the irregularities of its surface.

October 4.—A series of beds have accompanied us to-day lying directly under the red deposits: 1st, a very hard, cherty magnesian limestone; then loose thin layers of fine yellow limestone with partings of clay; then deep-yellow, ferruginous gypseous laminated limestone, with layers of fine calcareous nodules.

Near the base of the blue limestone is one layer of shells containing *myalina*, and many others, in the form of casts, which, with the character of the rock, indicate a permean formation.

October 5.—The red bed occupies a belt from 2 to 4 miles in width. The jurassic beds also covered an area half a mile wide; the transition series half a mile to a mile; then comes the cretaceous, extending off a long direction. The dip of the beds is about 8°. For several days we have seen the drift or erratic rocks to a great extent, and to-day the valleys and hills are covered with them to an unusual extent, which are composed of all the rocks in this region.

We ascended the high ridge to our right, which overlooks the Wind River valley. On the summit of this ridge I saw the Potsdam sandstone quite well developed, with some of its characteristic fossils. Far to the west we can see the vertical edges of the azoic and granitic rocks occupying a large area, and as we cast our eyes eastward to the plain country we look across the outcropping edges of the different fossiliferous rocks, and it seems to me quite plain that they all conform to each other.

The Potsdam sandstone is exceedingly variable in its character. Near the base it is a reddish flesh-color, very compact, composed of an aggregation of quartz pebbles cemented with silicious matter. Higher up it is arranged in thin layers of calcareous sandstone, with fossils; then still higher up it assumes a compact vitreous character. Many of the slates are covered with what appear to be fucoidal markings. The belt of permian and carboniferous rocks is from 2 to 4 miles wide, dip 12°. The Potsdam is here about 200 feet in thickness. The lower beds of carboniferous limestones are exceedingly compact, cherty, resting directly upon the Potsdam. Underneath the true permian is a red bed, which I have included in the permian, so that the red character of the material is not peculiar to the red arenaceous deposits above. The limestone is a yellowish white, very hard rock, containing few fossils quite imperfectly preserved, indicating the carboniferous era, however, and they are the same, lithologically, as seen in the Black Hills. They rest directly upon the compact silicious rocks of the Potsdam, but with an irregular surface. Although the erosive power of water has been such that most of the carboniferous rocks have been worn away from the central area of the mountains, patches are seen capping the summits of the ridge, showing that it once extended continuously over the whole area occupied by the mountains.

October 6.—Our road has taken us along a valley with walls of the brick-red material on either side for several days. To-day, in a deep cañon, I noticed some peculiar lithological characters which may be worthy of note. Near the middle of the bed is a layer of blue silicious limestone, which, with the strata above and below, present some variations. Below the limestone there is about 6 feet of the arenaceous material, which varies between a light ash color and a brick red. Sometimes it is wholly the one, sometimes the other with streaks or clouds of red; then comes the layer of blue, very hard cherty limestone, sometimes with a reddish or yellowish tinge, arranged in thin irregular laminæ ¼ to 2 inches in thickness, which are very much flexed by pressure; then a ferruginous light yellow and deep yellow sandstone, in layers from 6 inches to 8 feet in thickness, separated by thin seams of red marl 1 to 4 inches thick; sandstone bed 46 feet; red earth 27 feet in thickness. These red beds dip at various angles from 1° to 3° in different places; sometimes, however, the inclination is as great at 30°. Passing from the drainage of Powder river to that of the North Platte southward, we pass over the cretaceous beds inclining 20° for about 2 miles, and then come to the tertiary beds, which are more or less disturbed throughout this region. These beds are developed to an enormous thickness in this region, at least from 1,500 to 2,000 feet, and dipping at very high angles, often almost vertical, very often inclining 75° and 80°. They are composed of alternate beds of yellow and whitish sandstones, brown and gray sands and clays, with one conspicuous seam of red earth. These tertiary beds occupy the Platte valley for the most part, the cretaceous beds occasionally appearing from beneath the upheaved tertiary strata, and occupying very small areas.

I will, in a subsequent chapter, speak more in detail of the geology of this region, under the head of the geology of the Platte valley.

CHAPTER VIII.

A JOURNEY TO PUMPKIN BUTTE AND THE SOURCES OF THE SHYENNE RIVER.

DEER CREEK AND PLATTE VALLEY—TERTIARY BEDS ALONG THE ROUTE—LIGNITE BEDS—CHARACTER OF PUMPKIN BUTTE—RESULTS OF BURNING OUT OF THE LIGNITE BEDS—DENUDATION OF THE COUNTRY ALONG THE FOOT OF THE MOUNTAINS—RED BUTTES—WHITE RIVER TERTIARY BEDS—THEIR RELATION TO THE LIGNITE BEDS—LARAMIE PEAK—LONG'S PEAK—SHYENNE PASS—LARAMIE PLAINS.

On the morning of October 19 we left Deer creek, on the Platte river, taking an easterly direction across the country toward Pumpkin butte. After crossing the Platte at Berronett's trading post, we passed over the hills 300 to 500 feet in height above the waters of the Platte. These hills are composed of alternate beds of sands, clay, sandstones and impure lignites, all inclining from the mountains. The whole region from the Platte to Pumpkin butte is covered with the true lignite beds, in many places disturbed to some extent. There are a considerable series of ridges extending from the Platte to Powder river. The country is exceedingly barren, no vegetation except that which is peculiar to an arid climate and a loose sandy soil, very little water, and that strongly impregnated with saline substances, and very little wood except a few cottonwoods along the streams. A few stinted pines are seen on the hills; several species of sage grow quite abundantly. On the summit of the hills there is a red iron rust rock, which sometimes assumes the form of a conglomerate or an aggregation of small water-worn pebbles, mostly quartz, showing a change in the physical conditions. The whole rock is tolerably rich in iron ore and identical in appearance with No. 1, as seen on the Missouri near Blackbird hill. The highest point measured by the barometer was about 800 feet above the Platte, though a high ridge was upwards of 100 feet higher, with a bed of burnt clay on the summit, doubtless the same layer seen all along the base of the Big Horn mountains. There are numerous beds of lignite more or less pure, and great quantities of silicified wood, sometimes in the form of trees 50 feet long and from two to three feet in diameter, and looking very much like the water-worn driftwood that we see along our streams.

Pumpkin buttes are a most remarkable range of hills from 1,000 to 1,200 feet above the bed of Powder river, which runs near their base. This range is about six or eight miles long, and the inclination of the beds, though slight, is quite apparent. They are evidently monuments left after the surface erosion of the country to afford us some idea of the thickness of the tertiary strata that once existed here. The southwest side is by far the highest, and the trend about northwest and southwest. The north side is less abrupt, clothed with grass and sloping gently down to the open prairie, while the south side is very abrupt and very much eroded by the action of water. There is a considerable area on the surface, which is exceedingly smooth as if planed off by the action of water, and strewed over this surface are great quantities of erratic rocks, and among them some bones and fragments of turtles which are like those *found in the* White Pine tertiary bed.

The following detailed section of these buttes was taken in descending order:

1. Light yellow friable sandstone with numerous rusty seams 75 feet, passing up into a light gray rock composed of grains of quartz cemented with siliceous matter. The quartz is of different colors—clear white, milky white, black, &c.; the largest grains about the size of a pea. This bed is quite variable in character; sometimes it is a partial conglomerate of water-worn pebbles, the whole presenting the same examples of oblique laminæ as heretofore mentioned. Between the more compact quartzose rock 50 to 60 feet in thickness which caps the butte and the ferruginous, friable sand beds, is a thin layer, six inches, of laminated clay, of a bluish drab color. The compact bed of sandstone caps all these hills, and gives them the flat table-like surface which they present at a distance.
2. Alternate beds of lignite gray and yellow ferruginous, friable sandstone, with bluish ash-colored, gray and yellow reddish tinged marls and clays, with three thin seams, one to two inches thick, of impure lignite, 125 feet.
3. Indurated, yellow and ash-colored marls, with three small seams of impure lignite, with one thin layer, six inches in thickness, of reddish yellow sandstone, 60 feet.
4. Thin seam, 8 inches, of impure lignite with numerous fine crystals of selenite and many masses of petrified wood.
5. Variegated clays and marls with much sulphuret of iron, and two small seams of lignite, 33 feet.
6. Impure chocolate lignite with clay underneath and large quantities of selenitic crystals, 2 feet.
7. Light gray and bluish ash-colored indurated sandstone, laminated clays and marl, with one or two seams of chocolate-colored, impure lignite, 148 feet.

We then have similar rocks, except with some thick beds of lignite, sloping down to Powder river. Most of the beds in the above section have not before been seen in this region, and it is impossible to trace their parallels in other portions of the lignite basin.

Leaving Pumpkin buttes we proceeded towards the source of the Shyenne over a similar barren, treeless and very waterless region. We have also the same lignite formations, with now and then a bed of tolerably pure lignite. The country, however, is covered with the tertiary beds which are eroded so as to form Bad Lands in the form of conical hills and ridges gashed with innumerable gullies, formed of the myriads of little dry creeks which ramify through the country. There is near the source of the Shyenne a most remarkable series of hills of varied forms so connected together as to form a ridge which extends far across the country from the Platte to the Big Horn river. The summits of all these hills are covered with burnt rocks in a melted or semi-melted state, and they are from 150 to 200 feet in height above the surrounding prairie. All the country around is scooped out, as it were, and the surface is smoothed and clothed with grass, and thus the country is covered thickly with these rounded buttes, which are denuded so as to show the different colored strata corresponding in each butte over larger areas. We might suppose that these hills form the borders of a lake and that they had not been subjected to the same aqueous forces as the intervening country. It seems to have a well-defined eastern and western shore. Sometimes the lignite beds are from 6 to 8 feet in thickness and more or less pure, and in many localities fossil plants are most abundant and in a fine state of preservation. There is so great uniformity in the character of the country that it will be a needless repetition of details to describe the whole country in full. It is sufficient to say that it is everywhere a most bleak and barren district, and the principal vegetation consists of several species of sage and the well-known grease wood which is fond of the saline clay and sand of this region.

During the autumn and winter of 1859–'60 I made various tours along the Laramie mountains and the country bordering upon them. In order to avoid too much repetition I will condense the whole material as systematically as possible, commencing with the Red buttes, the most northern end of the Laramie range. I will simply in this place give the details of the geology from point to point, referring the reader to the chapter upon the physical geography of the mountain chains.

Near the valley of Bates's fork, the northern portion of the range of mountains gradually passes off into the prairie. To the southwest are the Medicine mountains, and in the west the Sweetwater, and toward the north the Big Horn range, with which I am inclined to think the Laramie mountains are more intimately connected. This is inferred from the fact that the lower anticlinals extend off in a north or northwest direction. Indeed the Red Buttes themselves are anticlinals, exposing simply the red beds, and though the strata dipping each way from a central axis may be seen extending across the country far to the north and west, yet, after leaving the Red Buttes, the jurassic ceases to appear and then the cretaceous, and finally only tertiary beds are seen until we reach the vicinity of the Big Horn mountains, when all the formations reappear in their regular order. Between the Laramie range and the mountains just mentioned, is a distance of 30 to 40 miles of comparatively plain country, occupied by the more recent tertiary and cretaceous formations, which are but slightly upheaved and in some places nearly or quite horizontal. At any rate there is an evident break in the elevatory forces, and the connection between the Laramie range and the Big Horn mountains is shown by low anticlinals extending off to the northwestward joining on to the Big Horn range. This locality is called the Red Buttes, from the fact that the red arenaceous deposits are revealed in their full development by the passage of the Platte through one of the upheaved ridges. We have here, near the head of Bates's fork, the central portions of the range, which are evidently composed of the red feldspathic granite. From this point to Pike's Peak, I did not see indications of the more recent igneous rocks, but the lower ridges were composed of a coarse red feldspathic granitic rock, containing much iron and readily decomposing, so that the superficial covering to a great thickness is composed of the debris of these rocks, but as we approach the central axis of which the lofty peaks form a part, we find the compact enduring red feldspathic granite which resists atmospheric agencies to an enormous extent. The stratified azoic works are less abundant and less conspicuously develped than in the Black Hills. Along the North Platte near the head of La Prele, the azoic rocks are seen presenting the same characters as near Fort Laramie and in the Black Hills, but it is near Raw Hide Peak and about 7 to 10 miles north of Fort Laramie that we see these rocks, quartzose mica and clay slates, schists and trap rocks in their full development and standing for the most part vertical. After passing Laramie Peak, the intermediate space between the last named peak and Long's Peak is occupied by a comparatively low ridge of upheaval, which is composed of the rotten or decomposing granitoid rocks before mentioned. I could see here no indications of the stratified azoic rocks.

These granitoid rocks are of various kinds, and containing more or less iron, but truly feldspathic in all cases.

I did not see any fossils in the rocks which I have considered as of the age of the Potsdam sandstone. Its first appearance in this range is near the source of La Prele creek, where it is exposed by a sort of anticlinal axis, and underneath a large thickness of carboniferous and red arenaceous rocks we can see its outcropping edges. I will here give the whole as taken from my field-notes: "Just back of La Prele trading post we have a fine example of the anticlinal axis. The strata dip nearly north and south, or a little east of north. The rocks on the north side of the axis are exposed down to the granite, which is nearly vertical dipping to the east. On the south side I see only the carboniferous limestones, which at one locality dip 84°, though the usual dip is about 32°. The valley between the outcropping strata is not more than one-fourth of a mile in width. On the south side are limestones with intercalated red marls, but this side is not half as high as the opposite side. There are layers of a hard yellow magnesian limestone 4 to 10 feet thick, with beds of red marl and reddish sandstone, with the most contorted laminæ, 10 to 50 feet in thickness, and having a dip varying from 38° to 48°. After going beyond the anticlinal ridge which occupies a belt about two miles in width, we see a fine park-like area about ten miles wide, before reaching the main crest of the mountains. On the north side of the anticlinal we have the following series of rocks: First, Potsdam sandstone, resting upon the upturned edges of a series of stratified azoic rocks, dipping east at all angles from 40° to verticality. They are composed of red feldspathic granites, quartz seams, dark steel-colored schists, mica and clay slates in alternate layers or beds elevated about 60 feet above the valley between the anticlinal. The Potsdam sandstone is from 30 to 50 feet in thickness; the lower portion is a subcrystalline quartz rock, fine-grained, then a friable sandstone with distorted laminæ, again a subcrystalline rock with a layer of quartz conglomerate, dip 20°. Resting conformably upon the Potsdam and dipping at nearly the same angle, 30°, is a series of beds of limestone evidently carboniferous: First, a yellow cherty limestone with many partings, but cherty all through, 80 feet. We then come to the summit of the ridge, which dips at the top 30°. We then pass over a little west of north across a small eroded valley to the upturned edges of a subridge, and continue the succession of the strata. Resting upon the limestone is a reddish sandstone, with layers of brick-red arenaceous material, 60 feet, dip 20°. Then about 200 feet, light yellow magnesian limestone, with drusy quartz cavities—quite rugged, capped with about 10 feet of gray calcareous sandstone, dip 15°. Then a bed of red sandstone and arenaceous limestone, with thin layers of the brick-red material 50 feet. Then 100 feet of calcareous sandstone like that seen below the red deposits. All around in this disturbed district we can see patches of the White River tertiary, remnants left after the erosive action of water. After leaving this point, the Potsdam was not again seen until near the source of the Chugwater creek, where it rests directly upon the reddish feldspathic granite rocks, which have evidently been subjected to great heat within a comparatively recent period, so that the sandstone has been more or less changed. We can trace it continuously from the source of the Chugwater to Long's Peak, and find it presenting the same peculiarities as above mentioned.

The carboniferous rocks are everywhere seen along the margins of the elevations, inclining at greater or less angles. Sometimes the erosive effects of water have been very great and have entirely removed all traces of the older rocks, or concealed them with a superficial deposit, as between Laramie and Platte rivers, along the base of Laramie Peak, where, for the distance of 30 miles, all the older rocks to the granite are concealed by a very recent tertiary deposit of great thickness. A few of its characteristic fossils occur at most of the exposures, but they are usually quite imperfect and comprise comparatively few species.

The brick-red deposits, without doubt, are co-extensive with the carboniferous rocks, though they are concealed for the most part, except at a few localities, by the overlying rocks. At the Red Buttes these deposits are finely developed, giving character and name to this region. Their next appearance is at the head of the Muddy, where they are exposed with a similar development to that at the Red Buttes. Again at the head of La Bonté, they reach a great thickness and contain gypsum in great abundance. All along the margins of the mountains we can see more or less indication of the presence of these deposits, but owing to the overlying cretaceous and tertiary rocks, they are concealed for the most part excepting at the localities mentioned.

The jurassic rocks are also co-extensive with the carboniferous and red marl deposits. At Red Buttes they are composed of sandstones, arenaceous limestones and limestones, with intercalations of arenaceous marls, and a profusion of fossils, *pecten*, *ostrea*, *pentacrinus*, &c., but as we go southward the jurassic beds diminish in thickness, and scarcely any fossils are to be seen, so that near Long's Peak these rocks are not more than 100 feet in thickness, nearly or entirely destitute of fossils. They seem to be composed of loose layers of sandstones and limestones, the intercalated laminated marls having almost entirely disappeared, and a gradual change occurs in the lithological characters, so that in the southwest it is difficult to determine a jurassic fountain at all, no fossils having yet been found which are decidedly characteristic of it in that region. In regard to the cretaceous and tertiary formation of this region, I will allude to them more in detail in giving the local geology. The cretaceous rocks are quite well shown in the region of the Red Buttes, and the area covered with the lignite and White River tertiary beds may be seen by referring to the geological map.

CHAPTER IX.

FROM RED BUTTES TO HEAD OF WIND RIVER.

EOLOGICAL FORMATIONS NEAR RED BUTTES—ANTICLINALS—LARAMIE RANGE—ITS CONNECTION WITH BIG HORN RANGE—WILLOW SPRINGS—WIND RIVER DEPOSITS—THEIR RELATIONS TO OTHER TERTIARY DEPOSITS—PINEY BUTTE—DIP OF BEDS—WIND RIVER VALLEY—FOSSILS OF THE WIND RIVER DEPOSITS—CAÑONS ALONG THE FOOT OF THE MOUNTAINS—POPO AGIE—LAKE FORK—GEOLOGY NEAR THE SOURCE OF WIND RIVER—CRETACEOUS DEPOSITS WITH FOSSILS—JURASSIC AND RED BEDS—SUPERFICIAL DEPOSITS, ERRATIC ROCKS, ETC—IGNEOUS ROCKS OF THE BIG HORN RANGE.

Leaving Deer creek I shall omit the details in regard to the tertiary nd cretaceous formations, and commence my observations from a point ear the Red Buttes. We find that by means of the upheavals the cre-aceous rocks, seldom any older than there, are exposed in a few places, ut that tertiary rocks predominate, covering most of the plain country. Ve have also mentioned that in the valley of Salt creek the tertiary trata are very much disturbed by the Sweetwater mountains on the one ide and the Big Horn mountains on the other, so that in many cases ey stand very nearly or quite vertical. I have also mentioned the ntimate connection of the Laramie range with the Big Horn mountains y means of an anticlinal axis which stretches off to the northwest, of hich Piney Butte forms a part.

At what is called the Red Buttes the Laramie range divides into two nticlinals, extending across the North Platte to the northwest. By hese anticlinals all the rocks in this region are exposed, down to the ed arenaceous deposits. The west side of the west anticlinal forms two f the Red Buttes, which are caused by the North Platte cutting through he ridges nearly at right angles, exposing the red deposits, jurassic and retaceous rocks.

The eastern portion of this anticlinal is comparatively small, and the orresponding strata are much lower in position than those upon the rest side. About two miles below we have a second anticlinal extend-ng across the North Platte nearly at right angles, the east side of which ssumes by far the greatest importance, although it reveals only jurassic nd cretaceous rocks. The west side of this is quite low and compara-vely small, so that this may in reality be called a connected double nticlinal. As we pass off to the northwestward toward the Big Horn ountains these two anticlinals unite and form a single anticlinal, vealing only the lignite tertiary beds until we come to Piney Butte, here the cretaceous and jurassic cease again; the internal force seems have lost a portion of its power and only the tertiary beds are posed for a considerable distance until we come near the base of the g Horn mountains. On each side of this anticlinal the strata are more less distorted, the beds becoming less inclined as we recede from the is. On the west side a synclinal valley is formed by the meeting of e disturbed beds, though near the Sweetwater mountains.

Near Willow spring we have a series of beds which from their litho-gical character I have supposed to be intermediate between the White ver tertiary and the true lignite beds, and from their appearance I would think that they extend far on to the Sweetwater mountains. The strata incline in the same direction with the older lignite beds, but at a less angle, showing a distinct but slight discordancy. These beds continue to the Sweetwater mountains, though the country as we approach the mountains has been smoothed by the eroding power of water to a great extent, and the surface is covered with a thick deposit of drift material. Along the immediate valley of the North Platte the black plastic clays of No. 2 are seen largely developed.

Proceeding in a northeast direction let us examine more in detail the anticlinal which connects the Laramie range with the Big Horn mountains. As we pass up the valley of the Salt creek, a branch of the North Platte, we find that the lignite beds are very much disturbed, often dipping at very high angles and consisting of alternate beds of sandstone, quite hard, and sandy marls and lignites, the loose material having been worn away and leaving the harder beds extending in lines across the country like high walls. The following section of the beds extending from the axis outward toward the Sweetwater mountains will explain my meaning more in detail:

1. Laminated carbonaceous clay and sand, dip 1°.
2. Yellow ferruginous calcareous sandstone, dip 7°.
3. Black laminated clay.
4. Yellow ferruginous sandstone, quite friable, dip 10°, capped at this place with a ferruginous arenaceous limestone.
5. From 4 to 5 is a valley one to two miles wide, quite grassy, with an exposure here and there, showing that the material is a yellow ferruginous marl, with layers of hard arenaceous rusty limestone, dip 48°. There are a good many of the layers of limestone varying from two to three feet in thickness.
6. Light gray, rather friable, sandstone, about 50 feet thick, forming a high wall extending far across the valley, dip 60°.
7. Laminated clays and sandy marls.
8. Thick bed arenaceous rust-colored ferruginous limestone, dipping 54°. Occasionally small seams of impure carbonaceous matter are seen.
9. About 14 layers of rusty arenaceous limestone, from 12 inches to 5 feet in thickness, dip 65°.
10. A valley covered with grass, one-fourth of a mile wide, one layer of gray sandstone exposed.
11. A series of alternate layers of very dark iron rust, brown, and yellow ferruginous sandstones, with variegated marly grits, dipping 61°. These beds are seen along the Platte and over the plain country northward toward Pumpkin butte. This series extends nearly half a mile in width.
12. Aggregation of small water-worn pebbles, and grains of quartz, yellow and gray, dip 53°.

We then came to the synclinal valley between the beds on the northwest side of the anticlinal and the southeast side of the Sweetwater mountains, and passing over the corresponding beds of tertiary dipping from the Sweetwater mountains. We also cross the cretaceous jurassic red deposits and carboniferous rocks in their order of sequence, and reach the central portion of the Sweetwater mountains, which is composed of eruptive rocks and granitic to a great extent.

Scattered over the valley are remnants of the Wind river deposits dipping from 1° to 6°. Near the hills there is a wide eroded valley one to two miles wide, occupied by rocks of cretaceous formations 4 and 5, *but not presenting* great exposure. We then come to No. 2 with its usual lithological characters and developed to a great thickness, composed of dark and light steel gray shale high upon the sides of the mountain, dipping 48°. At the base of the shale is a yellowish sandstone, resting upon the conglomerate and jurassic, which dips about 33°. Underneath are the gray jurassic beds dipping at the same angle and belonging to the same ridge. Then we have the red arenaceous beds and the cherty magnesian, dipping 12°. The igneous rocks prevail in the range and I suspect that to a very great extent the older sedimentary rocks have been melted as Potsdam, carboniferous, and a portion of the red arenaceous beds. The eruptive rocks are for the most part a dark gray trachyte. Indeed, we find masses of rock in the trachyte, as flint, &c., sometimes forming a sort of trachytic conglomerate. It also seems to be full of the crystals of silex, schorl, &c., some of it quite light. There are also many fragments of rock which look like slag or pumice, but still a very heavy rock melted. The eruptive rocks are very largely developed here and have a most modern appearance, but I am inclined to think that far in the distance west the granite occurs. The two most prominent peaks which are seen from our road, 1,500 to 4,000 feet high, are entirely trachytic and surrounded at base by the red arenaceous deposits. These peaks stand out further to the north than any other igneous rocks in this range. The eruptive and granitoid rocks are seen as far to the southwest as the eye can reach.

As we approach the divide between the Wind River valley and the banks of the Platte, we see outliers of the Wind river deposits in the form of denuded buttes 200 to 300 feet high, covered with variegated, yellow, and pinkish sandy marls and clays.

Scattered all over the country are small pebbles and fragments, more or less worn, of the underlying formations. The divide between the waters of the North Platte and those of the Wind River valley, as shown by the barometer, is 1,000 feet higher than Deer creek. After passing this point the Wind River valley deposits occupy the whole region, except in the immediate vicinity of the mountains. Reaching the Wind river we have the Big Horn mountains on our right and the Wind River range on our left with the various sedimentary rocks inclining along their flanks.

As we pass up the Wind River valley, after passing the mouth of the Popo Agie, these Wind river deposits increase largely in thickness, and near the head of Wind river they assume a development of from 1,500 to 2,000 feet in thickness, and are gashed by the erosive power of water into the most rugged "Bad Lands" I have ever seen in the west. We have first at the base a series of yellowish and light more or less sandy marls with quite wide pinkish bands, giving a picturesque effect to the scenery; these are from 400 to 600 feet in thickness. I found in them fragments of a turtle and a species of *helix*. As we ascend we have alternations of sandstones, clays and sands, and sandy marls more or less indurated, with but one local seam of lignite. This local seam I noticed near the summit of a sand butte, the highest hill in this region. Everywhere throughout the valley on both sides the more recent beds extend close up to the mountains, bearing the same relations to them that the White river tertiary beds do to the mountains in the vicinity of Fort Laramie. There is a vast amount of drift material scattered through the valley and especially is lodged on the abrupt summits of the high hills, composed in part of materials from the surrounding underlying formations, and from the mountains in the form of well water-worn rocks, not usually large, mostly quite small.

All these deposits indicate that the waters in which they accumulated were not deep, as is shown by the most conspicuous examples of oblique laminæ and markings indicating shore deposition. There is also much petrified wood, with a bed of sandy indurated marl, containing a large quantity of fresh water and land shells of the genera *helix*, *vivipara*, *unios*, &c.

Toward the sources of the Wind river, the upper portion of these recent beds seems to be composed of a very thick bed of sandstone, which forms a conspicuous feature in the surface character of the country. At the base it is a very coarse ferruginous grit made up of grains of quartz, both angular and water-worn, and small pebbles of various kinds; small nodular masses of ferruginous matter incrusted about a pebble; occasionally a small blotch of arenaceous laminated clay, three inches long and one inch thick; there are aggregations of quartz pebbles and grains of quartz. The laminæ of deposit are very oblique; above the sandstone is a bed of plastic clay about five feet thick, which has all the characteristics of No. 4 cretaceous, the dark clay with ferruginous matter and crystals of gypsum scattered through it. Above this is a continuation of the sandstone of the same character, sometimes approaching to a conglomerate, with rounded stones two to three inches in diameter. This sandstone continues upward about 280 feet, but toward the summit we see indications of a growing tranquility by a deposition of finer sediment with fewer irregularities in the laminæ of deposit. Underlying the sandstone are a series of thin layers of yellowish gray arenaceous hardened rock, from one-twelfth of an inch to two or three inches, with all sorts of mud markings on the surface. Here thin flat masses are scattered all over the hills and show very plainly that their surfaces were continually exposed to the atmosphere by the fluctuation of the waters. Near the head of Wind River valley is a high butte, which is a most important land mark in this region and affords a fine vertical section of these rocks, 800 to 1,000 feet in thickness. From the summit we have a fine view of the country in every direction. We can see that these recent tertiary deposits occupy the whole valley; that they jut up against the mountains on each side of us, for the most part in a horizontal position or but slightly inclined. On the head of the Popo Agie and southeastward for a considerable distance the older tertiary formations, as well as the cretaceous, jurassic, &c., are well shown along the Wind River mountains. From that point the more recent deposits begin to monopolize even the flanks of the mountains, jutting up against the base, concealing all the older rocks. Along the Lake Fork the cañons are very deep, and over the surface are scattered, in the greatest profusion, granite and other boulders, some water-worn, others angular. Passing the Lake Fork to the northwest, the slope from the base of the mountains becomes grassy and descends gently to Wind river. Though the slopes of the flanks of the Wind river range are concealed for the most part by the great development of the recent tertiary, we can see by the deep cañons that the sides of the mountains are flanked by thick beds of carboniferous limestone in a highly inclined position. On each side we have now numerous, very pretty, wooded branches emptying into Wind river. In many places along the Big Horn mountains the red deposits are revealed, but owing to the thickness of the superficial deposits they are not continuous along the margins, although underneath the surface they must extend as indicated in other localities.

The following section of the high butte extending down to the waters of Wind river will show quite clearly the character of these deposits:

1. *The summits of the* hills are composed of a fine greyish, ash-colored,

siliceous limestone, breaking into thin laminæ, which have a clinking sound under the hammer. These thin slabs show traces of vegetable remains. Fragments of a leaf like lypha or flag are abundant.

2. A ferruginous coarse-grained sandstone, incoherent laminæ of deposit, rather irregular, with many portions forming a sort of conglomerate of grains of quartz of various degrees of fineness, with many smooth water-worn pebbles of various kinds, mostly quartz or flint, of various colors; also small masses of clay and limestone made up of continuations from the formations in the vicinity. The whole bed indicates a greater or less disturbed condition of the waters at the time of its deposition, 30 feet.
3. A loose, friable, ferruginous sand, passing down into a laminated clay shale, with a good deal of vegetable matter, might be called an impure lignite bed, 6 feet.
4. A deep yellow, ferruginous and gray, coarse, incoherent sandstone. This is very similar to bed 2, and quite as variable, a large portion a fine conglomerate, 130 feet.
5. Alternations of thick beds of greenish-gray indurated sandy marls, with friable sandstone, 200 feet.
6. Ash-colored indurated sandy marl, less arenaceous than with numerous calcareous concretions, 150 feet.
7. Rather coarse friable sandstone, with concretions of gray laminated sandstone, 50 feet.
8. Indurated arenaceous argillaceous material of a greenish-ash color, with numerous rusty brown calcareous nodules, 30 feet.
9. Sandstone, like bed 7, 60 feet.
10. Ash-colored indurated marl, like bed 8, 20 feet.
11. Sandstone, 50 feet.
12. Light gray indurated sand, 20 feet.
13. Sandstone, 40 feet.
14. Ash-colored indurated marl, filled with small more or less spherical gritty nodules of a rusty-brown color, 15 feet.
15. Deep yellow ferruginous quartzose sandstone, forming to a large extent a conglomerate of water-worn pebbles, 20 feet.
16. Ash-colored indurated marl, with two or three layers of friable sandstone and two layers or bands of indurated ferruginous sand. There are also rusty brown arenaceous concretions in this bed, 20 feet.
17. Deep yellow ferruginous quartzose sandstone, an aggregation of granular quartz and sand interspersed with many worn pebbles of all kinds, some of which are three or four inches in diameter. This bed indicates great disturbance in the waters during its accumulation, 50 feet.
18. Ash-colored indurated marl, 20 feet.
19. Sandstone, 50 feet.
20. Greenish arenaceous indurated marly material, 10 feet.
21. A red band indurated sand and clay, 15 feet.
22. Ash-colored and yellow sandy marl, 10 feet.
23. Pinkish band sandy marl, 15 feet.
24. Grayish brown sandy material, 20 feet.
25. Pinkish arenaceous marls, with a few thin layers of gray sand and sandstone, 100 feet.

Higher up, near the sources of Wind river, beds 21 to 25, inclusive, reach a thickness of 400 to 500 feet, and by their red banded appearance and exceedingly great denudation add greatly to the picturesque effect of the scenery. These rest upon an irregular surface of cretaceous rocks, and at the base is a layer of greater or less thickness (sometimes wanting) of well worn pebbles. The cretaceous rocks appear quite abruptly, assuming a thickness of 100 feet of black plastic clay, with numerous concretions containing fossils, a small *baculite*, two or three species *inoceramus*, *scaphites*, *ostrea*, *Belemnite dentalium*, &c. The tertiary beds do not conform to the cretaceous, as is shown by the greatly diminished inclination of the strata. Immediately above the cretaceous, and seeming to be independent of the tertiary, is an irregular bed of conglomerate, made up of all the rocks in the vicinity, much water-worn. Sometimes it is 30 feet in thickness, ranging down to nothing. The first ridge of cretaceous No. 2 dips 30°, second 47°. Throughout No. 2 are several beds of sandstone with ripple markings and other indications of shoal water.

Near the forks of Wind river I ascended a valley to the mountains, and obtained an accurate section from the carboniferous rocks upward:

1. A series of carboniferous rocks, same as described along the Big Horn mountains, and inclining at various angles.
2. A series of alternate layers of arenaceous rock, with grayish ash-colored sandy clays. These are arranged in layers, varying from one-twelfth of an inch to 18 inches in thickness. Dip, 11°; thickness, 150 feet.

These rocks underlie the red deposits, and contain a good many casts of bivalves, Next in order above come the red deposits, the lower portion dipping 9°. These red deposits are arranged in alternate layers of rather compact, hard rock and a laminated, indurated material, the layers varying in thickness from a fraction of an inch to several feet; seldom, however, over four feet. We then have ash-colored sandy marls, capped with a bed of light red marly sandstone, inclining 5°. This sandstone passes up into a reddish sandy marl, and then into a gray marl, with layers of arenaceous limestone. The first layer is a cherty limestone, four and one-half feet thick, inclining 16°; then, overlying this, a laminated, arenaceous marl, 15 feet; then an arenaceous limestone, with some partings of marl, 6 feet. In the cherty limestone, which lies but little above the red deposits and appears continuous upward with them, I noticed a number of fossils, but so badly preserved that we could not determine their affinities. I however detected the jurassic *avicula*, and fragments of an *ostrea* like the one seen in the well-known jurassic beds. In the laminated marl was *ostrea*, and in the arenaceous limestone casts of bivalves like *hettangia*. We then have a continuation of the deposits upward in the next ridge. Ashen gray marl, charged with jurassic fossils—*ostrea*, *avicula*, *B. densus*—in the greatest abundance. There are many harder layers of what may be called shell limestone, full of the comminuted remains of molusca, 60 feet. Then comes a bed of light yellow, fine sandstone, with some portion of calcareous matter, quite tough, but arranged in thin slabs or in layers, 4 feet. These slabs show abundant indications of ripple-markings on their upper surface, and inclining 15°, which may be considered the general dip of the whole ridge. This calcareous sandstone contains *ostrea*, an abundance of crinoidal remains, among which *Pentacrinus asteriscus* is plain, and *B. densus*. Above is a bed of grayish brown laminated marl, with the usual fossils, with a few thin layers of arenaceous rock, with numerous mud-markings, 50 feet. Then a bed of arenaceous, brown limestone, filled with imperfect casts of fossils. This bed gradually parts with its calcareous matter as it passes upward, and becomes strictly arenaceous with three divisions, with arenaceous clay between, 30 feet. We then have a variegated bed of marls, with pinkish and greenish bands alternating, 50 feet. Then a layer of arenaceous limestone, with a reddish tinge. This bed is quite arenaceous, arranged in thin laminæ, which are often quite oblique, 4 to 6 feet. Above is a repetition of the variegated beds, 30 feet; then a bed of rusty brown, compact, arenaceous limestone, inclining 16°. The arenaceous material begins to predominate as we pass upward; fossils cease to appear, 40 feet. Above this are again a series of indurated, arenaceous marls; sometimes a band is seen in which clay enters as a large constituent. In the variegated series the purplish bands seem to predominate, 100 feet. In this series are two or three layers, 18 inches to two feet in thickness, of a whitish, fine magnesian sandstone, sometimes with a pinkish tinge; then a bed of very light-colored, fine magnesian sandstone, inclining 16°, laminæ of deposit quite oblique, 10 feet. Continuing upward are whitish and yellow sandstones, marls, sands, and clays of every color—deep dark purple, pinkish, whitish, yellow, brown, ashen gray, 200 feet, inclining generally at an angle of 17°. Toward the upper part of this series are layers of dark siliceous rock, and a very hard, rough, concretionary limestone, with veins of chalcedony all through it. Very near the upper part of this series of variegated, indurated beds is a layer, eight inches in thickness, of brown concretionary limestone, filled with *unios*, *melanias*, &c. This deposit is evidently of an estuary character, and is precisely like the one before observed between the cretaceous and jurassic deposits in the Black Hills, and local in character. Above these variegated, fresh-water beds is a series of yellow, arenaceous, thin, hard layers of rock, with mud-markings and partings of laminated, arenaceous marl, inclining 12°, 150 feet. These layers show an approach to shallow water, and, continuing upward, these laminated earths begin to grow darker in color, and to become a shaly, plastic clay, until we come to a bed of black plastic clay, with ferruginous concretions, as seen in the cretaceous in other localities, 60 feet.

These pass up into a similar series of yellow marls and sandstones, 40 feet. Overlying the last we have a black plastic clay, some portions a sort of black paste, 80 feet. In this bed I found some uncharacteristic fossils, bivalves, which have a great resemblance to the well-known fossils of No. 2, and between beds of black plastic clay is a bed of sandstone, like that which characterizes No. 2 in other localities, light yellow ferruginous, inclination 12°. The upper bed of plastic clay passes up into a brown indurated clay, which also passes up into a light ash-colored, hard, fine clay, which breaks into thin layers characteristic in many places of No. 2. These beds, though becoming of a lighter color, and towards the upper part becoming somewhat arenaceous, maintain the cretaceous characters. In a layer of argillaceous limestone I found distinct scales of fishes. These rocks dip from 10° to 14°, and gradually pass up into a most remarkable series, the most picturesque I have ever seen. They are composed of a series of variegated beds of sand, clay, and marls, with most conspicuous pinkish bands, which gives them so striking an appearance. They incline from 3° to 5°, and are the tertiary beds which form the base of the Wind River Valley deposits.

After passing the forks of the Wind river, we have the red sandstones of the red deposits on our left and a lofty wall of tertiary Bad Lands on our right. What is peculiar in this region is, that, while all the older rocks exhibit great disturbance and incline at large angles, the tertiary beds are nearly horizontal, showing that they were deposited after the mountain elevations reached a considerable height.

One of the most remarkable features in the surface character of this region is the conspicuous deposit of boulders. They represent all the formations in this vicinity. They are much worn, but all the evidence points to the conclusion that they were derived from the neighborhood. There are bluish cherty limestones, with carboniferous fossils; fragments of reddish micaceous sandstones, like Potsdam rocks; mica, schists, micaceous and feldspathic granites. This deposit seems to have been derived directly from the mountains, and, when obstructed by the side of a bank or cañon, to have deposited immense quantities of the loose rocks for some distance down the sides from the summit; and they seem to remain on the steep sides in such an uncertain condition that we would infer that, at least since their deposition, no violent paroxysmal effort has taken place. For example, the left banks of the little branches that flow into Wind river from the west are covered with a great thickness of these rocks, many of them of large size; and yet on the right bank no indications are seen. So also on the left bank of Wind river it would seem as though the icebergs had lodged against it and quietly deposited the burden of rocks which they had acquired in the more elevated mountains. This river runs at right-angles to the course of the glaciers and parallel with the mountains. Boulders of large size and in the greatest profusion cover the almost perpendicular sides. These rocks grow smaller and less numerous the further we recede from the mountains, and on the lower terraces we find comparatively few of them. From this fact I infer, first, that the higher terraces, which are usually covered with these rocks and in part composed of them, were formed prior to that period; second, that the lower terraces or bottoms are the result of causes either now in operation or which have operated during our historical period.

The recent tertiary beds continue, forming a wall on our right hand all the way to the source of Wind river, having very much the appearance of the true Bad Lands of White river, and apparently distinguished from them only in the predominance of the pinkish bands or red material which gives color to seven-eighths of the strata. The lower portion contains an increased amount of calcareous matter, and corresponds very closely with the turtle bed on White river. It contains fragments of turtles and land shells, with light calcareous concretions, containing crystals of spar in the center.

Before reaching the head of Wind river it would seem as though the Big Horn range had undergone a change in its structure. Before arriving at the head of Wind river I observed no indications of true eruptive rocks; but for 50 miles prior to the junction of the Big Horn range with the Wind River mountains we have a most rugged, jagged ridge of basaltic rock, having the appearance of stratification. It seems to present every variety of texture from an obsidian to a lava-like mass; from a completely melted rock to a partially changed sandstone. I can hardly conceive of the cause of so great a thickness of what appear like stratified deposits unless we may suppose them to be altered sedimentary rocks. These mountains are so rugged in their character that they have even defied the efforts of the trapper or Indian to explore them. Most of these temple-like hills have almost perpendicular sides, and their appearance does not favor investigation. The base of the mountains at this point is 7,000 feet above the sea.

CHAPTER X.

ROM WIND RIVER MOUNTAINS TO FORT UNION, ON THE MISSOURI RIVER.

SCENT OF WIND RIVER MOUNTAINS—GROS VENTRES FORK—TERTIARY BEDS ON WEST SIDE—FOSSILS—CRETACEOUS BEDS—RELATIONS OF THE DIFFERENT FORMATIONS ON THE WEST SIDE OF MOUNTAINS TO THOSE ON THE EAST SIDE—SNAKE FORK OF THE COLUMBIA—JACKSON'S HOLE—THREE TETONS—IGNEOUS ROCKS—VALLEY OF LAKE FORK—CARBONIFEROUS ROCKS—CROSSING THE MOUNTAINS TO THE VALLEY OF THE MISSOURI—LOW PASS—MADISON, GALLATIN AND JEFFERSON FORKS—QUARTZ SEAMS—SIGNS OF GOLD—TERTIARY DEPOSITS AT THE JUNCTION OF THESE STREAMS—BASALTIC ROCKS ALONG THE ROUTE—SMITH RIVER—CLAY SLATES WITH INDISTINCT VEGETABLE IMPRESSIONS—FORT BENTON—GEOLOGY OF THE DIVIDING RIDGE BETWEEN YELLOWSTONE AND MISSOURI FROM FORT BENTON TO FORT UNION—CRETACEOUS AND TERTIARY DEPOSITS—JUDITH MOUNTAINS—MUSCLE SHELL RIVER.

May 31, 1860.—We ascended the Wind River mountains to-day. On ur left was a bed of compact variable rock, parts of it a siliceous limetone, and others a sandstone, lying under the red marls, and inclining 7°. Still higher we find a ridge of carboniferous limestone, inclining 'om the sides of the mountains 33°. After reaching a point 1,500 feet bove the base of the mountains, we come to basaltic rocks, like those efore mentioned, and doubtless formed under the same influences. pproaching the crest of the great divide, we find the gray granite. It resents many varieties, but seems to have that uniform gray color. ome of it appears to be an aggregation of whitish quartzose angular rains interspersed, as it were, and cemented with plates or grains of ica, giving to the rocks a dark speckled appearance. Sometimes the ica occurs only in small quantities, and at others predominates; also hite seams of quartz run through the rocks, and the feldspar and mica re aggregated. There seeems to be comparatively little ferruginous atter in this granite, and it does not yield to atmospheric agencies as the ranite of the Laramie range. There are many valleys and grassy hills nong the mountains, and the highest portions of the range, 10,000 feet bove the sea, are covered with a superficial drift deposit, composed ostly of granite rocks much worn, indeed much like those we see in e beds of the streams and rivers. To the south we have the Green iver mountains, a ridge covered with pines, and to the west or southest are the Wahsatch mountains, apparently composed of basaltic ock. Our course to-day was southwest, and we traveled 18 miles in a raight line.

June 1.—On the west slope of the Wind River mountains we met with thick deposit of drift material, which as we descended to Gros Ventres ork soon expanded into a great thickness of recent strata, evidently uite recent tertiary. The banks of the Gros Ventres Fork present high luffs, some 300 to 600 feet high, but I should think that this formation ad been deposited after the surface of the country had attained for the ost part its present configuration. The strata consist of loose fine renaceous clays, the layers containing more or less arenaceous matter hich does not effervesce, and layers of harder rock, a fine-grained and coarse sandstone, and sometimes an aggregation of grains of quartz with ferruginous matter and particles of mica. The materials are all evidently derived from the vicinity. Some of the masses of rock present a compact fine siliceous structure and effervesce feebly.

June 4.—To-day the tertiary strata begin to assume a good deal of importance. We have the brick-like materials which result from the burning out of the lignite beds. There were also masses of indurated clay, covered with vegetable remains and impure lignite beds; indeed all the indications which the lignite tertiary beds present on the east side of the mountains. The beds are also much disturbed, inclining at various angles. The following section of the lignite beds was taken here, which will serve to show their resemblance to those on the eastern side of the mountains:

9. A yellow fine-grained sandstone and a dark gray limestone with a parting of clay. The limestone is quite brittle, breaking into thin laminæ, and contains impressions of dicotyledonous leaves and a distinct species of *unio*, 15 feet; inclination 28°.
8. Light yellow sandy marl, 15 feet.
7. Impure lignite, 4 feet.
6. A series of marly clay which, when saturated with water, forms a thick paste variegated in color. Near the summit, just below the lignite, is a thin seam four to six inches of hard shell limestone with the shells in the most comminuted condition. I recognize *unios*, *viviparas*, &c., sufficient to show that the deposit is fresh water 150 feet.
5. Alternate dark gray and brown yellow gray, fine sandy and clay layers, with some calcareous matter and a few seams of incoherent sandstone, sometimes assuming a concretionary character, 200 feet.
4. Impure lignite and clay, 8 inches.
3. Yellowish gray clay, 4 feet.
2. Impure lignite, 6 inches.
1. Yellowish clay with some calcareous matter.

The general inclination of all these beds was about 20°.

June 5.—We ascended a high ridge from which we could see to a great distance. Looking to the dividing crest of Wind River mountains we find the exposed belt of granite to be not more than four or five miles in width, and is gradually lost in the basaltic or eruptive range, which also renders itself conspicuous. The tertiary beds seem to reach fully up to the crest on the west side and often passing what appears to be the junction of the Big Horn range, even to the entire divide of the mountains. We also see, high up on the flanks of the mountains, a full series of the more recent tertiary beds with pinkish bands precisely similar to those in the Wind River valley. These pass up into yellow sandy marls and sandstones. I have estimated the entire thickness of the tertiary beds on the west side of the mountains at 1,200 to 1,500 feet. In the lignite beds and vicinity are great quantities of selenite and silicified wood. All over the highest hills near the crest of the mountains, 10,000 feet above the sea, are the recent tertiary beds. A large portion of the superficial tertiary strata incline from Wahsatch and Green River mountains, showing that these deposits were probably disturbed at the same time by the uplift of these ranges. In the distance are the Three Tetons, rugged peaks of erupted rocks, towering high above the rest. These peaks are sharply pointed, piercing the clouds like needles, and it is said that the trappers have never been able to get near them. So far as we have yet seen, at least 50 miles of the dividing crest of the mountains is covered with tertiary rocks.

June 7.—We passed up a ravine to-day which runs north and south, and is close to the divide which overlooks Snake river. The lignite strata incline nearly northeast at an angle of 40°, and as we ascend many of the lower members of the lignite strata are exposed. We also see quite large areas covered with eruptive rocks, and also a sort of basaltic conglomerate composed of large angular masses of rock cemented with the melted material. Mr. Bridges informed me that these same formations continue all along the Wahsatch mountains to Bear spring and Haur's fork, and down Snake river nearly to Blackfoot creek. It also covers the valley of the Yellowstone to points below the lake. There is simply a band of granite along the divide in the form of a narrow belt.

Descending the Gros Ventres to its junction with the Snake river we find the same tertiary beds prevailing to a great extent, and sometimes assuming a variety of lithological characters, at one locality a thickness of 200 feet of worn pebbles and sand, the whole inclining from 20° to 35°. Gradually the cretaceous rocks appear along the valley of the stream. A section of these rocks would be as follows:

3. A series of sandstone, arenaceous limestone, and laminated marls, 150 feet; inclination 20°.
2. A series of thin indurated beds of clay, sandy marl, limestone and sandstone, with six or eight seams of impure lignite which has ignited in several places, giving to the earth in contact a brick red color, 80 feet.
1. Gray ash-colored sandy laminated marls, with layers of fine sandstone—sandy matter predominates, 100 feet.

In the upper beds were quite abundant fossils, consisting of a huge *inoceramus*, two species *ostrea*, a large *pinna* four inches long, a *cordium*, and many small shells. The whole deposit indicates shoal water in a shore deposit, and there are also fragments of wood. As we descend the jurassic is exposed with *ostrea* and *B. densus*, and there is an enormous development of the red arenaceous beds, making a thickness of 1,000 to 1,200 feet or more. Near the middle of the red bed is a layer of gypsum four feet in thickness. There are other seams or layers of gypsum, each with partings of the red marl. The dip is quite variable, at one place 29°, at another 15°, and again 7°.

The cretaceous beds differ from those on the east side of the Wind River mountains, both lithologically and paleontologically, but the jurassic and red deposits are, so far as could be observed, precisely alike in their character and contents. We infer from these facts that all these formations at one time extended continuously over the entire divide of the Rocky mountains.

As we descend into Jackson's Hole we find the carboniferous limestones with their usual lithological characters, a very hard brittle yellow rock, with much cherty material, inclining 12° to 15°. There is one thick cherty layer, 15 feet thick, dark bluish color, inclining 12°. We find these limestones along the mountains on both sides of Jackson's Hole, but the central portions of the mountain ridges are composed of eruptive rock.

Near Snake river, on the right bank, is a rather low range of hills, which presented the appearance at a distance of being composed of stratified rocks. On examination the rocks appear to be a bluish, very hard cherty limestone, apparently carboniferous, 160 to 200 feet thick, passing up into a compact siliceous gray rock with a reddish tinge. In the limestone are numerous fossils, mollusca, and corals, but too much broken and obscure to determine. On the left side of Snake river I saw limestones charged with fossils, especially corals. These limestones are scattered promiscuously along the flanks of the lower hills and ridges, and while in many places they are in part or entirely removed by the erosive action of water, the evidence is clear that they were deposited here with a thickness fully equal, and were possessed of a similar character, to those on the eastern slope of the mountains. The valley of Snake river is broad, fertile, and beautiful, and very few traces of the tertiary beds are seen, and I am now inclined to think that we can see, to a very great extent, the configuration of the main portion of the Snake river basin as it was prior to the tertiary period; for the tertiary being of a loose friable material was easily eroded away, leaving along the banks large areas covered with it.

June 18.—Crossing over Snake river we ascend the pass 1,900 feet above the bed of Snake Fork. The mountain ridge over which we passed could not be less than 1,000 or 1,100 feet higher, so that these mountains are btween 9,000 and 10,000 feet above the sea. The highest, Teton, was measured with the sextant and made to be about 10,000 feet. All along the margins of the ridges we see a plenty of the blue, cherty carboniferous limestone; also, the siliceous rocks which lie above, and a great many granitic masses, and also gray micaceous slates. We have seen much of the carboniferous rock along our road to-day; also red arenaceous beds, with now and then an erupted ridge. The central portions of the mountains are composed entirely of the eruptive material.

June 19.—We travelled nearly due north 20 miles, down Pierre's fork into Pierre's Hole, a beautiful valley surrounded by mountains, about 15 miles wide and 30 long. On our right is the Teton range, composed entirely of eruptive rocks, with a general inclination west or a little north of west. It would seem as though this whole valley had been formed by the drainage accumulating in a fissure of the upheaval, for the mountains all seem to incline in the same direction. The hills are composed in part of a sort of vesicular trachyte, exceedingly porous, some of the cavities being an inch in diameter. The broad, level prairie is composed, to a large extent, of well-worn rocks, basalts, obsidians, granites, &c.

June 20.—We continued our course directly north, and soon began to ascend low ridges breaking the level of the prairie. These ridges extend down from the mountains on each side, and seem to give shape to the valleys of the multitude of little streams. We have here and there an exposure of the rocks, which are undoubtedly eruptive, and present the appearance of stratified deposits. It is arranged in more or less thin layers, some of which sound under the hammer like clink-stone, and quite compact. Sometimes the breakage joints or clearage are vertical in a single layer, but from their external appearance I would suppose the banks of the vertical rocks were a dark gray marly limestone, charged with fossils. There is also a good deal of uniformity in its composition, the only difference being that some of it is more compact than others. The eruptive material in this valley assumes a variety of form; some of it has a black, opaque crystalline appearance, like obsidian; then a sort of sandstone, easily decomposing, or, as it were, exfoliating; then a sort of lava, or slag; then a vesicular trachyte. There are also veins of quartz, sometimes ribbon-like, ¼ of an inch wide. The greater part of these rocks, however, would seem to have been melted or heated under comparatively little pressure. These rocks predominate, and, indeed, comprise almost the only rocks on the western slope, and may be called *a brasalt country*. Many of these rocks seem to yield very readily to the decomposing agencies of the atmosphere, and furnish entirely the soil of the valley, which is quite black and fertile, sustaining a luxuriant growth of vegetation. The streams that issue from the mountains are very numerous, the water pure as crystal, and the valleys clothed with rank herbage; but the timber, which fringes the little streams here and there, is very scarce. There are, also, many beautiful springs and lakes.

June 20.—We passed up the valley of the Lake Fork and crossed the dividing crest of the mountains to the Madison Fork of the Missouri. High hills of eruptive rock surround us on every side, with now and then small patches of limestone along their sides, inclining at various angles. There are, also, mica, schist, talcose slates, and quartzose limestones often underlying the layers of eruptive material, and conforming to them in inclination, which is from 30° to 60°. Many of the ridges are 2,000 feet or more above us, and are covered with snow. The Low pass is like a lawn—smooth and covered with grass, with a large superficial deposit composed of the rocks in the vicinity. It is plain that the eroding agency of water has had its effect in smoothing this pass, though it has not formed it. It is undoubtedly due, to a great extent, to a break in the continuity of the elevatory force. The mountains here do not seem to follow any fixed lines of fracture, or in fixed direction, but to be a series of protrusions, forming, in many instances, a continuous line for a great distance; but the irregularity of the outline of the crest is due, to a great extent, to the irregularity of the force along the line of continuity, though a small portion may be due to atmospheric agencies. The facts above stated are true from the fact that the different strata of sedimentary rocks, which must, prior to the upheaval of these ridges, have covered the surface, lie in regular order of sequence outward from the ridges. We have every variety of volcanic rocks and metamorphic conditions. Washed out of the Madison cañon and scattered over the terraces along that stream are every variety of granitoid rocks, mica, slate, hornblende, &c. There is every variety of these rocks, depending upon the greater or less predominance of some constituent, and disseminated through the rock are seams of white quartz. None of the red feldspathic rocks which so prevail in the Black Hills are seen in this region. Along the rivers are a series of terraces which are covered with boulders, slightly worn, exhibiting the rock character of the mountains from which these streams take their rise. As we descend the Madison we find that the valley seems to pass along a sort of anticlinal axis, and on each side lofty, nearly vertical walls of trachyte, arranged in thick layers. The lower portion appears to yield quite readily to atmospheric agencies, owing to the ferruginous matter contained, which renders it a loosely aggregated mass of crystals of feldspar. As we ascend upward the rocks become more compact, and the upper layers are a cellular trachyte. In some places the upper compact beds assume a columnar structure, breaking into the form of vertical columns; these break in pieces and cover the sides of the hills with masses of rock. Lower down on the Madison we find layers of the red feldspar, which present the appearance of stratified beds like the azoic rocks, with an inclination in the same direction with the overlying basaltic rocks. There are numerous seams of white quartz, also trap, running across the country in every direction, many of which indicate the presence of gold-bearing rock. The summits or crests of the high mountains are ragged, not from erosions since upheaval, but owing to the manner of the upheaval. Each peak assumes, to a certain extent, an independent uplift, with layers of rock inclining around from every side; and yet it is by a series of these peaks connected together, more or less, which forms a range. Wherever these peaks or groups of peaks are separated a short distance a low point is made in the range, which gives passage to streams. Very many of these low passes have no streams issuing from them at this time. The Madison forms a cañon by cutting through one of these lofty ridges at the upper portion of the Burnt Hole, and a second one at the lower end of the same valley. Still below the feldspar beds and near the junction of the Three Forks of the Missouri we have beds of exceedingly slaty character, inclining at angles of 31° and passing down into the granitoid rocks below.

In the valleys of these streams are a series of marls and marly sands and conglomerates, precisely like the upper beds of the White River tertiary. These marls are mostly of a flesh color, sometimes assuming the texture of a quartzose sandstone. Its greatest thickness in this region is about 200 feet, and not conforming to the carboniferous rocks beneath, but inclining in the same direction about 8°.

The carboniferous rocks are largely developed in this region, and incline at very large angles from the mountains. The lower part of these limestones have been so affected by heat that the stratification has been very nearly obliterated, and presents a most rough appearance. Above this is a bed which is undoubtedly carboniferous limestone changed, but which now very much resembles basalt but contains more arenaceous matter, and to have had the stratification but partially changed. From the Three Forks these limestones extend westward, or southwestward, about 20 to 25 miles, and then extend northward toward the gate of the mountains along the Missouri. It also extends to the northwest to a range of mountains, in which is the Blackfoot Pass of Lewis and Clarke.

July 3.—Visited the plateau, mentioned by Lewis and Clarke, between the mouths of the Gallatin and Madison. It is a long flat ridge of limestone, representing the portion of the inclined rocks which form the left side of the cañon below.

The rocks on that side incline 24°, continuing far on the distant hills. The base of this small ridge is a bluish cherty limestone, sometimes yellowish, very compact or hard, breaking into fragments just like the carboniferous limestones before seen. Dip 33°. This bed corresponds with a portion of the right side of cañon next to the water. There are traces of abundant fossils, as broken crinoidal remains and other mollusca. It weathers so as to expose upon its sides small flinty masses or chert. This bed passes up into a light gray limestone with drusy cavities, and breaking into irregular fragments in the direction of stratification, a form of fracture common to the carboniferous rocks. The dip of this bed is 31°. Obscure traces of fossils are seen. These layers continue on up, divided by thin partings; others are solid, from 6 to 20 feet in thickness. Then comes a bed without distinct lines of stratification, often assuming the form of a sort of conglomerate with masses of limestone on all sides, cemented together with sulphate of lime, dip 20°. There is then a return to the former condition of a yellow limestone. It is full of dog-tooth spar and seams of crystalline matter. I should estimate the limestone to be about 500 feet in thickness.

On the right side of the Gallatin, and dipping eastward from the cañon, at an angle of 8°, is a bed of yellow gray sandstone and marl. It does not quite conform to the carboniferous limestone, though dipping in the same direction. The Gallatin Fork, from its mouth to the point where it issues from the mountains, is about 50 miles, flowing through *a beautiful valley* well fringed with cottonwood trees, mostly bitter cottonwood. The upper portion of this valley has been most beautifully smoothed by the erosive action of water, leaving a space between the base of the mountain ridges and the upturned edges of the sedimentary rocks of 20 or 30 miles which is smooth like a lawn. The carboniferous rocks present a series of monoclinals of the most interesting character. Underneath them are a series of rocks which seem to represent the Potsdam sandstone. It is the most variable series which I have yet seen. In order of descent we have a reddish, rust-colored rock, mostly fine-grained, compact, quartzose, siliceous, almost the appearance of a metamorphic rock. It is sometimes made up of an aggregation of grains of quartz. Beneath are a series of thin strata of dark steel gray micaceous sandstone, sometimes becoming a fine aggregation of water-worn pebbles and dark brown clay slate gradually passing down into what appears to be a true eruptive rock, with vertical seams of white quartz running through it. I am inclined to think that the erupted rocks have been thrust in between the partings of rock, so that we have a bed of eruptive rock, and then a layer of the sandstone, and so on alternating.

From the Gallatin we passed up one of the little forks emptying into that river, over carboniferous rocks, on to the source of Smith's or Kame's river, which empties into the Missouri below the gate of the mountains. Reaching the vicinity of the mountains we find that the basaltic or eruptive rocks prevail to a very large extent over all others. On a little branch flowing into Smith's river near its source, we find a dark steel brown bed, 50 feet in thickness, a fine conglomerate at base, but gradually growing coarse until toward the summit it is composed of large angular blocks of mixed gray basalt, aggregated with a reddish material. The beds dip northeast 45°. The imbedded masses are more or less water-worn. This bed seems to continue a long distance, and is sometimes vertical, sometimes the pebbles are as much worn as those of the little streams, and it seems to me that they have been changed since deposition, for they now partake much of the color and character of the matrix, except that they are much harder. The basaltic rocks along our route are developed to an enormous extent and present every variety of texture, that which yields readily to atmospheric agencies predominating.

July 6.—Passing along the Smith's river I saw this series of curious sombre, apparently basaltic rocks, which, except for their structure and color, I would regard as cretaceous or tertiary. The whole series are arrayed in beds of marl with more or less compact layers of harder rock which project out the same as in those formations. In these upper beds I found fragments of wood and in the uppermost bed were fragments of leaves which I cannot but regard as of tertiary age, and that the whole series of beds have been greatly affected by heat so that the lowest beds have been entirely changed. Passing up the mountain we found ourselves in a synclinal basin with the strata dipping at a low angle, those at the southeast at an angle varying from 30° to 60°, apparently passing through the different formations from tertiary to carboniferous. The rocks do not show so many signs of heat as heretofore. Our course has been direct north and mostly through carboniferous rocks dipping about southeast at an angle of 20°. There is in the cañon that we passed through at least 1,000 feet of limestone exposed, and as we leave the cañon northward we find 200 to 300 feet of red marly limestones much like the red deposits we have before met with, only harder. These rocks are peculiar, differing from any before seen. They pass from a red loose slate down into a compact clay slate, gradually varying from a deep red to black thin slates, becoming more and more compact as we descend until they appear to be a melted rock, and the joints are so close that they separate the whole mass into small fragments. The rock does not effervesce at all with sulphuric acid, but is of a very compact texture. In regard to the age of these beds I can form no exact idea, no fossils being seen, though frequent sun cracks are seen upon the surface of the slates.

July 7.—We traveled about 25 miles to-day nearly due north, over upheaved slates. We passed from the head of Little Green river on to the source of Smith's Fork, and in this valley we find remnants of a recent deposit like the tertiary as seen about the valley of the Three Forks. Occasionally basaltic rocks are revealed underneath the slates where the stratification is nearly obliterated. Near the stream is a large development of granitoid rock. Along the flanks of the mountains we see the carboniferous limestones dipping 59°. Indeed, the greater portion of the lofty hills around are composed of carboniferous limestones, red and black slates, with now and then granitoid rocks.

Throughout the valley of Smith's Fork and to some extent in the high mountainous hills the recent yellow marl deposit is quite conspicuous. It is evident that it has been well developed in this region, but removed to a great extent by erosion. All through the valleys of the mountains we find an excellent soil and a good growth of vegetation. Descending Smith's river we find that it cuts its way through immense cañons of carboniferous limestones, with numerous ejections, however, of eruptive rocks. Ascending the high divide 1,000 feet, which separates Smith's Fork from the Missouri, we have an extensive view of the gates of the mountains, the main range of the mountains far to the northwest, and the broad extensive plain to the north and northeast through which the Missouri winds its tortuous course. The whole plain is covered with high plateaus, in part upheaved areas, but mostly remnants left after erosion. The lower mountains that surround this great Missouri valley are undoubtedly composed for the most part of carboniferous rocks with here and there eruptions of melted material. As we descend into the plain a series of reddish areno-siliceous rocks prevail, which I suppose are the equivalents of the red arenaceous deposits so often mentioned in other portions of this report. Their lithological characters are somewhat changed, but their position is very nearly the same. Along the gate of the mountains the carboniferous rocks flank the mountains, the central portions of which are eruptive granitoid rocks, mica, slate, &c. These soon disappear and for 50 miles the river flows through these red siliceous rocks dipping at a very small angle. Reaching the falls of the Missouri we see there a variegated series of marls and sands 1,000 to 1,200 feet. The falls of the Missouri are formed by the passage of the Missouri through thin red jurassic (?) rocks, the strata dipping from 1° to 3°. Commencing at the upper end, the first fall or rapid, as it might well be called, is about 5 feet, and formed of thin compact dull reddish brown arenaceous limestones 18 inches to 2 feet in thickness, with thin intercalations of marl. The bed of the Missouri above is formed of a layer of reddish brown arenaceous limestone with a tendency to laminations, in some portions compact. The sides of the channel are nearly vertical, and are composed of alternate beds of sandy marl and arenaceous limestone of a reddish brown color, then a light gray and rust brown sandstone, the rust brown sandstone being quite hard, while the light gray sand yields readily to atmospheric influences. As we pass below the falls, these rocks show a vertical front of 40 feet, with some layers of very hard clay slate with indistinct vegetable remains. One leaf has the appearance of a jurassic fern. On the left side the rocks dip 3°, and the layers that form the bed of the river about the 26-foot falls soon form the bed of the river below. These rocks continue until we reach a point below the falls, but prior to that time, distant from the channel of the stream we begin to see the overlapping edges of the cretaceous rocks, and when we reach Fort Benton we find them 800 feet in thickness. They here assume the form of black plastic laminated clay, with numerous calcareous concretions containing numerous cretaceous fossils. The surface of the country is gashed up into numerous ravines and gullies, rendering the traveling almost impossible. The yielding nature of No. 2 renders the formation very susceptible to atmospheric influences.

From Fort Benton we crossed the prairie country in an easterly direction not far from the foot of the mountains. We find the cretaceous beds predominate with here and there indications of eruptive rocks, and we know that the mountains that surround us on every side are very largely composed of that material. The country is covered with saline lakes, which add much to the desolateness of the scenery. We have near the Arrow creek a bed of erupted material thrust between cretaceous rocks, which presents a vertical wall of 150 to 200 feet at one point and then suddenly ceases. These small centers of effusion of melted rock seem to cover this whole region. The most conspicuous examples of ejected material are the Square Buttes, which is a general name for numerous peaks with broad flat upper surfaces and with a tendency to a lofty square columnar form. The cretaceous rocks, so far as I can see, seem to extend quite closely up to the mountain elevations, and everywhere present the lithological character of No. 2. Arrow creek is a small stream with a narrow fringe of cottonwood, surrounded with high bluffs forming very rugged features, properly called Bad Lands. On Arrow creek I found *ammonites*, *cardium*, *baculites*, *inoceramus*, &c. The cretaceous rocks in this region seem to belong entirely to No. 2, though Nos. 1 and 2 may be included. It is mostly a black plastic clay with now and then a bed of sandstone. The igneous rocks in this region show very distinctly the origin of the vast quantities of saline matter which covers the ground and mingles with the waters of the streams. These rocks seem to contain large quantities of this saline material, which gathers upon their surface, giving to the igneous peaks a whitish appearance. This may account for the great quantities of it which pervades the formations in the west.

Along the Judith river the cretaceous rocks are well developed, and near the base of the Judith mountains the sandstone which is so conspicuous along the Missouri is seen. It is so elevated as to form long, high, nearly vertical ridges, which are covered to some extent with pines. The terraces along the Judith are quite remarkable. From the lower terraces along the immediate bottom you rise 150 to 200 feet to a broad plateau as level as a floor, one to four miles wide, then to another 50 to 150 feet high, but still bearing marks of erosion. Looking along down the valley of the Judith, the country presents a very level surface, as if it had been smoothed by some agency that had acted with the utmost regularity. As we come into the vicinity of the Judith mountains, the variegated rocks belong to the jurassic and red or triassic (?) series. There are also carboniferous rocks, with some quite well preserved fossils. The central portions are composed of the igneous rocks, but would not occupy a large area on the map.

Leaving the Judith river and proceeding toward the sources of the Muscleshell, we again pass over cretaceous rocks for a long distance. On a little branch, west of the Muscleshell about 25 miles, a thick bed of sandstone makes its appearance, forming a sort of wall along the right bank of the stream. We begin also to see isolated ridges or buttes of the lignite tertiary, the beds dipping about 2° to the northeast. Just before reaching the Muscleshell we pass over a large developement of cretaceous No. 4, with *baculites*, *ammonites*, &c., in great numbers. Along the Muscleshell the country on the left side seems to be all cretaceous, while on the right side high ridges of tertiary covered with pines form the divide between the Missouri and Yellowstone. We traveled for nearly 50 miles almost within sight of the valley of the Yellowstone. The cretaceous rocks appear here and there in the valleys of the streams until we come nearly opposite Fort Sarpy, where the tertiary beds occupy the country in full force. From thence to the mouth of the Yellowstone we have described a similar region in other portions of this report. We passed near the dividing ridge between the Missouri and Yellowstone, and a more bleak and barren region could not well be found. The numerous little streams flow from each side into the two great rivers, cutting deep valleys through the comparatively yielding material, so that the surface is rugged in the extreme. In the latter part of summer and autumn the water is very scarce, and often for several days' journey we find it only in standing pools. Very little timber is seen, and that is of a most stunted kind. From the highest part of the dividing ridge many springs of water of excellent quality issue forth, but are soon lost in the dry desert land below. Beds of marl, sand, sandstone, &c., with more or less numerous beds of lignite, silicified wood, vegetable impressions; all these are seen in numerous localities, and it would be but repetition to redescribe them, so vast a region is covered with the formation, and so little variation does it present.

Everywhere in the western country, so far as my observations have extended, I have noticed to a greater or less extent the operations of those agencies that have produced the superficial deposits. From the sources of the Missouri river down to its mouth they may be regarded as one grand system of operations on a great scale, and I shall treat this subject more fully in another portion of this report.

CHAPTER XI.

Sections of lignite tetiary beds along slopes of Big Horn mountains—Tullock's creek—Rosebud—Wolf mountains—Clear Fork of Powder river—Sweetwater and Devil's Gate—Wind River valley—Little Popo Agie—Foot slopes of western side Big Horn mountains—Gypsum deposits—Ragged peak—Stinking creek—Gray Bull creek—Clark's Fork—Clark's pass—Hot Spring creek—Valley of the Yellowstone river—Henry's Caches hills.

Geological notes by C. M. Hines, M. D., attached to Lieutenant H. E. Maynadier's command, 1859-'60, *from time of separation of the commands on Tullock's creek. to Captain Raynolds's trail, near the head of the Crazy Woman's Fork of Powder river.*

September 3.—Section 1. Location: Detached ridges of the foot-slopes of the Big Horn mountains, and southwestern rim of the Great Lignite Tertiary basin.

Beginning at the base we have:

1. Gray sandstone.
2. Yellow marl.
3. Thin layer of lignite, 8 inches.
4. Bluish gray marl.
5. Light yellow sandstone, from 6 to 8 feet.
6. Yellow marl.
7. Lignite.
8. Bluish gray marl.
9. Sandstone, from 2 to 4 feet.
10. Summits of hills covered with porphyritic pebbles, rough agates, variegated.

September 4.—Tullock's creek. Character of the country same as yesterday. Hills lower on the west, or left bank of the creek. First appearance of Bad Lands. Portions of the bed of the creek covered with an alkaline efflorescence. Water, alkaline.

September 7.—Traveled up Tullock's creek, and to-day up its east fork. Appearance of the country from the 4th to this day (7th) the same. Part of the country traveled over to-day was rolling prairie. In the afternoon red hills first appeared; lignite, &c. Could not get a good section to-day. This day began the ascent to the divide between Tullock's creek and the Rosebud. The ascent was gradual. At the highest point of the divide we have—

Section 2.—

1. Yellow sandstone, 2 feet.
2. Ferruginous marl, (fine.)
3. Lignite, 3 feet.
4. Bluish gray marl.
5. Yellow sandstone, (rather fine,) from 5 to 6 feet.
6. Ferruginous marl.
7. Lignite, 2 to 3 feet.
8. Bluish gray marl.
9. Yellow sandstone, coarse and broken.
10. *Red, baked clay.*

The descent to the Rosebud was gradual, with a dark soil.

Section 3. (Left bank of the Rosebud.) The same formation exists here that we found on the hills, near the Yellowstone, on the day that we first saw that stream.

1. Thick layer of gray sandstone, 5 to 6 feet.
2. Yellow marl, (light.)
3. Compact gray grit, tinged with yellow, approaching sandstone.
4. Yellow sandstone, 1 foot.
5. About 15 feet, same as No. 3, fine grit with thin and broken layers of dark brown sandstone, the stria being interrupted; on top of this was—
6. Yellow sandstone, 2 feet, the whole mass having a dip to the north-northwest, standing detached from the surrounding rolling hills, and having an eroded or washed? appearance. Close to the main portion were several cone-shaped prominences, similar in formation to the first mentioned, having also the washed appearance.

September 9.—Wolf mountains.

Section 4. Right bank of the Rosebud. The same general features as on Tullock's creek, excepting that the tops of the mountains present a beautiful pink or carmine color; the surface of the hills being covered in some places with the broken and detached pieces of stone and burnt clay to the depth of 40 or 50 feet. Mingled with the pink is sandstone, some of it in a pulverulent form, and other portions again having a scoriated appearance. The lignite in this vicinity approaches more nearly to coal, and the beds increase in depth.

September 11.—Descent to Tongue river from the Rose Bud. Scoria near the Wolf mountains. Foot-slopes of the mountain covered with jagged and broken rock, the mass of rock vertical and fissured. Shales. A drift of gravel 2 feet in depth in the valley of Tongue river. Sandstone and yellow marl.

September 16.—Section 6. East Fork of Tongue river, (portion of.) Bad Lands, (tertiary,) also the Clear Fork of Powder river. Outcrop of lignite of better quality than any before seen. Bed of Clear Fork, variegated stone. Along the valley of this stream we found petrifactions in abundance. Large trunks of trees, whole stumps or roots in a complete state of petrifaction. At various points along this stream we found large masses of fossil shells, specimens of which were procured.

For some distance above our first camp on the Clear Fork, to the junction with Powder river proper, there is a thick outcrop of coal (lignite?) of the depth of 6 feet or upward, somewhat resembling Cumberland coal, but of looser texture and containing less bitumen, (any?) I tested this to ascertain its value as fuel, and found it of slow ignition, and burning with a clear flame. I have no doubt that this is the best specimen of coal as yet found north of the Platte in Nebraska Territory, and have no hesitation in saying that it may be used as fuel.

September 19.—Clear Fork. Eight miles below our yesterday's camp we discovered this strata of coal (lignite) on fire. Considerable smoke issued therefrom having a strong sulphurous smell. The heat at this point was so intense that we could not stand with comfort within 20 feet from whence the smoke issued. A thick layer of sandstone, lying immediately above it 4 feet, was completely calcined. From this point, at the same elevation, to some distance below the mouth of the Clear Fork, I noticed the red color given to the banks by the burning out of this coal bed. Here and there were portions which had escaped. The origin of the fire I was unable to account for, unless it contains within itself the elements of spontaneous ignition.

September 20.—Red hills on both sides of the stream.

1. Lignite, (or coal,) burnt out, (red.)
2. Bluish gray marl.
3. Yellow sandstone.
4. Yellow marl.
5. Lignite.
6. Bluish gray marl.
7. Yellow sandstone.

To-day we camped first on the main Powder river. The same order of sequence continues up the main Powder river for a distance of 35 traveled miles. At this point I found a red sandstone, (baked clay?) containing traces of fossil leaves. This material covered an area of about 300 yards on the left bank of the river, and appeared to be unconnected with any of the strata surrounding it. It was about 2 feet above the river bed, and was not noticed at any other point. Passing this, I found that the same formation existed to the mouth of the Crazy Woman's fork, and up that stream to the foot-slopes of the Big Horn mountains as found at the mouth of the Clear Fork.

1860.—Descent from Willow springs by Horse creek, to Independence Rock on the Sweetwater.

1. Sandstone.
2. Flesh colored marl, compact and granular coarse grit.

South mountain, on the right bank of the Sweetwater, has all the characteristics of the Laramie range. The range of hills on the left bank are of coarse granite, denuded, horizontal stria, and vertically fissured. Portions near Independence Rock honey-combed and loosely arranged. At the passage of the Sweetwater through the Devil's Gate, we have coarse granite, rising to the height of from 200 to 250 feet above the surface of the water, having vertical basaltic columns from 2 to 4 feet thick running through and at right angles to the mass. Dispersed through this basalt are veins of quartz from ½ to 2 inches thick, generally running in a diagonal direction to the basaltic columns.

May 20.—Section of a butte isolated, and near the southern rim of the Wind River valley. This butte is a fair representation of the Sweetwater valley.

1. A thick layer of coarse, gray sandstone.
2. Grayish, white or chalk color, with 2 or three streaks of a reddish brown color running through. Strata, horizontal. The height of this butte is from 150 to 200 feet above the plain.

Wind River valley.—The Little Popo Agie. This stream makes its exit from the mountains through a cañon of red (pink) stone. In the valley we have—

1. A pink line from 6 inches to 1 foot.
2. Light blue marl.
3. Light gray marl.
4. Brown sandstone; and
5. A drift of calcareous concretions, white. Above this comes the butte above mentioned.

May 25.—Foot-slopes of the western range of the Big Horn mountains. High, rolling hills and long slopes. Ascent to the mountains was gradual. From the base of the mountains upwards, I found—

1. White or gray marl.
2. Pink.

3. Greenish.
4. Pink.
5. Sandstone.
6. White or gray.
7. Pink, with pebbles of various hues.
8. A white or gray marl.
9. A thick layer of pink. All the foot-hills presenting this appearance.

Passing over a small plateau before reaching the main hills, I found large quantities of mica, reddish brown sandstone, spherical, basaltic boulders, having the appearance of iron. Upon being broken, the inside presented a much lighter appearance than the portion exposed to the weather, its color being dark gray. Lying among and mixed with these was a pink stone, with views of quartz, and mica granite running through. The surface at this point was covered with variegated pebbles.

There is also a soft ferruginous sandstone. In the mountains the top mass presents a light pink of sandstone and gravel in mass, as though thrown together promiscuously. There is also a layer of lime concretions containing fossil shells; a rather inferior specimen was obtained on account of its being inaccessible where this was exposed.

Yellow and pink earths are mixed with the stone in the hills. Highest points of the hills I found to consist of clay slate with vertical fissures, and a mass of dark gray or iron-colored rock, having a peculiar resonance, or ringing sound, upon being struck with a hammer. Soil in the valleys of a dark brown.

May 28.—First camp on the Big Horn after crossing the first range of mountains.

1. Red stone at base.
2. A thick bed of gypsum, 10 to 15 feet.
3. Sandstone.

A short distance from our camp and across the river is a red butte. The water here has a pinkish or light brick-color after a rain.

Yesterday's (27th) travel was from the mountain range to the valley, where our camp of the 28th was pitched. The foot-hills in this day's travel were composed of a mass of dark blue or brown slate in fine pieces, with some indications of lignite, (very impure and uncertain.)

June 1.—Location opposite and west of the Ragged Peak of the east range of the Big Horn mountains from base.

1. Sandstone.
2. Lignite, very impure.
3. Bluish gray marl.
4. Yellow marl.
5. Lignite.
6. Bluish gray sandstone, very soft, 6 feet.
7. Yellow marl, with
8. A thin streak of lignite.

June 2.—

1. Bluish gray marl.
2. Yellow marl, and at top about 20 feet of a
3. Reddish brown sandstone. On the highest point
4. Broken clay slate and concretions.

June 4.—Near No-wood creek:

1. Yellow marl.
2. Pink line.

3. Gray marl.
4. Sandstone.

This is repeated. The red lines in the second course above are much thinner, and all the strata horizontal. Pebbles on surface.

June 5.—

1. Gray marl.
2. Gray sandstone.
3. Yellow marl.
4. Pink line.

First part of to-day's travel soil dark brown, with fine pieces of clay slate.

June 7.—Between Gray Bull and Stinking.

1. Bluish gray.
2. Gray sandstone.
3. Pink line.
4. Bluish gray.
5. Yellow marl.
6. Sandstone—repeated.

June 7.—In the valley of the Gray Bull creek, I found large boulders of dark gray stone, similar to the same described as in the mountains. The bed of the stream is of the same, besides water-rolled flint stones.

On Stinking the appearance of the country changes somewhat. Here we find the pink strata less distinct, and above this—

1. Ferruginous marl.
2. Sandstone, from 15 to 20 feet deep; and above this—
3. Flint stones.
4. A very dark gray strata, with fine black sand.

Obtained evidences here of the existence of gold.

June 13.—Divide between Stinking and Sage creek:

1. Gray marl.
2. Gray sandstone.
3. Brown sandstone.

June 14.—On Sage creek—continuation. Above the brown sandstone in the valley is dark soil, or rather having the appearance of very impure lignite. From our first camp on Sage creek to Pryor's gap is of a gradual ascent, the foot slopes of the mountain having a pink color. Mountains dip to west. Pink limestone, and towards the valley we have sandstone concretions, (or coarse granitic quartzose rock;) below this—

1. Yellow marl.
2. Bluish white slate scales.
3. Very impure lignite.

Noticed also selenite. This extends all the way in the valley to Clark's Fork. The same appears at the head of Stinking. Divide between Clark's Fork and the Rosebud. Transition granite, of loose texture, having the appearance of an aggregation of crystals. Soil dark and loose.

From the Rosebud to the Yellowstone:

1. Gray marl.
2. Yellow marl.
3. Sandstone.
4. A thin black streak.

In the Yellowstone valley, cobble stones and water-worn flint, very thick. Probably old bed of the river. Large boulders in the bed of the Rosebud and Big Rocky, similar to those mentioned as being the greater mass of the western range of the Big Horn mountains.

June 29.—Left bank of the Yellowstone from the place of crossing to Twenty-five Yard or Shield's river.

1. Gray marl.
2. Yellow marl, one light and one ferruginous.
3. Sandstone concretions. Soil dark brown and mixed with slate scales.
4. A layer of sandstone concretions, broken, the fractures running at right angles to each other.

Highest points of hills a thick mass of yellow sandstone. This continued all the way by our route up Twenty-five Yard river to the Blackfoot pass in the mountains.

1. The central mass of limestone.
2. Pink-colored rock; at some points were veins of a darker hue running through vertically.
3. Pink strata.
4. Slaty concretions, or clay slate, light blue.
5. Sandstone.
6. Granite.
7. Tops of hills pink. Noticed stone very much like marble, but situated in such a manner that it could not be reached to determine.

July 6.—West side of Clark's pass:

1. Foot hills of mountains pink.
2. Clay slate.
3. Central mass of limestone.
4. Red stone on top.

Second or eastern range, conglomerate:

1. A mass of pebbles mixed with yellow clay.
2. Marl and red summit.

On emerging toward Twenty-five Yard or Shield's river, foot hills pink, with marl, slate and sandstone. Camp on a small creek or tributary of Twenty-five Yard river. The top of a foot hill was covered with a reddish brown sandstone, arranged in columnar order, having a fluted appearance. Beneath was yellow and brown clay.

July 8.—Left bank of the Yellowstone. On the hills large quantity of cobble stones; also in river bed.

1. Dark brown sandstone.
2. Ferruginous marl or clay.
3. Brown deposit.
4. Reddish brown sandstone.
5. Coarse sandstone, (crystalline ?) quartzose crystals.

One hill presented dark brown coarse sandstone (schist ?) having a dyke's appearance. A mass of quartzose or micaceous crystals runs through east and west; breadth four feet, depth about 30 feet. At the apex it turned south.

July 9.—To-day passed a small stream (Hot Spring creek) whose water was quite warm, and from whence steam issued in considerable quantities, making it unpleasant to retain the hand in the water longer than *one or two minutes*. This stream heads near the Snow mountains. *Apex of hills:* yellow sandstone, arranged in columnar order from 20 to

30 feet; soil, black with a dark purple tint in places; some yellow or ferruginous marl. Rock from base: 1. Gray. 2. Gray and yellow mixed. 3. Sulphur yellow. 4. Dark gray or iron color. 5. Yellow and gray. 6. Light gray.

The rocks mentioned in this section were irregular, the strata being wavy, dipping low at some places and rising again, and so on alternately. These rocks were rather soft and strata not permanent, at some places running into each other. They were in laminæ, thin and broken. The mass of light gray rock on the top had a vein of quartzose or micaceous (?) crystals, from 10 to 20 feet deep and four feet in width, north and south:

1. Base rock of river greenish yellow.
2. Next to this in the river bottom, gravel mesa.
3. Dark sandstone.
4. Dark, nodular concretions.
5. Gray marly grit.
6. Brown (or dark purple) deposit mixed with a black, broken slate.
7. Yellow sandstone of fine grit and nodular concretions of a dark reddish brown. This is also mixed up, and in the *brown* sandstone and to some extent in the yellow.
8. Gray marl.
9. Yellow marl.
10. Sandstone.
11. A dark purple bed of five or six feet in depth, slaty.

Above this was a white marly bed, mixed in and having a layer of stone (flint or concretion) above with a white coating. Some more marl intervened and then came yellow sandstone, ferruginous marl, and dark nodular concretions, some being very large; yellow sandstone, the whole having a *mixed* appearance, although the layers appeared to be horizontal. These dark concretions had the appearance as though they had been thrown there in a plastic mass.

July 13.—From base:

1. Sandstone. This stone was under water. I broke some pieces off, and found evidences of fossil plants in this only.
2. Gravel mesa.
3. Gray marl.
4. Yellow marl.
5. Brown sandstone.
6. Purple, or dark red, slaty.
7. Sandstone 10 feet, and nodular concretions.

The first layer of sandstone, honey-combed, with dark brown streak running through the mass. After this, gray and ferruginous marls; sandstone.

A dark, chippy, slaty layer.

Next a layer having a purple color where exposed to the atmosphere, but on removing the surface it is lighter colored, having more the appearance of rust of iron. Next comes a layer of loose concretions, *stone* covered with a white crust; then marls and sandstone, and on the summits of the highest points a layer of gravel variegated. Same as on river banks.

Right bank of the Yellowstone:

1. Light yellow and gray sandstone, 15 feet.
2. Yellow sandstone.
3. Very light *gray sandstone*.

4. Bluish gray marl, (slaty) clay.
5. Light yellow sandstone, 10 feet.
6. Dark *rust, or purple* color.
7. Yellow sandstone, 15 feet.

July 15.—Right bank—

1. Dark blue slaty squama.
2. A large mass of yellow sandstone, with brown stria, and vertical fissures. Above this was
3. Ferruginous *marl.*

Left bank, same day—

1. Gravel.
2. Gray marl.
3. Ferruginous marl.
4. Thirty feet solid yellow sandstone, with brown nodules in the mass. Above this about—
5. Twenty feet sandstone laminated.
6. Marl and gravel.
7. Marls, gray and yellow.
8. Sandstone (squama.)

Late in the day saw on both banks the dark blue, broken, slaty layer; then gravel, and at a distance, on the summit of an isolated point, saw again the *purple* layer, as before mentioned. Between the laminated sandstone was yellow clay in regular layers.

July 16.—A mass of sandstone and marls.

Pompey's pillar. This is an isolated butte on the right bank of the Yellowstone. It has been separated from the hills on the north by a change in the bed of the river. It is from 160 to 180 feet in height, and consists of alternate layers of yellow clay and sandstone; pebbly on top.

At camp, (left bank:)

1. Gravel.
2. Black clay slate.
3. Gravel.
4. Sandstone and sandstone concretions, with pebbles.
5. Gray marl and yellow marl (or clay) and sandstone alternately.
6. Selenite, and white incrustations.

July 18.—Noticed two changes in the strata to-day:

1. A bed of quartz or flint.
2. A layer of gravel having a light pink color, and a *blue* or lead-colored clay slate, (very soft.)

July 19.—Opposite the mouth of the Big Horn river, same as yesterday. To-day the blue clay slate becomes quite prominent. It is firmer and in regular layers. First appearance of *lignite* on the Yellowstone.

July 20.—Same as yesterday, except that the lignite here takes the place of the blue clay slate.

July 21.—Sandstone, sandstone concretions, blue and ferruginous marl, selenite, slaty, lignite.

Location, east of Porcupine creek, (near Table creek,) lignite and cretaceous.

July 23.—

1. Gray marl.
2. Ferruginous marl.
3. *Brown sandstone.*

4. Gray, blue, and ferruginous marl.
5. Sandstone.
6. Variegated pebbles.

July 24.—Bad Lands—

1. Lignite.
2. Bluish gray marl, ferruginous marl, sandstone, &c.

July 25.—Marls, lignite, sandstone, sandstone concretions, red baked clay first on Yellowstone.

July 26.—

1. Gray marl.
2. Ferruginous marl.
3. Lignite.
4. Gray marl.
5. Sandstone.
6. Red.
7. Ferruginous marl.
8. Gray marl.
9. Lignite.
10. Marl.
11. Sandstone and concretions.
12. Red.
13. Gray.
14. Sandstone.

Some evidence here (Henry's caches) of fossil leaves. They were, however, not in good preservation, not worth collection.

Henry's Caches hills:

1. Gray marl.
2. Bright yellow ferruginous marl.
3. Lignite.
4. Ferruginous marl.
5. Sandstone, and
6. Concretions having a conchoidal fracture. Thin layers of the same passing through the marl at intervals. On the summit red, baked clay.

On the summits of the highest points of Henry's caches, large layers of sandstone, cylindrical, and from four to six feet in diameter. Here found a kind of pumice. Tops of hills covered with honey-combed stone having a melted appearance; very rough and jagged.

July 28.—East portion of Henry's caches:

Section from base gray marl, lignite, red, lignite, ferruginous marl, lignite, bluish gray marl, yellow sandstone, bluish gray marl, and in the latter, at equal intervals, three layers of thin brown sandstone; nodules, then bluish gray marl, lignite, ferruginous marl, bluish gray marl, ferruginous marl, and sandstone in laminæ, over which was a thick layer of solid gray sandstone; light gray marl, very loose, and incoherent. Above all gravel. There were also sandstone concretions having a dark and conchoidal fracture. From this point to Fort Union I did not take a section, owing to Doctor Hayden's having been here on a former occasion.

CHAPTER XII.

GEOLOGICAL EXPLORATIONS IN KANSAS.

SOME NOTICE OF GEOLOGY UP TO 1867—EXPLORATIONS OF MESSRS. MEEK AND HAYDEN IN 1858—COAL MEASURE ROCKS AT LEAVENWORTH CITY—SECTION ON BIG STRANGER CREEK—GEOLOGY ALONG GRASSHOPPER CREEK—VERMILION CREEK—ZEANDALE—A BED OF COAL—BIG BLUE RIVER—KANSAS AND SMOKY HILL—PERMIAN ROCKS—THEIR PERMO-CARBONIFEROUS CHARACTER—GENERAL SECTION OF THE ROCKS OF KANSAS VALLEY FROM THE CRETACEOUS DOWN, SO AS TO INCLUDE PORTIONS OF THE UPPER COAL MEASURES—COMPARISON OF CARBONIFEROUS AND PERMIAN TYPES OF FOSSILS—NOTICE OF THE GYPSUM BEDS—GEOLOGY OF CHAPMAN'S CREEK AND SOLOMON'S FORK—DISCOVERY OF DICOTYLEDONOUS LEAVES IN SANDSTONE, INDICATING CRETACEOUS ROCKS—DESCRIPTION OF THE FERTILITY OF THE SOIL AND SOME OF THE RESOURCES OF KANSAS—LIST OF THE SPECIES MENTIONED IN THIS CHAPTER, WITH SOME REMARKS ON THE SYNONYMY, AND REFERENCES TO THE WORKS IN WHICH THEY ARE DESCRIBED.

During the summer of 1858, Mr. F. B. Meek and the writer, made an exploring tour into the Territory of Kansas, as it was then called. We were much aided by Major (now General) Van Vliet, for without his assistance as assistant quartermaster in the United States army, we should have failed of accomplishing our mission. As it was, our explorations were unusually successful, and on our return the geological results were embodied in a paper published in the Proceedings of the Academy of Natural Sciences at Philadelphia, January, 1859, to which nothing of importance has been added by subsequent explorations. It is republished in this report from the fact that its first publication was limited and the demand for the information contained in it has been great. Since the publication of that paper there have been several geological surveys, one in 1864 by Professor B. F. Mudge, and a subsequent one by Professor G. C. Swallow. Several small papers also have been published by Professor S. and Mr. Hawn, containing views differing from ours in some respects; still we have not yet seen any reason for changing our opinions, and we still regard them as correct. Professor Swallow's report I have not seen. In Professor Mudge's report the principal formations observed in Kansas are mentioned quite briefly, namely: Carboniferous, permian, triassic, cretaceous, and various superficial beds, but as yet the evidence in regard to the triassic is as uncertain and doubtful as in 1858. It is quite probable that it exists in some parts of the State. Professor Mudge, in his report, describes some footprints of birds in sandstone, which he supposes to be of triassic age. The locality where they were obtained is about 50 miles northwest of Fort Riley, on the top of a sandstone bluff, about 125 feet above the Republican river. He says: "We cannot speak with confidence in relation to the geological age of the strata which contained the footprints, as we found no other fossils near the locality except siliceous wood. A few miles distant we discovered some impressions of exogenous leaves which we suspected were in the same geological horizon as the tracks, but were unable at the time to verify it. We are inclined to place the deposit as high up as the lias. The beds of sandstone are *much changed from* their normal condition, principally caused by the presence of oxide of iron. The stratification is not regular, much of it showing an oblique deposit, with other indications of shoal water at the time the tracks were made." It is hardly necessary for me to state here that the geographical and geological position of this sandstone, as well as the description of its character, show most clearly that this sandstone is of the age and cretaceous formation No. 1, or Dakota group. The existence of large quantities of coal in this State seems now to be a settled fact. Professor Mudge estimates the area underlaid by it at 22,000 square miles. Salt, however, seems to be the great production, and bids fair to be a source of vast revenue to the State. Professor Mudge mentions and describes 12 State salt springs.

As it is merely our purpose on the present occasion to give rather briefly the results of some geological examinations made by us last summer in eastern Kansas, it will perhaps scarcely be expected that we should here enter into a historical review of the valuable labors of other explorers in that region. Hence we proceed at once to present such facts as came under our observation, and the conclusions they seem to warrant.

The route pursued by us while making these investigations was first from Leavenworth City, on the Missouri, across the country to Indianola, near the mouth of Soldier creek, on the Kansas; thence up the north side of Kansas and Smoky Hill rivers, to the mouth of Solomon's Fork. Here we crossed the Smoky Hill, and followed it up on the south side to a point near the 98° of west longitude; from which point we struck across the country in a southeast direction to the Santa Fé road, which we followed northeastward to the head of Cottonwood creek. Leaving the road here, we went down the Cottonwood valley some 30 miles, when we turned across the country nearly due northward to Council Grove. From the latter place we followed the Santa Fé road back southwestward about 24 miles, to a watering-place known as Lost Spring; here we again left the road and struck across the country in a northwest direction to Smoky Hill river, at a point nearly opposite the mouth of Solomon's Fork. We then traveled down the south side of Smoky Hill and Kansas rivers to Lawrence, where we crossed the Kansas and proceeded in a northeast direction back to Leavenworth City.

The first outcrop of rocks examined by us during the expedition is at a point just below the steamboat landing at Leavenworth City. At this place and for some distance above on the river, the formation is well known to belong to the upper, but not the highest portions of the great western coal measures. The section here, near the Leavenworth landing, presents the following beds, in descending order:

1. Bluish gray clay, exposing a thickness of about 3 feet.
2. Hard gray layer of *fusulina* limestone, 1¼ foot.
3. Yellow laminated clay, 7 feet.
4. Hard gray argillaceous limestone, with *fusulina*, 1 foot.
5. Gray, fine-grained argillaceous sandstone, with fucoidal markings, sometimes contains seams of limestone, 1 to 3 feet.
6. Gray, green, and blue, rather indurated clay, with, sometimes, near the base, many compact concretions of limestone, 2 feet.
7. Hard, light yellowish, gray limestone, usually of bluish tinge, far in beyond the effects of weathering. Contains *Spirifer cameratus*, *S. Kentuckensis*, *S. lineatus*, *Spirigera subtilita*, *Orthisina Missouriensis*, *Productus splendens*(?), *P. semireticulatus*(?), *P. pustulosus*, and *Fusulina cylindrica*, together with columns of *crinoids*, and spines and plates of *archæocidaris*; also jaws, teeth of *Xystracanthus arcuatus*, 15 feet.

8. Dark shale, passing up into gray less distinctly laminated clay, 5 feet.
9. Hard dark bluish impure limestone, containing *Fusulina cylindrica*, *Spirigera subtilita*, *Productus Rogersi*, *P. Prattenianus*, *Arca carbonaria*(?), an undetermined *monotis*, *Allorisma*(?) *Leavenworthensis*, *A. subcuneata*, *Myalina subquadrata*, *Leptodomus granosus*, and a large *bellerophon*, 1½ to 2 feet.
10. Gray, more or less laminated clay, becoming darker near the upper part, rising above the river 11 feet.

Attached to the surfaces of bed No. 9 there is usually from one to two inches of soft, dark, argillo-calcareous matter, containing great numbers of *Orthisina crassa*, with the undetermined species of *pecten*, *mytilus*, *schizodus*, *pleurotomaria*, &c.

All this section above No. 7 appears to vary considerably, at different places some of the beds being entirely wanting, or presenting quite different lithological characters at other localities not far from here. Owing to the dip of the strata, and partly to the fall of the river, the bed of limestone No. 7, which is elevated 18 feet above the river where this section was taken, rises as much as 25 feet above the level of the river, at a distance of one mile or less below, and on following the outcrop of these rocks along the shore above Leavenworth City, they were found to sink gradually beneath the water, so that at Fort Leavenworth landing, two miles above, (in a north direction from the exposure first examined,) all of beds Nos. 8, 9, and 10, as well as two or three feet of No. 7, were submerged. Should this dip continue at the same rate, without local undulations, the whole of No. 7 must pass beneath the river in less than two miles above the fort.

Immediately above No. 1 of this section, we saw no exposures of rock in place; but on a small stream about two and a half miles below Leavenworth City, and perhaps one and a half miles back from the river, there is an outcrop of soft fine-grained yellow sandstone, showing a thickness of 24 feet, underlaid by a bed of blue clay, of which a thickness of about four feet was exposed. We had no opportunity to determine the elevation of these beds above the river with sufficient accuracy to form a definite conclusion whether or not they hold a position above the section seen near the Leavenworth landing, though we incline to the opinion that they come in above it. In ascending the hills back of Leavenworth City we observed no outcrops of rock along the slopes until near the summit, where, at an (estimated) elevation of about 200 feet above the highest bed of the section at the river, there is an exposure of hard bluish gray impure limestone, weathering to a yellowish tinge, the beds of which are separated at places by partings of clay. Of this rock we saw a thickness of 16 feet. It is much used for building purposes, and quarried rather extensively back of Fort Leavenworth. At one of these quarries, amongst the loose material thrown out by the workmen, we found specimens of *Spirifer cameratus*, *S. Kentuckensis*, *S. planoconvexa*, *S. hemiplicata*, *Spirigera subtilita*, *Productus semireticulatus*, *P. Norwoodi*, *Leptodomus Topekaensis*, *Fusulina cylindrica*, *Terebratula millepunctata*, and fragments of *crinoids*, with *chætetes* and *fenestella* of undetermined species. Above the quarry there is a slope of some 40 or more feet to the summit of the hills, apparently occupied by clays; and the quarrymen informed us that there is immediately under the bed of limestone an eight-foot bed of clay, beneath which they had made no excavations.

West of this locality the surface of the country soon descends gradually into a depression connected on the north with the valley of a small stream flowing into the Missouri above Fort Leavenworth. In this immediate neighborhood the face of the country is slightly inclined to be hilly, but the soil is rich, and the long gentle slopes are clothed in the spring and summer months with a luxuriant growth of prairie grass. From several points near here we had a fine view of the broad rich valley, with its beautiful groves and scattering farm-houses along the little stream to the north of us. Beyond this, the road, after passing over some undulations, ascends to the summit of the country, which is rich elevated prairie land. At several places near the upper part of the slopes, some five or six miles from Leavenworth, we met with outcrops of light gray limestone, apparently in ten to twelve-inch layers, containing *fusulina*, *Productus semireticulatus*, *chætetes*, and small *cyathophylloid* corals. These beds probably belong to the same horizon as the limestone near the top of the bluffs back of Leavenworth, or may even hold a higher position. At Big Stranger creek, some fourteen or fifteen miles west of Leavenworth City, the following section was observed in descending order:

1. Slope, without any exposure of rocks, 60 feet.
2. Layers of limestone, weathering yellowish, containing *Spirifer cameratus* and *Fusulina cylindrica*, 8 feet.
3. Slope, probably occupied by shale or clay, 40 feet.
4. Grayish yellow limestone, with *Fusulina cylindrica* and *Spirigera subtilita*, 5 feet.
5. Bluish gray soft shale, or laminated clay with occasional harder sandy seams, 38 feet.
6. Coal, immediately overlaid by one inch of cone-in-cone, ½ foot.
7. Bluish gray laminated clay or soft shale, extending down to the creek, 18 feet.

Again on Little Stranger creek, some 12 miles southwest of Leavenworth City, there is a somewhat similar exposure, containing a twenty-inch bed of coal. This bed is worked to some extent on the land of Mr. Charles Stone, where the following section may be seen in the descending order:

1. Light gray, or bluish gray, soft calcareous sandstone, with harder layers, containing much argillaceous matter, with *Productus splendens*, (?) *Myalina subquadrata*, an undetermined *monotis*, and many fucoidal markings; exposing a thickness of 15 feet.
2. Blue laminated clays, more or less arenaceous above, 26 feet.
3. Coal, 1¾ foot.
4. Bluish gray, somewhat ferruginous, clay, rising above the creek 4 feet.

We have no means of determining what relations the rocks composing these two sections bear to the exposure at Leavenworth, but we think they hold a position between the bed of limestone seen near the top of the hills back of Leavenworth City and the upper bed of the section near the Leavenworth landing.

Between Big Stranger and Grasshopper creeks the road passes over a beautiful rich prairie, elevated about 350 or 400 feet above the Missouri. In crossing this prairie we met with no exposures of rock, the whole being covered by heavy quaternary deposits, into which wells have been sunk at several places, from 30 to 70 feet, without striking solid rock *in situ*. At one or two places, however, we saw masses of limestone which had been quarried for building purposes along a little stream two or three miles north of the road. These contained, among other fossils, *Spirifer cameratus*, *Orthisina umbraculum*(?), *Fusulina cylindrica*, and fragments of *fenestella*, with spines and plates of *archæoci-*

daris. We had no opportunity to examine the quarry from which this rock was obtained, but were informed that the bed is some 60 or 70 feet below the summit of the higher portions of the surrounding country. In descending from this elevated prairie into the valley of Grasshopper creek, at Osawkee village, we observed—

1. A bed of hard gray limestone near the summit of the slopes, containing great numbers of *fusulina*, 8 feet.
2. Slope, no rocks exposed, about 55 feet.
3. Outcrops of *fusulina* limestone, apparently 3 feet.
4. Slope, no rocks exposed, 50 feet.
5. Gray or bluish gray limestone, weathering yellowish, containing *Pleurotomaria humerosa*, *P. subturbinata*, and a large undetermined species of *bellerophon;* also *Allorisma* (?) *Leavenworthensis*, *Myalina subquadrata*, *pinna* undetermined, *Spirifer cameratus*, *S. planoconvexa*, and *Productus æquicostatus*, with great numbers of *Fusulina cylindrica*, 3 feet.
6. Dark gray indurated clay, 2 feet.
7. Rather soft argillaceous limestone, 4 feet.

The fact that several of the fossils seen here in bed No. 4 are the same species found in No. 5 of the section at Leavenworth landing, would seem to indicate that these beds occupy the same geological horizon. It is very difficult, however, to identify the same beds at different localities among these formations, in consequence of the fact that the fossils found in them usually have a great vertical range, and exactly similar strata are often repeated in various parts of the series. Should it prove to be the case that they do occupy the same geological horizon, it would show that there is here a gentle eastward dip; for the lowest bed of this section, on Grasshopper creek, cannot be less than 100 feet higher than the base of the section at Leavenworth City.

Still we incline to the opinion that the strata near here, if not almost horizontal, or merely undulating, have a general inclination towards the west, or somewhat north of west, and that the exposure on Grasshopper creek is composed of much more modern than those near the landing at Leavenworth City. At any rate, we saw an exposure at Lawrence landing, on the Kansas, composed of ledges of limestone, overlaid by clay, and having a decided dip to the west or north of west, at a rate of not less than fifty feet to the mile. This limestone consists of an upper hard gray layer, about three feet in thickness, resting on a soft gray arenaceous bed, of which some one or two feet were visible above the surface of the river when examined by us. In these beds we saw *Spirigera subtilita*, *Productus splendens* (?), and *Myalina subquadrata.* Above these about 11 feet of gray laminated clay were exposed, the upper part of the bed having a more yellowish tinge, and containing more arenaceous matter than the lower. If these beds continue to rise at the same rate towards the east, they must of course run out on the summit of the highest part of the country not far east of Lawrence; and the same inclination to the west or northwest would take them far beneath the horizon of the base of the section seen on Grasshopper creek. Above this exposure at Lawrence landing there is a space of about 160 feet in which no outcrops were seen, excepting some red and blue clays near the upper part of the hills, back of the town. Just above these clays some ledges of gray limestone were seen, apparently altogether about eight feet in thickness, containing *Fusulina cylindrica*, *Spirigera subtilita*, and *Spirifer cameratus.*

West of Grasshopper creek, on both sides of the Kansas, the country becomes lower near the river, but at a distance of some ten or twelve miles back, on the north side, it appears to be nearly as elevated as on the east of Grasshopper creek. Between this higher country and the Kansas there is a plateau, apparently elevated not more than 60 feet above the broad level prairie bottoms along the river; while on the south of the Kansas, some five or six miles southwest of Topeka, there are some isolated hills, apparently of the same elevation as the high country north of the Kansas. At several places after crossing Grasshopper creek, we met with some highly fossiliferous beds along the small streams, at an elevation of apparently about 80 feet above the Kansas. Below we give a section of these beds seen at a locality some eight miles southwest of the point where the exposures mentioned on Grasshopper creek were observed.

1. Rough seams and layers of concretionary limestone of bluish tinge, with partings of clay, containing *Terebratula millepunctata*, *Spirigera subtilita*, *Spirifer cameratus*, *S. Kentukensis*, *Retzia Mormonis*, *Rhynchochonella Uta*, *Productus Norwoodii*, *P. splendens*, (?) *P. semireticulatus*, *P. Prattenianus*, *Orthisina*, similar to *O. umbraculum*, also *fenestella* and *chætetes* of undetermined species, 4 feet.
2. Black shale, shading upwards, gradually, into laminated blue clay, 2½ feet.
3. Hard blue or gray limestone, with *Spirifer cameratus*, *Spirigera subtilita*, *myalina*, *pecten*, &c., 1 foot.
4. Bluish gray soft clay, with seams of hard limestone, 3 feet.
5. Light gray, somewhat granular limestone, with a few round grains and very small pebbles of quartz, 2 feet.

At another place on the south side of the Kansas, about 12 miles southwest of the point where the last section was seen, there is an abrupt bluff near the old Baptist Mission, composed of the following beds in the descending order:

1. Slope; no rocks exposed, 20 feet.
2. Hard yellowish gray limestone, with fragments of fossils, 4 feet.
3. Slope; no rock exposed, 18 feet.
4. Light gray, rather hard fine-grained sandstone, 3 feet.
5. Slope, 20 feet.
6. Fine-grained sandstone in thin layers, not well exposed, apparently 2 feet.
7. Slope, with occasional outcrops of hard gray limestone, 15 feet.
8. Yellowish and dark laminated clay or soft shale, with layers and nodular concretions of argillaceous carbonate of iron near base, 90 feet.*
9. Hard bluish argillaceous limestone, of which there was exposed in the bed of a small stream, not more than 13 or 15 feet above the river, a thickness of 1 foot.

After passing this locality we heard of a coal mine some three or four miles south of here, near the base of an isolated hill, known as Shanganunga mound. We did not visit this mine, but were informed that it is considerably above the summit of the last section, and that the bed is about 18 inches in thickness. The coal is said to be of good quality.

Above here, on both sides of the Kansas, the country continues to be rather low, no part of it being apparently more than 200 feet above the river. For a long distance above this there is a beautiful

* There may be some thin beds of limestone in this portion of the section, as every part of this 90-foot bed was not well exposed.

broad level bottom prairie on the north side of the Kansas, extending back from 4 to 6 miles, and as much as 18 or 20 miles along the river. Bounding this on the north, the country rises by a gentle, grassy slope, to an elevation of from 60 to about 100 feet, furnishing the most beautiful sites for dwelling houses.

For a considerable distance above the locality where the exposure near the old Baptist Mission was examined, the hills, especially near the river on the south side, appear to be mainly composed of rather heavy deposits of laminated clays and shales, with soft sandstones and occasional thin beds of limestone, containing the usual fossils of the upper carboniferous series. At the crossing of Mission creek, at an elevation of perhaps not more than 25 or 30 feet above the Kansas, exposures were observed, consisting first above of five feet of light gray laminated clay, resting upon two or three feet of soft yellow sandstone, which passes down into laminated arenaceous clays, of which some 8 or 10 feet were exposed above the creek.

Some 15 or 16 miles west of the point where the road crosses Mission creek, at a locality 6 or 7 miles south of the Kansas, there is a high elevation known by the name of Buffalo mound, rising as much as 450 or 460 feet above the river.

At one place a large creek, called on the maps Upper Mill creek, sweeps close along the northern base of this elevation, and has carried away the loose debris so as to leave the lower strata well exposed. The section here beginning at the summit of this hill is,

1. A slope of about 160 feet, along the lower forty feet of which we found loose specimens of *Spirifer cameratus*, *S. plano convexa*, *Retzia Mormoreii*, *Productus splendens*, *(?) Chenctes Verneuiliana*, *C. mucronata*, and *Fusulina cylindrica*, var. *ventricosa*, with fragments of *chætetes*, *crinoids*, &c., of undetermined species.
2. Bluish gray limestone in two layers, the upper of which contains columns of *crinoids*, *Productus Calhounianus*, &c., while *Myalina subquadrata*, *Orthisina Missouriensis*, *allorisma*, *pinna*, *monotis*, &c., of undetermined species, occur in the lower, 3 feet.
3. Slope, with no exposures of rock, 96 feet.
4. Rather hard mottled brown and light gray compact limestone, with a few *crinoid* columns; may be thicker, but only showing a thickness of 3 feet.
5. Brown, whitish and green clays, with rugged white calcareous concretions, 4 feet.
6. Fine argillaceous sandstone, with streaks of yellow and brown colors, 1½ foot.
7. Ash-colored clay, 10 feet.
8. Clays of red or brownish colors above; blue and green below, 3½ feet.
9. Deep brown clay, with rugged concretions of same color, 3 feet.
10. Hard light bluish limestone, with some rather large columns of *crinoids*, *Chonetes Verneuiliana*, &c., 2½ feet.
11. Brown, ash-colored, and blue laminated clays, which are more or less arenaceous, with, near the middle, some 5 or 6 inches black shale, 46 feet.
12. Gray and purple argillaceous limestone, with *pinna*, *productus*, and a few *fusulina*, 1¼ foot.
13. Green laminated clay, 4 feet.
14. Two or three layers of soft fine-grained sandstone, more or less argillaceous, and separated by seams of clay, 2 feet.
15. Bluish and ash-colored clays, 21 feet.

ternate layers of hard bluish gray limestone, and seams of clay ı sandy concretions, 3 feet.

ıther hard yellowish limestone, with *fusulina*, 2½ feet.

ıh-colored clay, not very well exposed, 15 feet

ıllowish impure limestone, with *fusulina*, 2 feet.

ıh-colored laminated clays—above the creek, 5 feet.

ıut 300 yards below where this section was taken the creek was 'ed to fall nearly a foot over a ledge of hard limestone; and one ırther down the bed of the creek is composed of a hard yellow one, containing great numbers of *fusulina*. At these localities Mill is probably not elevated more than 30 feet above the Kansas. ıalf a mile east, or southeast, of the point where the *fusulina* lime- was seen in the bed of Mill creek, and at a somewhat higher :on, we saw apparently the same bed of *fusulina* limestone showing ĸness of 3 feet. Under this there was at one place exposed a ess of some 4 or 5 feet of very fine yellow sandstone, with minute ı of mica. These exposures indicate a moderate dip of the strata ls the west or northwest. On the north side of the Kansas, in a ion a little west of north, and about 16 miles from the last ıned localities, we observed an outcrop on a small stream marked Creek" on the maps, presenting the following section, descending:

ms yellow magnesian limestone, alternating with clay, showing ickness of about 8 feet.

low soft granular magnesian limestone, containing *Productus woodi*, and an undetermined species of *myalina*, 4 feet.

e laminated black shale, 1 foot.

ıy, rather soft argillaceous limestone, 1 foot.

e, somewhat indurated, very fine calcareous clay, containing, at junction with the next bed below, *chonetes*, *Synocladia biserialis*, *tes*, and fragments of *crinoids*, 9 feet.

ms hard compact gray limestone, alternating with softer argillo- areous matter, and containing casts of many small *cypricardia*- shells, small *murchisonia*, *pleurotomaria*, *macrochielus*, *naticopsis*, *rophon*, &c., 2 feet.

ish laminated clays, weathering to drab color, 4 feet.

low, rather soft granular magnesian limestone, with imbedded ments of harder, more compact limestone, 5½ feet.

ish indurated calcareous clays, 3 feet.

base of this section is evidently not elevated much above the ıs, as it extends down to the bottom of a deep ravine, formed by ɜek, while its top appeared to be nearly on a level with the surface bottom prairie in the Kansas valley. These beds dip a little to the vest, and are very similar, especially the magnesian limestones, ne of the permian strata holding a position far above this in the some considerable distance west of here. Only about three miles r west we saw the following exposure on Vermilion creek:

pe of about 15 feet, with, near the base, some ledges of gray lime- e, amongst loose fragments of which we picked up specimens of *igera subtilita*, *Spirifer hemiplicata*, *Productus Norwoodi*, and *P. ıdens* (?) 15 feet.

pe, no rock seen, 26 feet.

t bluish and gray, more or less laminated clays, with irregular sandy ns and concretions, 12 feet.

ɜgular, hard, blue calcareous seam, 1 to 6 inches, ½ foot.

5. Blue clay, 2 feet.
6. Soft, decomposing, more or less laminated sandstone, 4 feet.
7. Blue clay 1 foot above the creek, 1 foot.

Almost directly opposite these localities, on the south side of the Kansas, some 3 or 4 miles back from the river and nearly on a line between the locality where we saw the exposures on Last Creek and Buffalo mound, but considerably below the level of the summit of the latter, we examined some exposures presenting beneath a slope of about 80 feet in descending order:

1. Hard bluish gray limestone, of which there was exposed 1 foot.
2. Rough yellowish magnesian limestone, with cavities lined with chalcedony, 3 feet.
3. Bluish and ash-colored clays, 5 feet.
4. Layer much like No. 2, 1 foot.
5. Yellowish green clay, 20 feet.
6. Bluish gray limestone in two layers, the upper of which contains columns of *crinoids*, *Productus Calhounianus*, &c., while *Myalina subquadrata*, *Orthisia Missouriensis*, *allorisma*, *pinna*, *monotis*, &c., occur in the lower, 3 feet.
7. Bluish and ash-colored clays, exposing a thickness of 5 feet.

The bed No. 6 of this section is evidently the same as No. 2 of the section at Buffalo mound, (page 110,) though here the dip of the strata has brought it lower. Its elevation above the Kansas at Buffalo mound must be about 250 feet.

We had no means of estimating very accurately its elevation where the last section was taken, though we do not think it as much as 175 feet above the Kansas. Ten miles farther west on the same side of the river, along a small stream marked Deep creek on the maps, at a point some four or five miles back from the Kansas and elevated perhaps as much as 40 feet above it, some outcrops were examined near Zeandale, presenting the following section, descending:

1. Long slope of about 100 feet, no rocks seen, 100 feet.
2. Dark argillaceous limestone, stained with iron and containing fragments of *crinoids*, 4 feet.
3. Soft decomposing argillaceous limestone, 2 feet.
4. Very hard light yellow compact limestone in one massive bed, containing great numbers of *fusulina*, also *Productus Calhounianus*, &c., 6 feet.
5. Ash-colored laminated clay, 22 feet.
6. Hard decomposing argillaceous limestone with *fusulina*, 3 feet.
7. Blue, green, and ash-colored clay, 18 feet.
8. Gray argillaceous limestone, with more or less ferruginous matter, 3 feet.
9. Light bluish clay somewhat laminated, 7 feet.
10. White decomposing argillaceous limestone with *Productus Calhounianus*, 1 foot.

We heard of a bed of coal some four or five miles above this, on the same creek, but were unsuccessful in an attempt to find the locality where it crops out. We were informed, however, by Mr. Pillsbury, an intelligent gentleman living at Zeandale, that the bed is from four to six inches in thickness, and overlaid by about three and a half feet of blue shale, strongly impregnated with alum. Above the latter, he said there is an eight or ten inch layer of dark argillaceous material, weathering to an *iron-rust color*, and containing many nodular concretions, perhaps of caronate of iron. From the information obtained in regard to the location and elevation of this coal bed, we are inclined to believe it must hold a position a little below the horizon of the middle of the slope at the top of the foregoing section. It is probably the highest bed of coal in the whole series of this region; at any rate we saw no indications of coal above it. Above a mile or a mile and a half north of the locality where this coal bed has been seen, the dividing ridge between the Kansas and Deep creek rises to an elevation of near 320 feet above the latter stream at the nearest point. Here at the summit of this ridge there are some thin outcrops of gray and whitish argillaceous limestone, showing on weathered surfaces a somewhat laminated structure, and containing at places large spines of a species of *archæocidaris;* beneath this there is about two feet of gray fragmentary limestone reposing on a more compact bed of hard gray limestone near three feet in thickness, and often cellulæ in the middle. Along the slope about 120 feet below the horizon of these beds, we found loose specimens of *Spirifer cameratus*, *Orthisina umbraculum*, (?) *Rhynchonella uta*, *allorisma*, *Synocladia biserialis*, &c. Just below these there were many loose slabs of light yellowish, fine-grained, calcareous sandstone, containing *productus*, *pecten*, and *fucoidal* markings. About 47 feet lower down the slope, and near 115 feet above the level of the Kansas, there is an exposure of light grayish yellow granular limestone, showing a thickness of three feet, in which we only saw fragments of a *chonetes*, and *crinoid* columns; large tabular masses of this rock were strewed along the slope for some distance below. At the mouth of Big Blue river, on the south side of the Kansas, there is an abrupt bluff, along which several slides have exposed many of the beds composing the high ridge mentioned six or seven miles below here. The dip, however, of the strata toward the west or northwest is so great that the limestone containing spines of *archæocidaris*, seen on the summit of the ridge below this, at an elevation of about 320 feet above the Kansas, is here, opposite the mouth of the Big Blue river, only elevated about 214 feet above the Kansas; consequently the three feet of grayish yellow limestone cropping out 115 feet above the Kansas along the slope of the ridge above mentioned, at the mouth of Blue river, has sunk beneath the level of the Kansas. This far we have scarcely attempted to draw parallels between the various beds seen by us at different places, in consequence of the fact that our observations were isolated, as must necessarily be the case in a mere reconnoissance, extended over a large area in a short space of time.

In addition to this, the group of rocks examined presents no extensive beds of limestone or other hard material, forming well-marked horizons, or continuous lines of outcrop, by which the relations between strata seen at different localities could be traced out. This difficulty is also greatly increased by the frequent repetition of precisely similar beds at different horizons in the series, and above all by the great vertical range of the organic remains. Consequently we have preferred to present separately the local sections examined, instead of attempting to construct a continuous general vertical section showing the order of superposition of the various strata. To do this successfully throughout all the various rocks of the whole Kansas valley, would require much more time than we had at our command. As our examinations along the Kansas and Smoky Hill rivers above this point were made in more detail, where the outcrops were more frequent and continuous, we have, as we believe, been able to trace out the connections and order of succession of the various strata with considerable accuracy. Hence we give below a general section of the rocks in this region, commencing with the cretaceous sandstones on the summits of the Smoky Hills, latitude $38^\circ 30'$ north, longitude 98° west, and descending through the various intermediate formations seen along the Smoky Hill and Kansas rivers, to the base of the bluff already mentioned, opposite the mouth of Big Blue river, on the Kansas. It is true, there are a few gaps in this section where we were unable to see the beds along some of the slopes, but as we know the position in the series, as well as the extent of these gaps, it will be easy to determine, when a greater number of exposures have been examined, the nature of the beds occupying them.

General section of the rocks of Kansas valley from the cretaceous down, so as to include portions of the upper coal measures.

1. Red, brown, and yellowish, rather coarse-grained sandstone, often obliquely laminated, and containing many ferruginous concretions; also fossil wood and many leaves of dicotyledonous trees, some of which belong to existing genera, and others to genera peculiar to the cretaceous epoch. Locality, summit of Smoky Hills, 60 feet.
2. Whitish, very fine grained argillaceous sandstone, underlaid by bluish purple and ash-colored clays. Locality same as preceding; 15 feet.
3. Long, gentle slope, with occasional outcrops of ash-colored red, blue, and whitish, more or less laminated clays, with thin beds of sandstone. Locality same as preceding, and extending down at places nearly or quite to the bluffs of Smoky Hill river; thickness about 200 feet.
4. Red sandstone, with some layers of hard, light gray calcareous sandstone, and both containing ferruginous concretions. Locality, bluffs Smoky Hill river, five or six miles above Grand Saline river; probably local; thickness seen about 15 feet.
5. Bluish, red, light yellow, and gray clays, and soft clay stones, with sometimes a few thin layers of magnesian limestone. In many places these clays have been traversed in every direction by cracks, into which calcareous and argillaceous matter have found their way, and subsequently become consolidated so as to form thin seams of impure yellowish limestone, which cross and intersect each other at every angle. The red clays are usually less distinctly laminated, contain more arenaceous matter, and often show ripple marks on the surfaces. Locality, bluffs along Smoky Hill river, above the mouth of the Grand Saline, 60 feet.
6. Light gray, ash colored, and red clays, sometimes arenaceous, and often traversed by cracks filled with calcareous matter as in the bed above, alternating with thin layers and seams of gypsum. Locality, near mouth Smoky Hill river, 40 feet.
7. Rather compact amorphous white gypsum, with near the base disseminated crystals, dark colored gypsum. Locality same as last, 4½ to 5 feet.
8. Alternations of ash-colored, more or less arenaceous clays, with thin beds and seams of gypsum above; towards lower part, thin layers of claystone, and at some places soft magnesian limestone. Locality same as last, 50 feet.
9. Rough conglomerated mass, composed of fragments magnesian limestone and sandstone, with sometimes a few quartz pebbles, cemented by calcareous and arenaceous matter; variable in the thickness and probably local. Locality, south side of Smoky Hill river, 10 or 12 miles below Solomon's Fork, seen 18 feet.

0. Bluish, light gray, and red laminated clays, with seams and beds of yellowish magnesian limestone, containing *Monotis Hawni*, *Myalina*

perattenuata, *Pleurophorous* (?) *subcuneata*, *Edmondia* (?) *Calhouni*, *pecten* undetermined, and *spirigera* near *S. subtilita*, also *Nautilus eccentricus*, *Bakevellia parva*, *Leda subscitula*, *Axinus rotundatus*,* and undetermined species of *bellerophon*, *murchisonia* &c. Locality, near Smoky Hill river, on high country south of Fort Riley, as well as on Cottonwood creek, 90 feet.

11. Light grayish and yellow magnesian limestone, in layers and beds sometimes alternating with bluish and other colored clays, and containing *solemya*, a *myalina* near *M. squamosa*, *Pleurophorous* (?) *subcuneata*, *Bakevellia parva*, *pecten* undetermined and an *enomphalus* near *E. rugosus;* also, a *spirigera* allied to *S. subtilita*, but more gibbous, *Orthisina umbraculum* (?) *O. Shumardiana*, &c. Locality, summit of the hills near Fort Riley and above there; also seen on Cottonwood creek, 25 to 35 feet.

12. Light grayish yellow, rather granular magnesian limestone, containing spines and plates of *archchæcidaris*, a few fragments of small *crinoid* column, *spirifer* similar to *S. lineatus* but perhaps distinct; also, some *spirigera* seen in beds above, *Orthisina Shumardiana*, *O. umbraculum*, and *Productus Calhounianus*. Forms distinct horizon near summit of hills in vicinity of Fort Riley, also seen on Cottonwood creek, 7 to 8 feet.

13. Soft argillo-calcareous bed, apparently local. Kansas falls, 5 feet.

14. Light grayish and yellowish magnesian limestone, containing many concretions of flint, also the same *spirigera* found in beds above, and *Productus Norwoodi*, *P. Calhounianus*, with *Discina tenuilineata*, and an undetermined *monotis*. Fort Riley and below, also at Kansas falls and on Cottonwood creek, 38 feet.

15. Alternations, bluish, yellowish, and brown clays, with a few thin seams of limestone. Fort Riley, Kansas falls, also below Fort Riley, and on Cottonwood creek, 35 feet.

16. Light yellowish magnesian limestone, containing *fucoidal* markings, fragments of small *crinoid* columns, *pecten*, *allorisma*, *spirigera*, *Orthisina umbraculum* (?) *O. Shumardiana*, *Discina tenuilineata*, &c. Lower quarry at Fort Riley, and at other places above and below Fort Riley, as well as on Cottonwood creek, 4 feet.

17. Alternations of blue, red, and light gray clays, with sometimes thin layers and seams of magnesian limestone. Fort Riley, 28 feet.

18. Light gray and whitish magnesian limestone, containing *spirigera*, *Orthisina umbraculum*, (?) *O. Shumardiana*, *Productus Calhounianus*, *Acanthocladia Americana*, and undetermined species. *cyathocrinus*, lower part containing many concretions of flint. Fort Riley and on Cottonwood creek; whole thickness about 40 feet.

19. Brown, green, and very light gray clays, alternating; contains near the upper part fragments of *crinoid* columns, *Synocladia biserialis*, *spirigera*, *Productus Norwoodi*, *chonetes*, *mucronata*, *Orthisina Shumardiana*, *O. umbraculum*, &c., with teeth of *Petalodus Alleghaniensis*. Fort Riley, 14 feet.

20. Alternations of rather thin layers light yellowish magnesian limestone, and various colored clays; the limestone layers containing *monotis*, *Synocladia biserialis*, &c. Locality same as last, 33 feet.

21. Slope, no rocks seen. Below Fort Riley, 25 feet.

22. Whitish or very light gray magnesian limestone, rendered porous by cavities left by the weathering out of numerous *fusulina*. This is the highest horizon at which any remains of *fusulina* were met with. Some 4 miles below Fort Riley, along a creek on the south side of the Kansas, and apparently not more than 10 feet above it, 2 feet.

23. Bluish, light gray, and brown clays, with occasional layers of magnesian limestone. *Chonetes mucronata*, *Orthisina umbraculum* (?) *monotis*, *fusulina*, &c. Ten miles below Fort Riley, 35 feet.
24. Hard, very light yellowish gray magnesian limestone, with *fusulina*, and spines of *archæodaris*. Forms a marked horizon near the same locality as last, 6 feet.
25. Slope, with occasional exposures, thin layers of *fusulina*, limestone, and seams of gray limestone containing *myalina*, *monotis*, *pecten*, and fragments of *Synocladia biserialis*. Near same locality as last, 36 feet.
26. Light gray argillaceous limestone, showing on weathered surfaces a somewhat laminated structure; contains large spines of *archæocidaris*. Near Ogden ferry and Manhattan, 9 feet.
27. Gray limestone, often fragmentary, with much clay above; lower part hard, and more or less cellular in middle. Locality same as last, 5 feet.
28. Whitish clays and claystones, with a thin layer of hard compact gray limestone near the middle. Locality same as last, 10 feet.
29. Light greenish indurated clays. Same locality, 3 feet.
30. Hard, heavy bedded, white argillaceous limestone, containing *monotis* and *avicula*. Ogden ferry and below there, 5 feet.
31. Very thinly laminated dark green shale. Three miles nearly east of Ogden ferry, on McDowell's creek, also at Manhattan on the Kansas, 1 foot.
32. Light greenish and flesh-colored hard argillaceous limestone, with *Spirifer cameratus*. This is the highest horizon at which we found this species. Same locality, 3 feet.
33. Alternations of bluish, green and red, more or less calcareous laminated clays, light gray limestones and claystones, with *pecten*, *monotis*, and fragments of *crinoid* columns. Same localities, 30 feet.
34. Alternations bluish, purple, and ash-colored calcareous clays, passing at places into claystones, and containing, in a thin bed near the middle, *Spirifer planoconvexa*, *Spirigera subtilita*, *Productus splendens*, (?) *Rynchonel Uta*, &c. Locality same as preceding, 12 feet.
35. Blue, light gray, and greenish clays, with occasional harder seams and layers of claystone and limestone. Same locality, 33 feet.
36. Somewhat laminated claystone of light gray color, with more or less calc-spar near lower part. Manhattan, 19 feet.
37. Alternations of dark gray and blue, soft decomposing argillaceous limestone, with dark laminated clays, or soft shale, containing great quantities of *Fusulina cylindrica*, *F. cylindrica*, var. *ventricosa*, *Discina Manhattanensis*, *chætetes*, and fragments *crinoids*; also *chonetes*, *verneuiliana*, *C. mucronata*, *Productus splendens*, (?) *Retzia Mormonii*, *Rhynchonella Uta*, *Spirigera subtilita*, *Spirifer cameratus*, *S. planoconvexa*, *enomphalus*, near *E. rugosus*, and *Synocladia biserialis*; also *Cladodus occidentalis*. Locality same as last, 18 feet.
38. Soft bluish shale, with yellow laminated arenaceous seams below, containing *fucoidal* markings. Same locality, 25 feet.
39. Two layers gray argillo-calcareous rock, separated by 2 feet of dark green and ash-colored clays. The calcareous beds contain fragments of *crinoids*, *chonetes*, and *myalina* of undetermined species. Same locality as last, 4½ feet.
40. Light greenish, yellow, and gray clays and claystones, extending down nearly to high-water mark of the Kansas, opposite the mouth of Blue river, 27 feet.

The foregoing general section of the strata seen along the valley of *Kansas and Smoky* Hill rivers, from the mouth of Blue river to the

98° of west longitude, is presented in its present form, more with a view of illustrating the vertical range of the organic remains found in these rocks, than as an attempt to group the beds into formations that may be expected to preserve their distinctive lithological characters throughout areas of any great extent. As this has necessarily been done from a knowledge of only a portion of the fossils characterizing these strata, it is quite probable, when more extensive collections are obtained, that it may be found necessary, even on this principle, to classify and group the beds somewhat differently. We are also aware that some of these beds probably increase or diminish greatly in thickness, or may even entirely thin out, at no very great distances from the localities where we saw them.

Among the more peculiar features of the series of rocks represented by this general section, and in part by the preceding local sections, may be mentioned, first, the great number of thin layers and beds; and secondly, the frequent repetition of similar beds at various horizons. Again, the almost entire absence of heavy massive strata of limestone, or other hard material possessing sufficient durability to form perpendicular escarpments of much extent, is worthy of note. As a general thing, the limestones vary from only a few inches in thickness to from one to three or four feet, and rarely, as in Nos. 14 and 18, attain a thickness of from 38 to 40 feet. Although various light-colored laminated clays and soft argillaceous shaly beds predominate, and arenaceous matter is not unfrequently present, it is somewhat remarkable that dark bituminous shales and beds of coal are rarely met with, even among the outcrops seen along the Kansas, below the mouth of Blue river, belonging to the upper coal measures, and holding a position below the base of the foregoing general section; while through a considerable thickness of beds belonging to higher portions of the coal measures included in the lower part of this section, as well as through the strata containing permian fossils above, beds of coal and dark carbonaceous shale appear to be almost if not entirely wanting.

It will be observed we have in this general section, without attempting to draw lines between the systems or great primary divisions, presented in regular succession the various beds with the fossils found in each, from the cretaceous sandstone on the summits of the Smoky Hills, down through several hundred feet of intermediate doubtful strata, so as to include the beds containing permian types of fossils, and a considerable thickness of rocks in which we find great numbers of upper coal measure forms. We have preferred to give the section in this form because, in the first place, the upper coal measures of this region pass by such imperceptible gradations into the permian above, that it is very difficult to determine, with our present information, at what particular horizon we should draw the line between them, while, on the other hand, it is equally difficult to define the limits between the permian and beds above, in which we found no fossils.

Beginning near the base of this section, we find we have in great numbers the following well-known and widely distributed coal measure fossils, viz: *Fusulina cylindrica*,* *Chonetes verneuiliana*, *Productus splendens*, (or a closely allied species,) *Retzia Mormonii*, *Rhynchonella Uta*, *Spirigera subtilita*, *Spirifer cameratus*, *S. planoconvexa*, and an *enomphalus* similar to *E. rugosus* of the coal measures, while the few new and undetermined

*In Russia, *Fusulina cylindrica* is said to occur only in the upper part of the lower carboniferous series; but the fossil generally referred to that species in this country appears to be confined to the coal measures. We have some doubts with regard to its identity with the Russian species.

species associated with these are, for the most part, also decidedly more nearly allied to carboniferous than permian forms. We should here remark, however, that we occasionally met with a species of *monotis*, allied to the permian species *M. speluncaria* and *Synocladia biserialis*, also regarded in the Old World as a permian genus, at horizons far beneath the base of this section, between Manhattan and the Missouri. We even found a single specimen of this *monotis* as low down as bed No. 9, of the section taken near the landing at Leavenworth City, which must occupy a position several hundred feet below the lowest beds of the above section. Still, as this shell is very rare in these lower rocks, and the *synocladia* is a distinct species from the well-known permian form of the Old World, while they are both, at these horizons, associated with great numbers of the common well-known coal measure species, we can only regard their presence in these beds as establishing the existence of these genera at an earlier period in this country than in the Old World.

This, it seems to us, is more philosophical than it would be to place all this great thickness of strata, with their vast numbers of well known coal measure species, in the permian, merely because we also find with these occasionally a few forms which would in the Old World be regarded as characteristic of the permian epoch. Taking it for granted then that we have carried this section down far enough to include not only all the beds containing almost exclusively permian forms, but a considerable portion of the upper coal measures, it will be interesting to notice, as we ascend in the series, how far each of the coal measure species mentioned in the lower part of the section, as well as of a few others that occur above and below, range upwards. Thus we see that *Fusulina cylindrica* var. *ventricosa*, *Chonetes verneuiliana* and *Retzia Mormonii* were not met with above division No. 37; while *Spirifer plano-convexa*, *Productus splendens* (?) and *Rhynchonella Uta*, were not observed above 34, nor *Spirifer cameratus* above 32. *Fusulina cylindrica*, of the slender variety, so common in the coal measures of Kansas and Missouri, was not seen above 22; nor was any species or variety of that genus observed above this horizon.

Apparently the same species of *monotis*, mentioned at various horizons far beneath, were occasionally met with in 30, 25, 23, and 20, generally associated with the same species of *synocladia*, ranging far down into the upper coal measures.

In division No. 19, we again met with the *Synocladia biserialis*, and a *spirigera* allied to *S. subtilita*, if not identical, along with a new species of *chonetes*, we have called *C. mucronata*, which ranges down into the beds near the base of the section. Along with these, were also *Productus Norwoodi* and *Orthisina Shumardiana*, both of which are common in the coal measures far below, and a large *orthisina* similar to *O. umbraculum*, but apparently more finely striate. Ascending through the intermediate beds to No. 12, we continue to meet with nearly all the species mentioned in 19, with the exception of *Chonetes mucronata*. We also have, first in 18, a large species of *productus*, called *P. Calhounianus* by Professor Swallow, very similar to some varieties of *P. semireticulatus*, but thought by Professor Swallow to present well marked internal differences. There is likewise added in 16 a large *allorisma* and a *spiriger* similar to *S. subtilita*, but much more gibbous; and in 14, *Discina tenuilineatus*, together with apparently the same *monotis*, so often mentioned below. In 12 we also have added a small *spirifer*, similar to *S. lineatus*, but perhaps more nearly allied to the permian species, *Martinia Clannyana*, King. The succeeding bed above, No. 11, appears also to contain a mingling of permian with coal measure forms, for we have in it the following permian types, viz: *Myalina*, very similar to *M. squamosa*, *pleurophorus*, (?) *subcuneata*, *Bakevellia parva* and *Monotis Hawni*, along with an *enomphalus* near *E. rugosus*, the same gibbous *spirigera*, similar to *S. subtilita*, *Orthisina umbraculum* (?) and *O. Shumardiana*.

On passing into the next division above, No. 10, we find we have lost sight of all the characteristic carboniferous forms, unless the *spirigera* mentioned in some of the beds below be regarded as only a variety of *S. subtilita*, from which, however, we think it specifically distinct; for with this exception, nearly all the fossils seen by us in this division are such as would be regarded as permian types. Although the number of *species* found by us in No. 10 is not great, *individual* specimens are often numerous. Above this horizon we saw no more fossils, through a great thickness of various colored clays, clay stones, &c., until ascending to the cretaceous sandstones crowning the Smoky Hills. If we do not admit the existence of an intermediate group of rocks, connecting by slight gradations the permian above with the coal measures below, and must draw a line somewhere, below which all is to be regarded as carboniferous and all above as permian, we should certainly, upon paleontological principles alone, carry this line up as far as the top of division No. 11. The passage from the carboniferous to the strata containing permian types, however, is so gradual here that it seems to us no one undertaking to classify these rocks, without any knowledge of the classification adopted in the Old World, would have separated them into distinct *systems*, either upon lithological or paleontological ground, especially as they are not, so far as our knowledge extends, separated by any discordance of stratification, or other physical break.* Indeed the fact that some of the permian types occurring in No. 10 were first introduced in beds below this, containing many carboniferous species, would seem to indicate that even No. 10 may possibly have been deposited just before the close of a period of transition from the conditions of the carboniferous to those of the permian epoch. The apparent absence of fossils in the beds above No. 10 renders it impossible, with our present information, to determine with certainty the upper limits of the series containing permian forms. It is true there is at places a kind of conglomerated mass, occupying the horizon No. 9, which might appear to form a natural line of division between the beds containing the permian fossils and those above, in which we found no organic remains; but this seems to be local, and although there is a new feature presented by the zone of gypsum deposits above it, we find between the beds and layers of gypsum, and far above the horizon at which they occur, bluish, greenish, and other colored clays, not only similar to those between the beds and layers of limestone containing the permian fossils in division No. 10, but also precisely like the laminated clays between the beds of limestone of the upper carboniferous series far below. Again, in these clays of the gypsum zone, as well as through a considerable thickness of clays above it, there are occasional seams of claystone, which sometimes pass into seams of magnesian limestone, exactly like some of those containing permian fossils in division No. 10. We saw no fossils in these seams amongst the gypsum-bearing beds nor higher in the series, but it is probable they may yet be found in some of the more calcareous portions.

* We have been informed by Dr. J. G. Norwood, former State geologist of Illinois, that the rocks in that State, referred by him and others to the same epoch as the Kansas permian beds, rest unconformably upon the coal measures. This, however, would be impossible in Kansas, since no disturbances of the strata occurred there until after the close of the cretaceous era. which would, of course, not only cause the cretaceous and carboniferous, but all intermediate beds to dip at the same angle.

Another fact, apparently indicating some kind of relation between the gypsum-bearing beds, as well as some of the higher deposits, and the rocks below is, that we often find, both in the clays between the beds of gypsum and those between the limestone containing the permian fossils, the same peculiar appearance caused by the cracking of the clays and subsequent infiltration of calcareous matter as seen in division No. 5. At some places the thin plates of limestone, formed by the impure calcareous matter filling these cracks, may be seen ramifying through some rather thin beds of these clays in all directions, so as to cross and intersect each other at every angle. Where beds of this kind have been exposed for any length of time along near the tops of bluffs, the softer clays filling the interstices often weather out, so as to have a curious cellular mass, with the numerous angular cavities. From these facts we are inclined to suspect—though we are fully aware that it is a question which can only be determined upon evidence derived from organic remains—that not only the gypsum-bearing deposits, but a large portion, if not all, of division No. 5 belongs to the same epoch as the beds containing the permian fossils below.

Between No. 5 and the cretaceous above there is still a rather extensive series of beds in which we found no organic remains; these may be jurassic or triassic, or both, though, as we have elsewhere suggested, we rather incline to the opinion that they may prove to belong to the former. As we have fully discussed the question in regard to the cretaceous age of the highest division of the foregoing section in a paper read before the academy in December last, and in an article in the American Journal of Science, January, 1859, it is unnecessary for us to add anything further on that subject here. As already stated, our observations along the Kansas valley, to within twelve or fourteen miles of the mouth of the Big Blue river, were too isolated to determine in all cases the relations between outcrops seen at different places. Consequently, although we saw at several points along this part of the valley indications of a westward or northwestward inclination of the strata, we were left in some doubt whether or not there is a general inclination of the rocks in that direction between Wabounse and the Missouri. Above this point, however, our observations being more connected, and the exposures more continuous, we were able to determine very satisfactorily that there is, at least from near Wabounse, a uniform dip towards the west or northwest. So that in ascending the Kansas valley from this region, we are constantly meeting with more and more modern rocks, as those we leave behind pass beneath the level of Kansas. To illustrate this more clearly, we would, in the first place, remark that a bed of light grayish yellow granular magnesian limestone, mentioned as occupying a horizon about 115 feet above the Kansas, two or three miles west of Zeandale, passes beneath the level of Kansas before reaching the mouth of the Big Blue river, a distance of near seven miles; while another bed (No. 26 of the foregoing section) seen on the very summit of the hills two or three miles north of Zeandale, at an elevation of about 320 feet above the Kansas, was observed opposite Manhattan, at the mouth of Big Blue river, only some 214 feet above the Kansas. Again, bed No. 12, of the foregoing general section, which was seen at a locality nearly opposite Ogden, at an elevation of about 363 feet above the Kansas, is at Fort Riley, eight or nine miles further west, elevated only some 215 feet above Kansas. Above Fort Riley this bed forms a marked horizon, and can be followed by the eye without interruption for several miles along the hills on both sides of the river. We observed it gradually sinking as we ascended the Kansas valley, until at a point on Chapman's creek. Some fifteen miles a little south of west from Fort Riley we saw it nearly down on a level with the Kansas; beyond this it was not again met with on the north side of the Kansas, but we saw it at somewhat higher elevations on the south side of the river a little west of this. As the distance by an air-line from the locality nearly opposite Ogden, where this rock occupies a horizon at an elevation of 363 feet above the Kansas, to the mouth of Chapman's creek is about 23 miles, the dip would appear to be not far from 15½ feet to the mile.

It must be borne in mind, however, that the average fall of the Kansas, at least below Fort Riley, according to the barometrical observations of Colonel Frémont and others, is near 1½ foot to the mile, and that if we assume the distance by the windings of the river between Chapman's creek and Ogden to be about 30 miles, it would make the elevation of the Kansas at the former locality some 45 feet greater than at Ogden, which would reduce the dip to a fraction less than 14 feet to the mile. Still, as the direction of the dip in this region is to the *north* of west, and the direction of the mouth of Chapman's creek from Ogden is considerably *south* of west, it is probable the inclination of the strata here is greater than the above figures would indicate, and that it may not be less than 20 feet to the mile, in a northwest direction. From the foregoing statements it will be seen that in consequence of the dip of the strata to the northwest, and in some slight degree to the fall of the Kansas and Smoky Hill rivers, the whole of the foregoing general section below No. 12 passes beneath the level of the Smoky Hill, between the mouth of Blue river and Chapman's creek. Consequently, the limestones of the succeeding beds above being thinner and less durable than those below, and separated by heavy beds of clay, we find, as might be expected, that the country here in the region of the mouth of Chapman's creek is much lower than at Fort Riley and below. On reaching the mouth of Solomon's Fork we found the face of the country characterized by long, gentle, grassy slopes, no part of it near the river being apparently elevated more than about 60 or 70 feet above its surface. A short distance beyond this we caught the first glimpse of the Smoky Hills, which were seen in a direction a little south of west from us, rising above the surrounding low country like dark blue clouds above the horizon. On approaching these we found them always situated several miles back from the river, and rising some 350 feet above it. The immediate bluffs of the river here are generally composed of divisions No. 4 and 5 of the foregoing general section, and that portion of these hills above the level of the summits of the bluffs along the river is made up of division Nos. 3, 2, 1 of the same section. On the south side of the river these hills have but a comparatively thin capping of the sandstone No. 1, but on the north side we saw it showing a thickening on some of them of 60 feet. From some of these hills on the north side of Smoky Hill river, between it and the Grand Saline, we had an extensive and beautiful view of the surrounding country. In the north and northwest many similar hills were in sight, and as the dip of the strata here is in that direction it is probable some of these are not only chiefly made up of the sandstone No. 1, but surmounted by the other cretaceous beds Nos. 2 and 3 of the Nebraska cretaceous series; indeed, Dr. Engleman found all these formations occupying this relation on Republican river, not more than 70 miles north of this.* Although this paper is merely designed to give a brief sketch of the leading geological features of those

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* See Report of Secretary of War, December 5, 1857, p. 467.

portions of northeastern Kansas visited by us, we cannot close it without alluding to the truly great agricultural and other natural resources of this new and interesting territory. We mean no disparagement to other portions of the Mississippi valley when we state that after having traveled extensively in the great west, and after having seen many of its most favored spots, we have met with no country combining more attractive features than Kansas Territory. Her geographical position gives her a comparatively mild and genial climate, intermediate between the extremes of heat and cold, while the rich virgin soil of her beautiful prairies is admirably adapted to the growth of all the great staple grain and root crops of the west. It is true that in some districts there is rather a deficiency of timber, but as a general thing there is along the streams sufficient for the immediate wants of the country. In addition to this, the wonderful rapidity with which forests are known to have sprung up on similar prairie lands in Missouri, as the country became settled so as to keep out the annual fires, shows that the present scarcity of timber should not be regarded as presenting any serious obstacle to the settlement of the most extensive prairie district in Kansas. Before going out into the interior of the Territory we had expected to find the whole country immediately west of Fort Riley comparatively sterile; on the contrary, however, we were agreeably disappointed at meeting with scarcely any indications of decreasing fertility as far as our travels extended, which was about 60 miles west of Fort Riley. Here we found the prairies clothed with a luxuriant growth of grass, and literally alive with vast herds of buffalo that were seen quietly grazing as far as the eye could reach in every direction.

Even on the high divide between the Smoky Hill and Arkansas rivers, south of this, we found the soil rich and supporting a dense growth of grass; and from all we could learn from persons who have gone further out, the same kind of country extends for a long distance beyond this towards the west. Hence we infer that the belt of unproductive lands between the rich country on the east and the eastern base of the Rocky mountains on the west is much narrower than is generally supposed; and even this so-called desert country is known to possess a good soil, which may be rendered fruitful by artificial irrigation.

In regard to the mineral resources of Kansas we have at present only time and space to say a few words: As already stated, coal is known to exist, though its extent is not yet fully determined, at several localities in the region of Leavenworth City, while the geological structure of the country, as well as discoveries already made, warrant the conclusion that this important and useful mineral abounds at many localities south of there. Limestone suitable for building purposes and the production of quicklime exist throughout large areas, while inexhaustible beds of gypsum are known to occur at several places not far west of the mouth of Solomon's river. Near this place we likewise saw in the lower cretaceous rocks crowning the summits of the Smoky Hills deposits of iron ore, but were unable to determine, in the limited time at our command, whether or not it exists in large quantities. Of the discoveries of gold in the mountains on the western border of Kansas much has been said; nothing, however, but a thorough geological survey, by authority of the State government, can lay before the public such full, accurate and reliable information on these subjects as will bring from the older States the capital, skill, and enterprise necessary to develop the great natural resources of the country.

List of the species mentioned in this chapter, with some remarks on the synonymy, and references to the works in which they are described.

FORAMINIFERA.

Fusulina cylindrica, Fischer, Oryct., Moscow, p. 126, p. 18, figs. 1–5. In Russia this species is said to occur only in the upper part of lower carboniferous or mountain limestone. Yet the species usually referred to *F. cylindrica* in this country, so far as our knowledge extends, is not found below the coal measures. From this fact, and some slight differences we observe between our specimens and the figures of the Russian species, we suspect a careful comparison of good specimens may possibly prove them to be distinct. Ranges in Kansas from division No. 22 of the foregoing section, far down into the coal measures. Found at numerous localities between Manhattan and the Missouri, usually in great numbers.

Fusulina cylindrica, var. *ventricosa*, Meek and Hayden, Proc. Acad. Nat. Sci., Phila., Dec. 1858, p. 261, Div. No. 37, of foregoing general section at Manhattan, on the Kansas, and at Juniata, on Big Blue river.

BRYOZOA.

Synocladia biserialis.—Professor Swallow refers this species with doubt to *S. virgulacea*, Philips, Sp. in Trans. Acad. Sci., St. Louis, vol. 1, p. 179, and points out some of the characters in which it differs, stating at the same time, in case it should prove to be distinct, that *biserialis* would be a good specific name for it. We regard it as quite distinct from Philips's species, not only in scarcely ever having more than two rows of cellules, but also because the (?) gemuliferous vesicles, instead of being merely "tubercular and open at the summit," have the form of short, but distinct spines apparently closed and rather obtusely pointed at the apex. The branches or connecting process are likewise less distinctly angulated between the longitudinal stems, than in *S. virgulacea*. Occurs at Fort Riley in No. 19 of foregoing general section, and at various lower horizons on the Kansas below there, down into the upper coal measures.

Acanthocladia Americana.—In the Trans. Acad. Sci., St. Louis, vol. 1, p. 180, Professor Swallow refers this species with a query to *A. anceps*, Schlot, sp., and remarks that it differs from that species in having "the rows of cellules diagonal to the axis of the stems, instead of longitudinal, as represented by King, and on ridges like that figured by Goldfuss." He also further remarks that "it is less regularly branched, and not so distinctly pinnated as those delineated by Goldfuss and King." In the specimens in our collection, the cellules are more numerous, and much more crowded than in *A. anceps*, as figured by King. The specific name *Americana* was suggested by Professor Swallow.

We found this species in Division No. 18 of the foregoing general section on Cottonwood creek.

ECHINODERMATA.

Cyathocrinus —— (?)—A few scapular plates bearing some similarity to those of *C. ramosus*, Schlot, sp., were met with by us in division No. 18, but they are proportionably much thicker, and the articulating surfaces quite different. Cottonwood creek.

Archæocidaris —— (?)—In No. 12 we found spines and detached plates of apparently an undescribed species of this genus, but they were too much weathered to show clearly the specific characters. The spines are rather slender, terete, nearly straight, and provided with short scattering spinous processes, directed rather obliquely outwards and forward. Cottonwood creek.

Archæocidaris —— (?)—The spines of this species are much larger than the last, and apparently destitute of spinous processes. They are as much as from three to four inches in length, nearly or quite straight, and not flattened or compressed. Division No. 26, Manhattan, and in same position on Cottonwood creek.

BRACHIOPODA.

Discina tenuilineata, n. sp.—We have only seen the lower valve of this species, which is extremely thin, nearly orbicular, and provided with a narrow perforation extending from very near the center about half way out to the margin. The inner surface is ornamented by distant, extremely slender, distinctly elevated lines of growth, arranged concentrically around a point very nearly in the middle of the valve. The apex of the upper valve was probably nearly central. Diameter 0.50 inch.

Locality and position.—Cottonwood creek, division No. 16.

Discina Manhattanensis, n. sp.—Shell rather small, nearly circular; upper valve moderately elevated, apex rather obtusely pointed; located a little less than half the diameter of the shell from the posterior edge. Surface black and shining, marked by fine closely set concentric lines. Lower valve unknown. Greater diameter from 0.32 in. to 0.46. Found in great numbers in division No. 37, opposite Manhattan, on Kansas river.

Productus splendens (?)—Norwood and Pratten, Jour. Acad. Nat. Sci., Phila., N. S. vol. 3, pl. —, fig. 5. We refer this shell to the above species with some doubt; it is always smaller than the figure given by Norwood and Pratten, and rather more convex over the visceral region of the larger valve, while the smaller valve appears to want the band-like flattening around the border mentioned in the description of *P. splendens*. The ears extend beyond the body of the shell, are distinctly vaulted, and rarely have more than one spine on each, often none. The spines, however, are more numerous over the surface of the larger valve, being in this respect more like *P. muricatus*, N. and P., but both valves want the concentric wrinkles represented in the figures of that species. This neat little *productus* is found in great numbers between Fort Riley and Manhattan, as well as at the latter place, in division No. 34; also at various horizons below that in the upper coal measures of Kansas.

Productus Norwoodi, Swallow, Trans. Acad. Sci., St. Louis, vol. 1, p. 182. A few specimens of this species in our possession have the extreme point of the beak of the larger valve flattened or truncate, as though it had in the young state been attached to some marine body by that part of the shell. We have also in several instances found other shells associated with this species, with small disks not more than 0.20 inch in diameter, attached by the whole surface as well as by a series of small spines seen radiating from the margin. May not these little bodies be the young of this species?

We think the specimen figured by Professor Marcou in his work on the Geology of North America, plate 6, fig. 1, as *P. pustulosus*, is the same as the above species, and quite distinct from *P. pustulosus*. It occurs in Kansas, at various horizons, from No. 14 far down in the upper coal measures. We found it at Fort Riley, and numerous places between there and the Missouri, as well as at Leavenworth City.

Productus Rogersi, Norwood and Patten, Jour. Acad. Nat. Sci. Phila., N. S., vol. 3, p. 9, pl. 1, fig. 3. This species is nearly related to the last, and when the shell is exfoliated, may be easily confounded with it. *P. Norwoodi*, however, appears never to have the distinct concentric wrinkles of this species, nor do the pustules, at the base of the spines, have the tendency to elongate into indistinct ribs as in *P. Rogersi*. Professor Marcou has figured in N. Am. Geol., pl. 5, fig. 6, as *Productus scabricules*, a shell very like this. Kansas valley below mouth Blue river, in upper coal measures.

Productus pustulosus (?)—Phillips's Geol. Yorkshire, vol. 2, p. 316, pl. 7, fig. 15. We have a specimen agreeing very nearly with this species in its external markings, but it is much narrower and the beak of the larger valve more extended, in which respect it differs quite as much from *P. punctatus*. Near steamboat landing at Leavenworth City, in coal measures.

Productus Prattenianus, Norwood, Jour. Acad. Nat. Sci., Phila., N. S. vol. 3, p. 17, pl. 1, fig. 10. In coal measures at Indian creek, and at Leavenworth city.

Productus Calhounianus, Swallow, Trans. Acad. Sci., St. Louis, vol. 1, p. 181. This fine large shell is scarcely distinguishable from *P. semireticulatus*, var. *antiquus*, but Professor Swallow, who has seen the interior, thinks it presents well marked internal differences. It occurs in No. 12, and below, at Fort Riley, also on Cottonwood creek. Professor S. thinks it even ranges down into the lower carboniferous.

Chonetes Verneuiliana, Norwood and Pratten, Jour. Acad. Nat. Sci. Phila., vol. 3, p. 26, pl. 2, fig. 6, N. S. Occurs in Kansas, in division No. 37, at Manhattan, and perhaps in upper coal measures at lower horizons.

Chonetes mucronata, Meek and Hayden, Proc. Acad. Nat. Sci., Phila., Dec. 1838, page 262. Lower part of the section at Fort Riley, (division 9,) and down near the base of the foregoing general section, also in same position on Cottonwood creek.

Orthisina crassa, Meek and Hayden, Proc. Acad. Nat. Sci., Phila., Dec. 1858, p. 261. Occurs in coal measures near landing at Leavenworth City.

Orthisina umbraculum (?), Schlot, sp. Petrefakt, vol. 1, p. 256, and 2, p. 7. We find in Kansas, ranging from 16 to 19 of foregoing sections, many specimens of a large species of Orthisina having almost exactly the form and other characters of *O. umbraculum*, excepting that the striæ appear to be more numerous. According to Koninck that species has about 108 striæ on each valve, while on our Kansas specimens we count from 160 to 200, consequently we suspect it may be a distinct but closely allied species; if so, we would propose to designate it by the name of *O. multistriata*. We found it at Fort Riley, and at several locations between there and Blue river; also in same position on Cottonwood creek.

Orthisina Missouriensis, Swallow, Trans. Acad. Sci., St. Louis, vol. 1, p. 219. This is a very peculiar plicated species, often much distorted. When partly imbedded in the matrix, it frequently bears a striking resemblance to *Plicatula striato-costata*, Cox, 3d vol. Dr. Owen's report on the Geological Survey of Kentucky, p. 558, pl. 8, fig. 7, of atlas. Common in the upper coal measures of Kansas, at Leavenworth City, and west of there.

Orthisina Shumardiana, Swallow, Trans. St. Louis Acad. Sci., vol. 1, p. 183. Although, like the last, a plicated species, this is more symmetrical, and presents other well-marked differences. Ranges from No. 11, down some distance in upper coal measures. Found at Fort Riley, and between there and Blue river.

Terebratula millepunctata, Hall, Pacific Railroad Report, vol. 3, p. 101, pl. 2, figs. 1–2. We have the impression that this species is probably identical with *T. bovideus*. Morton, (Silliman's Jour. vol. 29, p. —,) from Ohio. Our Kansas specimens appear, however, to be more elongated than those figures by Dr. Morton, and may be distinct. In form they resemble very much some varieties of *epithyris elongata*, Schlot, sp. as figured by King, in Prem. Fos. Eng., pl. 6, particularly the narrower varieties, such as fig. 35. The beak of our Kansas shell, however, is not truncate but pointed, the perforation being on the outside, and a little removed from the extremity. If it is identical with *T. bovideus*, Morton's specific name will have to take precedence, being the older. It remains to be determined whether its internal characters agree with *terebratula*, as now restricted.

This is a rather common form in the upper coal measures of Kansas, and southward. We found it near the summit of the hills back of Leavenworth City, also at Indian creek near Indianola, &c.

Rhynchonella Uta, (*Terebratala Uta*, Marcou, Geol. N. A., p. 51, pl. 6, fig. 12.) We have from the upper coal measures in Kansas many specimens of a species agreeing exactly with Professor Marcou's description of the above species. These we suspect may possibly go into the genus *camerophoria*, King, if not into *rhynchonella;* at any rate they are certainly not *terebratula*. We are inclined to the opinion that a shell described by Professor Swallow in the Trans. Acad. Sci., St. Louis, vol. 1, p. 219, under the name of *Rhynchonella (camerophoria) osagensis*, may be identical also with the above; yet Professor S. says his species has from "two to six" plications in the sinus of the dorsal valve, while in the shell before us, of which we have quite a number of specimens, there are invariably but two plications in the sinus.

Quite common in division No. 94, at Manhattan, and at several localities between there and the Missouri, in the upper coal measures. Professor Marcou cites it as a mountain limestone species, but we know nothing of its existence in rocks of that age.

Retzia Mormonii, (*Terebratula Mormonii*,) Marcou, Geol. N. A., p. 51, pl. 6, fig. 11. We found this species quite abundant in division 37, at Manhattan, where it is associated with the last. It also ranges far below this in the upper coal measures between Manhattan and the Missouri, being quite common near the summits of the hills back of Leavenworth city. Dr. B. F. Shumard has described a species in the Trans. Acad. Sci. St. Louis, under the name of *Retzia punctilifera*, which we suspect may possibly be a variety of the above, but as he describes it as having usually in the dorsal valve "a moderately wide, shallow sinus, which extends from the front nearly to the beak," and the species before us, of which we have many specimens, has no traces of a sinus, we are left in doubt. In other respects his description agrees exactly with our shell, and he also states that he has it from Kansas Territory. Professor Marcou found this species at the Salt Lake City, Utah, in a rock he refers to the mountain limestone. We have never seen it from below the coal measures.

Spirifer Kentuckensis, Shumard, Geol. Survey of Missouri, part 2, page 203. Found in upper coal measures near the top of bluffs, back of Fort Leavenworth, also near the landing at Leavenworth City, and at other localities between the Missouri and Blue river.

Spirifer cameratus, Morton, American Jour. Sci. vol. 29, p. 150, pl. 11, *fig. 3. This is the* same species as has been determined by Professor

Hall, described by Dr. Roemer as *S. Mensebachanus*, (Kreid von Texas, p. 88, pl. 11. fig. 7,) and subsequently by himself as *S. triplicatus*, in Stansbury's Rep., p. 420, pl. 4, fig. 5. Professor Marcou has recently figured it in his work on the Geol. North America, page 49, pl. 8, fig. 3, as a variety of *Spirifer striatus*, Martin, from which it is quite distinct. He found it at Pecos village in a rock he refers to the lower carboniferous or mountain limestone. It has a great geographical range, being common in the coal measures from Pennsylvania to the Rocky mountains, and from Nebraska to New Mexico; we have never seen it, however, from lower carboniferous rocks.

Spirifer hemiplicata, Hall, Stansbury's report, p. 409, pl. 4, fig. 3. Upper coal measures near summit of hills back of Leavenworth, and at other localities between there and Blue river.

Spirifer lineatus. *Anomites lineatus*, Martin. *Spirifer lineatus* of Phillips. Geol. Yorks., 2, p. 219, pl. 10, fig. 17, and of other authors. We have, from near Leavenworth landing, in the coal measures, a *spirifer* apparently identical with the above. It appears not to range very high in the upper coal measures of Kansas.

Spirifer ——. In division No. 12, above Fort Riley, a few imperfect specimens of a small, smooth *spirifer*, similar in some respects to *S. lineatus*, but apparently more like *Martinia*, *Clannyana*, King, from the permian of England.

Spirifer planoconvexa, Shumard. Geol. Report Missouri, 2d part, p. 202. We found this handsome little shell quite abundant in the upper coal measures, (divisions 34 and 37,) at Manhattan; also at Juniata, on Big Blue river, and near summit of hills back of Leavenworth City.

Spirigera subtilita, *Terrebratula subtilita*, Hall. (Stansbury's Report, p. 409, pl. 4, fig. 1—2.) *Spirigera subtilita* of Dr. George Shumard, Trans. St. Louis Acad. Sci., vol. 1. This is a very abundant species in Kansas; we found it ranging up at least as far as division No. 37, at Manhattan, and met with some obscure forms resembling it still higher in the series. From these horizons it ranges far down in the other members of the coal measures. Several of our specimens collected at Leavenworth City show that it was provided with internal spiral appendages, as in the *spirifer*, and consequently cannot remain in the genus *terebratula*, as now restricted. It has a wide geographical range, and is almost everywhere the companion of *Spirifer cameratus*. Professor Marcow figures it in his work on the Geology of North America, pl. 6, fig. 9, from a formation in the Rocky mountains, which he refers to the lower carboniferous, but we have never seen it from any position below the coal measures.

Spirigera——(?) At Fort Riley, and above there, as well as in the same position on Cottonwood creek, we found, ranging from division 18 up to 10 of the foregoing section, a *spirigera* resembling *S. subtilita*, but much more gibbous in form; it also appears to have a much thicker shell. If distinct from *S. subtilita* this might be designated by the specific name, *gibbosa*.

LAMELLIBRANCHIATA.

Monotis Hawni, Meek and Hayden, Trans. Albany Inst., vol. 4, March 2, 1858. Professor Swallow thinks this species not distinct from *M. speluncaria*, Schlot., sp. Although like that species, it is quite variable, and some of its varieties are very similar to it; after a careful comparison of a large number of individuals with King's figures and descriptions, we still regard it as distinct. We have never seen any of its various forms with the beak of the larger valve elevated so far above the hinge as in figs. 5, 6, 7, and 8, pl. 13, of King's work; nor do any of our specimens possess the peculiar oblique posterior sulcus, cited above.

High country south of Kansas Falls; also above there on Smoky Hill river and Cottonwood creek, in division No. 10.

Myalina (Mytilus) peratenuata, Meek and Hayden, Trans. Albany Inst., vol. 4, March 2, 1858. Our description of this species was made out from one of the more slender varieties of this shell sent to us from near Smoky Hill river by Mr. Hawn. We were probably wrong, however, in referring to it a specimen in our possession from a locality on the Missouri, opposite the northern boundary of Missouri; and we even suspect the rock from which this latter specimen was obtained may belong to an older epoch.

The species above cited is, we think, identical with *M. permianus*, of Swallow, Trans. Acad. Sci., St. Louis, vol. 1, p. 187. And we also suspect the form he describes in the same paper as *Mytilus (Myalina) concavus* is only a broader variety of the same; at any rate we have these two forms, and every intermediate gradation between them, from the same bed. Locality and position same as the preceding.

Myalina squamosa, (*Mytilus squamosa*, J. de C. Sowerby, Morris's Catalogue, p. 93, *Myalina squamosa* of some other authors.)

Of the form, we refer with doubt to the above species; we have but one imperfect specimen. As far as the characters can be made out it agrees with this species. We found it in division No. 11, at Kansas Falls, above Fort Riley.

Myalina subquadrata, Shumard, Missouri Geol. Rept., 2d part, p. 207, pl. c, fig. 17. Upper coal measures, Leavenworth City, on the Kansas, at Lawrence and other localities in Kansas valley below mouth of Big Blue river.

Edmondia (?) *Calhouni*, Meek and Hayden, Trans. Albany Inst., vol. 4, March 2, 1858. We are still in doubt in regard to the generic relations of this species, having procured no better specimens than that first described by us. We suspect it may be a *cardinia*. Near Smoky Hill river, in division No. 15.

Bakevellia parva, Meek and Hayden, Trans. Albany Inst., vol. 4, March 2, 1858. This is probably the same species referred by Professor Swallow to *Avicula antiqua*, Munster, *Bakevellia antiqua* of King and others. In describing this species we spoke of its very near relation to *B. antiqua*, but pointed out some characters in which it differs. At that time we had seen but a few imperfect specimens; since then, however, we have obtained many others, a careful examination of which causes us still to regard it as distinct from *B. antiqua*. Of a large number of individuals, we have never seen any one half the size of the smallest, nor one-eighth the size of the largest figures of that species given by King, while the cardinal area is also proportionably much narrower in our shell. Division No. 10, on Smoky Hill river and Cottonwood creek.

Area carbonaria, Cox. Vol. 3, Geol. Report Ky., p. 567, pl. 8, fig. 5. Our fossil is smaller and less distinctly striate, but exactly the form of the above. Near Leavenworth landing. Coal measures.

Leda subscitula, Meek and Hayden, Trans. Albany Inst., vol. 4, March 2, 1858. Division No. 10, Smoky Hill river and Cottonwood creek.

Pleurophorus (?) *subcuneata*, Meek and Hayden, Trans. Albany Inst., vol. 4, March 2, 1858. Our specimens of this species being casts, we are left in doubt in regard to its generic relations. We suspect it may be a *cardinia*. Same locality and position as preceding.

Axinus (Schizodus) ovatus, Meek and Hayden, Proceed. Acad. Nat. Sci., Phila., Dec., 1858. This is very much like the permian forms, *S. rotundatus* and *S. truncatus*, but we found it in a rock on Cottonwood creek, which we regard as below the permian.

Axinus rotundatus, Brown, Trans. Manch. Geol. Soc., vol. 1, p. 31, pl. 6, fig. 29. We have referred this little shell to the above species with some doubt, but we have seen no characters by which it can be distinguished. No. 10, near Smoky Hill river.

Allorisma (?) Leavenworthensis, Meek and Hayden, Proc. Acad. Nat. Sci., Phila., Dec., 1858, p. 263. Upper coal measures, Leavenworth City.

Allorisma subcuneata, Meek and Hayden, Proceed. Acad. Nat. Sci., Phila., ec., 1858, p. 263. Locality and position same as last.

Allorisma (?) altirostrata, Meek and Hayden, Proceed. Acad. Nat. Sci., Phila, Dec., 1858, p. 263. Upper coal measures, Grasshopper creek.

Allorisma (?) Cooperi, Meek and Hayden, Proceed. Acad. Nat. Sci., Phila., Dec., 1858, p. 264. (*Panopæa Cooperi*,) Meek and Hayden, Trans. Albany Inst., vol. 4, March 2, 1858.) Near Helena, in upper coal measures.

Leptodomus granosus, Shumard, Trans. Acad. Nat. Sci., St. Louis, vol. 1, p. 207. Upper coal measures, near summit of hills, back of Leavenworth City; also near Leavenworth landing.

GASTEROPODA.

Pleurotomaria humerosa, Meek and Hayden, Proceed. Acad. Nat. Sci., Phila., Dec., 1858. In upper coal measures at Grasshopper creek.

Pleurotomaria subturbinata, Meek and Hayden, Proceed. Acad. Nat. Sci., Phila., Dec., 1858, p. 264. Locality and position same as last. In the proceedings of the Academy above cited, the locality of this species is *erroneously* given as at Helena.

Bellerophon ——(?) We found a small undetermined species of this genus in division No. 10, on Smoky Hill river and near Cottonwood creek; also casts of a large species at Leavenworth landing and Grasshopper creek, in the upper coal measures.

Enomphalus ——(?) The species here alluded to was found in Nos. 11 and 37 of the foregoing general section. Either it or a very closely allied species also ranges far below this in the upper coal measures. It is nearly related to, if not identical with, a species Professor Hall has described in the Iowa report under the name of *E. rugosus*.

CEPHALOPODA.

Nautilus eccentricus, Meek and Hayden, Trans. Albany Inst., vol. 4, March 2, 1858. Smoky Hill river, division No. 10.

FISHES.

Xystracanthus arcuatus, Leidy, upper carboniferous rocks at Leavenworth landing.

Cladodus occidentalis, Leidy, division No. 37 of foregoing general section. At Manhattan.

Petalodus Alleghaniensis, Leidy, Jour. Acad. Nat. Sci., vol. 3, p. 161. Division No. 10 of foregoing general section. Fort Riley.

CHAPTER XIII.

TOUR TO THE BAD LANDS OF DAKOTA—GEOLOGY FROM FORT RANDALL TO MOUTH OF RAPID RIVER—SAND HILLS—FOSSIL REMAINS—LITTLE WHITE RIVER—OREODON BED ON HEAD OF LITTLE WHITE RIVER—WHITE EARTH CREEK—RUGGED CHARACTER OF THIS PORTION—TITANOTHERIUM BED—VEINS OF CHALCEDONY—SECTIONS OF MIOCENE BEDS ON WHITE RIVER AND NEAR BEAR CREEK—ZONE OR BELT OF ORGANIC REMAINS—REASONS WHY IT WILL BE DIFFICULT TO MAKE A LARGE COLLECTION IN THE FUTURE—BASIN-LIKE CHARACTER—NORTH SHORE OF BASIN—CRETACEOUS BEDS—ISOLATED BUTTES OF THE PLIOCENE BEDS.

During the summer of 1866 I made a tour to the Bad Lands of Dakota, under the auspices of the Academy of Natural Sciences of Philadelphia, for the purpose of clearing up some uncertain or doubtful points in the geology of that most interesting region. With a letter of introduction from Professor Joseph Henry to General Grant, stating the object of my mission to that country, I procured from the general an official order requiring all commanding officers in the departments of the Missouri and the Platte to furnish all the facilities for carrying out my scientific explorations in their power not inconsistent with the public service. I also received great courtesy and aid from General P. St. G. Cooke at Omaha City, and General Myers, chief quartermaster of that department, from Major H. Dyer, in command at Fort Randall, who furnished me with my entire outfit, that being my starting point from the Missouri. From all the United States army officers that I met I received every possible kindness and facility that could be afforded. It has always been the policy of the army to advance the interests of science, especially in these far western regions, and I think it may be safely affirmed that they have done more for the natural history and geography of the far west than any other class of professional men.

I left Fort Randall August 3, 1866, with a six-mule team, five soldiers, a guide, Indian hunter, and my faithful assistant, James Stevenson, who has been with me for years, traveling over various portions of the west. Our wagon was the largest of the army type, covered, and loaded with rations for our entire party for sixty days. We passed up the valley of Garden creek, which flows by the fort. There is a fringe of trees on each side of the creek, for the most part elm—a few cottonwoods. Like all the country bordering on streams, this portion is filled with ravines, rendering traveling laborious. Where the bluffs are cut No. 3 is seen, especially along the Missouri; but a little distance back from the river the black shales of No. 4 are visible and occupy the country. This creek is called Garden creek from the fact that for many years the officers and soldiers of Fort Randall have cultivated vegetables at different points on its bottom lands, and with few exceptions they have been quite successful. The white band in No. 4 is well shown here, and is doubtless due to the intermixture of white sand with the blue clay. I have as yet collected no fossils from No. 4 in this region, but I think they must occur here from the fact that at the great bend in the same rock there are large quantities of finely preserved shells. On the high hills are ledges of bluish siliceous limestone, which show that outliers of the great tertiary basin are found here, and also that the limits of this formation extended much further than at the present time, probably far on the north side of the Missouri, but that the beds have since been removed by the erosive action of water. On Ponka creek, 20 miles to the westward, the cut hills show that the underlying rocks are composed of the dark shales of No. 4, still everywhere on the distant hills we find traces of the tertiary beds. These beds belong to what are termed the Loup River beds, and are of pliocene age.

At the mouth of Turtle creek, we have the Forked Buttes, two hills which form prominent land marks. Their summits are capped with from 30 to 40 feet of porus, gritty limestone, which has been worn away much by atmospheric agencies. Below is a bed of yellowish sandy marl, in which I found a few fragments of a turtle and some horse teeth, enough to determine the geological position. The buttes are about 200 feet in height above the level prairie, or about 600 feet above the bed of the Niobrara. There are about 200 feet of tertiary rock and 400 of cretaceous No. 4. The upper sandy rocks of these buttes form a ledge on the summit, and the looser material being worn away beneath, large masses have fallen down on the sides of the hill. On one of the buttes the summit forms a smooth table-land. The strata being horizontal, the conclusion follows that the whole surface for at least 200 feet in thickness, and probably much more, and for an almost indefinite extent around, has been worn away, and swept down the Missouri. The valley of Turtle creek, in which we are camped, (August 4,) as well as that of the Niobrara is very beautiful, clothed with a thick covering of grass of the richest green, upon which our animals delight to feed. The valley or bottom of the stream is from one-half to a mile in width, the hills sloping gently down. There are abrupt terraces about eight feet high midway on either side. Near our camp there is a cut bank which shows No. 4 with as much distinctness as on the Missouri, but no fossils could be found. At another locality I found a bone belonging to the great mosasaurus, which was once a denizen of the great cretaceous sea. The spongy portions of the bone were filled up with silex in the form of chalcedony, which was quite translucent.

As we proceeded up the valley of the Niobrara, on the north side, even for 50 or 60 miles, the river cuts down into the cretaceous rocks, but gradually the tertiary beds begin to appear and to cover the upland country. There is also evidence of considerable thickness of a recent deposit made up of the transported materials of older tertiary beds. These beds also contain fragments of turtles, doubtless *Testudo Niobrarensis*, which is found very abundantly on the Loup Fork and Niobrara river. The surface of the country is covered more or less with waterworn pebbles. About midway between the mouth of Turtle creek and that of Rapid river, the recent or pliocene beds take possession of the country. At the summit there is a bed of hard, light gray sandstone, which gives the abrupt character to the numerous ravines; beneath it is a bed of light gray sand, which contains many fossil remains. At another locality is found from two to four feet of chalky limestone, breaking into thin laminæ, filled with small fresh-water shells. Beneath this are six or eight feet of gray friable sandstone, filled with fragments of bones; below, light yellow marl, with sandy layers of harder rock, 100 to 300 feet thick, containing in great quantities many kinds of bones in a more or less fragmentary condition. This last locality is about 25 miles below the mouth of Rapid river. These deep ravines, which are very numerous, and from their geological structure having more the form of cañons, render traveling quite impossible with wagons, and very difficult with pack mules, except by passing around the heads of them all, at a distance of from five to eight miles from the Niobrara river. Much has been said of the pine timber along this stream and its branches. I would simply say that it is of very poor quality, not much of it, and quite inaccessible.

For a considerable distance before reaching Rapid river the sand hills are very conspicuous on the south side of the Niobrara. Indications have been seen several times on the north side, but no well-defined hills. Rapid river really forms the eastern border of the sand hills on the north side of the Niobrara. These hills form a remarkable feature of the surface of the country in this region. They cover an area of about 20,000 square miles; the surface composed of loose moving sand, which is blown by the winds into round or conical hills, and these hills in turn are wrought upon by the winds and are scooped out and moved farther eastward. They occupy much of the country on both sides of the Niobrara, rendering traveling almost impossible. Our wagon wheels sank into the soft sand one to two feet. The vegetation is very scarce, a few plants clinging with a sort of hopeless tenacity to the sides of the hills, and in some cases protecting them from the winds. The yucca, or "Spanish needles," seems to grow even more luxuriantly in this almost soilless region.

Near Rapid river the denuded tertiary hills contain a great many fragments of bones and teeth, several species of horses, and more particularly the bones of an elephant and mastodon. The articulations are of enormous size; and so abundant were they that we might have loaded our wagon in a single day. The evidence is clear that a considerable variety of species and vast numbers of individuals were entombed in these sandy beds. Some of the specimens exhibit the appearance of having been water-worn, and most of the teeth have a tendency to split into laminæ or crumble in pieces. The large bones and fragments of teeth undoubtedly belong to the elephant which Dr. Leidy described as *Elephas imperator*, and pronounced it to have been a third larger than any ever before known, extinct or recent; and also to a moderate-sized mastodon, *M. mirificus*.

Rapid river joins the Niobrara in about longitude 100° 23′, and is named Mini-chá-du-ra-wák-pa by the Dakota Indians. At its mouth it is about eight yards wide, with a valley from one-fourth to one-half a mile wide, fringed for a few miles up the stream with trees, but soon becoming entirely destitute of trees. It is the most beautiful creek we have seen since leaving the Missouri; the soil is fertile, and the whole valley is clothed with the finest grass. No region could be better adapted for grazing purposes. I am certain that toward the head of this stream I saw many acres of grass that would furnish two to three tons of hay each. Leaving Rapid river we passed over the hills gently sloping towards the source of Little White river. After coming to the divide between Niobrara and Little White river, we descended eight miles to the river bottom. The country all around Little White river is exceedingly rugged, reminding one of the Bad Lands proper. No human being has ever explored this portion of the country before. There is a bed of hard rock that caps the high hills which aids in protecting their summits; but many of them are entirely denuded, and look quite white in the distance. It is easy here to ascertain the source of the material of the sand hills. Along the river are from 400 to 600 feet of pliocene sand, much of it loosely aggregated together. The beds are made up of thin layers, with sometimes a bed of fine chalky material, but exhibiting all the irregularities of deposition seen along our river banks. All these beds, becoming so easily decomposed, are incoherent. Sand is the result, which at once becomes subject to the winds. The harder layers project out, adding much to the ruggedness of these mural fronts. I can see no marked dip in any direction, but the beds appear to be horizontal everywhere, so that we must have seen already from 800 to 1,000 feet of the pliocene beds. There are some very excellent fossils, as teeth and jaws of horses, fragments of turtles.

This portion of Little White river is too rugged for settlements, but an excellent region for Indians. The stream varies from 12 to 15 yards in width, runs swiftly, averaging about one foot in depth, bottom mostly quicksands. Leaving this portion of Little White river we passed over the rugged hills west and southwestward, and again struck the same stream near its head, where it is entirely destitute of trees. It is here, however, a fine clear running stream, 9 or 10 yards wide. The surface of the country, and especially the highest hills, are covered with water-worn pebbles of all kinds. We here saw for the first time the peculiar flesh-colored beds which characterize the White River territory, and in searching among the denuded spots I found a few fragments of *Oreodon Culbertsonii*. This formation is so peculiar that although description may not fully show the difference between it and the pliocene beds, yet the eye can detect it anywhere. There is a small thickness of what may be called a drift deposit here, containing great quantities of water-worn teeth and bones. I detected those of the horse and mastodon. From this point to White Earth creek, a tributary of White river, the little streams flow between steep banks, which caused us some trouble, inasmuch as we were obliged to bridge them all. The pliocene beds have disappeared, and the miocene beds of White river occupy the entire country. Our course was nearly westward, along the heads of the little streams that flow into White river. Eagle Nest Butte is a very prominent landmark, and aids us much in determining approximately the thickness of these tertiary beds originally. It is a long square hill, from about 500 feet above the prairie around, and is capped with some of the pliocene beds. In 1855 I passed near the base of this hill, and spent some time in examining it. Upon the summit I found several species of the remains of mammals characterizing the pliocene beds. We have here a presentation of about 600 feet of tertiary rocks. From the remains already gathered from this region we see how abundant these animals must have been in ancient times, and yet one-fiftieth part can never meet the eye of man. Countless numbers of them must have been destroyed by erosion, and only a small portion, now and then, by special favor of aqueous agencies, is disentombed.

Our traveling has been very difficult along this divide. Never before did a wagon pass along this route. We have made up our minds that no portion of the country is wholly impassable for wagons, which is an important matter in a military point of view. We can see, far to the northward, the long ranges of peaks and domes which are usually called the "Bad Lands." The basis rocks all along our route are the cream-colored indurated marls, denuded in a few places. There is also a much more indurated bed which caps the hills, which I have called the red grit bed in my former explorations. Above this there is, in many localities, a layer of limestone. The tops of these hills must be from 1,000 to 1,200 feet above the bed of White river.

Along these little creeks are terraces 30 to 50 feet high, and when cut by the stream they present about 10 feet of loose drift-like material, and beneath a homogeneous deposit of cream-colored marl more recent than that of the hills around. I think, therefore, that these terraces represent two distinct geological periods. The more superficial deposit of coarser material sets down upon the cream-colored marl quite irregularly. Along the valley of White Earth creek, these terraces are shown in a most marked manner and cut up into miniature Bad Lands, as it were. One of them cut by a little stream shows the following section, ascending:

1. Original marl bed with an irregular surface.
2. A variable bed of worn pebbles, all of tertiary origin.
3. Yellow fine sand, irregular in deposition, incoherent and variable in thickness.
4. A capping of pebbles like bed 2; the whole about 30 feet in thickness.

I simply present this section here to show a deposit of even more modern date than any of the true tertiary beds. The sand of No. 3 is the same as that composing the sand hills before alluded to. There are here several large hills of sand 80 feet high moved about more or less by the wind, the sides of the hills only being slightly protected by a thin covering of grass and other plants. In this terrace formation are layers filled with fresh water and land shells of the genera *helix*, *planorbis*, *lymnea*, *paludina*, *succinea*. Very few of these shells are found in the little streams in this vicinity at the present time, and I am inclined to the opinion that they once existed here in the greatest abundance, that is, that the conditions for the healthy existence of these fresh-water shells were formerly much more favorable than now. The old mammalian remains have been entirely lost in the reconstruction, and there were no other bones of more recent date to show the fauna of that period. There are several dark bands as of clay mingled with vegetable matter, but this formation is mostly composed of the eroded material of the old tertiary beds.

On every side arose the unique picturesque forms of the Bad Lands, more wonderful and fantastic than at any other point before visited by me. Some portions look in the distance like cream-colored basaltic columns, others an amphitheater or the shape of arcs of a circle with a vast number of seats in many rows, one above the other; others resemble gothic temples, domes, towers, and fortresses. The west side of White Earth creek has much the appearance of a huge French palace, and as the early morning sun rests upon it every nook and corner seems lighted up with a strange wild beauty. The sides of these washed hills are worn into furrows, and every few feet there is a layer two to four feet in thickness, harder than the rest, which projects out, forming in many instances a sort of verandah. All these beds are full of calcareous and aluminous concretions which break in pieces on exposure to the atmosphere. Running through the beds in every direction, but vertical to the stratification, are seams varying from one inch to four feet, of fine clay or silex in the form of chalcedony. This is caused by the filling up of cracks or fissures. This feature characterizes all of the area occupied by the miocene beds.

On White Earth creek, and on White river at this point, the titanotherium bed, the lowest bed of this great basin, is 120 feet thick, and the oreodon bed above from 150 to 200 feet. This bed is of a deep cream color, composed of mud or marl, with bands varying from a dull reddish brown to a light gray. Toward the summit the light gray bands increase, and there are numerous but thin layers of rusty-colored sandstone. The sides of the washed hills are here very nearly perpendicular, looking like immense mud walls. Mixed with the debris at the base of the hills are great quantities of rocks, sometimes thinly laminated sandstone clay concretions with irregular fracture, or small masses of limestone and some layers of flint. The titanotherium bed contains more silex than any other bed in this group, In many places the rounded summits of the hills, composed of the materials of this bed, are literally paved with the sharp fragments, and the vertical seams run in every direction across the surface from one and one-fourth to one inch in thickness. There are also numerous globular masses of chalcedony scattered through the bed, some of which are very beautiful as cabinet specimens. Much of this lower bed resembles the clays of cretaceous formation No. 4, and the same vegetation seems to love to draw its nourishment from its surface. I am quite inclined to think that the cretaceous beds were called upon to contribute somewhat largely towards its formation. The lower portion of titanotherium bed is composed mostly of a greenish gray clay with pinkish bands, but toward the summits are numerous lighter bands, which give it the banded appearance in the distance. Although the two beds, titanotherium and oreodon, are quite distinct and the practiced eye can detect them anywhere, yet the line of separation between them is difficult to define, so imperceptibly does the one graduate into the other. In the dry season the traveling is most excellent, but even a small shower will render the materials of these beds a most tenacious, slippery mud, rendering traveling next to impossible. The oreodon bed in a dry time is indurated almost like solid rock, so that a mule in traveling over it scarcely makes an impression.

There is some chalcedony and at different points evidently local ledges of sandstone. The whole bed is filled with hard masses or concretions from the size of a musket ball to a foot or two in diameter. That portion from which the greater part of the fossils is taken is a homogeneous mud marl from 40 to 60 feet thick; above come lighter bands for 60 feet, and similar mud marl, again, 60 to 80 feet, which has a few fossils in it, now and then a good turtle and a few fragments of bones and teeth. In the White River valley, at this point, the country is more marked in its ruggedness than in any portion of what is known as the Bad Lands. There is no sinking away of the surface, as some have supposed, but a simple washing out of the country into innumerable gullies or cañons, and in some instances removing 400 or 500 feet of the entire mass for many square miles in extent, leaving only isolated pyramids, peaks, and columns as witnesses. Indeed, one may travel for miles over a level plateau clothed with grass, when suddenly we come to an abrupt descent from 400 to 600 feet to a plateau below, upon which are set as it were these pyramids, long ridges, denuded columns, &c.; but the strata are all horizontal, and as we pass from point to point each bed corresponds in each separate ridge, column, or pyramid, so that we know that the beds once extended in unbroken continuity all over this country, and we also see that there has been no dislocation of the strata. We can, however, in many localities follow the outer rim of this great lake basin, and in some localities this shore-line indicates a depression of 60 or 80 feet. The best illustration is seen along the north side of the great basin from Bear creek, a tributary of the Shyenne, to Pinan's spring, the source of Teton river. This shore-line resembles much that of any of our northern lakes: a gradual slope, while the little streams, which have cut their way through to flow into the Shyenne, reveal with perfect clearness the relations of the tertiary beds to those of the cretaceous beneath.

I will now give a couple of local sections of these tertiary beds taken at different localities, perhaps 20 or 30 miles apart, and although they differ somewhat it will be seen at a glance that they are substantially identical. There is a good deal of uniformity in the lithological character of these beds even over large areas. Section taken near White river, descent:

9. Light gray or brown at top arenaceous, 10 to 15 feet.
8. Homogeneous flesh-colored marl, 50 feet.
7. Grayish brown clay and sand, 20 feet.
6. Flesh-colored marl with a light cream band in the middle, 10 feet.
5. Drab brown arenaceous material, 60 feet.
4. Flesh-colored marl, 30 feet.
3. Arenaceous marl, (flesh color, 8 feet; light gray, 2 feet; flesh-color, 10 feet; light gray, 30 feet; flesh-color, 5 feet; light gray, 1 foot; flesh-color, 2 feet; light gray, 10 feet,) 68 feet.
2. Flesh-colored or buff marl with concretionary layers, rust-colored outside, light gray arenaceous inside, 30 to 50 feet.
1. Titanotherium bed, greenish gray clay, 120 feet.

One of the peculiar features of all the beds of this basin is that there is a slight change of color without apparent change of material, giving to a section seen in the field a peculiar banded appearance. Bed 3 is a fine illustration. Near Bear creek, on the north side of the Bad Lands, we find the following section in descending order:

5. Flesh-colored marl with a banded appearance, (25 feet light gray, 4 feet flesh-color, 6 feet light gray, 4 feet flesh-color,) 39 feet.
4. Indurated clay with fine sand, varying from drab brown to bright gray, 50 to 60 feet.
3. Flesh-colored or buff marl. Oreodon bed, 40 to 60 feet.
2. Gray and reddish bands, arenaceous clay passing up gradually into oreodon bed, 40 feet.
1. Greenish gray clay passing up into gray banded arenaceous clay, with some layers of fine white limestone, chalcedony, &c. Titanotherium bed, 60 feet.

Cretaceous beds.

Rust-colored clay with pinkish bands, with concretions, covered "with cone in cone." This bed is of the age of No. 5 and contains some cretaceous fossils, the most conspicuous of which is *Baculites grandis*, 50 to 60 feet.

In White River valley we find the lowest bed of this tertiary basin, Titanotherium bed, exposed very well, but no trace of the cretaceous beds beneath. I have also seen the same bed near Raw-hide Butte with a few of the large bones. Several fine specimens of this great pachyderm have been collected near Bear creek, but I am of the opinion that no more will be found, except uncharacteristic fragments of bones. I searched diligently over a large area where the former specimens were found, and also at other localities, and my efforts were fruitless. The remains have never been found above this bed, and as the bed is exposed over a very small area comparatively, there is very little hope now of any other specimens ever being found.

The Bad Lands evidently form a basin, the sides sloping gently down from the Shyenne and rising at the divide of White river, so that the oreodon bed is on a level with the cretaceous bed No. 4, which composes the plateau. Standing on the cretaceous plateau, on the north side of the tertiary basin, the Bad Lands with its picturesque dome and pyramid-like forms, looms up in the distance. The titanotherium never forms the same kind of rough lands like the higher beds, but rounded hills like those formed by the cretaceous clays. The pinkish bands which seem to prevail everywhere add to the picturesque appearance.

As this is our point of departure for home, after our labors in the Bad Lands, we will look back for a moment to dwell upon a few points. It is supposed by many that this miocene formation, occupying an area at least 100 miles long and 60 to 80 broad, will furnish to the world an almost limitless supply of specimens of fossil remains. Already over 40 species of extinct vertebrata have been discovered and disentombed, which will be mentioned more in detail in a subsequent portion of this report. I would reply to that supposition that the supply of good specimens is already very nearly exhausted, and that the labor required to collect will prevent in the future the possibility of large collections being obtained.

There seems to have been a belt or zone on both sides of the divide between White river and the Shyenne, about eight miles wide and 10 to 20 long, where these remains were exposed by erosion in great quantities. Formerly it was not a difficult matter to collect a ton of these rare and valuable fossils in a few days, now it requires as many months. Since the discovery of this basin two large collections have been made by Dr. Evans, one by Mr. Culbertson, and three by the writer, besides some smaller collections by numerous individuals whose names are not known to me. Among these specimens Dr. Leidy has already recognized more than 700 individuals of a single species, *Oreodon Culbertsonii*, a sort of ruminant pig, combining some of the characters of a camel, deer, and hog. I had canine teeth for tearing flesh, ruminant teeth like those of a deer and evidently chewed its cud. Now this area over which these remains seemed so abundantly distributed, has been most carefully searched and every specimen that could possibly meet the eye has been gathered.

If we pass beyond the limits of this belt we find a few remains, it is true, but they are very scarce, and usually in an extremely fragmentary condition.

I have hunted all day among the most rugged of the washed hills on White river and did not obtain 50 pounds weight of fossils—not a good head or turtle among them. At various times I have traversed nearly all this great basin, and I think I speak with a degree of confidence when I say that not more than one more large collection will ever be brought from that country, and that will be gathered with the greatest amount of labor.

There is another point which I will refer to here. Many scientific men have said to me, "in a few years these remains will be exposed by the washing of storms as abundantly as ever." I would say that during the past summer I examined with great care the ground so carefully searched over by Mr. Meek and myself in 1853, just 13 years ago, and that passed over by myself and assistant in 1855, 11 years ago, and in that time I doubt whether a single specimen has been exposed by the rains. I looked diligently for the slightest evidence in that direction and could find none. Even the debris around a turtle or head which we had gathered at that time seemed to remain undisturbed. It is to be recollected that atmospheric influences do not operate here as in regions east of the Mississippi. It is safe to say that not more than 10 or 15 inches of rain falls here during the year.

After securing our wagon-load of the fossil remains of mammals and turtles, we started for the Missouri river by way of what is called the Old Fort Pierre road. I do not think that wagons had passed over it since 1855, and in consequence the trail had in many cases almost or entirely disappeared. After leaving Bear creek we ascend a very steep hill, and then travel eastward for 50 miles, or with a broad level plateau covered with fine grass and almost as level as the quiet sea on our left hand, while on our right are the tall domes and spires of the Bad Lands. We travel as it were along the northern rim of this great tertiary lake. We travel, however, over the cretaceous beds. Bear and Sage creeks have long been noted places for cretaceous fossils. They are found here in large quantities in fine dark-bluish calcareous concretions, nearly globular in form, from 3 inches to 10 feet in diameter, and immediately on exposure to the atmosphere they have a tendency to crack into pieces, so that with a moderate-sized hammer one may knock them in pieces and work out the beautiful shells like bullets from a mold—*ammonites*, *baculites*, *scaphites*, *nautilus*, and a great variety of other shells of remarkable beauty.

Near the head of Teton river are several hills extending out into the prairie from what I have regarded as the rim of this tertiary basin, composed of yellow marl, but full of rounded calcareous concretions; and these concretions are charged with fresh-water shells, as *Helix lymnea*, *planorbis*, *physa*, &c., shells of the same genera as those now living in a little stream within a hundred yards of the hill, called Pinan's spring. These hills are also capped with ledges of silicious limestone, which contains some shells which are very beautiful, composed entirely of chalcedony. Fish remains are also quite abundant, but fragmentary. These beds are evidently more recent than any seen further to the west, I think very near the summit of the miocene. Still further on about 10 miles I found some beds of a yellow rusty sandstone, very fine-grained, in thin layers. On the upper surface of these layers were numerous tracks of marine shells, and trails of marine worms, which were certainly of great geological interest. They belong to the age of No. 5, or the Fox Hills group, and represent the shore-line of the great cretaceous sea in this region. I have attempted to account for these markings in this way: that as the tide receded, the small shells and worms washed up by the waters would struggle across the fine soft sand toward the water again, the gasteropodons' shells plowing furrows through the mud, and the little worms making the little trails, and the return tide sweeping over the markings, fills them like a mold. It is thus that they are preserved as witnesses of the great geological past.

The next point we come to is Grindstone Hills, which are long square hills on each side of the road, 50 miles distant from the Bad Lands, and like Bijoux Hills and Medicine Butte, form distant outliers of the great pliocene lake. There is here 150 or 200 feet of sandstone, some portions' a fine conglomerate or pudding-stone made up of water-worn pebbles, and among the rocks are found some fragments of teeth and bones much water-worn. These hills, scattered over the country, seem to act as witnesses or monuments to show the vast extent of erosion in this country. With the exception of these isolated hills, our entire road from Bear creek near the base of the Black Hills, by way of Fort Pierre to Fort Randall on the Missouri, was over cretaceous beds. In the neighborhood of Medicine Hills there were a large number of long ridges and hills, which were plainly remnants of pliocene beds. We arrived at Fort Randall after an absence from that point of 52 days, and having made the circuit of 650 miles with a six-mule team and a wagon weighing 1,775 pounds, one of the largest size.

Our conclusion was, that any portion of this rugged country, with care and patience, may be traversed with any number of wagons for military purposes.

CHAPTER XIV.

ƷEOLOGY OF NORTHEASTERN DAKOTA—NIOBRARA GROUP ON THE MISSOURI AT YANCTON—OSTREA CONGESTA AND OCCURRENCE OF REMAINS OF FISHES—CRETACEOUS SERIES—FROM YANCTON TO JAMES RIVER—CHARACTER OF THE INTERMEDIATE COUNTRY—GEOLOGICAL STRUCTURE OF THE VALLEY OF JAMES RIVER—RED QUARTZITES—OCCURRENCE OF NOS. TWO AND THREE—FROM JAMES RIVER TO SIOUX FALLS OR FORT DAKOTA—ERRATIC ROCKS STREWED OVER THE SURFACE—RED QUARTZITES AT SIOUX FALLS—FROM SIOUX FALLS TO PIPESTONE QUARRY—VERTICAL SECTION OF ROCKS AT PIPESTONE CREEK—AGE OF ROCKS IN WHICH THE PIPESTONE LAYER IS LOCATED—ANALYSIS OF ROCK—INDIAN HISTORY—PROFESSOR HALL'S GEOLOGICAL NOTES.

The following chapter, with the exception of some changes, was pub- ished in the American Journal of Science for January, 1867. It is eproduced here to give the facts a wider circulation, especially in those arts of the country where that most valuable journal may not be acces- ible. The object of the chapter is simply to record some observations n the geology of northeastern Dakota made by me in October, 1866, ›gether with an account of a short visit to the celebrated Pipestone uarry. No positive inference is drawn as to the age of the rocks in 'hich the Pipestone layer is located, from the fact that no well-defined rganic remains could be found. Therefore certain facts are noted down 'ith the hope that they may hereafter aid in the solution of the problem f their age, inasmuch as their geographical distribution seems to be uite extended.

In October last, after my return from a tour of explorations to the *Iauvaises Terres* or Bad Lands of White river, I took advantage of an pportunity that presented itself to visit some portions of Dakota Ter- tory, on the north side of the Missouri river, not hitherto examined by ıe. I there made my starting point the village of Yancton, the capital f Dakota Territory, located on the Missouri about 12 miles above the ıouth of the James.

At this point we observed a large exposure of the yellow calcareous arl beds of No. 3, Niobrara division, forming along the river nearly ertical bluffs, extending sometimes several miles. The rock varies in xture from a nearly white, soft chalk, much like our chalk of com- erce, to a somewhat compact limestone which is used for burning into me, and for building purposes. ~~Thick beds of this chalk present a arked rust color, from the presence of a greater or less amount of the eroxide of iron; otherwise it could hardly~~ be distinguished from the ıalk of Europe, and without doubt would serve the same economical ırposes. The organic remains found here are not very numerous in ›ecies. The most abundant shell is the *Ostrea congesta*, Conrad, which ›ems to have been as gregarious, and to have aggregated together uch in the same way as the little oyster, which is exposed when the de recedes along the shores of the sea islands of South Carolina. ear the base of No. 3 there are layers of rock several feet in thickness, ade up almost entirely of one or more species of *inoceramus*, one of hich has been identified as *I. problematicus*. The fish remains are quite ımerous, diffused throughout the rock. Fragments consisting of jaws, bs and scales, are found in the greatest abundance, and Mr. Propper, a resident of Yancton, has succeeded in securing some nearly perfect specimens (undescribed) from the quarries there. This group of rocks extends for 400 miles along the Missouri river, and I am convinced that when carefully studied, it will be found to represent the white chalk beds of Europe, and be employed for similar economical purposes.

The cretaceous rocks of the Missouri river have been numbered in the order of superposition, Nos. 1, 2, 3, 4, 5, and all of these divisions have been located in the geological scale by the unmistakable evidence of their organic remains. We find, therefore, that this portion of Dakota is occupied exclusively, or nearly so, by the middle member of the cretaceous series. The soft and yielding nature of No. 3 is well shown by the topographical features of the country, where all the slopes are gentle in their descent, and for the most part covered with a thick growth of grass, for the soil which is composed of the eroded materials of this group is quite fertile, and in ordinary seasons produces excellent crops, and is especially adapted to the growth of cereals.

From Yancton our course was nearly north, up the west side of James river. Our path led over a gently rolling prairie for 65 miles, with not a tree or a bush to greet the eye. There were no cut bluffs along the little streams over which we passed; the sides of the hills bordering the valleys sloping at a very moderate angle, and being covered with a thick growth of grass. No rocks were seen in place until we arrived at Fort James, about 12 miles below the mouth of Firesteel creek, a branch of James river. Erratic rocks of all sizes and texture were visible on the surface everywhere, more especially in the valley of James river and its tributaries.

At this point on James river, uncovered by the scooping out of the valley, is a large exposure of reddish variegated quartzites, differing somewhat in structure and appearance from any rocks hitherto observed by me on the upper Missouri. They cover a considerable area in the valley of the James at certain localities, but nowhere are they exposed at a thickness of more than 20 or 30 feet. Indeed they have been much worn by water, so that they project above the surface in large square masses, suggesting to one in the distance a village of log-houses.

The rocks are mostly reddish and flesh-colored quartzites, so compact that the lines of stratification are nearly obliterated. They also appear to be metamorphic. There is, however, a horizontal as well as a vertical fractere, and the horizontal fracture breaks across what appear to be original laminæ of deposition. These lines or bands are seldom horizontal; but much waved and inclined, as if the materials had been deposited in shoal or troubled waters. The illustrations of ripple or wave markings in these rocks are very numerous and beautiful. There is considerable variety in the texture of the rock; some of it is a very fine, close-grained quartzites, so that when worn by water it presents a smooth, glistening surface like glass. Again, it is filled with small water-worn pebbles, forming a fine pudding-stone; again, there are layers of siliceous sandstone, which separate into slabs varying from one-fourth of an inch to several inches in thickness. This rock is very useful for building purposes, and has been employed at this point by the United States army officers in erecting the numerous buildings that constitute the fort. I looked diligently wherever the rock had been quarried for some traces of organic remains, but none were visible. Resting upon the quartzite at this locality is a bed of black plastic clay, precisely like No. 2 cretaceous, as seen along the Missouri river near the mouth of the Vermilion. I found no fossils in this rock, but there were numerous specimens of selenite in crystals, which characterize it in other localities. Resting on No. 2 is the chalky marl of No. 3, not differing in structure from the same rock before described as occurring at Yancton, on the Missouri river. It here contains an abundance of its characteristic fossil *Ostrea congesta*. The thickness exposed is about 50 feet, but from an examination of the slope above, I estimated its entire thickness at this point at from 80 to 100 feet.

The formations at this locality, in descending order, are as follows:

a. Yellow chalky marl No. 3.
b. Black plastic clay, with selenite crystals, undoubtedly No. 2.
c. Reddish and rose-colored quartzites.

From Fort James we again proceeded across the undulating prairie, in a direction a little south of east, about 65 miles, to Fort Dakota, at Sioux Falls on the Big Sioux river. Nothing of special interest, in a geological point of view, met our eye except a small exposure of the reddish quartzite in the valley of Vermillion river. The soil of the prairie over which we passed, and also the superficial deposits as shown along the streams, gave unmistakable evidence that the surface features of all this region are due to the wearing away of the cretaceous rocks Nos. 2 and 3, and that they are the immediate underlying formations. The most characteristic features which met the eye everywhere were the boulders, which cover large areas so thickly as to render cultivation impossible until they are removed. These rocks, however, will be found to be very useful to future settlers for building and other economical purposes.

At Sioux Falls there is a remarkable exhibition of the same red and variegated quartzites described at James river. They are here exposed only in the valley of the river by the removal of the superincumbent cretaceous rocks. The falls are five or six in number, extending a distance of half a mile, and have a descent of 110 feet in all, forming the most valuable water-power I have ever seen in the west. About 10 feet from the top of the rocks, as seen at this locality, is a layer of steatitic material, mottled, gray, and cream-color, very soft, about 12 inches thick, which is used sometimes for the manufacture of pipes and other Indian ornaments. When the quartzites have been subjected to the attrition of water, they present the same smooth glassy surface as before mentioned. There are also beds of pudding-stone, and the most beautiful illustrations of wave and ripple markings that I have ever observed in my geological explorations.

I was unable to discover any well defined fossils, but wherever the surfaces of the rocks had been made smooth by the attrition of water, quite distinct rounded outlines of what appeared to be bivalve shells could be seen, so numerous that the rocks must have been charged with them. The matrix is so close-grained and hard that on breaking the rock no trace of the fossil could be found. I am confident, however, that the rock is filled with organic remains, but they cannot now be separated from the matrix so as to be identified.

From Sioux Falls to the celebrated Pipestone quarry the distance is just 40 miles, measured with an odometer. Direction a little east of north. We passed over a similar undulating prairie, with but one small tree along the route, and but one rock exposure, and that occurs about four miles south of the quarry. The rock is a very hard quartzite, composed largely of water-worn pebbles, quartz, jasper, small clay nodules, chalcedony; some of the rock is a quartzose sandstone, other portions are fine-grained siliceous rock. It lies in regular layers or beds, dipping at an angle of about 5° 30′ south of east.*

* I am greatly indebted to Colonel Knox, commandant of Fort Dakota, at Sioux Falls, for important *facilities in my examinations.*

On reaching the source of the Pipestone creek, in the valley of which the Pipestone bed is located, I was surprised to see how inconspicuous a place it is. Indeed, had I not known of the existence of a rock in this locality so celebrated in this region, I should have passed it by almost unnoticed. A single glance at the red quartzites here assured me that these rocks were of the same age with those before mentioned at James and Vermilion rivers and at Sioux Falls. The layer at Pipestone is about the lowest rock that can be seen. It rests upon a gray quartzite, and there are about five feet of the same gray quartzite above it, which has to be removed with great labor before the pipestone can be secured. About 300 yards from the pipestone exposure is an escarpment, or nearly vertical wall, of variegated quartzite, extending directly across the valley. Each end of the wall passes from view beneath the superficial covering of the prairie. It is about half a mile in length. About a quarter of a mile further up the valley there is another small escarpment, so that the entire thickness of the rock exposed at this point is about 50 feet. Not a tree can be seen; only a few small bushes growing among the rocks. There is a little stream of clear pure water flowing from the rocks, with a perpendicular fall of about 30 feet, forming a beautiful cascade. The evidences of erosion were very marked, and the question arose, how could all the materials which must once have existed here, joined on to these walls, have been removed, except by a stream much larger and more powerful in its erosive action than the one at present flowing here? There is a slight inclination of the beds, from 1° to 3°, about 15° south of east.

About 200 yards southeast of the quarry are five massive boulders, composed of a very coarse flesh-colored feldspathic granite, very much like that which forms the nucleus of the Black Hills.

The first detailed account of the Pipestone quarry that I have been able to find is that of Catlin, in this Journal, (1,) 38. In Nicollet's excellent report there is a much more careful and accurate description of the rock and the locality, but neither of these gentlemen hint at the probable geological age. The first attempt to determine the age of the rocks in which the pipestone is located was made by Professor Hall, in a paper read before the American Philosophical Society not long since. In that paper he regards them as of the same age with the Huronian rocks of Canada and Lake Superior.

At the time Mr. Catlin made his visit to the quarry, he sent a portion of the pipestone to Professor C. T. Jackson, of Boston, for analysis. Prof. J. gave it the name of Catlinite, with the following composition:

Water	8.4
Silica	48.2
Alumina	28.2
Magnesia	6.0
Peroxide of iron	5.0
Oxide of manganese	0.6
Carbonate of lime	2.6
Loss, (probably magnesia)	1.0
	100.0

The pipestone layer, as seen at this point, is about 11 inches in thickness, only about 2¼ inches of which are used for manufacturing pipes and other ornaments. The remainder is too impure, slaty, fragile, &c. *This rock* possesses almost every color and texture, from a light cream to a deep red, depending upon the amount of peroxide of iron. Some portions of it are soft, with a soapy feel, like steatite; others slaty, breaking into thin flakes; others mottled with red and gray. A ditch from four to six feet wide, and about 500 yards in length, extending partly across the valley of Pipestone creek, reveals what has thus far been done in excavating the rock. There are indications of an unusual amount of labor on the part of the Indians in former years to secure the precious material.

This rock has been used for many years past by the Indians of the northwest for the manufacture of pipes; and it was formerly the custom of some of the tribes to make the locality an annual visit to secure a portion of the precious material. They placed a higher value on the rock because, while being so firm in texture, it is so easily wrought, and because they could make far more beautiful and showy pipes than from any other material known to them. Besides, this was, and is now, the only locality from whence the true pipestone can be obtained; and the labor is so great in throwing off the five feet of solid quartzite that rests upon it, that the rock has always been rare. For a mile or two before reaching the quarry the prairie is strewed with fragments that have been cast away by pilgrims.

Nearly all of our writers on Indian history have invested this place with a number of legends or myths. They have represented the locality as having been known to the Indians from remote antiquity. All these notions, I am convinced, will disappear before the light of a careful investigation of the facts. It is quite probable that the rock has not been known to the Indians more than eighty or one hundred years, and perhaps not even so long a period. I could not find a trace of a stone implement in the vicinity, nor could I hear that any had ever been found; and, indeed, nothing could be seen that would lead one to suppose that the place had been visited for a longer period than fifty years. All the excavations could have been made within that time. There are many rude iron tools scattered about, and some of them were taken out of the ditch last summer in a complete state of oxidation.

Again, it does not appear that in the mounds which have been opened in the Mississippi valley so extensively, any trace of this rock has ever been found. It is well known that the pipe is the most important of the dead man's possessions, and is almost invariably buried with the body; and if a knowledge of this rock had extended back into the stone age, it is almost certain that some indications of it would have been brought to light in the vast number of mounds that have been opened in the valley of the Mississippi. Pipes and other ornaments made from steatite have been in use among Indians from the earliest indications of their history, and they are still manufactured from this material on the Pacific coast.

Now the question arises as to the age of the rocks we have attempted to describe, and which include the pipestone layer. Owing to the absence of well-defined organic remains, the problem becomes a difficult one. Their exceedingly close-grained, compact, apparently metamorphic character would direct one's attention to the older rocks, perhaps some member of the azoic series; but if the impressions seen at Sioux Falls are those of bivalve shells, we must look higher in the scale. But in order that we may arrive at an approximate conclusion, let us look at the geology of the surrounding country.

We already know that the limestones of the upper coal measures are exposed at Omaha City, and continue up the Missouri river to a point near De Soto, almost twenty miles farther, where they pass from view beneath the bed of the river. Overlapping them is a coarse sandstone composed of an aggregation of particles of quartz, cemented with the peroxide of iron. This assumes every color, from a deep dull red to a nearly white. The layers of deposition are very much inclined and distorted. Near Blackbird Hill numerous dicotyledonous leaves have been found, and many of these plants occur in a quartzite so close-grained that the lines of stratification are nearly or quite obliterated; yet the impressions are distinct. This quartzite forms a valuable quarry near Sioux City. The coal seam included in this formation (lower cretaceous No. 1) crops out 40 miles up the Big Sioux, or within 60 miles of Sioux falls. Between Sioux City and Yancton we have at least three members of the cretaceous series. Near Fort James we find that two members of the cretaceous series (Nos. 2 and 3) rest upon the quartzites. The surface features of the whole country, with the soil and drift, indicate that the immediate underlying rocks are of cretaceous age. Is it not possible, therefore, that the quartzites that include the pipestone beds belong to the supra-carboniferous, triassic perhaps, or even to an extension downward of cretaceous No. 1?

YELLOWSTONE AND MISSOURI EXPLORING EXPEDITION.
CAPT. W. F. RAYNOLDS, TOP'L ENG'RS, COMMANDING.

REPORT

ON THE

RETACEOUS AND TERTIARY PLANTS,

BY

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CHAPTER I.

PHYSICAL GEOGRAPHY OF THE NORTH AMERICAN CONTINENT DURING THE CRETACEOUS AND TERTIARY PERIODS.

The tree of knowledge, like the "tree of life," bears many kinds of fruit, and her leaves are also for "the healing of the nations." The object that may be proposed to the scientific investigator, and that which apparently engrosses his attention, is perhaps of the simplest and most prosaic character; and yet the sciences are so linked together—being but expressions of parts of the grand system and plan of the universe—that each necessarily shares in some degree the symmetry and beauty of the great whole.

In the earlier periods of history the entire material universe was shrouded in darkness impenetrable by human eyes; and the Creator and Ruler of this universe, except as made known through revelation, existed in the imagination of man as a vague and shadowy power, clothed in such attributes as appealed most strongly to the dominant passions of a savage or semi-barbarous people. In the growth of knowledge, investigations into the mysteries of nature were prompted by simple and material impulses. The cultivation of plants which might serve for food, and the study of those which accident discovered to possess remedial powers, laid the foundation for our science of botany. In the same way, observation of the characteristics, habits, and distribution of animals which contributed to the subsistence of man, resulted in a perception of the system which prevails throughout the animated world, and gave us ultimately our geological classification. Again the search for metals which were found to be useful by the primeval man gradually developed the knowledge we now have in all its refinements of their character, distribution, and metallurgy; to mineralogy, with its varied and beautiful forms; and to geology, which includes not only a knowledge of the composition and structure of the earth as we now find it, but from this is evolving the history of all the great changes which it has suffered through the lapse of ages. Showing to us the dawn and gradual development of animal and vegetable life, bringing before our eyes a grand and harmonious array of extinct forms, which far outnumber the living ones, geology is greatly expanding our knowledge of the present fauna and flora of the earth's surface, in filling the wide gaps by which their system and completeness are broken. Thus, associated with astronomy, it has given us our first intelligent perception of the magnitude, as well as the plan of the created universe, and of the power and wisdom of Him whose work it is.

In the exploration of the vast field which science has opened to it, the mind of man has expanded in every direction; and it is not too much to say that the highest triumphs of the human intellect have been attained in the solution of problems which our better knowledge of the material universe has presented to our efforts. Though much has been accomplished, far more still remains as legitimate and most ennobling work for this and future generations. The progress already made gives us glimpses of something grander and more beautiful beyond, and we may confidently look to the study of the phenomena of nature as promising to our children and children's children the most healthful, profitable, and elevating objects which could occupy their thoughts.

As we review the history of the growth of the sciences, we everywhere see illustrations of the truth of the axiom with which these remarks began. At first a few, and then in greater number, the students of nature, inspired each by an interest of comparatively narrow and local character, devoted themselves to the investigation of the phenomena that were immediately before them. In some cases the object which absorbed the attention of the investigator was a purely material, and frequently a mercenary one. In other instances the devotee of science, inspired by the highest and most unselfish enthusiasm, has given his life to the study of the details of a system running through some limited subdivision of the animal or vegetable world. In still other cases a fancy for certain trivial and superficial characters possessed by shells, mineral, coins, or books, has led to the accumulation of materials which have been converted to better uses by more enlightened and systematic workers; and last of all a passion for acquisition, as extravagant and irrational as avarice, has urged on collectors to scour the earth and sea for materials valueless to themselves, but which in other hands have contributed vastly to the advancement of science.

Already the number of these earnest and indefatigable workers is to be reckoned by thousands, and while most are occupied and satisfied with the local and limited triumphs which they achieve, not knowing nor caring what others are doing in other places and on other themes; yet since, as has been said, all the sciences are linked together, all conscientious research has a general value, and is a contribution to the common stock of knowledge which may have manifold uses. We may compare the realm of nature to a vast domain shrouded in obscurity, into which a thousand investigators penetrate, each with a special end in view, and following a narrow track in which he lights his steps; but all unconsciously to him, his little lamp throws some rays of light far into the surrounding shadows. And now to one who holds a commanding stand-point, the light of the thousand lamps which dot the darkness has so far dispelled it that all the great features of the landscape come out with more or less distinctness, and the plan, the harmony, and the beauty of a creation of which we had heretofore seen but a fragment begin to reveal themselves. Over all this vast world of thought, until now hidden from our vision, are strewed the evidences of the unity and grandeur of the universe, and its thorough exploration will develop truths which cannot fail to ennoble and happify the human race—truths, which not only have their bearing on the economy of everyday life, which tend to make two blades of grass grow where only one grew before, but which must affect most profoundly both our mental and moral natures. Thus the sciences are to become a potent element in the elevation of humanity, and in the development of our race to a higher degree of perfection, continuing the progress which is traceable from the dawn of creation.

These thoughts have been suggested by the view which recent investigations have opened to us of the history of the continent on which we live; its growth from an island nucleus; its constantly changing outlines—at one time presenting broad continental surfaces, at another nearly submerged beneath the ocean—the various phases, which, like dissolving views, are presented by its ever-changing physical geography. Already we get most appetizing glimpses of the varied flora, which clothed the plains and mountains of our ancient world and which, like the strange fauna that inhabited its surface, move through our field of vision, as they did through the ages, in grand procession, sometimes blooming in beauty and full of cheerful life, at others expressive of savage grandeur and brute force.

It would be foreign to my purpose here to pass in review, however briefly, the chapters which have been already written of the geological history of our continent; but in presenting, as I am now able to do, some relics of the forests which covered its surface during two geological periods, specimens which reveal much in regard to the aspects of nature in our western world during those far-off ages, I shall perhaps add to the value of this contribution by briefly bringing it into relation with the other facts which go to make up, so far as it is known, the history to which I have referred.

Very briefly, then, the changes that have taken place in the growth of the American continent are somewhat as follows:

The oldest rocks of which we have any knowledge are those which form the series called by Sir William Logan the Laurentian. They are best known by their exposures in Canada, where they occupy the surface in a broad belt extending from Labrador to Lake Superior, and thence northward. This great group of rocks was previously denominated by Foster and Whitney the azoic series, because up to that time no evidence of life had been obtained from them. Since then, however, fossils, or those regarded as such by our best authorities, have been discovered in more than one locality in this formation, both in Canada and the Old World; and in addition to this we find in the Laurentian series limestones of great thickness and extent which were undoubtedly in great part of organic origin. There are also found here beds of phosphate of lime, and iron ores containing a notable percentage of the same mineral, which could hardly have been derived from any other source than from animal organisms; like those indeed which during the later geological periods have contributed to the formation of beds of fossiliferous and phosphatic iron ore. It is also true that in the unmetamorphosed silurian rocks, what has been called the primordial fauna—until recently the oldest known—is too varied and highly organized to represent the dawn of life upon the earth, so that we may fairly conclude that the Laurentian rocks, many thousand feet in thickness, were formed from the ruins of a pre-existing continent, and were deposited as mechanical or organic sediments about its shores in an ocean replete with life, but of which distinct record is generally obliterated by the metamorphism to which they were subsequently exposed. The Laurentian area in Canada has apparently never been submerged since its first elevation, and it stands now as the oldest known portion of the earth's surface.

In the valley of the Mississippi, and in the far west, the Laurentian rocks are usually covered and concealed by more recent formations; but that they once existed, and even now exist, over a great area of our territory, is certain, both from the character and thickness of the silurian rocks made up of their ruins, and the facts observed by myself in the cañon of the Colorado, where the silurian strata were deposited around, and are now found abutting against pre-existing rocky masses which were islands in the silurian ocean; and islands of sufficient altitude and area to furnish from their debris many thousand square miles of paleozoic sediments. We are justified, therefore, in concluding that a great continental area has existed in the position of the central portion of the North American continent from the earliest geological times, and that our great mountain systems at the far west date back—though not in their present forms—to a period anterior to the paleozoic epoch.

During the silurian and devonian periods the northern portion of our continent was submerged beneath the ocean, the climate was milder and more uniform than now. This is proven by the area occupied by limestones (sea mud) of these ages, and by the discovery of the same genera and species of mollusks in the silurian rocks in different portions of the United States and the shores of the Arctic sea.

The *silurian system* is represented in America by a series of strata corresponding in a general way with those of the Old World, which contain a similar fauna, and a large number of species supposed to be identical with those of this country. During this period animal life consisted of foraminifers, mollusks, radiates, and crustaceans, but so far as we yet know included no vertebrates; though, since the remains of fishes have been tound in the silurian of the Old World we may expect them to be discovered here. The vegetation of the silurian period seems to have been entirely marine, at least no traces of land plants have as yet been discovered in rocks of that age.

The *devonian period* is largely represented in America, and like the silurian was a great limestone-making era, that is, a period when an open sea covered a large part of our continent. Its rocks and fossils correspond in a general way with those of the same formation in Europe and other parts of the world. There, as here, its fauna is strongly marked by the presence of sharks and armor-plated ganoid fishes, some of which must have been 15 or 20 feet long. In the devonian strata we find the first remains of land plants, trunks of coniferous trees, frequently of considerable size, and in the upper part of the formation a more varied flora including many ferns and having the general character of the flora of the carboniferous period.

For our knowledge of this flora we are indebted principally to Professor Dawson, of Montreal; and it has been derived mainly from the devonian rocks of the British Provinces, especially New Brunswick. In the far west the devonian strata have been recognized at different points all the way to California, and yet they are generally concealed by more recent formations, so that their lithological characters and fossil contents are imperfectly known. So far as observed, however, the devonian rocks of the west are all marine, and indicate the prevalence of an open sea over a considerable portion of what is now and was previously dry land.

The *carboniferous period* is perhaps more distinctly marked in North America than anywhere else upon the surface of the globe, and the rocks which were formed during its continuance present a closer parallel with those of the same age in Europe than do those of any other formation.

During this period the mountain limestone, the millstone grit, and the coal measures were deposited in regular succession, as in the eastern hemisphere, with a correspondence of fauna and flora in each. Yet it is true that many European lower carboniferous species are characteristic of the coal measures here.

In this country, as in the Old World, the most characteristic fossils of the carboniferous formation are the coal plants, and since more than 150,000 square miles of our territory are occupied by coal fields, the vegetation of the coal period in the thousand localities where the coal measures have been opened has very fully revealed itself to us. More than 500 species of coal plants have been already recognized on this continent, and about one-third of these have been identified with species found in Europe. As this would indicate, the flora of this period is essentially alike on the two continents, very few genera having been discovered here which had not been before found in Europe.

On our continent the coal measure rocks, with their associated beds of coal and coal-plants, extend with more or less interruption from Santa Fé, New Mexico, and Fort Belknap, Texas, through the valley of the Mississippi, New England, to Nova Scotia, and even reappear as far north as the Melville islands. Through this immense reach of latitude the fossil flora is nearly the same, a fact which proves not only the monotony of vegetation throughout the world at this period—more highly organized plants having then had no existence—but a remarkable degree of uniformity in the physical conditions of the earth's surface.

In regard to the physical geography of our continent during the carboniferous age, it would seem that the greatest land-surface was in the region east of the Mississippi, and that here, the Alleghanies not yet having been elevated, that land was comparatively low, with broad margins of marsh, especially on its western side, in which the ferns, *sigillariæ*, *lepidodendra*, &c., formed dense jungle-like forests, where a moist, highly carbonated atmosphere stimulated vegetable growth to an unparalleled degree, and where the temperature, uniform and not too elevated, favored its preservation in the bitumenized and concentrated form in which it should be most useful to the far-off but coming man.

In the lagoons of open water in the coal marshes the finer particles of thoroughly macerated vegetable matter were deposited in a homogeneous paste, which, when consolidated, became our cannel coal; and in these lagoons and bays existed various forms of aquatic life, among which were many of the carboniferous fishes of the Old World, *megalichthys*, *paleoniscus*, *cœlucanthus*, *diplodus*, &c., with some genera not found elsewhere. Here, also, appeared our first reptiles—aquatic amphibians, allied to our *menopoma* and *menobranchus*—some of which obtained a length of several feet.

Over the area now occupied by the central and western portion of our continent the sea prevailed during the carboniferous period, for there we find the carboniferous strata to be almost exclusively represented by massive limestone, the organic sediments deposited in a broad but shallow ocean crowded with animal life. In this ocean there were here and there islands upon which land plants grew—and such a one was situated were Santa Fé now stands.

As a whole the carboniferous period was one of continental subsidence. This is indicated by the fact that over the great area of our coal basins the strata which accumulated in succession at or near the water level now have a thickness of 1,000 to 2,000 feet, which measures a depression to that extent, to say nothing of what may have been removed by subsequent erosion. This subsidence was somewhat local in character or varied in degree in different localities, being far greater in Nova Scotia than elsewhere.

The carboniferous period was terminated by a continental elevation, attended by great physical changes, of which the Alleghany chain of mountains, then formed, constitute the most conspicuous monument. During this period of elevation the triassic strata were deposited, a series of red sandstones and shales, with highly colored marls, impregnated with salt and gypsum. Strata of this character—such as occur in other portions of the geological column, as, for example, in the Clinton and Onondaga groups—indicate shoal water and a retreating sea, in which wide mud flats were swept by tidal currents, where evaporation was rapid, and where, in lagoons and on exposed surfaces, the saline constituents of the sea water would be concentrated and retained. Such a condition of things would be unfavorable to the existence of animal or vegetable life, and as a consequence we find these red, saline, and gypsiferous strata almost entirely destitute of fossils. Here and there, however, especially in the far west, in California and northern Mexico, deeper and more quiet waters favored the existence of mollusks, and there, in shaly limestone, has been found by Professor Whitney and his assistants a fossil fauna closely allied to that of the trias of the Old World. In some localities dry land also existed, and there, as at Richmond, Virginia, on Deep and Dan rivers, North Carolina, and Los Bronces, in Sonora, beds of coal, which now have considerable economical value, were formed by the vegetation it sustained. At these localities and at Abiquiu and San José, New Mexico, great numbers of fossil plants have been obtained, which present a remarkable contrast with those of the immediately preceding age. The flora of all these localities is marked by the presence of numerous cycadaceous plants, now for the first time introduced upon the earth's surface. With these cycads are various ferns and conifers, the whole forming a flora very unlike that of the coal period, and in all its generalities similar to that of the triassic rocks of the Old World. Among the cycads and ferns are several species apparently identical with those found in Europe; and of the conifers, the most remarkable genus, *haidingera*, is very characteristic of the Old World triassic flora.

The next chapter of the world's history is that of the *jurassic* age, of which we seem to have upon this continent but a limited representation; our jurassic rocks occupying a relatively small area, and, so far as known, at present restricted to the western portions of the continent. In the region bordering on the Upper Missouri, at some points in the Great Basin of California and Sonora, limestone strata have been found which contain characteristic jurassic fossils—*belemnites*, *ammonites*, &c. These were undoubtedly deposited in the ocean that bordered the triassic continent on the west, and were perhaps contemporary with the upper portion of the triassic series.

We have nowhere as yet found any plants in the jurassic rocks, and have no means, therefore, of comparing the flora of America during that period with that of the lias and oolite of the Old World.

The *cretaceous period* has left behind it a grand series of monuments on this continent, from which may be read all the more important facts of its history. In some localities the strata of that age attained a thickness of 3,000 to 4,000 feet, and they now occupy more of the surface of the continent than those of any other formation. The era of the deposition of these strata was one of continental subsidence, in which the area of dry land was, especially at the west, greatly reduced. In the region east of the Mississippi the change of level was comparatively slight, and resulted in the addition of but a narrow margin of cretaceous rock, much of which has doubtless been cut away by the waves of the Atlantic—extending from Martha's Vineyard around our Atlantic and Gulf coast to Mexico. The northeastern portion of the continent seems not to have shared in this depression, as no cretaceous rocks have yet been found there. West of the Mississippi, however, a broad area, extending from the Arctic sea to Mexico, and having a width of a thousand miles or more, which had previously been dry land and covered by forests, was gradually invaded by the sea, sunk beneath its waters, and for the most part deeply covered by its calcareous deposits. The space at our command will not permit us to give all the facts from which this inference is drawn. Suffice it to say that over a great part of the area I have described the lower cretaceous strata, which corresponds in age with the gault of England, are coarse, thick-bedded sandstones and conglomerates, which everywhere contain the impressions of broad-leaved dicotyledonous trees, and in many instances beds of lignite, sometimes fifty feet in thickness. These are generally somewhat irregular, as though of drifted materials. The lithological characters of this member of the series, as well as its fossils, prove that it is composed of the immediate debris of the land, and it was gradually submerged beneath the ocean, sand, gravel, leaves, trunks of trees, &c., &c., is, in fact, simply an unbroken series of sea beaches.

These coarser beds are followed in the ascending series by strata of more or less pure limestone, highly charged with characteristic cretaceous mollusks, (*inoceramus*, *ammonites*, *baculites*, *&c.*,) the natural accumulation from the waters of the ocean, and forming a marked contrast with the mechanical sediments and terrestrial fossils of the underlying beds.

That the encroachment of the ocean was from the east and south towards the Rocky Mountains is proved by the fact that as we go from Texas and Arkansas in that direction we find the limestones becoming less pure, containing more inorganic material, (sand and clay,) until in New Mexico and Colorado but little true limestone exists in the whole formation.

During this submergence there was oceanic communication between the Gulf of Mexico and the Arctic sea, as the cretaceous strata stretch in unbroken sheets from Texas northward to and through the British possessions. All the eastern half of the continent was, however, out of water, for we find no cretaceous rocks deposited upon it; and the same is true of a considerable portion of the far west. In California the cretaceous beds reach but little way up the flanks of the Sierra Nevada, and in some portions of the Rocky Mountain country no traces of these rocks can be found.

The plants to which I have referred as forming the characteristic fossils of the lower cretaceous beds are of special interest, as they open a new chapter in the botanical history of the world. Although the region which furnishes them has been but partially surveyed, and collections made under the most unfavorable circumstances, already fully fifty species of forest trees are represented in these collections, and fragments obtained of at least as many more. The character of the vegetation which they reveal is that of a fertile surface and of a temperate climate, a vegetation, indeed, similar to that which now grows over the greater portion of the United States.

A fact of still greater interest is that we here find representatives of quite a number of the most characteristic genera of our present forest, viz: *diriodendron*, *magnolia*, *sassafras*, *platanus*, *fagus*, *populus*, *&c.* So modern is the aspect of this flora that it is not surprising that when submitted to the fossil botanists of the Old World it was by them pronounced to be of tertiary age. A portion of this flora is represented in the figures and descriptions which follow, and a much larger number of fossil plants from this horizon, collected by myself or others in New Jersey, Kansas, New Mexico, Colorada, Utah and Vancouver's Island are now in my hands, and others still have been described by Heer and Lesquereux; all of which confirm the statements which I have heretofore published in regard to our cretaceous flora, viz: "That on this continent vegetation was revolutionized at the close of the triassic period, when the cycadaceous flora, which then prevailed on the earth's surface, was succeeded by the 'reign of Angiosperms' in the introduction of a hundred or more species of forest trees, in great part belonging to the genera now living in the temperate portions of our country." From that early period the aspects of our flora do not seem to have *materially changed*, showing a stability and constancy in the physical conditions which prevailed here, such as is not indicated by the facts observed in other countries.

Of the flora of the upper cretaceous strata we have, as yet, but a very imperfect view, from the facts before stated, that over the greater portion of the area now underlaid by cretaceous rocks the sea existed during all the later ages of the period; and it was only here and there that land plants continued to grow on shores that were subsequently submerged so that they could be buried and preserved. In the districts I have examined in Colorado, Utah, and New Mexico, shore lines continue to exist to the close of the cretaceous period, and there I have found, in the shales, sandstones and lignites, at several levels, traces of plants which grew at a period later than those described in the succeeding memoir, derived from the lower cretaceous beds. From this it is evident that the vegetation of the continent experienced no very marked change throughout the cretaceous period. Many genera found in the lower beds recur in higher ones, while the new species seem to belong to genera largely reprrented in the tertiary flora, which is still more allied to that of the present day. It is probable, however, that we shall find that by the contraction of the land surface the climate of the remaining portion of the continent became more insular in character, and was thus capable of supporting a vegetation more characteristic of a lower latitude.

Tertiary period.—After the deposition of the upper cretaceous strata—such as correspond with the white chalk of England—the sea retreated from the area it had invaded at the commencement of the cretaceous period; and this retreat would seem to have been considerably rapid, from the fact that over most of the area covered by the cretaceous sea we find no evidence of the deposition of the strata corresponding in age to those of the first and lowest division of the tertiary, the eocene. In the region east of the Mississippi, on the shores of the Gulf and Atlantic, the eocene beds form a conspicuous member of the tertiary series, but in the far west they have not yet been recognized. The miocene strata occupy a large area in the far west, but, except in California, where they compose a great part of the coast mountains and cover the base of the Sierra Nevada, they are altogether of fresh-water origin. In the area of the Great Basin between the Sierra Nevada and the Rocky Mountains these lacustrine deposits are largely developed, and in the region of the plains they extend in a series of local basins from the north line of Texas far up into the British possessions.

Conclusive evidence of the progressive elevation of this portion of our continent is afforded by the observations of Dr. Hayden, who found the lower beds of some of these fresh-water deposits containing estuary shells, oysters, &c., showing that at this period salt water had access to them. Subsequently further elevation prevented the influx of the sea, and they were filled with a succession of fresh-water sediments. During this elevation the arm of the sea, which, in the cretaceous and lower tertiary ages, extended up the valley of the Mississippi to and beyond the mouth of the Ohio, gradually contracted, and the tertiary beds were left as parallel belts of deposit from its waters, covering a "V" shaped area along the lower Mississippi, including the eastern portion of Arkansas, the State of Louisiana, the western and southern portions of the State of Mississippi, and thence reaching around along the coast up on to the Atlantic shore. In the miocene epoch, therefore, our continent had nearly the outlines which it exhibits at the present time, and the topography of the eastern portion remained almost unchanged At the west, however, great changes took place, particularly marked by the elevation of most of the great mountain chains which traverse that region. It should be borne in mind, however, that, as has been before stated, these mountain chains have been represented by lines of elevation from the earliest geological periods, and in subsequent oscillations of level they seem to have acted simply as hinges or joints, upon which the plates of the continent turned.

These mountain masses were not wholly submerged during the silurian period, but the carboniferous sea swept over nearly all parts of them. In the great cretaceous subsidence they were but partly covered, and since then they, with the table lands which they crown, have remained far above the sea and the general level of the continent, and exposed to atmospheric erosion during all subsequent ages, now exhibit the most striking evidences of the potency of this agent to be found upon the earth's surface.

From the fresh-water miocene tertiaries, to which I have referred, Dr. F. V. Hayden has obtained a magnificent series of fossil plants, and from these and the overlying pliocene beds, a still more interesting collection of the remains of vertebrate animals. Of these tertiary plants a large number are figured and described in the following pages, in which are enumerated most of the species collected by Dr. Hayden on the different expeditions which he has organized or accompanied for the exploration of the country bordering the Upper Missouri. As a whole, the flora which they represent is strikingly like that of the lower miocene of Europe, which has been so amply illustrated in the beautiful work of Professor Heer, several species being identical and the generic correspondence remarkably close. It will be noticed, however, that there is here an entire absence of the Indo-Australian plants which give character to the flora of the eocene, and to a certain degree to that of the miocene of Europe. On the contrary, we have a grouping of plants which is closely copied by the flora of our southern States at the present day. The great fan palms which Dr. Hayden discovered are the only plants in the collection which have a tropical look, but these are associated with poplars, sycamores, hazelnut, mulberry, &c., which are very significant of a temperate climate, while, so far as yet observed, the tropical element in the miocene flora of Europe, formed by *cinnamomum*, *hakea*, *dnyandra*, &c., is here entirely wanting.

In the cretaceous rocks of Vancouver's island, and the tertiaries of Bellingham bay, species of *cinnamomum* have been found, as also in the eocene deposits of the Mississippi valley, and the eocene lignites of Brandon, Vermont—fossils which are indicative of a warmer climate than that which now prevails at these points; so that we have evidence that during the cretaceous period the climate of Vancouver's Island was warmer than that of the interior of the continent; and that during the eocene period the climate of the eastern half of the continent was warmer than now, corresponding in some degree to the tropical climate which prevailed in Europe during the same epoch.

In the collection of fossil plants recently described by Professor Heer, from Disco Island, off the west coast of Greenland, under the parallel of 70°, he finds *Sequoia langsdorfii*, *Quercus olafseni*, *Corylus McQuarrii*, and *Rhamnus eridani*, which are characteristic of the miocene of Europe, with a *salisburia;* all showing that during this period a climate equally mild with that of our middle States prevailed so far north. With this fact before us, and that of the discovery in Iceland of a similar flora which includes a *liridendron* scarcely distinguishable from our own, we are led to expect to find in the miocene of the central portion of our continent a flora of a decidedly tropical character. Such, however, has not been the case, and the plants collected by Dr. Hayden on the upper Missouri, as well as those derived from the miocene strata of Bellingham bay, Birch bay, &c., on the northwest coast, unmistakably indicate a climate but few degrees warmer than that of the present day.

From the pliocene beds of the upper Missouri we have as yet obtained no plants, but the interesting series of vertebrate remains collected by Dr. Hayden, to which reference has been made, comes partly from the miocene and partly from the pliocene strata. These represent a fauna very different from anything now living on this continent, showing that our plants have experienced far less changes than our animals. This fauna includes *elephas*, *mastrodon*, *rhinoceros* (three species,) and a great variety of ruminants, rodents, carnivoras, &c., forming more than sixty species, many of them of large size. Such a grouping of animals might be considered indicative of a warmer climate than the present; but the associated plants contain some living species, and are all closely allied to our present flora. Of the fresh-water shells found in these beds the same may be said; and the plants obtained from California and the valley of the Mississippi, from strata which correspond very closely in age with those containing the pliocene vertebrates, include a still larger number of living species.

We have every reason to believe, therefore, that during the miocene and pliocene tertiary periods the form and climate of our continent were similar to what they now are; that, while the climate was a little warmer, the aspects of nature were not greatly different from the present, and that the isothermal lines were carved across the continent very much as now. This is indicated by the flora on the northwest coast, which includes several of Dr. Hayden's upper Missouri species, and yet with them some which he did not find and such as are indicative of a somewhat warmer climate.

The Drift period.—Having such an approach to the present condition of our continent during the later tertiary ages, when many of our living species of both animals and plants were introduced, we have been very slow to accept the evidence which the glacial epoch furnishes us of a revolution in the physical geography of our country, scarcely less in degree than that recorded by any portion of the geological history. It would be foreign to my purpose to discuss here all the phenomena of the drift period, and it will be sufficient to give conclusions without the proofs upon which they rest, merely remarking that these conclusions are now generally accepted by those who have had the best opportunity of observing the facts. They are in general terms as follows:

First. That during the drift period a great depression of temperature took place over our continent, and that, at a corresponding period in the chain of events, (whether synchronous or not,) a similar cold period occurred in the Old World.

Second. That during the prevalence of this cold term ice covered the greater part of the hemisphere down to the parallel of 38° or 40°, and covered the summits of our western mountain ranges down to the northern line of Mexico and Arizona. South of these limits we have no proof of the existence of glaciers, and if they had existed they would have been sure to leave their traces behind them. During this cold interval the fauna and flora of the northern portion of our continent must have been driven southward many degrees below their previous and present range.

Third. After a longer or shorter period of continuance the climate again changed, the temperature was elevated, the ice was melted, the glaciers withdrawn to Greenland on the one side and to the northern portions of the Rocky Mountains on the other.

Fourth. By the melting of the accumulated snow and ice the central portions of the continent were flooded and the basin of the great lakes was filled by an unbroken sheet of fresh water. From this were deposited the oldest drift materials, stratified clays and fine sands, which rest upon the glacial surface. Upon these clays are found beds of boulders and masses of transported rock derived from the far north, which must have been floated southward on the surface of this inland sea and dropped upon the fine and stratified sediments that covered its bottom.

It is also evident that during the ice period the northern portion of our continent was considerably elevated, as the channels of all the draining streams were then deeply excavated, (to be subsequently partially filled with sand, gravel, &c.,) and are now traversed by streams which in some instances are flowing 100 or 200 feet above their ancient beds. During this interval the deeply eroded trough of the Hudson, the channel of the Mississippi, the mouth of the Columbia, and the Golden Gate must have been excavated.

This elevation was perhaps sufficient cause for the increase of cold, for it was doubtless attended by a great expansion of our continental surface toward the north, which would be a further source of cold. The elevated portion would serve as a condenser, and, with the temperature below 32°, would arrest and accumulate the precipitation which now forms the great streams which drain the northern half of our continent.

The period of the melting of the ice was one of depression, as on the Atlantic coast it was followed by the deposition of drift clays which reach high above the present ocean level. This depression was perhaps in itself sufficient to restore the climate to its previous standard.

The few fossils found in the drift deposits of the interior of the continent are the remains of coniferous trees of species which now live throughout its northern portions, (balsam fir, red cedar, white pine, &c.,) while on the Atlantic coast the drift clays contain large numbers of marine mollusks, and these, as might have been expected, are arctic or sub-arctic in character.

As to the effect produced by the cold period upon animal and vegetable life, it would seem probable that many of the larger vertebrates which lived on our continent during the pliocene age were destroyed by it, as very few of them still exist; but in regard to our plants the observations made on the pliocene flora seem to prove that nearly all the species of that period are still living and in the same localities, so that it would seem certain that the life-destroying power of the cold period was limited to those portions of the continent lying north of the 38th parallel. That the pre-existent flora and fauna were driven southward and suffered a narrowing of their range is unquestionable; and this was perhaps fatal to the largest of our land animals, but it had little effect on the flora and molluscous fauna, which are found to be essentially the same that they were before the glacial epoch.

On the whole the effect of the ice period was highly beneficial to the portions of our continent most affected by it, as all the asperities of the surface were ground down and diminished, while the depressions were more or less filled and the whole covered with comminuted materials which, spread smoothly over the underlying rocks, formed a surface particularly favorable for cultivation.

CHAPTER II.

THE BOTANICAL RELATIONS OF THE CRETACEOUS AND TERTIARY FLORAS IN NORTH AMERICA.

The study of fossil plants is the most difficult branch of paleontology, from the fact that the organisms represented by these fossils are generally of large size, and it rarely happens that more than broken fragments of their trunks, or their more or less perfect foliary appendages, re obtained for examination. The same is true in regard to the remains f vertebrate animals, but plants are organisms of a lower order, which mbody so much less of the principle of life, that their fragments, except heir flowers and fruits, are far less suggestive. In common with the ntire organisms, they represent a much more limited relation with other ortions of the natural world, and are therefore less pregnant in meanng. As it is true, however, that every organism fills a definite place in e chain of being, and in its nice adjustment to its surroundings exhibits symmetry but faintly figured by geometric forms, so every portion of at organism embodies to a greater or less degree the radical idea upon hich the whole is built.

The study of paleontology, by showing the intimate relations which xist between extinct organisms and those now living, as well as the utual dependence of the minor parts of the individual, and their relaonship to its entire organic structure, has thrown great light upon the eory of anatomy, both animal and vegetable, and thus upon scientific assification; and so far as regards the animal world, this truth is now enerally recognized and constantly employed. It was first demonrated by Cuvier in his study of the fossils of the Paris basin, and has nce formed the basis of paleontological study. Fossil botany has not een carried so far, yet much progress has been made in the same direcon. The minute study of the fragments of plants preserved in our lder or more recent strata has already contributed much to our knowlge of the structure and relations of our living plants; and although is not proven that generic and specific differences, expressed in the xterior forms used in our classification, are represented by parallel differences running through all their anatomical structure, yet the obserations already made show that important truths may lie buried even the most minute cell of organized tissue. We are therefore prepared believe that these external differences which divide the vegetable orld are merely superficial expressions of distinct organic laws or plans hich pervade the entire structure of each plant. This view receives nportant support from the microscopic study of silicified woods, which as proved that where the preservation of the different tissues is comlete they all afford valuable data for classification. Up to the present me, however, the microscopic structure of our living plants has not een sufficiently investigated to be largely used in making comparisons mong them, or with those which are extinct. In regard to the form nd structure of the foliary appendages, fossil botanists have shown that ese are far more significant of the relationship of the plants which ear them than has been heretofore considered true; and we have every ason to believe that when by sufficient study we have become more miliar with the details of structure in these all-important organs, we all find that they are as characteristic and distinctive of the plants to which they belong as are the fruit and flowers now so largely used as criteria for comparison.

The Linnean system of classification has been properly abandoned, not merely because it was based upon the study of one set of organs, but because these organs were grouped according to an artificial method from special characters, and from the number of certain parts. In the natural classification which has superseded the artificial, all the organs and appendages, from the root to the summit of the plant, are made to give their testimony in its classification. The result of the employment of that method has been to show that all the parts are mutually dependent, and the same law is true in regard to the leaf, flower and fruit that prevails in the structure of the higher animals; so that we should no more have the fruit and flowers of a *solanum* associated with the trunk and leaves of a *pyrus*, than we could have the claws of a carnivore with the teeth of a ruminant.

The botanist who occupies himself in the study of recent plants, and who finds, as he often does, the whole group of external characters insufficient to clear the subject of specific relations of all doubt, is not likely to regard with much faith or favor deductions from a single set of characters; yet it happens that a large part of his labor and perplexity comes from an effort to solve the mooted question, what is a species? and to draw definite lines between nearly related plants, where perhaps no such lines exist in nature. There is little doubt that in most cases his work would be facilitated and obscure questions illuminated by careful study of the minute structure of the different parts, and it is true that those portions of the organism once considered insignificant are more and more appealed to as a basis of classification.

In the Old World many of the best living botanists have occupied themselves with the study of fossil plants, and they have not only found in this study attractive and dignified occupation for minds of high order, but one of increasing interest, from which they have already deduced truths of the greatest value to botanical science. The magnificent works published by Brongniart, Unger, Gœppert, Lindley Heer, Geinitz, Webber, Massolongo, and others, are not only honorable monuments of their industry and learning, but invaluable contributions to science, without which our knowledge of the present as well as the former world would be far more incomplete than it now is.

The information afforded by the accompanying figures and descriptions of the flora of this continent during the cretaceous and tertiary periods, it need hardly be said, is in the highest degree partial and fragmentary. They include, as we know, but a small portion of the plants which grew in our country during these early ages, and the specimens obtained give us a very imperfect view of the plants which they represent. They consist almost exclusively of leaves in a better or worse state of preservation, without trunks, branches, fruit, or flowers. It is evident, therefore, that much remains to be supplied as material for the description and history of the plant-life, of which we here have evidence; while the few species common to the collections made by different persons at the same or in different localities, as well as the very numerous fragments obtained or seen of plants distinct from these, all show the richness of the flora of which they form part, and prove that a large number of genera and species not only existed during these periods, but have left records behind them which will ultimately be used in the restoration of these floras. It is also quite certain that where the leaves are preserved with such beauty and delicacy, as in the case of many of these specimens, the twigs, buds, fruit, and perhaps flowers, are also preserved, and will some time contribute their evidence on the questions which now occupy us. The reason why more of these organs are not included in the collection is doubtless this: that men find that which they seek, or, rather, they do not find that which is not sought, and the collections which include the specimens under consideration were mainly made by those who did not realize the importance of securing the inconspicuous organs of fructification with the leaves.

To give the greatest success to his investigations, the fossil botanist must collect his own material, and, watching the work in quarries and mines, or, better still, carefully conducting his own explorations, let nothing which can throw light on this subject pass through his hands. From the fact that no considerable excavations have been made in the rocks that have furnished these fossils, the collections being made by exploring parties, traversing a new country in hurried reconnoissance, obtaining fossils only from some chance exposure, in some clean-washed stream, bed, or crumbling cliff, it is surprising that so large a number of well-marked specimens have already been secured, and we may confidently look forward to more thorough exploitations of this field as promising results not inferior in interest to any that have been achieved by fossil botanists in any other portion of the world.

The material now presented is, as has been remarked, but a portion of that already obtained from the cretaceous and tertiary rocks of the far west, and all that has been procured is but a fragment of what exists as a reward to future explorers. It may therefore be thought that it would be better to wait until further collections were brought in, till more and more perfect material were obtained, before any attempts were made to illustrate the botany of our cretaceous or tertiary continents. It is true, however, that these fossils have a geological value quite independent of their botanical relations. Characteristic as they are of certain formations, and serving as they will do for the identification of strata, it is important that they should be given to the public as soon as possible. They also include much that is new, important, and reliable in regard to the botanical character of the floras which they represent, and, while giving the element of uncertainty which clings to some of these specimens its proper value, botanists will undoubtedly be gratified to obtain even the imperfect glimpses which they give of a hitherto unknown world in the domain of nature.

THE CRETACEOUS FLORA.

It is only within the last ten years that we have obtained any information whatever in regard to the nature of the vegetation which clothed the land that represented North America during the cretaceous period. Previous to that time large collections of fossils had been made from rocks of this age on the Atlantic and Gulf coasts, but the beds which furnished them were marine sediments, and the fossils they contained were principally mollusks and radiates, but included also fragments of skeletons of cretaceous saurians, *mosasaurus*, *hadrosaurus*, &c., and teeth of *ptychodus*, a selachian fish. In these remains there was found a generic correspondence with those of the middle and upper cretaceous beds of the Old World, and many species were recognized as the same found there.

In 1855, Dr. F. V. Hayden made the second of his numerous journeys of exploration into the country bordering the Upper Missouri; journeys which have resulted in such important contributions to our knowledge of the geology of the interior of the continent. At this time he was connected as geologist and naturalist with an exploring party sent out by the War Department under Lieutenant (now General) G. K. Warren, corps of topographical engineers, United States army. In the great mass of interesting materials brought in by Dr. Hayden, were a number of angiospermous leaves, obtained from a red sandstone lying at the base of the cretaceous formation at Blackbird Hill, in Nebraska. Outline sketches of some of those leaves were sent to the distinguished fossil botanist, Professor Oswald Heer, of Zurich, Switzerland, and by him they were pronounced of miocene age, and referred to the genera *laurus*, *populus*, *liriodendron*, &c.; a narrow lanceolate leaf being considered identical with *Laurus primigenia*, Ung.; a broad rounded one with *Populus leuce*, Ung., both found in the miocene of Europe. At the same time the fossils themselves were submitted to me for examination, and regarding the so-called *Populus leuce* as generically identical with some large rounded leaves described by Zenker, from the cretaceous sandstone of Blankenburg, Germany, I considered this florula as of cretaceous age, confirming the conclusions of Messrs. Meek and Hayden, who had referred the deposit from which it came to that period. The plant called *Laurus primigenia* by Professor Heer I considered a *salix*, and the other leaves as representing the genera *platanus*, *populus*, *fagus*, *liriodendron*, *sassafras*, *magnolia*, &c. Unfortunately Professor Heer had only sketches of part of these leaves; and while I had the specimens all before me, I had no specimens of the cretaceous flora of Europe, but only figures and descriptions of the comparatively few leaves found there in this formation, by Zenker, Dr. Debey, Steihler and others. It was, therefore, quite impossible that we could then make an intelligent comparison of the two floras. The genera recognized among these plants by Professor Heer and myself were for the most part living in our forests, and largely represented in the miocene strata of Europe. It is not surprising, therefore, that Professor Heer should have considered them of tertiary age, and that this opinion should be shared by many others.

Soon after the discovery of these plants by Dr. Hayden, he went again to Nebraska and Kansas, accompanied by Mr. Meek, and collected from various exposures of the lower cretaceous sandstones numerous additional specimens of the same, and different species. Subsequently I went myself to the region where these leaves were collected, and spent some two years in the study of the geology of the interior of the continent;

exploring a large area occupied by cretaceous rocks in Kansas, Colorado, New Mexico and Utah. During these explorations I obtained from the cretaceous strata, at a great number of localities, angiospermous leaves, which include some of the species obtained by Dr. Hayden, with many others; all of which are described in the report of the San Juan expedition not yet published. In numerous instances, as Dr. Hayden had done, I obtained these leaves from the sandstone overlaid by calcareous beds, containing *Gryphæa pitcheri*, *Inoceramus problematicus*, and many other unmistakable cretaceous fossils. These leaves I found to be the characteristic fossils of the strata in which they were first discovered, and was able to obtain them at nearly every exposure which I examined. In the end I had before me, collected by Dr. Hayden and myself, at least fifty distinct species of leaves of this character from this horizon, with fragments, scarcely sufficient for description, of perhaps as many more.

Though Mr. Meek, Dr. Hayden, and myself had thus demonstrated the truth of the position first taken by us in regard to the age of the beds that furnish these leaves, the flora which they represent was so modern in its character that the European paleontologists were still unwilling to admit the possibility of its being older than tertiary; and it was only when, in 1863, M. Marcou and Professor Capellini made a special journey to Nebraska, and collected fossils from the same localities that had yielded them to Meek and Hayden, that the fact was admitted that this flora was really of a cretaceous age.

The plants collected by Messrs. Marcou and Capellini embraced sixteen species, which have been described by Professor Heer in the Memoires de la Societé Helvetique des Sciences Naturelles, 1866, viz: *Populus litigiosa*, *P. Debeyana*, *Salix nervillosa*, *Betulites denticulata*, *Ficus primordialés*, *Platanus Newberryana*, *Proteoides grevilliæ formis*, *P. acuta*, *P. daphnogenoides*, *Aristolochites dentata*, *Andromeda parlatorii*, *Diospyros primvæa*, *Cissites insignis*, *Magnolia alternaás*, *M. Capellinii*, and *Liriodendron Meekii*.

It is an interesting fact that of these sixteen species, but three are identical with those obtained from the same quarries by Meek and Hayden, or those collected by myself elsewhere, an illustration of the richness of the flora which they represent. My own observations prove this richness still more clearly, for, as I have said, in the outcrops of the lower cretaceous rocks at the west I have detected at least a hundred species of conifers and angiospermous trees. Of these it rarely happened that in the chance exposure, a cliff, or water-washed surface, anything like a perfect specimen could be detached and brought away. As a consequence, we have in the figures and descriptions now published or prepared, but a very imperfect view of the flora of the cretaceous period on this continent, even as it has been exhibited to my eyes, and there is every reason to believe that but a small proportion of its elements have as yet been observed at all.

On the western margin of the continent it is well known that the cretaceous strata are quite largely developed; having been recognized in Sonora, California, Oregon, Washington Territory, and Vancouver's Island. From the latter locality quite a number of fossil plants have been obtained, which have been described by Professor Heer, Mr. Lesquereux, or myself. The first knowledge which we obtained of the cretaceous beds of Vancouver's Island was derived from the description by Mr. Meek, (Transactions of the Albany Institute, vol. 4, page 37,) of some fossil mollusks collected by Dr. Turner. Subsequently (in 1858) the collections made by the United States northwest boundary commission were placed in my hands for examination. They included fossil plants from the coal beds of Nanaimo, Vancouver's Island, which were associated with *inoceramus*, *pholadomya*, &c., previously described by Mr. Meek, and which plainly indicated their cretaceous age. These plants were described by the writer in 1863. (Boston Journal of Natural History, vol. 7, No. 4.) Previous to that time the fossil plants collected by Dr. Evans, United States geologist of the Territory of Oregon, were committed to Mr. L. Lesquereux, the well known botanist, who published descriptions of them in the American Journal of Sciences, (2d series,) vol. xxvii, p. 359. Of these the following were from Nanaimo, viz:

Populus rhomboidea..Lesqx.
Quercus benzoin.. "
" *multinerois* .... "
" *platineros* .... "
Cinnamomum Heerii .... "
Salix islandicus .... "
Ficus sp.. "

with which are enumerated, but not described in full, a *platanus* with the same nervation as *Quercus platinervis;* a *chamaerops* agreeing with *Sabal Lamanonis*, Bergh, common in the European miocene; a fine *Salisburia*, very variable in the outline of its leaves, and named *Salisburia polymorpha*, Lesqx.; also a small piece of a fern referable to the genus *lastrea*, and a *sequoia*, probably identical with *S. sempervirens.*

The Bellingham Bay plants described by Mr. Lesquereux consisted of species of *smilax*, *Quercus planera*, *cinnamomum*, *persoonia*, *diospyros* and *acer.*

By Mr. Lesquereux the plant-bearing strata of Bellingham bay and Vancouver's Island were regarded as of the same age, and from the resemblance of the species they contain to those found in the miocene of Europe, he pronounced them to be of that date, (Op. Cit., vol. xxvii, p. 362.) In a subsequent number of the American Journal of Sciences (vol. xxvii, p. 85) is published a letter from Professor Heer upon these plants, of which sketches had been sent him by Mr. Lesquereux. In these notes the extinct flora of Vancouver's Island and Bellingham Bay are considered of the same age and brought still nearer the miocene of Europe; quite a number of species being regarded as identical with those found at Oeningen, &c.

Since that time a collection of fossil plants made by Dr. C. B. Wood, at Nanaimo, Vancouver's Island, and at Buzzard's Inlet, British Columbia, was sent by Dr. Hooker to Professor Heer for examination. From the coal mine at Nanaimo but a single species in this collection was obtained, viz: a conifer considered by Professor Heer as identical with *Sequoia langsdorfii*, Br. sp., a species common in the miocene of Europe.

From these facts it will be seen that the modern aspect of the fossil flora of Vancouver's island has produced the same misapprehensions as the cretaceous flora of Nebraska. This, however, is not to be wondered at, and conveys no reproach to the eminent scientific men who have been misled by it. The identification of species by few and fragmentary specimens, or still worse, by sketches, is a difficult and hazardous task for any one to perform, and in regard to the generic relations of the plants described, it can only be said that previous to the discovery of such modern genera as *liriodendron*, *magnolia*, *sassafras*, &c., in the cretaceous rocks, they were naturally regarded as belonging to the present or tertiary flora. It is also true that the flora of the cretaceous period in the Old World has, until recently, been considered, from the number of cycads it includes, as a continuation of the jurassic flora. It is also marked e presence of numerous East Indian forms, none of which have as een discovered on this continent. There is no more doubt, how- that the plant-bearing strata of Vancouver's Island are cretaceous in regard to those of Nebraska. A very large number of creta- mollusks have been collected, both in the overlying beds and those ining the plants, as was stated by the writer, in 1863, in the report ich reference has been made) on the fossils collected by the bound- ommission.

regards the strata containing the plants and coal of Bellingham it is possible that both formations are there represented. Many of lants collected in this locality by Dr. Evans have been pronounced rofessor Heer as identical with miocene species of Europe, and e to add to that list *Glyptos trobus Europæus*, which I have ed from the shores of Bellingham Bay.*

m Orcas Island, which occupies an intermediate position between gham Bay and Vancouver's Island, a collection of plants was made r. George Gibbs, of the boundary commission, in which the species vith perhaps one exception, different from those obtained from the two localities mentioned. These include some ferns, palms, and l-leaved plants described in the report to which I have alluded, e they are referred doubtfully to the cretaceous age.

e fossils collected by the exploring expedition at Birch Bay, north ellingham Bay, are unquestionably of miocene age, and seem to been derived from deposits connected with those from which Dr. d obtained his specimens, and, with a portion, at least, of the Bel- am Bay deposits.

mbining the contributions thus made to our knowledge of the cre- us flora, and referring to this formation all that we now know g there, we have the following "list of genera and species:"

North American cretaceous plants.

lus rhomboidea,	Lesqx.	Nanaimo, V. I.
Islandica,	do.	do.
usbenzoin,	do.	do.
multinervis,	do.	do.
platinervis,	do.	do.
momum Heerii,	do.	do.
uria polymorpha,	do.	do.
lium Kennerlii,	Newb.	do.
sp.,		do.
lium cuneatum,	do.	
olia cuneata,	do.	Orcas Island.
pteris Gibsii,	do.	do.
opteris (Asplenium) elongata,	do.	do.
lus Debeyano,	Heer.	Nebraska.
giosa,	do.	do.
nervillosa,	do.	do.
nus Newberryana,	do.	do.
omeda parlatorii,	do.	do.
yros primæva,	do.	do.

. Gabb, of the California geological survey, who has recently visited Bellingham ronounces all the strata exposed there to be cretaceous. This may be true in regard coal beds, and the strata from which many of the plants have come—possibly all; that case there have been errors in labeling some of the fossil plants which have come y hands, as a few of those reported as "from Bellingham Bay" are clearly miocene.

Phyllites Vannonæ,	Heer.	Nebraska.
Aristolochites dentata,	do.	do.
Cissites insignio,	do.	do.
Ficus primordialis,	do.	do.
Magnolia alternans,	do.	do.
M. Capellinii,	do.	do.
Liriodendron Meekii,	do.	do.
Betulites denticulata,	do.	do.
Proteoides daphnogenoides,	do.	do.
P. acuta,	do.	do.
P. grevilliæformis,	do.	do.
Leguminosites Marcouanus,	do.	do.
Sapotacites Haydenii,	do.	do.
Populus cyclophylla,	do.	do.
Phyllites obcordatus,	do.	do.
Sassafras cretaceum,	Newb.	do.
Liriodendron prinævum,	do.	do.
Araucaria spatulata,	do.	do.
Quercus salicifolia,	do.	do.
Magnolia obovata,	do.	do.
Platanus latilobus,	do.	do.
Fagus cretacea,	do.	do.
Populus elliptica	do.	do.
P. mycrophylla,	do.	do.
P. cordifolia,	do.	do.
Sphenopteris corrugata,	do.	do.
Pyrus (?) cretacea,	do.	do.
Acerites pristinus,	do.	do.
Alnus grandifolia,	do.	do.
Salix flexuosa,	do.	do.
S. cuneata,	do.	do.
S. membranacea,	do.	do.

At the base of the cretaceous series in New Jersey occurs a coarse, soft sandstone and beds of sandy clay which contain a large number of fossil leaves, many of which, collected by Professor George H. Cook, of New Brunswick, by Messrs. Meek, Hayden and others, have been submitted to me for examination. Unfortunately most of these leaves are inclosed in a material so coarse and friable that they have been much broken and are scarcely susceptible of accurate study. They form, however, quite a rich flora, which includes a number of species not yet obtained from the cretaceous beds of the west, with others that are apparently identical with some obtained by myself on the banks of the Whetstone creek in Western Kansas. Among these plants is a beautiful conifer, generically new, as indicated by its cones, which are in a good state of preservation. The plants from this district have not as yet been carefully studied, and they form an attractive subject for future investigation. In the circumstances of their fossilization they resemble the plants of the west and apparently indicate an invasion of the ocean, occasioned by a subsidence by which the limits of the continent were contracted, but to what extent on its eastern margin we have no means of determining accurately.

By referring to the list of plants on a preceding page it will be seen that the cretaceous strata of the west coast include some forms not yet discovered in the Kansas and Nebraska beds. Among these, *Salisburia*, *sabal*, *cinnamomum*, &c., are indicative of a warm climate. Possibly genera may hereafter be detected in the plant beds of Kansas, aska and New Mexico, but as yet we have no intimation of their ence, and there is nothing now known in the cretaceous flora of region which gives it a tropical or even sub-tropical character. will be remembered that this vegetation grew upon a broad conti- ıl surface of which the central portion was considerably elevated. would give us a physical condition not unlike that of the continent e present day, and it would seem to be inevitable that the isother- ines should be curved over the surface somewhat as they are at nt. It may very well happen, therefore, that we shall find the s and cinnamons restricted to the western margin of the cretaceous nent. It will be seen by the notes now given of the tertiary flora ır continent that at a later date palms grew in the same region e these cretaceous plants are found, but cinnamon and other trop- lants seem to be entirely wanting in the tertiary flora of the cen- arts of the continent, while on the west coast both palms and cin- ns lived during the tertiary period as far north as the British line. ave, therefore, negative evidence from these facts—though it may versed at an early day by further observations—that the climate e interior of our continent during the tertiary age was somewhat er than during the cretaceous period, and that during both the relative differences of climate prevailed between the central and rn portions that exist at the present day.

THE TERTIARY FLORA.

As has been said in regard to our cretaceous flora, our knowledge of the vegetation which clothed this continent during the tertiary period has all been gained within a very few years, and is still exceedingly imperfect. The first notice of the fossil plants collected from our tertiary deposits is given by Professor J. D. Dana in the geology of the exploring expedition. This comprises figures and brief descriptions of a number of fossil plants from Birch Bay, near the mouth of Frazer's River, on the northwest coast. Subsequently the specimens collected by by Professor Dana were described more in detail in the paper to which reference has before been made, published in the Boston Journal of Natural History, vol. vii, No. 4. The plants collected by the exploring expedition included the following species, viz:

Glyptostrobus Europœus..............................Br. sp.
Taxodium occidentale..............................Newb.
Smilax cyclophylla..............................Newb.
Rhamnus Gaudini (?)..............................Heer.
Carpinus grandis (?)..............................Ung.

Of these, *Taxodium occidentale* is closely allied to *T. dubium* of the miocene of Europe. The *glyptostrobus* is apparently identical with the European miocene plant; *Smilax cyclophylla* is the analogue of *S. orbicularis*, while the *carpinus* and *rhamnus* are referred doubtfully to the European species of which the names are given them.

From the strata associated with the coal beds of Bellingham Bay, fossil plants had been collected by several persons, but none had been described from that locality, until in 1859 a series of specimens, collected by Dr. Evans, geologist of Oregon, were placed in the hands of Mr. Lesquereux, and described by him in the American Journal of Science, (2d series,) vol. xxvii, p. 359.

The following list includes the tertiary species of the collection, viz: *Planera dubia*, (Lesqx.,) *Quercus Evansii*, (Lesqx.,) *Q. Gaudini*, (Lesqx.,) *Cinnamomum crassipes*, (Lesqx.,) *Persoonia oviformis*, (Lesqx.,) *Diospyros lancifolia*, (Lesqx.,) *Acer trilobatum (?)* (Al. Br.)

In the next volume of the Journal of Science, page 85, is published a letter from Professor Oswald Heer, of Zurich, Switzerland, containing some notes on these fossil plants, of which sketches had been sent him by Mr. Lesquereux. *Planera dubia* (Lesqx.) is regarded by Professor Heer as identical with *P. Ungeri*, of Europe; *Cinnamomum crassipes* (Lesqx.) is said to be hardly distinguishable from *C. Rossmaesleri* (Heer;) *Salix islandica* (Lesqx.) is compared with *Salix macrophylla* (Heer;) *Quercus benzoin* (Lesqx.) is referred to *Oreodaphne Heeri* (Gaud.;) *Quercus Gaudini* (Lesqx.) is said to be probably identical with a species from the Italian tertiaries, and *Salisburia polymorpha* (Lesqx.) the representative of *S. adiantoides*, Ung.,* &c.

In 1863 I described the fossil plants collected by the northwest boundary commission in the Boston Journal of Natural History, and among them the following species were enumerated: *Equisetum robustum*, N., *Sabal Campbellii*, N., *Taxodium occidentale*, N., *Quercus flexuosa*, N., *Q. Banksiæfolia*, N., *Q. elleptica*, N.

Populus flabellum, N.; derived from the tertiary beds of the main land on the northwest coast.

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* *It is asserted by* Mr. Gabb (report of J. Ross Browne, United States Commissioner, p. *189,) that all these strata* at Bellingham Bay are cretaceous. If that should prove true it *would require a revision* of this comparison.

At a later period, a number of fossil plants obtained from the eocene and miocene beds of the valley of the Mississippi, and from the lignite deposits of Brandon, Vermont, were examined by Mr. Lesquereux, descriptions of portions of which have been published.

From the eocene strata he obtained *Cinnamomum Mississippiense* (Lesqx.,) *Calamopsis Danæ*, (Lesqx.,) and a number of fossil fruits; among which he recognized *carya*, *fagus*, *aristolochia*, *sapindus*, *cinnamomum cissus*, *carpinus* and *nyssa*. (American Journal of Science, 2d series, vol. xxxii, p. 355.) From the miocene beds of the Mississippi Mr. Lesquereux has obtained species, not yet described, of *quercus*, *cassia*, *morus*, (?) *laurus*, *persea*, *rhamnus*, *terminalia*, *magnolia*, *rhus*, *sabal*, *cinnamomum*, *ficus*, and *smilax*, with the living species *Cornus sericea*, *Olea Americana*, *Magnolia acuminata*, and the extinct species *Magnolia rotundifolia*, (Lesqx.,) and *Populus rhomboidea*, the latter supposed to be identical with one before described from the cretaceous strata of Vancouver's Island. From the miocene (?) tertiary, Somerville, Tenn., Lesquereux enumerates:

Laurus Carolinensis,	Living.
Prunus Caroliniana,	
Quercus myrtifolia,	
Fagus ferruginea,	
Salix densinervis, (Lesqx.)	Extinct.
Quercus (?) *crassinervis* (?) (Ung.)	
" *Saffordii*, (Lesqx.)	
Andromeda dubia, (Lesqx.)	
" *vaccinifolia*, affinés,	
Eleagnus inequale, (Lesqx.)	

From Mississippi, *Rhamnus marginatus*, (Lesqx.,) *Quercus Saffordii*, (Lesqx.,) and *Magnolia Hilgardiana*, (Lesqx.)

From some tertiary beds in New Jersey, supposed by Professor Cook to be pliocene, I have received a small collection of plants which includes a three-lobed *liquidambar*, a *cercis*, and one or two species of oak.

By far the largest representation of our tertiary flora is, however, contained in the collection made by Dr. Hayden on the Upper Missouri, of which the greater number of species are figured and described in the present memoir. These plants are from the lignite tertiary, proved by the associated fossils to be of miocene age. They were collected at various points on the Missouri River, at Fort Clark, at Red Spring 13 miles above, at Fort Berthold, at Crow Hills 100 miles below Fort Union, at Fort Union, at the mouth of the Yellowstone, on O'Fallon's Creek, and 100 miles above the mouth of the Yellowstone, in the valley of that stream.

The association of the plant-bearing beds at these points will be seen from the following sections furnished by Dr. Hayden:

Section at Red Spring—

1. Ferruginous marl, 10 feet.
2. Variegated bands of argillaceous grit, 30 feet.
3. Seam of impure reddish lignite, 2 inches.
4. Yellowish gray grit, with numerous concretions, in horizontal layers, filled with beautiful impressions of leaves, 10 feet.
5. Seam of lignite, 2 inches.
6. Yellowish gray sand with argillo-calcareous concretions, laden with impressions of dicotyledonous leaves, 10 feet.
7. Earthy lignite, 3 inches.

8. Yellow and drab clay and sandstone, containing argillaceous concretions with vegetable impressions, 15 feet.
9. Dark reddish earthy lignite, 4 inches.
10. Yellow argillaceous grit, 20 feet.
11. Alternate layers of lignite and clay, varying in thickness at different localities within a distance of four miles, 4 to 15 feet.
12. Heavy-bedded friable sandstone, very ferruginous, varying in color from yellow to gray and yellowish gray. Same bed, I think, as seen at Fort Clark and on the summit of Squaw Hills, containing so many fossils. Here we have *Melania Nebrascensis*, *Paludina multilineata*, and *Corbula mactriformis*, 40 feet.
13. Seam of lignite, 2 inches.
14. Gray argillaceous grit, 4 feet.
15. Lignite of excellent quality, 2 feet.
16. Bluish gray clay, slightly arenaceous, 6 feet.
17. Lignite near water's edge, quite pure, 3 to 4 feet.

Beneath bed 17 may be seen at low water a heavy-bedded gray sandstone.

Section near Fort Union—

1. Ferruginous marl, with arenaceous concretions, caps the hills, and is covered with angular blocks of granite; sometimes the upper part of this bed for several feet in thickness is composed of concretionary sandstone, forming ledges. Most common fossil, *Paludina trochiformis*, 20 to 30 feet.
2. Drab indurated arenaceous clay, 20 feet.
3. Impure lignite with numerous crystals of selenite, 12 inches.
4. Gray and drab indurated clay, contains at various localities very abundant impressions of leaves of dicotyledonous trees with a species of fern, 50 to 70 feet.
5. Impure lignite with much silicified wood. One mass lay in the bed 18 inches in diameter, and 30 feet in length, 18 inches.
6. Gray indurated sand, with a slight mixture of clay, contains numerous fresh-water mollusca, as *Paludina trochiformis*, *P. retusa*, *P. Leai*, *P. Leidyi*, and *Melania Nebrascensis*, also many fragments and entire stumps of silicified trees, among the debris of which I noticed that the shells were most abundant, 30 feet.
7. Impure lignite, 4 inches.
8. Dark gray and drab indurated sand, 20 to 30 feet.

Section at O'Fallon's Creek—

1. Yellowish flesh-colored marl. The upper portion of the bed is a rather coarse-grained reddish sandstone, with many large unios, too imperfect to characterize, 20 to 30 feet.
2. Reddish drab indurated clay, 10 feet.
3. Dark drab indurated clay, 30 feet.
4. In all, over 3 feet:
   - Earthy lignite, 2 inches
   - Dark drab indurated clay, 4 inches
   - Impure lignite, 2 inches
   - Yellow clay with concretions, 2 feet
   - Impure lignite, 2 inches
   - Carbonaceous clay, 3 inches
   - Impure lignite, 2 inches
5. Dark drab indurated arenaceous clay, 30 feet.
6. Lignite, quite pure, 18 inches.
7. Deep yellow ferruginous grit, contains a few shells, as *Paludina corbula, &c.*, and impressions of leaves, 25 feet.

gnite, quite pure, 18 inches.
ry dark carbonaceous clay, 8 to 15 feet.
gnite of good quality, 2 feet.
t gray sand, reaching to water's edge at this point, though repos-
n cretaceous formation No. 4, a few miles below, exposed, 30 to
et.

of the species are common to several of these localities, and
n be no doubt of the parallelism of the beds which contain them.
lluscous fossils which accompany them have been carefully stud-
Mr. Meek, and are considered by him indicative of the miocene
he list of species obtained from this horizon by Dr. Hayden is
ws:
species which occur elsewhere are indicated in ruled columns, of
\ = West.Coast; B, Arctic America; C, European miocene; D,
ing.]

	A	B	C	D
um, sp. (Newb.)				
ites, sp.				
n inerme, (Newb.)				
sensibilis, (L.)	. .	. .	*	*
'ampbellii, (Newb.)	*			
racilis, (Newb.)				
m occidentale, (Newb.)	*	*		
Langsdorfii (?) (Br. sp.)	. .	*	*	
trobus Europæus, (Br.)	*	. .	*	
rotundifolia, (Newb.)				
ascensis, (Newb.)				
cifolia, (Newb.)				
ta, (Newb.)				
folia, (Newb.)				
sa, (Newb.)				
ta, (Newb.)				
rix, (Newb.)				
rostrata (?) (Ait.)	. .	. .	. .	*
ricana (?) (Walt.)	. .	. .	. .	*
lifolia, (Newb.)				
ulata, (Newb.)				
s Haydenii, (Newb.)				
is, (Newb.)				
oldsii, (Newb.)				
ophilla, (Newb.)				
ntiquorum, (Newb.)	. .	. .	. .	?
triloba, (Newb.)				
tiqua, (Newb.)				
microphylla, (Newb.)				
) nervosa, (Newb.)				
tes concinnus, (Newb.)				
m asperum, (Newb.)				
olatum, (Newb.)				
errata, (Newb.)				
s affinis, (Newb.)				

	A	B	C	D
S. (?) membranaceus, (Newb.)				
Amelanchier similis, (Newb.)				
Aralia trilobata, (Newb.)				
Aristolochia cordifolia, (Newb.)				
Cornus acuminata, (Newb.)				
Quercus (?) dubia, (Newb.)				
Catalpa crassifolia, (Newb.)				
Phyllites venabus, (Newb.)				
P. carneosus, (Newb.)				
P. cupanioides, (Newb.)				
Carpolithes strialus, (Newb.)				
Calycites polysepala, (Newb.)				

These fossils are generally well preserved in a calcareo-argillaceous rock of a light drab color, upon which the leaves are delineated with a distinctness that renders them pleasant objects of study, as well as attractive specimens for the cabinet. They are usually detached with their petioles, in such numbers and forms as indicate maturity, and a common cause of fall, such as an annual frost. The mollusks, associated with them, show that they were deposited in the sediment which accumulated at the bottom of some fresh water stream or lake, and they are generally spread out so smoothly and so entire, that it is evident no violence, not even the action of a rapid current, could have been attendant upon their deposition. The sediment which inclosed them was usually very fine; a fact also indicative of a tranquil state of the water in which they were suspended.

The explorations of Dr. Hayden prove that this miocene lignite formation occupies the beds of extensive lakes, which filled deep basins on the surface of the continent when it had but recently emerged from the cretaceous sea. As has been remarked elsewhere, the lower members of the series contain a few estuary shells; showing the access of salt water at the period of their formation, but during the deposition of by far the greater portion of these beds, the water of the ocean was entirely excluded from the basins in which they accumulated. By tracing the outline of these deposits, Dr. Hayden has demonstrated that sheets of fresh water once covered surfaces in this portion of the continent which, in extent, rivalled the great chain of fresh-water lakes which exist elsewhere in our country at the present day. There is, therefore, every reason to believe that the remains of ligneous plants which compose this collection were derived from trees which grew along the shores of the lakes and streams of the tertiary continent; that then, as now, alternations of season prevailed, by which the foliage of these trees was periodically detached, and that, falling into the waters beneath, or near them, and sinking to the bottom, they were enveloped in mud precisely as leaves of our sycamores, willows, oaks, &c., accumulate at the bottom of our streams and lakes at present.

In comparing the group of plants here presented to us with those now living upon the surface of the earth, any one will be at once struck with the resemblance which they present to the flora of the temperate zone, and more particularly with that of our own country. In their study I have constantly found that on making comparisons with the plants of remote, and especially tropical countries, an entire want of resemblance, or affinity at once discovered itself, and the only instructive comparisons nade have been with the present vegetation of our country, that of the niocene tertiaries of Europe, and with the living plants of China and Japan. There is every reason to believe that future observations will nake immense additions to this flora, and satisfactory comparisons and generalizations will only be possible when a far more complete series of ts plants can be subjected to study. It is also true that as yet little other than the leaves of these plants have been collected and employed n the deductions made from them. From the character of the sediments which enclose these leaves, it is quite certain that the fruit and seeds are also preserved in the strata from which they were derived, but as hey are less conspicuous and noticeable than the leaves, they are little ikely to be found unless especially sought, and it will only be when they are made the special objects of search that they will be discovered, and end their important assistance in the solution of the problems which he leaves present. For the want of such information as these organs vould supply, some of the material included in the collection does not iow admit of satisfactory classification, and the references of some of he leaves to the genera under which they are placed must be regarded is provisional and liable to modification by further research. Quite a iumber of these plants are, however, so largely represented in the collection, so well preserved, and so clearly allied to the genera and species vith which we are familiar, that they constitute fair material from vhich to infer the general characters and affinity of the flora of which hey form a part. In this list may be mentioned the *glyptostrobus*, of vhich the stems, bearing the leaves of different forms, the cones and the terile capitula are all present, and so closely resemble the specimens lescribed by Professor Heer from the miocene of Europe, that they night almost be considered the originals from which his figures were aken. The living analogue of this plant is *G. heterophyllus* of China.

The *taxodium* now described is evidently a close analogue of *Taxodium* *'ubium* of the miocene of Europe; differing from that well-known species nly in the uniform rounding of the bases and summits of the leaves.

The fossil which has been doubtfully referred to *Sequoia Langsdorfii* vould probably be regarded by foreign botanists as identical with that pecies, but for the reason given in the remarks upon that plant, it seems o me quite doubtful whether it was a *sequoia*, and more probable that it vas a *taxodium* allied to our deciduous cypress.

The great fan palm (*Sabal Campbellii*) collected by Dr. Hayden seems o be a representative of *Sabal major* of the European tertiaries, and *'abal palmetto* of our southern States. From both these, however, it is istinguished by the large number of folds in the leaves, and from *S.* *ıajor* by its flat unkeeled petiole. The plate now given of this species epresents the under surface of the leaf and petiole, but the collection lso contains fragments showing the upper surface; and in the collecons of the northwestern boundary commission are specimens obtained 'om the coast near Frazer's River, which exhibit in fine preservation the pper surface of the base of the leaf and a large portion of the petiole. 'rom these latter specimens the species was originally described in the ournal of the Boston Natural History Society.

The numerous species of *populus*, of which figures are now given, will ot fail to attract the attention of those whose interest runs in this direcon. Several of them seem to be new to science, and show, for the most art, a greater affinity with the foreign poplars, *P. Alba*, &c., than with ie specimens more common on this continent, though a single one, *P.* *matrix*, evidently belongs to the group of which our balsam poplar may e taken as the type. The little species, described under the name *P.* *tundifolia*, presents some anomalies in form and structure as compared with most of our poplars, but its resemblance to another species contained in this collection, *P. elliptica*, and one contained in the collection of the northwest boundary commission which I described under the name *P. flabellum*, have induced me to class them together. Among living species it has a striking analogue in *Populus pruinosa* now growing in Songaria.

The several species of *platanus* which the collection contains, form a striking and interesting portion of this group of plants, and all seem to be quite distinct from the fossil species hitherto described, or any now living. Of our American sycamores, the leaves of *P. occidentalis* are much more toothed, while those of *P. racemosa* are more deeply lobed than any of these. *P. aceroides*, a species from the tertiaries of Europe, is more closely allied to our living ones than these seem to be. The largest and finest of those now described, (*P. nobilis*,) in its smoothness of surface, crowded and parallel nervation, departs more widely from the typical species of *platanus* than the others, and has more the appearance of a tropical plant. An extensive series of comparisons have, however, suggested no affinities closer than those with the living *platanus*, and I have little doubt that in these leaves, of which the collection contains a large number, we have representatives of the noblest and most beautiful species of the genus.

Two of the species of *corylus* present no characters by which they can be distinguished from the two now distributed over the temperate portions of our continent, (*C. rostrata* and *C. Americana*,) and I have, therefore, not felt justified in considering them distinct. The *carya*, figured, seems to me clearly to belong to this genus, and to be closely allied to one of our living species. The *tilia* also is not far removed from *T. heterophylla*, one of our southern living species; while the *negundo*, *sapindus*, &c., seem to be the representatives of the genera and species now growing near the regions from which these fossils come.

From this flora, considering it the analogue and progenitor of that which now occupies our territory, we miss some important elements, and such as we may confidently expect will be supplied by future collectors. Among the most striking of these deficiencies may be mentioned *acer*, *quercus*, *magnolia*, *liriodendron*, *liquidambar*, *sassafras*, &c., some of which, as we know, began their life upon the continent during the cretaceous period, and all of them were members of the miocene flora of the Old World. *Liquidambar*, *quercus*, and *magnolia* occur in the pliocene beds of New Jersey, *magnolia* and *quercus* in the miocene strata of the Mississippi valley; *fagus* also, which is wanting in the collection, has been obtained from the eocene by Mr. Lesquereux.

On comparing this flora with that of the miocene rocks of the west coast, we find *smilax*, *quercus*, *salix*, *oreodaphne*, *acer*, and *cinnamomum*—all of which are represented there—to be wanting here, while the *sabal*, *glyptostrobus* and *taxodium* are common to the two floras.

Until further collections shall be made from the plant beds of the upper Missouri, it is evident that the deductions from the negative evidence of absent genera and species must be regarded as unsatisfactory, but it is a fact not without its significance that the genus *cinnamomum*, which was largely represented in both the cretaceous and tertiary deposits of the west coast, and in the eocene of the eastern portion of the continent, should be entirely absent from the large amount of material collected by Dr. Hayden.*

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* If it is true, as now seems probable, that a large part of the Bellingham Bay deposits are cretaceous, that would account for this marked difference between the plants collected by Dr. *Evans, Mr. Gibbs, &c.*, from those collected by Dr. Hayden.

We are at least justified in saying that from the evidence now before us, we must conclude that the flora of the banks of these inland lakes of the miocene period was that of a temperate climate, not warmer than that of the middle portion of our southern States, and somewhat less warm than that of the eastern portion of our continent during the eocene period, or the western, during the miocene age.

The notes on some of the species contained in the collection made by Dr. Hayden, *Sequoia Langsdorfii. Sabal Campbellii*, *Onoclea sensibilis*, &c., have a bearing on the general questions to which reference has been made in the preceding pages, but the occurrence of an *onoclea* among these miocene plants, and a species which I cannot distinguish from the living one, seems to me a fact of so much importance as to require some additional comments.

The fern frond found by the Duke of Argyle in the leaf beds of the Island of Mull, and figured by Professor E. Forbes in the Journal of the Geological Society of London, (vol. vii, 1851, p. 103; Pl. II, Figs. 2*a*, 2*b*,) and named by him *Filicites* (?) *hebridicus*, is unquestionably identical with this. The specimen from which the figures I have referred to were taken, seems to have puzzled Professor Forbes somewhat, for he doubted if it was a fern; and Professor Heer, in his reference to the fossil plants of the Island of Mull, (Flor. Tert. Helvet., vol. iii, p. 314,) says: "The most remarkable species is *Felicites* (?) *hebridicus*, a fern which by its nervation differs greatly from those of the continent." All these facts give this fossil special interest, for in addition to its relations to its living representatives—of which we cannot but consider it the progenitor—it adds another to the list of plants common to the miocene strata of Europe and America.

Of these—either representative or identical species—the number is now so great that they plainly indicate a land connection between the continents at that period; and since many genera, and this, with probably some other species, at that time common to the Old and New Worlds, have disappeared from Europe while they continue to flourish here, it would seem to follow that these were American types which had colonized Europe by migration; and that when their connection with their mother country was severed they were overpowered and exterminated by the present flora of Europe, which, as Professor Gray has shown, is mainly of N. Asiatic origin.

The fact to which reference has just been made, viz: the occurrence of *Onoclea sensibilis* on the Island of Mull, off the west coast of Scotland, while it has not been found in the tertiary beds of other parts of Europe, is indicative—so far as it goes—not only of an American connection during the miocene period, but of an American origin for that species; and so by inference of the other genera and species common to the two continents during that epoch.

If this inference should be confirmed by future observations, we should then see how the eocene tropical or subtropical flora of Europe was crowded off the stage by the temperate flora of the miocene; which latter, accompanying a depression of temperature, had migrated from America, while the eocene flora retreated south and east, and is now represented by the living Indo-Australian flora—characterized by its *hakeæ*, *dnyandræ*, *eucalypti*, &c., &c., which form so conspicuous an element in the eocene flora of Europe. This theory would account for the presence of these tropical forms in the lower miocene of Europe, while so far as yet observed they are entirely absent from the miocene flora of America. In Europe a few of the eocene forms lingered behind in the grand exodus of that flora, and mingled with the more boreal and occidental barbarians by which the country was overrun; while in America these which we now call Asiatic forms, never had an existence.

That this bridge between America and Europe was in a temperate climate is proved by the character of the plants which passed over it. On referring to a terrestrial globe it will be seen that by way of Greenland, Iceland and the Hebrides, there are no very wide gaps to be spanned; but a connection by that route would carry us so far into the Arctic zone that none of the plants which we suppose to have made that journey could have withstood the cold if the climate had been the same as at present. We have conclusive evidence, however, that it was not so, for on McKenzie's River, Disco Island, on Iceland and the Island of Mull, we have in the recurrence of parts of the very flora under consideration, proof, not only of a warmer climate at the far north during the miocene epoch, but that a part of the plants which formed the miocene flora of Europe, actually did travel that road; at least that they visited all these localities, and, in the buried remains of generations which were never to see the promised land, left us imperishable records of the reality of this migration.

That we cannot, without further study, assign a cause for this great change of climate in the northern part of our continent, is no proof against its existence, for the facts still remain; the cause of the phenomena is simply a thing to be learned. Several possible causes might be mentioned, but of those which suggest themselves, the deflection of the Gulf Stream seems to me the most natural, simple and best to account for an elevation of the temperature of Greenland, Iceland, &c. Whether this cause would be sufficient to account for all the phenomena is at least doubtful. A diminution of the land surface at the north, if it could be proved, would help to solve the enigma. Probably several causes conspired to produce this effect, but they were apparently local, or at least terrestrial, as a cosmical cause, producing a general elevation of temperature on the earth's surface, would have given us a tropical flora on the Upper Missouri, whereas we find in the miocene flora there, as yet, really no tropical plants.