
REPORT

OF

A. C. PEALE, M. D.

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WASHINGTON, D. C.

DEAR SIR: I have the honor to transmit herewith my report for the season of 1872. I have divided it into six chapters. The first I have devoted to the description of a short trip into Colorado and Utah, made before the organization of the party was completed. The second chapter contains an account of our progress from Fort Ellis, Montana Territory, to Gardiner's River, in the Yellowstone National Park, including an account of the Hot Springs at the latter place. The third chapter contains a description of the springs in the Yellowstone Valley, from Gardiner's River to Yellowstone Lake. The fourth chapter is devoted to the geyser-basins of Fire-Hole River.

The time we were in the geyser-basins was somewhat limited, and the observations must therefore be to some extent necessarily incomplete. To work up this most interesting section thoroughly will require the time of at least one entire season, so that data may be obtained as to the influence the different portions of the year may have upon the geysers. Then, also, more could be definitely learned in regard to their regularity or irregularity. As far as the time permitted, I have endeavored to make the observations as complete as possible.

At this point I wish to express my thanks to Dr. F. M. Endlich, of the Smithsonian, for assistance rendered in analysis. That I am able to present so many analyses, especially of specimens from the geysers, is due largely to his assistance. I wish also to refer to Mr. W. B. Platt, of the expedition, who also assisted in analysis.

My fifth and sixth chapters I have devoted to the consideration of the Madison and Gallatin Valleys. Appended to the report are catalogues of the rocks and minerals collected during the summer. I have incorporated in them the specimens collected by both branches of the expedition. I have also done the same in the catalogue of thermal springs, which is appended to the report. In the latter catalogue I have, for the sake of comparison, included observations of some of the springs taken in previous years (principally by Long and by Frémont) wherever there was no doubt as to the localities being the same.

The collections of geyserite this year are particularly large, and present all the varieties in form and texture to be found in the region.

In conclusion I wish to express my thanks to all the members of the expedition for their uniform kindness and co-operation. I would refer particularly to Mr. T. O'C. Sloane, who for a while acted as my assistant, and who, by his zeal and activity, contributed largely to the collections.

To the editors of the "New York Illustrated Christian Weekly" I am indebted for some of the best wood-cuts illustrating my report.

Trusting this report may prove satisfactory, I have the honor to be your obedient servant,

A. C. PEALE.

Dr. F. V. HAYDEN,
United States Geologist.

CHAPTER I.

COLORADO AND UTAH.

While the expedition was being organized at Ogden, Utah Territory, Mr. W. H. Jackson was ordered to make a photographic tour through a portion of Colorado. Fortunately, I was able to accompany him, and while assisting him took a few notes in regard to the lithology and geology of the places we visited. Colorado City and Golden City were our principal points, and it is of them I will speak more particularly. We were limited as to time, and the area over which we passed was so small that I shall have to restrict all I have to say to each immediate locality; still I hope it may not be without some little interest. We left Omaha on the 20th of May, and the following evening reached Denver, in Colorado Territory. In passing, let me say a word or two about Denver. Thirteen years ago a log-cabin represented this city, that now contains a population of over 14,000 people, and which is in every way a thriving and prosperous place, bidding fair to become the metropolis of the far West. Four years ago there was not even a mile of railroad in the Territory, and to-day Denver is the center of five distinct lines of railroad, and still more are being built. The city is beautifully situated on the banks of Cherry Creek, about twelve miles from the mountains. The plain upon which it is built is so covered with the superficial drift of the mountains that the underlying rocks are entirely concealed. There is little doubt, however, as to what they are, for, as we proceed toward the mountains, we come upon the upturned edges of Tertiary sandstones, containing beds of coal, the tipping up of which is explained by the grand range immediately in front of us, from which Gray's Peak and Long's Peak raise their snowy heads, seeming almost to pierce the heavens. Leaving Denver we took the Denver and Rio Grande Railroad to Colorado Springs, some seventy-six miles farther south. This railroad is a narrow-gauge road, and the first of any length that has been built. It threatens to work an important revolution in the railroad-system of the West. The road gradually ascends upon leaving Denver until we reach the summit of the Colorado divide. This is a spur or high ridge, projecting from the mountains at right angles to their trend. It forms the dividing line between the waters of the Platte River and those of the Arkansas. It is very thickly timbered, and lumbering is carried on quite extensively. The ascent from Denver to the summit of the divide is very gradual, and it is a little difficult to believe that one has ascended 2,000 feet. The elevation of the divide at the summit is 8,000 feet above the sea. Smoky-quartz crystals are found here quite abundantly, and are called topaz by the people. I was shown several good specimens said to have been picked up near the railroad. The rocks as seen from the cars seem to be mostly red and gray Tertiary sandstones. From the divide the railroad has a gentle descent, and after a ride of twenty-four miles, passing some beautiful scenery, we reach Colorado Springs. This is a new colony, just established on the line of the railroad. It is about eight miles from the mountains. Its site is covered with local drift from the hills. To the east the country spreads out into the plains. We spent several days at Colorado Springs, making excursions to the various points of interest. Our first day was spent in the "Garden of the Gods," about four miles northwest from Colorado Springs and two miles north of Colorado City. This interesting and peculiar place is a valley in the foot-hills of the range, and is

inclosed by an almost vertical wall of massive sandstone of Cretaceous age. The rocks which we find inside have been subjected to an immense deal of erosion, and the many ridges and tower-like forms left standing throughout the garden are the remnants of the parallel strata which dip to the northeast at a very great angle. In some places they seem to dip a few degrees in the opposite direction. As we go toward the mountains, the dip decreases. These rocks are fine-grained sandstones, of a deep brick-red color, with here and there layers and spots of a lighter red, and sometimes white. The ridges are exposed for some distance to the north, while to the south, after bending toward the east, they appear to be covered by the *débris* from the mountains. The entrance to the "garden" is through the "Beautiful Gate," an opening through one of the highest ridges of red sandstone. We estimated the height of this ridge to be 300 feet. The northern end is considerably higher, and viewing it so as to see the end alone the resemblance to the tower of a grand cathedral induced us to call it "Cathedral Rock." Another collection of rocks inside the "garden" had the name of "Montezuma's Cathedral." On the western surface of the ridge mentioned above, the water has worn quite a large cave. The sandstone is very soft in most places and can be readily crushed in the fingers. The softness is due probably to the effect of the weather. As we go toward the west the hardness increases. Outside of the red layers, and a few hundred feet farther to the east, there is a layer of white sandstone parallel to the red and tipped up at the same angle, about 70°. Outside of this, and in contact with it, is a bed of gypsum which is of considerable thickness. From it I obtained specimens of selenite and satin-spar. The specimens of amorphous gypsum I obtained are exceedingly beautiful, the white variety being of course the most abundant. I got also some very pretty pink varieties.

The following day we spent in visiting Glen Eyrie and the Soda Springs on the "Fontaine qui Bouille." Glen Eyrie is also sometimes called the "Little Garden of the Gods," from its resemblance to the "Garden of the Gods," which we first visited, and which is farther to the south. The entrance is through a natural gateway, cut through a massive ridge of gray sandstone by Camp Creek, which flows through the glen. The sandstones are covered with moss, giving them a most picturesque appearance, and General Palmer, who has made his home here, has given them the name of "Painted Rocks." The ridge forms a high wall, dipping northeast at an angle of 60°. The age of this sandstone is Cretaceous. Just inside of it there is a layer of limestone, which is probably Jurassic, and next to this is a layer of gypsum, the continuation of the bed I mentioned above. Then follow soft, red sandstones, corresponding to those in the "Garden of the Gods," although they are lighter in color, at a distance seeming to be of a flesh-color. They are eroded into curious, fantastic forms. One in particular deserves mention. It is a mass of red rock, 30 feet in diameter, and rising to the height of 200 feet. It is a monolith, the top of which is larger than at the base, and looking at it one almost expects to see it toppling over. It is called "Needle Rock." The area included in the "Little Garden of the Gods" is much less than in the other garden. The red sandstones, as we approach the hills, become harder, seeming to be almost crystalline, and have a deeper color. The angle of the dip has decreased, and at this point is only 20°. Where Camp Creek has cut its way through these hard layers there is a fine exposure of the strata. Here is Glen Eyrie proper, and a wild, weird-looking place it is. The dark-red rocks and the bright-green foliage, through which we catch an occasional glimpse of the stream, form parts of a picture well worthy the

visit of one who loves the beautiful. We did not have time to penetrate farther up the cañon, but below these sandstones I believe there are Carboniferous limestones. The thickness of these rocks, however, is not very great. I cannot give the exact thickness, as I had no means of measuring them.

Leaving Glen Eyrie we passed a second time through the "Garden of the Gods", and after a ride of some six miles reached the Springs on the Fontaine qui Bouille, a branch of the Arkansas River. There are five principal springs. The first one is the "Manitou" or "Doctor Spring." It is on the left bank of the river, and is quite small, measuring hardly a foot in diameter. The water contains a large percentage of carbonic acid, and there is a slight bubbling, caused by the escape of the gas. The water is more agreeable to the taste than that of any of the other springs. There is quite an abundant deposit of carbonates about the spring reaching to the edge of the river. The overflow of water is very small. The water contains about two drachms of solid matter to the gallon. Its temperature was 57° F. It is feebly alkaline. An analysis, made by Mr. Frazer in 1869, revealed the following contents:

Carbonate of soda.
Carbonate of potassa.
Carbonate of lime.
Chloride of sodium.
Alumina.
Trace of iron.

The next spring is the "Comanche." This is a chalybeate spring, situated in a small thicket, on low, marshy ground, on the right bank of the river, near the water's edge. There is no deposit about, save a slight one of oxide of iron, and the escape of gas is very insignificant. The iron is quite perceptible on tasting the water. Its temperature was 48°·5 F.

The next spring, in size the second, is the "Shoshone." It is also on the right bank of the river, and is close to the wagon-road. There is a continuous escape of carbonic-acid gas from it, but the taste of the water does not compare with that of the Manitou. It is surrounded by considerable deposit, consisting mostly of carbonates of soda and potassa, with also a trace of sulphur. (Frazer, 1869.) Its temperature is 55°·5 F. Below the Shoshone Spring, on the edge of the river, is the "Nashataga," an unimportant spring, having a temperature of 52° F.

The largest spring is the "Bathing Spring." It is almost opposite the Manitou, and has a very abundant deposit, in which the opening of the spring is about five feet in diameter. The escape of gas is more violent than in any of the other springs. Its temperature is 60° F. Water is conveyed from it in iron pipes to a bath-house, which has been recently erected. An analysis of the deposit from these springs, made by Dr. Drown in 1871, is as follows:

	Per cent.
Chloride of sodium.....	36.69
Chloride of potassium.....	10.01
Bicarbonate of soda.....	24.01
Sulphate of soda.....	4.78
Bicarbonate of lime.....	15.62
Bicarbonate of magnesia.....	8.89
Total.....	100.00

The names of some of the other unimportant springs are the "Iron Ute," "Navajo," the "Arapahoe," and the "Pawnee."

Frémont visited these springs in 1843 and took the temperature of two of them. I will give his temperatures and those I took in tabular form, so that they can more easily be compared. His upper spring corresponds, I believe from his description, to the Bathing Spring, and the lower spring to the Shoshone.

Temperatures of Frémont, July, 1843.

Time.	Temperature of upper spring.	Temperature of lower spring.	Temperature of air.
11 a. m.	69° F.	60°.5 F.	73° F.
Sunrise.....	61	58	66
Sunset.....	54.3	57	57.5

Temperatures, May, 1872.

Name of spring.	Time.	Temp. of air.	Temp. of spring.
Bathing Spring.....	Afternoon.	70° F.	60° F.
Shoshone.....	Afternoon.	70	55.5
Comanche.....	Afternoon.	70	48.5
Manitou.....	Afternoon.	70	57
Nashataga.....	Afternoon.	70	52

A comparison of the above tables would seem to show that in the last twenty-nine years the water of the springs has become cooler. Some of the difference in temperature may, perhaps, be due to the difference in thermometers used. A large hotel has been built near the springs for the accommodation of invalids and tourists, and there is no doubt that before long this will be one of the favorite sanitariums of the West. The site of a village has also been laid out, to which the name of Manitou has been given. Leaving the springs we followed the road up the cañon to the Ute Pass. The road through this pass leads to the silver mines of the South Park. It has been cut through solid granites. The cañon is a most romantic one, and the stream rushes down the deep, narrow gorge in a series of cascades and falls. The largest fall, Ute Fall, is 60 feet in height. The granite through which the stream has cut its way is a red porphyritic granite, presenting a beautiful appearance, due to the large red crystals of feldspar, (*Orthoclase*.) The mica is somewhat smaller in quantity and of a black color. The rock would doubtless be capable of a very high polish. As a building-stone I do not think it will have much value, as it readily breaks down on exposure to the weather. I noticed at various places on the walls of the cañon stains and discolorations, due to the infiltration of mineral waters.

The junction of the sedimentary rocks with the granites is well shown in the pass. In some places the former are lifted high upon the hills, dipping northeast, at angles varying from 10° to 30°. The rock immediately upon the granites is a hard fine-grained sandstone containing irregular seams of pebbles. Its color varies from a yellowish gray to red. The dip was north 40° east; angle, 20°.

Our next trip was made to Chiann Cañon, through which Chiann Creek flows to join the Fontaine qui Bouille. In company with Messrs.

Nettleton, Fuller, and Potter, and Dr. Gatchell, of Colorado Springs, we started early in the morning, and after a ride of four miles over the mesas, reached the mouth of the cañon, where we left our wagons and mules and proceeded the rest of the way on foot, carrying the photographic apparatus and materials on our backs. The cañon is very narrow and the granite walls rise precipitously on either side to the height of 600 feet above the bed of the stream. We were obliged to cross and recross the stream many times in order to get along, as the banks in some places were too steep to allow our passing along them. After a walk of about a mile and a half we came to a fall, or rather a series of falls, which prevented any farther progress up stream. There were three distinct falls, one above the other, the entire height being 300 feet. The water in falling strikes numerous ledges, which churn it into a mass of foam. It has worn in the solid granite a rounded basin surrounding which are walls reaching the height of 800 feet. The best view of the falls is to be had about a quarter of a mile below on the side of the cañon. At a point 300 feet above the bed of the creek we have a magnificent view of the entire falls, while back of them rise the hills which stand at the foot of Pike's Peak, and in the fore-ground, far below us, we catch a glimpse of the creek as it reflects the sunlight through the foliage of the pines.

The following is a list of the minerals I obtained while at Colorado Springs: Snowy gypsum, pink gypsum, selenite, satin-spar, (fibrous gypsum,) yellow calcite, (crystallized,) amazon stone, (orthoclase,) amethyst, smoky quartz, white quartz, opal, and agate.

We left Colorado Springs on the 27th of May, and on the 29th arrived at Cheyenne, Wyoming Territory. On the 3d of June we started on a second trip, our destination this time being Golden City. Golden City is about twenty miles, almost due west, from Denver, at the base of the foot-hills of the main range of the Rocky Mountains. It is situated in a valley, between the hills and two mesas, or table-like mountains. They stand between the town and the plain, and between them is the Golden Gate, through which Clear Creek flows out to the plains. Both the mesas are surmounted by layers of basalt. The north mesa, called Table Mountain, is about a mile in width and a little more than two miles in length. On the western side, overlooking the town, is a prominent mass of bare rock, which is called the Castle. The south mesa has the same width as the one on the north, but is longer, extending for four miles. The upper portion of the basalt capping these mesas is more compact than the lower layers and is somewhat columnar. Beneath the basalt are Tertiary formations—sandstones and clays. The surface of the mesas is somewhat irregular and covered with grass. They form the grazing-grounds for large herds of cattle. The Tertiary beds continue some distance west of the mesas, and contain coal. The principal bed varies in thickness from a few inches to eight feet. It is almost vertical. There are four openings into it, three of which are owned by the Mineral Land Company and leased to the Hazleton Company. Only one of them, however, is worked at present; one of the others has been burned out—since which work has not been resumed—while the third is filled with water. A fourth opening is owned by Judge Johnson. Only enough coal is mined to supply the local demand. The ridge above the coal is a white sandstone containing impressions of deciduous leaves, while beneath the coal is a bed of clay. The strike of these beds is almost due north and south. Below the coal-beds are red and gray sandstones with a layer of limestone. These sandstones rest immediately on the metamorphic rocks at an angle

of about 45°. The effect of erosion here has been to so level these beds that it is difficult to trace the succession of the various layers.

We made several excursions while at Golden City, one of which was up Clear Creek Cañon, through which the Colorado Central Railroad, a narrow-gauge road, runs. When finished it will penetrate to the mining-districts of Georgetown and Central City. When we visited it the road-bed was graded some ten miles above Golden City. The creek has cut its way through the hills in a tortuous course, leaving high walls of gneiss and granite standing on either side. In the gneisses I obtained garnets and magnetite. There has been some gold-mining carried on in Clear Creek Cañon, but I judge it was with but little profit. At any rate, at the present time the diggings are abandoned.

From the office of the Colorado Central Railroad I obtained specimens of ores from Central City, consisting mainly of gold quartz, pyrites, and argentiferous galena.

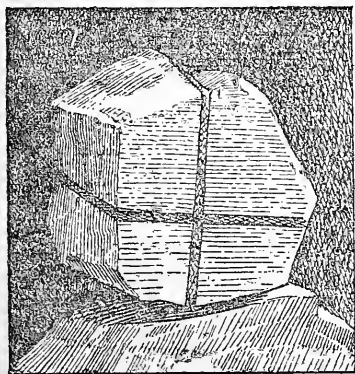
Having completed our work we left Golden City and started for Ogden, Utah Territory, where we joined the main party in camp on the 8th of June. The Wasatch Range, at the foot of which the town of Ogden is built, has a trend north and south. Its geological structure is beautifully shown in the many cañons which cut deeply into it almost at right angles to the trend. It is in these cañons that the profitable mines of Utah are situated. The cañons near Ogden are Ogden Cañon and Weber Cañon. Through the latter the Union Pacific Railroad finds its way into the Great Salt Lake Basin. Between these two there are a number of smaller cañons which cut the mountains only partially. Two of these, immediately back of our camp, are Taylor's Cañon and the Waterfall Canon. In the former there is a limekiln in operation. Here also some miners claim to have discovered tin. An examination of specimens proves, however, the absence of any metal and showed the specimen to consist almost entirely of hornblende. The Waterfall Cañon is named from the occurrence in it of a fall some 300 feet in height. The water falls over a ledge of white quartzite. Above it rises Mount Bechler, whose height is 9,716 feet. The base of the mountains near Ogden is for the most part a red syenite, whose specific gravity is about 2.6. This syenite passes into granite and gneiss. It contains, in places, veins of hornblende, and the gneisses have veins of quartz with specular iron. Several of these veins have had openings made into them by prospectors. The largest is just south of the Waterfall Cañon. It is four feet in width and penetrates the rock to a depth of thirty feet horizontally. The walls on either side are gneisses, stained with the green carbonate of copper, (malachite.) The gangue is quartz and serpentine. Associated with the specular iron or micaceous hematite are iron pyrites and stainings of copper. The iron is in veins varying from the fraction of an inch to two inches in thickness. On the north side of Ogden Cañon I found another opening, much smaller, in chloritic schists, which, at this point, lie just above the syenite. The gangue here was white quartz, containing veins of micaceous hematite. The schists contained numerous veins of quartz. Above the metamorphic rocks there are heavy beds of quartzite, the lower bed of which is conglomerate, the siliceous matrix containing pebbles of bright-red jasper. The quartzites have a specific gravity of 2.6 and are mostly of white color, although in some places they are pink and again dark brown, becoming highly ferruginous. Above the quartzites are heavy beds of dark-blue magnesian limestones of Silurian age, above which are Carboniferous limestones. I was shown a specimen of graphite from near North Ogden, a village six miles above Ogden. At the upper end of Ogden Cañon galena is found associated

with carbonate of copper in limestones. This corresponds to the location of the most productive silver mines in Utah. They are almost situated in limestones at the heads of the cañons, and the ores are ores of lead containing silver. The minerals I obtained at Ogden are the following: micaceous hematite, iron pyrites, galenite, magnetite, graphite, azurite, malachite, garnets, quartz, chlorite, talc, serpentine, jasper, hornblende, serpentine, and calcite.

On the 19th of June Mr. Jackson started on a photographic trip to Little Cottonwood Cañon, on which trip I accompanied. From Ogden to Salt Lake City we took the Utah Central Railroad, which skirts the edge of the mountains. The granitic rocks extend for some distance below Weber Cañon, but as we near Salt Lake City the limestones form the base of the mountains, near which are a number of limekilns. The limestone for the kilns seemed to be taken from the upper layers, probably because the lower ones are siliceous, as at Ogden.

The cañons which cut through the Wahsatch Range near Salt Lake City are as follows, in their order from north to south: Red Butte, Emigration, Parley's, Mill Creek, Big Cottonwood, and Little Cottonwood. At the head of the latter are some of the best silver mines to be found in Utah, and among them is the famous Emma mine. Leaving Salt Lake City we take the State road, and after a ride of ten miles in a southeasterly direction, passing between thriving farms dotted with comfortable-looking houses, we turn to the left and strike across the country to the mountains. Directly before us is the highest point in the Wahsatch Range, the Twin Peaks, over 12,000 feet above sea-level. As we ride along we see distinctly marked on the sides of the mountains in front of us the water-lines of the former shore of the Great Salt Lake. These old shore-lines are distinctly marked on the mountains, on all sides of the lake, and on the islands in the lake. We pass over numerous terraces and at length reach the mouth of the cañon. Here there are no less than seven distinct terraces, some of them, however, due to the action of the Cottonwood Creek. Near the mouth of the cañon there are smelting-works, to which ore is brought from the mines

Fig. 25.



BLOCK OF GRANITE WITH FELDSPATHIC SEAMS.

at the head of the creek. Inside the cañon we find ourselves between high granite-walls, rising precipitously on either side of the creek. The first thing to attract our attention is the conspicuous bedding of these granites. The dip is east at an angle of 50° to 70° . The granite is of a light-gray color, composed of white feldspar, (orthoclase,) quartz, and black mica. The bottom of the cañon is strewn with boulders of granite, which lie scattered over it in inextricable confusion. In many of them (Fig. 25) I noticed veins of feldspar of about two inches in width crossing each other at right angles. Another noticeable feature in these granites is the occurrence of rounded pebble-like masses, of a dark color, inclosed in the gray matrix. Professor Silliman, (Silliman's Journal, vol. iii, page 196,) referring to these, says "These granites are probably metamorphic, of conglomerates, an opinion first suggested to me by Professor W. P. Blake." As he also further states, there is a pebble-like roundness in

the particles of quartz in this granite which points to a mechanical origin. The rock is quite uniform in its structure. A mile or two in the cañon we came to a small village called Graniteville. It is near here that the granite, of which the Mormon temple is being built, is quarried. Instead of working into the rock on the sides of the cañon, the quarrying is confined to the huge blocks of granite which are scattered over the bottom on both sides of the creek. Some of these blocks are immense, measuring 30 feet square. They are split into the required size. Our road for about five miles leads us between the granite walls that tower far above us, surmounted by dome-like masses, whose summits are covered with snow, giving origin to the numerous falls and cascades which abound on the sides of the cañon. The Little Cottonwood Creek flowing past us falls about 500 feet to the mile. It rushes along furiously over its rocky bed, seeming to be at war with the immense boulders that dispute its right of way. As we proceed we leave the granites behind us, and above us project the sharp, jagged edges of quartzite beds. These quartzites have a reddish color, and are followed by slates upon which rest thick beds of white limestone. The lower beds are crystalline and probably Silurian, although I was unable to find any fossils in them. The upper layers are dolomitic, and are Carboniferous in age. It is in these limestones that the ores occur. The principal mine is the Emma. Unfortunately, owing to a disturbance at the time of our visit, I was unable to see the Emma mine, but visited the Flagstaff and the Silver Star. I quote the following analysis and remarks upon the ore of the Emma mine from an article by Professor Silliman:*

I am able to present an analysis of an average sample of 82 tons (=183,080 pounds) of first-class ore from the Emma mine, made by James P. Merry, of Swansea, April, 1871, which is as follows:

	Per cent.
Silica	40.90
Lead	34.14
Sulphur	2.37
Antimony	2.27
Copper	0.83
Zinc	2.92
Manganese	0.15
Iron	3.54
Silver	0.48
Alumina	0.35
Magnesia	0.25
Lime	0.72
Carbonic acid	1.50
	90.42
Oxygen and water by difference	9.58
	100.00

The quantity of silver obtained from this lot was 156 troy ounces to the gross ton of 2,240 pounds.

This analysis sheds important light on the chemical history of this remarkable metallic deposit, and will aid us in the study of the paragenesis of the derived species. It is pretty certain that all the heavy metals have existed originally as sulphides, and we may, therefore, state the analysis thus, allowing 8.52 per cent. sulphur to convert the heavy metals to this state:

Silica	40.90
Metallic sulphides	52.60
Al, .35; Mg, .25; Ca, .72; Mn ² Mn, .20	1.52
	95.02
Water, carbonic acid, and loss	4.95

*American Journal of Science and Arts, vol. iii, page 193.

This calculation assumes that the sulphides are as follows, viz:

	Per cent.
Galenite.....	38.69
Stibnite.....	3.30
Bornite.....	1.03
Sphalerite, (blende).....	3.62
Pyrite.....	5.42
Argentite.....	0.54
	52.60

This statement excludes the presence of any other gangue than silica, and, considering that the ores exist in limestone, the almost total absence of lime in the composition of the average mass is certainly remarkable. The amount of silica found is noticeable, since quartz is not seen as such in this great ore-chamber, nor, so far as I could find, in other parts of the mine. The silica can have existed in chemical combination only in the most inconsiderable quantity, since the bases with which it could have combined are present to the extent of less than $1\frac{1}{2}$ per cent.; nor do we find in the mine any noticeable quantity of kaolin or lithomarge resulting from the decomposition of silicates, nor are there any feldspathic minerals. It is most probable that the silica existed in a state of minute subdivision, diffused in the sulphides as I have seen it in some of the unchanged silver-ores of Lion Hill, in the Oquirrh Range.

The absence of chlorine and of phosphoric acid in the analysis corresponds well with the absence of the species cerargyrite and pyromorphite, of which no trace could be found by the most careful search among the contents of the mine.

From the Flagstaff and Silver Star I obtained specimens of wulfenite, aurichalcite, galenite, lithomarge, massicot, cervantite, and cerussite. The wulfenite I found in minute, brilliant, yellow, tabular crystals, in cavities in ochraceous ores, and also associated with cerussite. Other minerals found at this locality are azurite, malachite, calamine, anglesite, sphalerite, pyrite, argentite, antimonial, galenite, anglesite, kaolin, and limonite.

A specimen of galena from the Vallejo tunnel of the Silver Star mine yielded, on examination, a small percentage of silver.

Among the rocks I obtained while at Ogden were specimens of aplite, protogine, hornblendic gneiss, protogenic gneiss, chlorite, schist, and micaceous schist.

Before closing this chapter I wish to express my thanks to Messrs. Nettleton and Somers, of Colorado Springs, and the officers of the Colorado Central Railroad in Golden City, for favors and information afforded us while in Colorado.

CHAPTER II.

FORT ELLIS TO GARDINER'S RIVER.

On the 22d of June the expedition was divided into two parties at Ogden, and I found myself a member of the party which was to make Fort Ellis, Montana, the base of operations. Accordingly, after a long and tedious stage-ride, we pitched our tents near Fort Ellis on the 29th of June. Fort Ellis is situated at the head of the Gallatin Valley, on one of the many small streams that contribute to form the East Gallatin River. The Gallatin Valley is one of the most fertile in Montana Territory, and is surrounded by ranges of mountains which contain choicest bits of scenery as well as contribute to the wealth of the Territory. The principal towns of the Gallatin Valley are Bozeman, Hamilton, and Gallatin City. The former contains a population of about five hundred inhabitants. Between Bozeman and Gallatin City there are numerous well-cultivated and productive farms.

The streams that form the headwaters of the Gallatin River have cut profoundly into the mountain-ranges, exposing their structure in the most beautiful manner. The first of the cañons to which I will refer is Spring or Rock Cañon. This cañon forms a most interesting subject of study, and will answer admirably as a type of the others. It is a V-shaped chasm, cut through the end of an anticlinal range by the stream. The trend of this range is northwest and southeast. The first thing that attracts our attention after we are fairly inside the cañon is the occurrence, on the left-hand side of the creek, of an arch that crosses the road, and, describing a semicircle on the hill, again crosses the road at the upper end of the cañon. (Fig. 26.) The first prominent bed we meet is a layer of coarse, gray calcareous sandstone, containing fragments of fossils. Proceeding up the cañon we find the center of the arch is occupied by masses of Carboniferous limestone, which tower far above the creek, giving a most picturesque appearance to the cañon. Still farther along we come to the other extremity of the arch and find the same layer that we saw at the opposite end. Following this layer at the western end of the cañon, that nearest Fort Ellis, we find the dip at the bed of the creek to be south 45° west; angle, 30° - 40° . Farther along we find it to be south 80° west, the angle remaining about the same. Still higher up on the ridge it is north 50° west; angle, 15° - 25° ; and when we reach the highest point on the ridge it dips due north at an angle of about 25° . Taking this same layer again at the level of the creek, this time at the eastern end of the cañon, we find the dip to be in the same direction, although the angle is greater. As we go toward the south it approaches more and more to the vertical, until the dip becomes northeast and the range therefore becomes a true anticlinal. The reading just above the creek on the northern side gives a dip of south 45° west; angle, 70° . As we follow

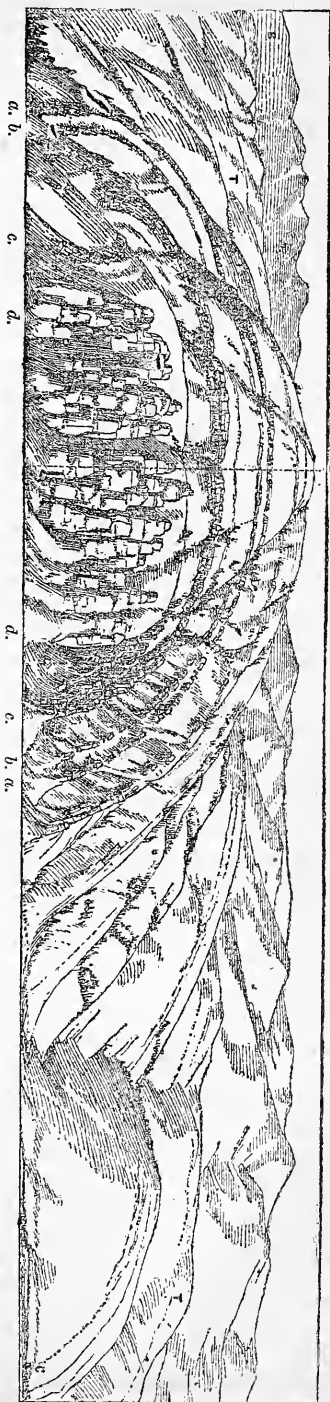
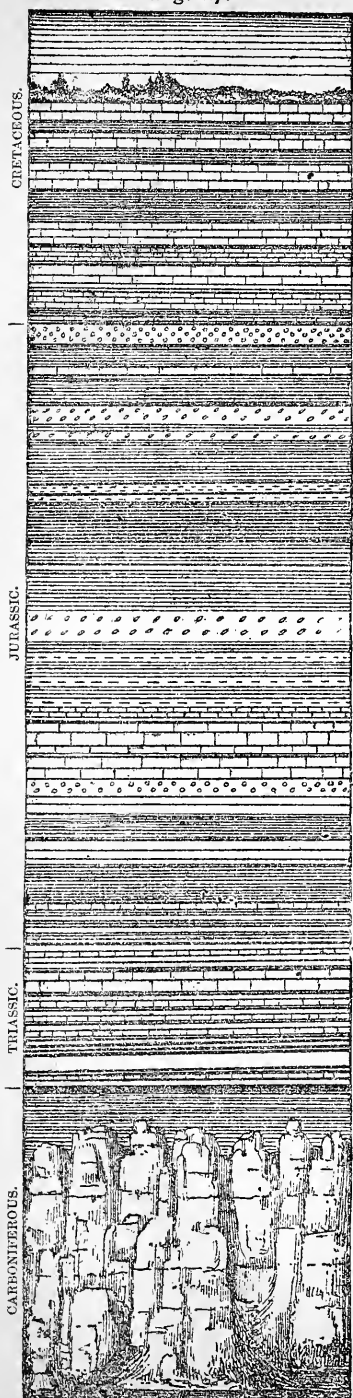


Fig. 26.

Fig. 27.



SECTION OF THE BEDS IN SPRING CAÑON.

the ridge toward the north, it is south 30° – 35° west; angle, 80° – 85° . Still higher up it is south 20° west; angle, 85° ; and then becomes, within a very short distance, south 10° west; angle, 88° – 90° . As we progress it passes the vertical and dips northeast at a high angle, which gradually decreases, the dip becoming more and more northerly until the arch is completed. At the western end of the cañon beneath the limestone, which immediately succeeds the fossiliferous sandstone, there is a fine exposure of quartzite-beds, the top layers of which are somewhat calcareous. Then comes a layer of conglomerate made up of green and brown flint pebbles, varying from the size of a walnut to eight inches in diameter. Associated with these pebbles are geodes of quartz, some of which contain calcite.

The best section of all the beds exposed in Spring Cañon is obtained in the center of the cañon at the point marked in Fig. 26 by the dotted line S. We commence at the top of the hill, which rises 1,160 feet above the level of the creek. The first bed we notice is a highly metamorphic-looking quartzite, which crops out along the summit of the hill. Its general color is a dull red, passing in places into a dull purple and again becoming light gray, with bright red and yellow streaks. Some of them have an almost flinty fracture. We estimated the thickness of the beds at 50 feet. Next below these beds are quartzites and light gray sandstones followed by conglomerates, in the lower layers of which the pebbles are very fine. The conglomerates are followed by brown limestones and sandstones, the weathering of which gives a red tinge to the soil. These beds are succeeded by fine, dark-gray calcareous sandstones, which break into laminae of from two to four inches thickness. Next to these are the coarse-grained fossiliferous sandstones that I have referred to above, (layer No. 7 in the section,) containing fragments of *Ostrea* and *Camptonectes*. They might almost be called siliceous limestones from the amount of lime they contain, but they are made up of coarse grains of sand and more properly deserve the name of sandstones. Inter-

laminated with them are light-brown shale-like sandstones, which are quite soft and break into numerous laminae. The layers of this sandstone vary in thickness from a few inches to eight feet. Just below these beds are very coarse-grained limestones. The thickness from the bottom of these limestones to the top of the light-gray sandstones mentioned above is 260 feet. The coarse limestones are followed by fine-grained compact limestones, the weathered surfaces of which are white. These pass by gradations into bluish argillaceous shales, containing a large percentage of lime, (layer No. 11 in the section.) These shales weather of a white color and contain the following fossils: *Trigonia Americanus*, *Pinna*, *Camptonectes*, and *Modiola*, proving their Jurassic age. They are very fine-grained and separate into laminae of half an inch to two inches thickness. They are very brittle also, and break readily, the plane of cleavage being at right angles to the plane of deposit. The angle of dip of these beds is 20°. The distance from the bottom of these layers to the top of the compact limestone is 100 feet. All the above beds to the conglomerates are probably Jurassic, while those above are Cretaceous. Next below the limestones are five feet of yellowish-brown sandstone, followed by a bed of quartzite containing veins of quartz and calcite in geodes, from which I obtained large crystals of calcite of the variety known as dog-tooth spar. The lower portion of this bed, which is about ten feet thick, is very irregular in composition, seeming to have been deposited in rough waters. It is succeeded by four feet of very compact quartzite, which in turn is followed by a pebbly conglomerate of two feet. Next comes eight feet of quartzite succeeded by alternate beds of quartzite and limestone, the thickness of the whole being 110 feet. Next come 30 feet of red sandstones, which are probably Jurassic, although not even a trace of any fossils can be found in them to prove it. The upper layers of these red beds contain lime, the percentage of which decreases as we descend. The angle of the dip is about 25°. The succession of these beds is shown in the section given below. Below the red beds are immense beds of carboniferous limestone, reaching to the bed of the creek, a distance of 435 feet. The upper layers of this limestone are arenaceous. The force that caused the tipping up of the strata in Spring Cañon was some distance to the south and was dying away at this end of the range, so that the older beds were not elevated sufficiently to be exposed to the action of the stream and are therefore not shown. The carboniferous beds are crushed together in a confused mass, and it is difficult to get at the true dip. The creek cutting through them has left huge masses standing out on the sides, resembling castles, towers, &c.

The following section, corresponding with Fig. 27, will perhaps show the succession of the beds more clearly. The thicknesses are estimated.

	Thickness in feet.
1. Red, purple, and gray metamorphosed sandstones	50
2. Brown limestone	
3. Gray sandstones	
4. Conglomerates	175
5. Brown limestone and interlaminated sandstones	
6. Gray sandstone	360
7. { Coarse calcareous fossiliferous sandstone	
8. { With interlaminated shaly sandstones	
9. Coarse limestone	
10. Compact limestone	5
11. Shaly argillaceous limestone	
12. Yellow-brown sandstone	10
13. Quartzite with veins of calcite	

Thickness
in feet.

14. Compact quartzite.....	4
15. Conglomerate.....	2
16. Yellow limestone.....	3
17. Cherty limestone.....	15
18. Quartzite.....	5
19. Limestone.....	20
20. Calcareous sandstone.....	4
21. Limestone.....	4
22. Sandstone.....	15
23. Quartzite.....	15
24. Yellow calcareous sandstone.....	5
25. Red sandstone.....	5
26. Purple and greenish sandstone.....	2
27. Spotted purple sandstone.....	4
28. Brick-red sandstone.....	4
29. Purple sandstone.....	3
30. Greenish-white quartzite.....	2
31. Purple sandstone.....	5
32. Arenaceous limestone.....	} 435
33. Limestone.....	

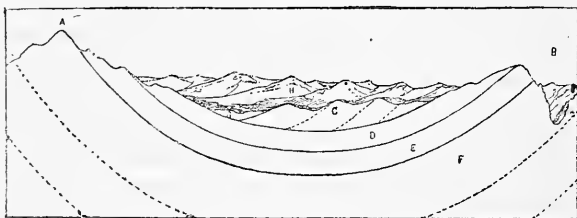
Outside of the quartzite bed, with which I have headed the above section, there is a succession of beds of hard quartzites and conglomerates followed by soft sandstones of steel-gray colors. Just below these sandstones, which are Cretaceous, there is a layer of hard, green shale containing fossils. Outside of them there occurs a bed of limestone. All these beds curve around the Spring Cañon layers, to which they seem to be conformable. Above the Cretaceous beds there is an immense thickness of brown and dark-gray Tertiary sandstones, (Eocene,) containing beds of coal. They also follow the curve of the Cretaceous beds and are seemingly conformable to them. They extend for four or five miles.

About five miles north of Spring Cañon there is a range, the Bridger Range, the trend of which is north and south. I shall here refer only to the southern end and western side of this range, reserving any further consideration of it to a subsequent chapter. Near the southern end of the range there is quite a high peak known as Bridger's Peak, which is 9,000 feet above the sea. The crest of the range is made up of Carboniferous limestone, dipping southeast, containing *Hemipronites crenestria*, *Productus longispinus*. Then follows a succession of beds as we found them in Spring Cañon. Following these, and still dipping southeast, are the Cretaceous beds that we noticed outside of Spring Cañon. In a layer of hard, green shales I found *Gryphaea*, *Avicula*, *Pinna*, *Inoceramus*, *Turritella*, *Crassatella*, &c., proving their undoubted Cretaceous age. Next we find the Tertiary sandstones, which are unconformable to the Bridger layers. There is therefore between Spring Cañon and the Bridger Range a synclinal valley the floor of which is Cretaceous filled in with the Tertiary sandstones, dipping northwest, north, and northeast at an average angle of 40°. Many of these sandstones are calcareous and contain veins of calcite. The thickness of these beds must exceed 1,000 feet, and from the specimens of fossil-plants found in them they are for the most part Eocene. Some of the upper layers may be of Miocene age.

Opposite Fort Ellis, between our camp and Bridger Peak, there are bluffs composed of Pliocene sandstones, marls, and conglomerates. The strata are for the most part horizontal, although inclining sometimes at a very small angle, which is never more than 5°. The height of these bluffs above the level of the creek is 175 feet. They are the remnants of Pliocene formations that once spread over the entire valley of the Gallatin, and formed the bottom of a vast lake that spread over what

are now the valleys of the Jefferson, Madison, and Gallatin Rivers, reaching to the junction of the three streams. The hills between the Gallatin and Madison, and between the Madison and Jefferson, are Pliocene, remnants of the same beds, and when we ascend the mountains on the southern border of this old lake-basin the whole plan lies spread out before us. Each of the rivers has cut deeply into these Pliocene rocks, and their valleys are the results of the erosion that has taken place since the draining of the ancient lake. The question of priority of elevation of the Bridger Range, and that into which Spring Cañon is cut, is one of some interest. That there has been more than one force at work to give the surface its present configuration is evident. The question is, whether or not they acted synchronously. The forces that elevated the layers of Spring Cañon and those of Bridger were, I take it, entirely distinct from each other and separated by long periods of time. The Bridger Range was the first to be elevated, and its elevation occurred probably about the end of the Cretaceous period, and before the beginning of the Eocene, while the range running south from Spring Cañon was elevated some time after the Eocene and prior to the deposition of the Pliocene strata. This is proved by the fact that the Cretaceous rocks on one side of the valley are conformable to the Bridger Range and on the other side to the Spring Cañon layers, while the Eocene rocks are conformable only to the latter, and the Pliocene rocks have been affected by neither range. I believe also that the

Fig. 27a.



SECTION FROM SPRING CAÑON TO BRIDGER PEAK.

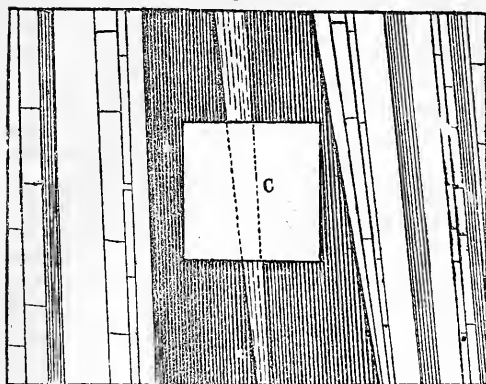
A, Bridger Peak; B, Spring Cañon; C, Tertiary; D, Cretaceous; E, Jurassic; F, Carboniferous; G, Drift; H, Tertiary hills.

River we find Pliocene sandstones and marl capped by basaltic plateaus, while at Fort Ellis there is nothing of the kind, and we will see in a subsequent chapter that, some distance farther south, we find Eocene beds lifted high up on the mountains. The section shown in Fig. 27a will give the relations of the beds between Spring Cañon and Bridger Peak.

I have referred above to the occurrence of coal near Fort Ellis. The only rocks in which I noticed it were those of Eocene age. At only one point has there ever been any mining attempted. This one point is east of Spring Cañon, about four miles southeast of Fort Ellis. Coal was discovered here in 1867 by two blacksmiths, of Bozeman. Colonel J. D. Chestnut, hearing of the discovery, offered to furnish provisions to get men to work into the bed, if they would give him a share. This they did, and afterward left him sole owner of the claim, which includes one hundred and sixty acres. Fig. 28 is a section of the coal bed, C showing the opening into it. The shaft penetrates the bed in a horizontal direction, and has reached a depth of 250 feet from the entrance. The width of the shaft is 14 feet at the widest part. The bed of coal is considerably wider, and dips north 50° east; angle, 80° . On each side of the coal there are beds of bluish argillaceous sand-

stones, which are followed by coarse, gray sandstones. When the bed was first opened there were several seams of clay in it, but as the shaft penetrated deeper they gradually thinned out, and at present there is only

Fig. 28.



a a, Sandstone; *vv*, Coal; *d*, Seam of clay; *C*, Opening into coal.

one in the center of the coal, having a thickness of about twelve inches. The coal is a lignite, and is well adapted for blacksmiths' purposes. It is used, I believe, by blacksmiths of Bozeman, who like it very much. Some of the coal was taken to Helena, and is said to have yielded five cubic feet of gas to the pound. As the shaft goes deeper the quality of the coal seems to improve. Up to the present time there has been but little demand for coal. One reason of this, perhaps, is the abundance of timber in the mountains

near Bozeman, and another reason, perhaps, is that hitherto there have been few facilities for transportation, the road through Spring Cañon having only lately been completed. There is but little doubt, however, that ultimately this coal will be extensively used. When the Northern Pacific Railroad is built through this region the utility of the coal-beds near Fort Ellis will become more and more apparent.

I have made the following analysis of the coal. No. 1 is a poor specimen, No. 2 medium, and No. 3 the best. The coal is black, (brown in powder,) has a high luster, irregular fracture, specific gravity. The coke is moderately good, and has a high luster:

Analysis No. 1.

	Per cent.
Water.....	6.00
Volatile matters.....	32.90
Coke.....	44.10
Ash.....	17.00

100.00

Analysis No. 2.

	Per cent.
Water.....	3.00
Volatile matters.....	41.50
Coke.....	43.50
Ash.....	12.00

100.00

Analysis No. 3.

	Per cent.
Water.....	7.00
Volatile matters.....	34.50
Coke.....	50.50
Ash, (white).....	8.00

100.00

For purposes of comparison I insert here analyses of coal from Utah :

Analysis of coal from Evanston, Utah, (mine of the Rocky Mountain Coal and Iron Company.)

	Per cent.
Water.....	7.00
Volatile matters.....	42.00
Carbon.....	45.00
Ash, (reddish).....	6.00
	100.00

Average of three analyses of coal from Evanston, Utah, by Persifor Fraser, jr., and F. Platt, esq., (United States Geological Survey of Wyoming, 1870, page 184.)

	Per cent.
Water.....	5.83
Volatile substances.....	37.40
Ash.....	7.46
Fixed carbon.....	49.50
	100.19

The following is an analysis of coal from the mine of Buel & Bateman, at Coalville, Utah Territory. This was formerly called Sprigg's mine :

Analysis.

	Per cent.
Water.....	6.50
Volatile substances.....	41.70
Carbon.....	44.80
Ash.....	7.00
	100.00

Analysis of specimen, from the same mine, by Persifor Fraser, jr., (United States Geological Survey of Wyoming, page 183.)

	Per cent.
Water and volatile substances.....	50.80
Ash.....	3.60
Fixed carbon.....	45.60
	100.00

About a mile or two south of Spring Cañon I visited a second cañon which another branch of the Gallatin has cut in the range. The general direction of the stream in this cañon is north 75° east. The exposure of the Upper Cretaceous beds is perhaps better here than in Spring Cañon. The first exposure is a bed of white crystalline limestone, dipping south 50° west; angle, 50° . This limestone is followed by red and yellow sandstones, which are themselves succeeded by a bed of brown limestone, weathering bright yellow. These occupy between one and two hundred feet. Then follow the soft, gray sandstones that I noticed near Spring Cañon and Bridger Peak. They continue for about half a mile, when we come to Jurassic rocks, the first bed of which we recognize as one of the Spring Cañon layers. It dips south 40° west; angle, 85° . It is followed by the same beds we saw in Spring Cañon. They are in fact only a continuation of the same. The Carboniferous lime-

stones form the center of the ridge, the outer layers on either side dipping in opposite directions, on the eastern side dipping northeast and those on the western side southwest. The general strike is south 30° east. The exposures in the cañon were very fine, but I found nothing differing from what I have described in Spring Cañon.

On the 13th of July I started on a trip to Mystic Lake, about twelve miles nearly south from Fort Ellis. After a pleasant ride over the grassy plain that slopes gently from the mountain's edge we began to ascend and soon found ourselves entangled in a mass of dead and fallen timber. After considerable trouble we reached the summit of the hill to find that we had to descend again on the opposite side. The hills are so covered with vegetation and *debris* that the character of its rocks cannot be made out certainly. High up on the sides, however, there are small exposures of limestones and sandstones, and it is probable that the valley is underlaid by Cretaceous formations. What their exact relation is to the ridge running south from Spring Cañon it is rather difficult to determine, though it is probable that the trail runs through a synclinal valley on one side of which lies the Spring Cañon Ridge.

The trail leads us now through pine-forests and anon across beautiful little valleys, each a garden of wild flowers. At last, after crossing several ridges, we reach the lake. Mystic Lake is the head of Boseman Creek, one of the branches of the East Gallatin River. Near it, on a level fully one hundred feet higher, are two exquisitely beautiful lakes, whose beauty is half hid by the trees fringing their banks. One of them we named Emerald Lake, from the deep-green tint of its waters.

The valley in which these lakes are situated is synclinal, one side being the continuation of the Spring Cañon Ridge and the other a spur running south from Mount Ellis. Opposite the lake, to the southeast, there is a volcanic range, at the base of which we find the Spring Cañon layers, having a general dip to the southwest. The other side of the synclinal cuts obliquely across the lower end of Mystic Lake, the strata dipping north 40° east; angle, 50° - 60° . At present the lake is about three-fourths of a mile in length and about one-fourth of a mile wide. It once extended farther up the valley and lay in a saucer-like depression. From the gradual elevation of the valley or some other cause, as the draining of the lake by the erosion caused by its outlet, at present it occupies the lower end of the valley, lying on the edges of the Cretaceous, Jurassic, and Carboniferous strata.

The course of the stream of which Mystic Lake is an expansion is about south 20° west, making an angle of about 60° with the strike of the strata. On the western shore of the lake there are exposures of Jurassic sandstones and limestones precisely like those of Spring Cañon, and in which occur *Ostrea* and *Camptonectes*. Below the Jurassic come immense beds of quartzites and limestones, the upper layers of which are undoubtedly Carboniferous, containing *Productus longispinus*, *Spirifer lineata*, *Hemipronites crenestria*, *Productus scabriculus*, *Zaphrentis*, &c. The thickness of these beds is over 2,000 feet, and the lower strata should probably be referred to a lower geological horizon than the Carboniferous. As we go south the strata turn more and more toward the west. As we go toward the north we find Mount Ellis, the extreme northern end of the spur or ridge. The elevation of Mount Ellis is 8,419 feet above the sea. It is composed mainly of Carboniferous limestones, while to the west and at the base are gneissic rocks. The elevation of this ridge was probably contemporaneous with that of the Bridger Range, as its formation seems to be similar. As we follow the ridge southward it curves until the trend is almost east and west. It probably once formed

a portion of the southern shore of the ancient lake, as the Bridger Range did part of the eastern shore, while Mount Ellis and Bridger Peak may have been promontories projecting into it. The action of volcanic forces within a very short distance, however, has complicated matters to such an extent that any opinion must be conjectural, and future careful study will be required to prove or disprove. The elevation of the lake above sea-level is 6,468 feet, which is 1,533 feet higher than the elevation of our camp at Fort Ellis. The synclinal valley, which I referred to above, has no later rocks than the Cretaceous. Why there should be no Tertiary beds here is perhaps a little difficult to understand. That there have never been any is evident, or there would be some remnant or trace of them left. Erosion could scarcely have removed all without some trace being left. Moreover, this is not a valley caused by erosion. Perhaps the elevation of this point, which may have been greater in the past, precluded the possibility of the Tertiary beds reaching this point.

Bozeman Creek, leaving Mystic Lake, flows at first a little west of south, and turning flows more toward the west, until finally it flows in a northwesterly direction. At first it cuts its way in a deep gorge almost at right angles to the strata, over which it rushes in a series of cascades half hidden by the overhanging vines and brush. Within a quarter of a mile it falls about five hundred feet. Just below the lake it is joined by a stream coming in from the left. It heads at the base of the volcanic range, which lies to the east of Mystic Lake. Following the course of this creek there is a bed of volcanic breccia which has flowed from the head of the valley. It is composed of sharp angular fragments of basalt, varying in size from three inches to a foot. The prevailing colors are black and a brick red. The cementing material of this breccia seems to contain fragments of sandstone like those seen in the Eocene beds. The belt covered by this bed of breccia is not over a quarter of a mile in width.

The minerals I obtained while at Fort Ellis are as follows, viz: rhomb-spar, dog-tooth spar, quartz, agate, red and yellow jasper, and coal.

We left Fort Ellis on the 20th of July and started for the valley of the Yellowstone. For about three miles our course was in an easterly direction, when we turned toward the southeast and followed one of the branches of Mill Creek, the stream that flows through Spring Cañon. Our road led us over Tertiary sandstones. Camp No. 2 was in a monoclinical valley, near the head of Mill Creek. The hills on the east side of the valley were Tertiary, while those on the west, dipping in the same direction, were Cretaceous. The former were about 400 feet high and composed of sandstones, the texture of which varied, some of the layers being quite soft, while others were very hard, seeming to have been metamorphosed. Many of them contained impressions of deciduous leaves, which Professor Lesquereux has determined to be Eocene. Among them he found *Platanus aceroides*, *Fagus antipoffi*, *Salisburia polymorpha*, *Juglans denticulata*, and *Gymnogramma Haydenii*. He says, "The most interesting discovery is that of *Salisburia polymorpha*, described from Evan's specimens of Vancouver's Island, a long time ago." This would indicate a correspondence in the Tertiary flora of the Pacific coast, and that on the east side of the Rocky Mountain divide as at present constituted, and thus points to the modern elevation of the range. Mr. Meek finds also a correspondence in the Cretaceous shells of the two localities referred to, and says also that they do not correspond to the forms found farther east, which would lead us to suppose that at the period of their deposition the divide of the Rocky Mountain must have been more to the

eastward of the present divide. One of the layers containing the best fossils showed a plane of cleavage that was oblique to the plane of deposit, rendering it extremely difficult to get perfect specimens. The color of these sandstones was mostly a gray, passing in places into a greenish tint. Intercalated with them were some beds of basalt, which was probably the cause of the metamorphism observed. In climbing over these hills I found numerous indications of coal-beds, one of which was just above our camp. There was no outcrop visible, but a prairie-dog in burrowing had penetrated the bed, and revealed its presence by the coal he had dug out. On the 21st I visited the hills west of camp. The first ridge was 416 feet above the level of the creek, and composed of gray and green sandstones containing *Inoceramus* and other Cretaceous fossils. The dip of these strata is 50° northeast; angle of inclination, 65° . The layers between this ridge and the Eocene on the opposite side of the valley, having been soft sandstones, have been washed away to form the bed of the stream. From this first ridge I ascended to the next, still higher, but parallel to the first. The first strata were light-gray sandstones, very much metamorphosed. These beds, which I take to be of Cretaceous age, continued for about half a mile, and were followed by 50 feet of coarse, reddish sandstones, the lower layers of which were conglomerate. Next came a layer of very hard sandstone containing fragments of fossils. This was about 10 feet in thickness, and is followed by 30 feet of white quartzite. The summit of this ridge is 818 feet above the valley and 402 feet above the top of the first ridge. I followed it until the timber obstructed my passage, and I returned to the valley. These beds are a continuation of those exposed at Spring Cañon, and are underlain by the Jurassic and Carboniferous. Our course on the 21st was up the valley to its head, when we crossed the divide to Trail Creek, a tributary of the Yellowstone River, which we followed and camped in the valley of the Yellowstone. This divide is 5,821 feet above the sea. The strata here have been so leveled and covered with *débris* and vegetation that it becomes very difficult to trace the various beds. It is probable, however, that they curve toward the east and cross the valley, for a few miles after leaving the divide there is on the left-hand side of the road an exposure of Carboniferous limestones dipping a little east of north. On the right hand, a few miles to the south and west, there are numerous volcanic peaks, their sharp, jagged edges standing out boldly against the sky. As we neared the valley of the Yellowstone, we came to a bed of volcanic breccia, resembling that at Mystic Lake and originating evidently in the same center of eruption. Trail Creek has cut through this breccia, leaving a high butte standing on the left bank of the creek a few miles from its mouth. The top of this butte seems to be composed of compact rock. A few miles from the divide on Trail Creek there are coal-beds, none of which, however, have ever been mined.

Camp No. 3 was in the Yellowstone Valley, on Eight-Mile Creek, a few miles from its junction with the river. The valley of the Yellowstone is filled with Pliocene deposits of about 150 feet thickness, on top of which there are horizontal beds of basalt, which once probably extended over the whole valley, forming an immense plateau through which the river has cut its bed, removing immense quantities of material. The basalt is covered with local drift from the mountains. The foot-hills on the western side of the valley are composed of volcanic breccia. There has evidently been more than one period of eruption, for farther up the valley there are several layers of basalt, between

which there are Pliocene sandstones. The columnar form is beautifully shown in many places throughout the valley.

From Camp No. 3 I ascended the foot-hills which lie to the west, bordering the Yellowstone Valley. These hills rise about 3,000 feet above the level of the river. Proceeding three miles from the river we reached the base of the hills and found the lower ones composed almost entirely of breccia, while farther back we find laminated trachytes, which are inclined at an angle of about 40° , as though the lava had been poured forth in successive layers and, after cooling, had been tipped up by subsequent volcanic action. It is probable that under this volcanic mass we would find all the sedimentary rocks, from the Cretaceous to the Carboniferous or even lower. A few miles from the river, where the small streams have cut deeply into the hills, we find rocks containing Cretaceous fossils. Farther up, however, the volcanic rocks conceal all the underlying formations.

Our next camp, No. 4, was some eight or ten miles farther up the valley, on a basaltic plateau near Bottler's ranch. The general elevation of this plateau above the river is between 100 and 200 feet. Near Bottler's there are several good exhibitions of basaltic columns, and on the opposite side of the river the underlying marls and white sandstones. A few miles west of Bottler's we find ourselves in the midst of volcanic rocks of all kinds and colors, basalts predominating. The prevailing color of these rocks is a brick-red and dull purple. Scattered over the hills, as well as throughout the entire valley of the Yellowstone, we find chips of black obsidian, chalcedony, agate, and jasper. I got some very good specimens of red jasper associated with blue chalcedony, and also specimens of olivine from the basalt.

We left Bottler's on the 24th, and started up the valley, camping in the afternoon (Camp No. 5) on Cañon Creek, eleven miles above Bottler's. Cañon Creek joins the Yellowstone just after the latter has emerged from the second cañon. (Fig. 29.) The rocks of the second cañon are all gneissic, and as I described them in the report for 1871, I will pass them here. Between Bottler's and the second cañon

Fig. 29.



SECOND CAÑON OF YELLOWSTONE RIVER.

the trail leads us along the western side of the Yellowstone, being part of the way at a considerable height above the river on bluffs of volcanic

breccia. The prevailing color of this breccia is a gray, but the included masses have an almost infinite variety of color, green, purple, and red masses being abundant.

On the 24th of July, in company with Messrs. Wakefield and Savage of the expedition, I started up Cañon Creek from camp No. 5 with the intention of crossing the hills west of the second cañon and striking the Yellowstone River near Cinnabar Mountain, where the party expected to camp. The valley of Cañon Creek is quite wide and well watered, there being several small lakes bordering it. We followed the course of the stream but a short distance, when we struck up on the hills. The volcanic rocks here seem to be in contact with the gneisses. Scattered among the volcanic rocks I found silicified wood in abundance. After a long and arduous climb over the lower hills we reached a long ridge of volcanic breccia, which seemed to be a spur of the main ridge, and to the summit of which it led. It projected from it at a right angle. So following it up we at last gained the top, and found ourselves on the edge of a precipice, which formed a portion of the opposite side of the ridge. Looking over the precipice we saw we were on the top of a blank vertical wall of over 2,000 feet in height. The elevation of the mountain we were on was 9,478 feet above sea-level and 4,377 feet above the camp (No. 5) we had just left. The view from the summit, however, repaid us well for our toilsome climb. To the south and west the entire country seemed to have been subjected to the most intense volcanic action, followed by an immense amount of erosion. Somber-colored ridges, with sharp, piercing peaks and conical crater-like points, with deep gorges between, testify to the former disturbances. All about us were deep banks of snow. In order to descend we were obliged to follow the ridge toward the north until we came to a spur projecting at right angles from it. This spur sloped gradually to the valley of Cinnabar Creek, a small stream tributary to the Yellowstone River. We descended on this spur to Cinnabar Creek, and then followed it around Cinnabar Mountain, reaching camp at night-fall. Cinnabar Mountain shows a patch of the sedimentary rocks that everywhere else near here seemed either to have been covered by the outflow of lava or to have been washed away. It is probable that both causes have operated. The northern portion of the mountain is made up of granitic rocks, a continuation of those seen in the second cañon. Upon these rocks rest quartzites, followed by limestones, the upper layers of which are undoubtedly Carboniferous. The limestones are followed by quartzites again. One ridge of this quartzite forms the northern wall of the Devil's Slide, while the southern wall is formed of a dike of dark-green porphyritic rock. This dike probably separates the Carboniferous from the Jurassic. Between these two almost vertical walls the softer material has been washed out. Adhering to the dike are pieces of a blue-clay slate, and following it we find Jurassic beds of slates and limestones containing *Myascites subcompressa*, *Pholadomya*, and *Camptonectes*. Next come Cretaceous beds, in which there are indications of coal, and containing *Scaphites*, *Ventricosa*, *Baculites*, *Ostrea*, *Inoceramus*, and *Trigonia*. All the beds I have mentioned above have a dip to the southwest and an inclination of from 50° to 80°. About a half mile above the Devil's Slide we find that the beds seem very much crushed together, and within a very short distance dip southwest, and are horizontal and dipping northeast. A visit to one of the high peaks in the neighborhood gave us a clew to this curious contortion of the strata.

On the morning of the 26th of July Messrs. Gannett, Brown, and myself started to make the ascent of the peak, which lay to the south-

west of camp. Our way was up a long ridge, which seemed to us to lead to the summit of the peak. The rocks were immediately beneath us were Cretaceous sandstones. On reaching the timber-line (9,442 feet above sea-level) we found we would have to finish the ascent on foot, as the slope became too steep for the horses. So dismounting we picketed them, and started for the summit. The sandstones over which we passed reach within 500 feet of the top, dipping to the northwest. The summit of the peak seemed to be made up of an immense pile of broken-up volcanic rock, (a rusty-gray trachyte.) When we were within about 500 feet of the top a storm came up, and we were enveloped in clouds. The ascent here was very difficult, as the fragments of rock were very sharp, and most of them loose, sliding from beneath us as we climbed over them. Mr. Gannett succeeded in attaining the highest point and depositing his instruments, when he discovered that he was in the midst of an electrical cloud, and his feelings not being of the most agreeable sort he retreated. As he neared us we observed that his hair was standing on end, as though he were on an electrical stool, and we could hear a series of snapping sounds, as though he were receiving the charges of a number of electrical frictional machines. Mr. Brown next tried to go up, but received a shock which deterred him. The cloud now began to settle about us, and we descended some 500 feet, and waited until the storm passed over. About 4 o'clock in the afternoon we succeeded in reaching the top, and Mr. Gannett found the altitude of the peak to be 10,992 feet above the sea. We named it Electric Peak. The eastern side is hollowed, and from the base two small creeks flow to join the Yellowstone. Between the peak and the Hot Springs, on Gardiner's River, there must have been a center of volcanic action, for the sedimentary beds opposite the springs dip in the opposite direction to that of the beds on the western side of Electric Peak, and the space between is filled with volcanic material, from which a cone-like mountain rises. This will also explain the crushing together of the strata above the Devil's Slide. Descending the peak after completing our observations we reached our horses about 6 o'clock in the evening, and soon were on the way toward camp, with, however, but little hope of reaching it that night, as the main party had started up the river in the morning after we left camp. After dark we camped on the banks of Cache Creek, some miles from the valley of the Yellowstone. The next day about noon we reached

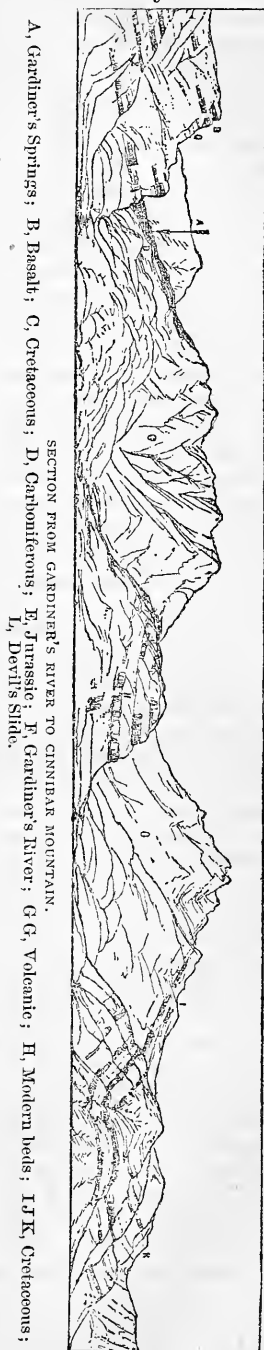


Fig. 30.

camp at the Hot Springs, on Gardiner's River. Opposite the springs there is a high wall, which presents the edge of Cretaceous and Lower Tertiary strata for a vertical distance of nearly 2,000 feet. The river has cut its way through a sort of a monoclinical valley, resting on either Carboniferous or Jurassic beds, while on the east side of the river we have the Cretaceous beds I spoke of above. The lower layers are very calcareous, and contain thin beds of limestone, from which I obtained good specimens of calcite and Iceland or double-refracting spar. Near the forks of the river, about half a mile above the springs, we have exposures of lower beds, in which there are seams of earthy lignite, associated with which I observed selenite, coating some of the argillaceous sandstones. There is an exposure of this earthy lignite some four miles farther down the river, a continuation probably of the same beds. Near the top of the wall there are Tertiary beds intercalated with basalt. The topmost layer of the latter stretches away to the east in a broad plateau, and on the edge the columnar form is well shown. It probably once extended on both sides of the river, and came from a point west of the springs. All the beds mentioned above dip to the northeast at an angle which averages about 15° . The limestones which dip under Gardiner's River extend under the Hot Springs, and are probably the source of the lime observed in the waters and deposits. The section shown in Fig. 30 will perhaps show more clearly the relations of the various beds near the Hot Springs. The springs were so fully described in the report of last year (1871) that I will not take the room to describe them again, inasmuch as it would be a mere repetition. We spent two days in camp there this year, during which time I made a more complete record of the springs and their temperatures and noted the changes that have taken place since our last visit. Since then there have been a number of cabins and bath-houses erected, and notwithstanding the difficulties of reaching the springs there were about thirty persons there enjoying the benefits to be derived from drinking and bathing in the waters.

The top of the gorge in which the springs are situated is 1,285 feet above the level of the river. I will commence with the springs at the level of the river. These are seven in number, and remain about the same as they were last year, with the exception that some of them have been artificially enlarged. The temperatures here are lower than we find higher up, and the springs are filled with bright-green *Confer-voidea*. The following table gives all the points of interest in regard to these springs:

Springs at the level of the river.

Time of observation, 8.30-8.40 a. m., July 29, 1872.—There was no perceptible gas given off.

No.	Size of spring.	Depth.	Temperature of air.	Temperature of spring.	Elevation above sea-level.
	<i>Inches.</i>	<i>Inches.</i>			<i>Feet.</i>
1	12x12	3	70° F.	104° F.	5,750
2	30x30	12	70	104	5,750
3	-----	-----	70	111	5,750
4	24x24	-----	70	114	5,750
5	{ Artificially enlarged. }	-----	70	112	5,750
6		-----	70	94	5,750
7		-----	70	132	5,750

As we go from the river up the hill toward the main springs we meet with a large pool of hot water of about 100 feet diameter. It is 230 feet above the level of the river, and on its edge there are several springs. Of two I took the temperatures, and found them both to be 140° F., the temperature of the air being 65° F. and the time of observation 8 a. m. A short distance farther up we came to the main mass of springs, arranged on a series of terraces at different levels. The first terrace is 528 feet above the level of the river. The principal springs are on the first ten terraces, and as we go up the valley we find that, although there were once many springs here of a most active character, at the present time they have nearly all died out. The first four or five have the hottest springs. The boiling-point at these springs varies from 199.5 to 200.9. I give the temperatures, &c., below in tabular form. The observations were all made on the 28th of July.

Number.	Position of spring.	Time of observation.	Size.	Depth.	Gas given off.	Temperature of air in Fahrenheit.	Temperature of spring in Fahrenheit.	Elevation above sea in feet.
1	First terrace...	8.40 a. m.	5 ft. × 7 ft.	6 in.	Sulphuretted hydrogen	70	150	6,278
2	...do	8.40 a. m.	Fissure of 30 ft.	...	...do	70	152	6,278
3	...do	8.40 a. m.	Fissure of 14 ft.	...	...do	70	160	6,278
4	...do	8.40 a. m.	Fissure of 6 ft.	...	...do	70	158	6,278
5	Second terrace...	9.00 a. m.	20 in. × 20 in.	12 in.	...do	69	144	6,304
6	...do	9.10 a. m.	15 in. × 35 in.	12 in.	...do	69	162	6,304
7	...do	9.20 a. m.	40 in. × 50 in.	16 in.	...do	69	162	6,304
8	Fourth terrace...	9.25 a. m.	29 in. × 20 in.	36 in.	...do	72	152	6,412
9	Fifth terrace...	9.30 a. m.	50 in. × 60 in.	24 in.	...do	74	152	6,465
10	Sixth terrace...	12.30 p. m.	...	...	...do	80.5	150	6,491
11	...do	12.30 p. m.	...	...	...do	80.5	148	6,491
12	...do	12.30 p. m.	...	...	...do	80.5	148	6,491
13	...do	12.30 p. m.	...	...	...do	80.5	142	6,491
14	...do	12.30 p. m.	...	...	...do	80.5	152	6,491
15	...do	12.30 p. m.	...	...	...do	80.5	148	6,491
16	...do	12.30 p. m.	...	...	...do	80.5	152	6,491
17	...do	12.30 p. m.	...	...	...do	80.5	152	6,491
18	Seventh terrace...	10.00 a. m.	150 ft. × 70 ft.	10 ft.	Carbonic acid	72	150	6,551
19	...do	10.00 a. m.	100 ft. × 50 ft.	10 ft.	Sulphuretted hydrogen	72	154	6,551
20	Eighth terrace...	9.45 a. m.	9 ft. × 13 ft.	3 ft.	...do	72	122	6,556
21	Ninth terrace...	10.10 a. m.	20 in. × 2 in.	6 in.	...do	74	157	6,591
22	...do	10.12 a. m.	100 ft. × 25 ft.	5 ft.	...do	74	162	6,591
23	...do	10.14 a. m.	4 ft. × 7 ft.	18 in.	...do	74	162	6,591
24	...do	10.14 a. m.	2 ft. × 3 ft.	3 ft.	...do	74	162	6,591
25	...do	10.15 a. m.	2 ft. × 3 ft.	1 ft.	...do	74	162	6,591
26	...do	10.15 a. m.	2 ft. × 3 ft.	6 in.	...do	74	162	6,591
27	Tenth terrace...	10.30 a. m.	2 ft. × 3 ft.	1 ft.	...do	74	120	6,596
28	...do	10.30 a. m.	3 ft. × 3 ft.	6 in.	...do	74	162	6,596
29	Eleventh terrace...	10.35 a. m.	6 in. × 6 in.	7 in.	...do	74.5	154	6,603
30	...do	10.40 a. m.	6 in. × 2 in.	6 in.	...do	74.5	148	6,603
31	...do	10.40 a. m.	10 in. × 12 in.	5 in.	...do	74.5	150	6,603
32	Twelfth terrace...	12.20 p. m.	...	...	...do	78.5	160	6,681
33	...do	12.20 p. m.	...	...	...do	78.5	162	6,681
34	...do	12.20 p. m.	...	...	...do	78.5	160	6,681
35	...do	12.25 p. m.	...	...	...do	78.5	162	6,681
36	...do	12.25 p. m.	...	...	...do	78.5	160	6,681
37	...do	12.26 p. m.	...	...	...do	78.5	162	6,681
38	...do	12.26 p. m.	...	...	...do	78.5	160	6,681
39	...do	12.28 p. m.	...	...	...do	78.5	160	6,681
40	Thirteenth terrace...	11.00 a. m.	...	...	...do	78	142	6,758
41	...do	11.00 a. m.	Fissure of 3 ft.	...	...do	78	149	6,758
42	...do	11.00 a. m.		...	...do	78	142	6,758
43	...do	11.00 a. m.		...	...do	78	142	6,758
44	...do	11.00 a. m.	Geyser-like tubes.	...	...do	78	108	6,758
45	...do	11.00 a. m.		...	...do	78	130	6,758
46	...do	11.00 a. m.		...	...do	78	144	6,758
47	...do	11.00 a. m.		...	...do	78	144	6,758

Number.	Position of spring.	Time of observation.	Size.	Depth.	Gas given off.	Temperature of air in Fahrenheit.	Temperature of spring in Fahrenheit.	Elevation above sea in feet.
48	do	12. 05 p. m.	Geyser-like tubes on mounds.	.....	.....do	78	148	6,758
49	do	12. 05 p. m.		.....	.....do	78	146	6,758
50	do	12. 07 p. m.		.....	.....do	78	130	6,758
51	do	12. 07 p. m.		.....	.....do	78	140	6,758
52	do	12. 10 p. m.		.....	.....do	78	140	6,758
53	do	12. 10 p. m.		.....	.....do	78	142	6,758
54	Fourtee'h terrace	11. 11 a. m.	12 in. $\times$ 12 in.	8 in.	Carbonic acid	74	96	6,779
55	do	11. 11 a. m.	3 in. $\times$ 4 in.	12 in.	do	74	92	6,779
56	do	11. 12 a. m.	6 in. $\times$ 6 in.	4 in.	do	74	103	6,779
57	do	11. 12 a. m.	1 ft. $\times$ 2 ft.	4 in.	do	74	102	6,779
58	do	11. 13 a. m.	1 ft. $\times$ 1½ ft.	2 in.	do	74	110	6,779
59	do	11. 13 a. m.	8 ft. $\times$ 3 ft.	3 ft.	do	74	112	6,779
60	do	11. 15 a. m.	4 ft. $\times$ 3 ft.	2 ft.	Sulphuretted hydrogen	74	108	6,779
61	do	11. 40 a. m.	Fissure 60 feet long.	.....	.....do	74	145	6,779
62	do	11. 40 a. m.		.....	.....do	74	145	6,779
63	do	11. 40 a. m.		.....	.....do	74	140	6,779
64	do	11. 45 a. m.	Fissure 54 feet long.	.....	.....do	74	130	6,779
65	do	11. 50 a. m.		.....	.....do	74	116	6,779
66	do	11. 50 a. m.		.....	.....do	74	118	6,779
67	do	11. 50 a. m.		.....	.....do	74	120	6,779

The elevation of the ridge just above the fourteenth terrace is 7,035 feet.

Fig. 31.



BASINS OF HOT SPRINGS AT GARDINER'S RIVER, YELLOWSTONE NATIONAL PARK.

The greatest change in the springs was noticed on the ninth and twelfth terraces. The former in 1871 was almost entirely covered with water, through which the various springs could be noted by the points of ebullition. It was impossible to walk anywhere but around the edge. Now, however, the most of the water has disappeared, and only the springs remain, and one can walk almost anywhere on the terrace. On the twelfth terrace there are a great many new springs, all of which have a high temperature. Carbonic-acid gas can be detected in the springs of the fourteenth terrace by the taste. These springs are hid in the grass, and it is only by careful searching that they are found.

Dr. Endlich has made the following analysis of the deposits from these springs:

	Per cent
Loss at 110° C.... 1.75 per cent. }	32.10
Loss at ignition.. 30.35 per cent. }	
Lime.....	57.70
Silica.....	3.32
Ferric oxyd.....	3.62
Alumina.....	3.31
Magnesia.....	Trace.
Soda*.....	Trace.
	100.05

Figures 31 and 32, drawn by Mr. Holmes, will perhaps give the reader a good idea of some of the peculiar formations noticed at these springs. Fig. 31 shows the pools or basins which were so fully described by Dr. Hayden in the report for 1871, and which form one of the most beautiful features of the springs. The

water in all of them is either warm or hot according to their position, the lower ones having the coolest water. The water has also that exquisitely beautiful blue tint which is beyond description, and which forms such handsome contrasts to the white, marble-like basins in which it is. The water pours from one basin to another and forms stalactitic processes, which hang from their sides as seen in the picture. At the bottom of the upper basin in the illustration the processes have united with those formed

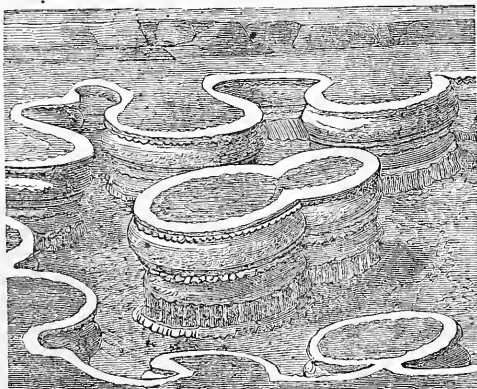


Fig. 32.

ORNAMENTAL RIM OF EXTINGUISHED SPRING, GARDINER'S RIVER.

from below by the dropping of the water, while in the lower basin they have not yet come together, but still form true stalactitic processes. Over the outside surfaces of the basins we find also bead-like processes, caused also by the dropping of the water. The great amount of lime in these deposits gives them a beautiful white appearance.

CHAPTER III.

GARDINER'S RIVER TO MUD-VOLCANOES, YELLOWSTONE VALLEY.

We left the Hot Springs on the 29th of July and made our next camp on Black-Tail Deer Creek near the Yellowstone, a few miles above Gardiner's River. Our camp was on a portion of the plateau that extends eastward from the top of the bluff-wall opposite the springs. The rock immediately beneath us was a violet-colored trachyte containing crystals of sanidine. Between our camp and the Yellowstone River there were some exposures of Carboniferous limestone, evidently the direct

*By spectroscopic examination.

prolongation of the layers noticed in the last chapter as occurring at Cinnabar Mountain. Just below these outcroppings the river passes through the third cañon, the rocks of which are gneissic, upon which the limestones rest. On the west side of the river there are fine exposures of black micaceous gneiss, inclining southeast. On the opposite side there are three streams which cut their way to the river through the solid granite. About a mile east of camp I visited a butte of limestone which rose above the surrounding volcanic rock like a huge monument. The dip was southwest at an angle of about 50°. From these layers I obtained *hemipronites*, *spirifer*, and *rhynchonella*.

The following day we moved our camp to the Yellowstone and pitched our tents in a beautiful grassy valley on Elk Creek, about one mile from the Yellowstone River. About two miles above us the East Fork of the Yellowstone joined the main river. Our camp (No. 9) was 334 feet lower than the previous one, (No. 8.) The descent from the plateau was rather abrupt, and gave us a chance to see the structure of the Eocene beds, which were here composed of coarse, yellowish-brown sandstones, intercalated with basalt and trachyte. The sandstones in some places are conglomerate, and all are considerably metamorphosed. Some of the layers contained impressions of deciduous leaves, among which Professor Lesquereux has found *Platanus nobilis*, *Fagus antipofi*, and a new species described in his report. The volcanic rocks, mostly basaltic, contained a large percentage of iron, and, on weathering, presented a rusty appearance. In some I found green jasper and chalcedony. The valley of Elk Creek below our camp presented a curious appearance. The river and the small streams have cut their way deeply through the Tertiary beds, leaving table-like buttes standing between each one, being capped with a volcanic layer, the top of which is perfectly level. They are merely the remnants of layers that once extended over the entire valley. Beneath the volcanic layers the soft gray and brown sandstones have yielded readily to the action of the water, and the cañons are deep, with perpendicular walls.

The Tertiary beds seem to rest immediately on the gneissic rocks at this point, and before their deposition there was undoubtedly a great deal of erosion. The thickness of the Tertiary beds, including the volcanic layers, is about 400 feet. Throughout the valley in which we were camped there was an immense number of granite-boulders of all sizes, which were evidently washed down the valley of the East Fork, for we find them strewn along that river for some distance above its junction with the Yellowstone. On the east side of the Yellowstone, near Hell Roaring Creek, there are some high granite mountains, and the entire surrounding country is very rugged and will some day form a most interesting field of study. Our time was too limited to attempt to penetrate it at all. Near the junction of the two forks of the Yellowstone there has been a bridge thrown across the main stream. Just at this point we find an exposure of granite. This passes into micaceous gneiss, which is overlaid by sandstones, on top of which there is a bed of conglomerate, made up mostly of volcanic fragments. Crossing the river we soon find ourselves surrounded with volcanic rocks. A short distance from the river there is an isolated table-like butte, rising 600 feet above the level of the river. It is capped with basalt of considerable thickness, beneath which are soft Tertiary sandstones. The floor of the butte is quite level, and is strewn with granite-boulders. It is evidently only another remnant of the basaltic layer I have referred to above, which once extended over an immense area. As we proceed up the Yellowstone, it becomes thicker. Follow-

ing the river we found that a short distance above the bridge it emerges from a deep cañon. At the lower end of this cañon there are a number of hot springs on the edge of the river. We could distinguish at least four. They were surrounded by a considerable deposit of sulphur and iron. They give off sulphuretted hydrogen abundantly. We were some 500 feet above them, and yet the surrounding air was strongly impregnated with it. It was impossible to reach the springs to take their temperatures. The cañon is about a mile in length, extending from the mouth of Tower Creek, opposite Tower Falls. It is one of the finest cañons I have ever seen. The walls are perpendicular and the river flowing below is a perfect torrent, of an emerald-green tint, capped with white foam. The fall of the river for $2\frac{1}{2}$ miles is 229 feet. On the western side of the cañon the rocks have been weathered into towers, with sharp pinnacles, giving it a most picturesque appearance.

The height of the eastern wall is 346 feet above the level of the river opposite Tower Falls. At the lower end the height probably reaches 500 feet. This wall, from top to bottom, is composed as follows:

- | | |
|--------------------------|-------------|
| 1. Soft, gray sandstone. | } 346 feet. |
| 2. Columnar basalt. | |
| 3. Conglomerate. | |
| 4. Columnar basalt. | |
| 5. Trachyte. | |
| 6. Limestone (?). | |

The layers of basalt mentioned above, Nos. 2 and 4, extend the length of the cañon and present the most regular hexagonal columns that I have ever seen anywhere in the West. It was impossible to obtain the exact measurements, but I should estimate those in layer No. 2 to be 15 feet in height, while those of No. 4 were probably between 20 and 30 feet. The conglomerate No. 3 was probably about 100 feet in thickness, and composed of large fragments of all kinds of rocks, the volcanic predominating. It was so infiltrated with sulphur that the whole bed had a bright-yellow color, especially noticeable at the upper end of the cañon. The sandstones on the top were very soft, and had weathered so as to give a rounded top to the wall. The general color of the trachyte was a violet, and it rested, I am inclined to think, on limestones, although on this point I am not quite certain. Above the cañon the Yellowstone River flows through quite a wide valley, which on one side is comparatively open and on the other side bounded by high hills, which slope to within a short distance of the river's edge. Just above this valley is the lower end of the Grand Cañon. Both sides of the river above Tower Creek have once been the seat of hot-springs, whose most active period has been long passed. There are at present only a few springs remaining on the western bank, while on the east there are extensive deposits containing sulphur, selenite, and alum. We spent four days in camp No. 9, while Dr. Hayden and a small party made a side trip to Clarke's Fork of the Yellowstone. During this time, in addition to some trips to Tower Falls and the vicinity, I also made two trips up the East Fork of the Yellowstone to a locality where one of the members of the expedition discovered some very fine crystals of anethyst. This locality is some ten miles from the main Yellowstone. The specimens are found on a hill on the left side of the river. It is about 1,000 feet in height and the summit entirely destitute of timber, the rock covering it being basaltic. Over the basaltic floor, quartz, agate, jasper, and silicified wood are found in quantity. There seems once to have been a forest standing here which the lava has inclosed

and silicified. Imbedded in the rock we find numerous cylindrical masses of chalcedony a foot and more in diameter. In some of these masses we can still trace the form of the woody fibers, while others have bits of silicified wood that has not been changed to chalcedony. In the center of many of these cylinders we find crystals of amethyst. They are large and have a fine color. If we had been able to penetrate to a greater depth there is no doubt but that we would have found still handsomer specimens. In other specimens the wood seems to have formed a nucleus around which the quartz has crystallized, chalcedony forming the center and milky quartz the exterior. In one place on this hill I found a great variety of jaspers, with also agates and semi-opal.

The following is a complete list of the minerals found at this locality: Amethyst, (amethystine quartz,) limpid quartz, milky quartz, (ferruginous quartz,) chalcedony, carnelian, chrysoprase, prase, banded agate, flint, red, yellow, gray, blue, and black jaspers, semi-opal, and calcite.

The calcite is found in the center of agate-geodes. The jaspers are very fine, containing three and four colors in some of the pieces. The crystals of quartz and amethyst are all large and fine.

Throughout the entire valley of the Yellowstone quartz, chalcedony, agate, and obsidian-chips are common, while almost all the trachytes contain crystals of sanidine. Among the specimens brought from Clarke's Fork were argentiferous galena; and the blue and green carbonates of copper from the Clarke's Fork mines.

We left Elk Creek on the 4th of August, and made our next camp at the foot of Mount Washburne, on the eastern side, in a small, densely-timbered valley bordering the Grand Cañon. Close to our camp there was a small gully containing some springs, of which I recorded the temperatures. A small stream ran through the gully, and throughout the entire bed there were springs whose presence was revealed by the bubbling of carbonic acid and sulphuretted hydrogen through the water. On either side of the stream there are abundant deposits, of a white color, containing lime, silica, and sulphur, giving evidence that at some past time this place was the seat of a large group of active springs, of which those now existing are a mere trace. It may not be many years before they will be entirely extinct. The specific description of these springs is as follows: No. 1 is eight feet by five, and gave off sulphuretted hydrogen abundantly. The temperature was only 52° F. No. 2 is three by four feet, and has a temperature of 53° F. Nos. 4 and 5 were merely small holes in the deposit on the bank of the stream. The temperature of the former was 94° F. and that of the latter 115° F. The remaining springs were as follows: No. 6, 188° F.; No. 7, 188° F.; and No. 8, 190° F. The boiling-point here would be 198° 3 F. The temperature of the air during these observations was 76° F., the time being about 7.30 a. m. The elevation above sea-level was 8,117 feet. From this group of springs we caught a glimpse of a white spot through the trees, which indicated that there were more springs to the north of these. Toward this place we turned our heads, and while riding along through the woods we came to a pool of water which would measure probably thirty yards by fifty. The surface of the water was almost all in agitation from the number of points of evolution of carburetted hydrogen. The temperature of the water was only 54° F., while the air still remained at 76° F. This pool was on about the same level as the springs mentioned above. A short ride from this pool brought us to the spot we were seeking, and we found ourselves in the midst of an active group of mud springs or salses. The springs are distributed over the side of a hill which steams from top to bottom. It was a most hor-

rible-looking place, and brought to our minds pictures of the infernal regions. The black and red colors of the mud and iron deposits gave the hill the appearance of having been burned, while here and there were masses of bright-yellow sulphur. The air was filled with the fumes of sulphuretted hydrogen. The noise made by the throbbing and pulsating masses of mud was continuous. This, with the splashing and spluttering of some of the springs, the plop-plop of the thicker mud, combined with the unearthly appearance of the scene, made us feel that we were on dangerous ground, and in walking about the springs we did so carefully, fearing that we might break through the crust. The mud in these springs is black in some, lavender-colored in others, and again yellow, while in consistency it is of all grades, from that of a thick mush to a mere inky-black water. In the thick-mud spring the steam seems to escape with an effort after several vain attempts. The mud rises in a hemispherical mass, falls and again rises, and after several repetitions the steam bursts from it, sometimes throwing the mud to a distance of 20 feet.

I divide the springs at this locality into two groups, the second group being some distance higher up the hill. The following is the description of the springs in the first group: The first one contained a rather thin lavender-colored mud. It is a cavernous-like opening on the side of the hill, and is the topmost spring of about five springs that are situated in a line, one above the other, at different levels. There seems at one time to have been a fissure here which determined their position. It was the only spring of the five that could be approached, but the temperature even of this could not be taken on account of the steam coming from it. It was probably at the boiling point. The mud was in active motion, and the steam came from it with a continuous roar. The spring also gave off sulphuretted hydrogen gas.

No. 2 was a large pool of muddy water, through which a number of steam jets forced their way, giving the spring the appearance of a sieve full of water, through the bottom of which the stream was forced. The temperature of the water was 194° F., and the air 78° F., the time of observation being about 9 o'clock in the morning. This spring was 30 feet above No. 1. Near it there was a spring of very thick, blue mud, the temperature of which I was unable to take, it not being safe to approach near it, as the mud on the banks was very soft.

A short distance to the right of No. 2, and a little above it, is No. 3, a large, yellow, muddy pool 30 feet by 50 feet in diameter, in which there was a great deal of bubbling, the water near the edge of the spring being especially agitated. The temperature was 140 F., the air remaining at 78° F. On the banks of this pool there was an abundant deposit of sulphur and alum. No. 4 is the most active spring of the group. It is about 20 feet higher up the hill than No. 3, and is about 30 feet in diameter, somewhat irregular in shape. The mud has formed a rim about it which is 2 feet above the spring on one side and 3 feet on the other. It contains a very thin blue-black mud, which is in violent ebullition, rising at times to the height of 3 and 4 feet. A dense column of steam, mingled with sulphuretted hydrogen gas, is continually escaping from it. I was able to take the temperature only at the edge, where I found it to be 190° F.; air, 78° F. In the center it was probably at the boiling point, which at this elevation is 198.2 F. About 20 feet below No. 4, and a little to the right, is No. 5. It is 15 feet long and 5 feet wide at the widest place, being somewhat triangular in shape. One edge of the bank over-

hangs the water and coated with a deposit of sulphur, which is deposited by the sulphuretted hydrogen gas. The water here is cleaner than in any of the surrounding springs. The center of the spring is in violent ebullition from the escape of steam. The temperature of the water at the edge of the spring was 184° F., the air being 78° . The second group has a general elevation of about 150 feet above the first, and is also situated on the slope of a hill. The first spring in this group we called the "Mush-Pot." It is about 20 feet in diameter, and has three openings, each about 10 feet in depth. The mud at the bottom of these holes is very thick and of a bluish-black color. The mass heaves and throbs as the steam escapes through it. It was impossible to take the temperature of the mud, as the steam scattered it in all directions, rendering it impossible even to look into it with safety.

No. 2 was named the "Paint-Pot," the mud in it resembling lead-colored paint. The entire surface was in violent agitation. The diameter of this spring is narrower at the top than at the surface of the mud, which was eight feet below the surface of the ground. The mud is scattered in all directions, as in the last-mentioned spring, rendering it impossible to obtain its temperature. At intervals of about three minutes it seems to take a rest, remaining quite for a few seconds.

No. 3 is a fissure of nearly 100 feet in length, in the course of which there are a number of black-mud springs, their average temperature being 185° F., while the air was 79° F. This fissure is about 100 feet above spring No. 1.

No. 4 is a similar fissure of about the same length. It is about 100 feet above the preceding one, and contains mud-springs of the same character, the average temperature being 190° F. The boiling-point at this elevation is $197^{\circ}.6$ F. All around this fissure there is an abundant deposit of sulphur and alum, the sulphur-crystals being exceedingly brilliant and delicate.

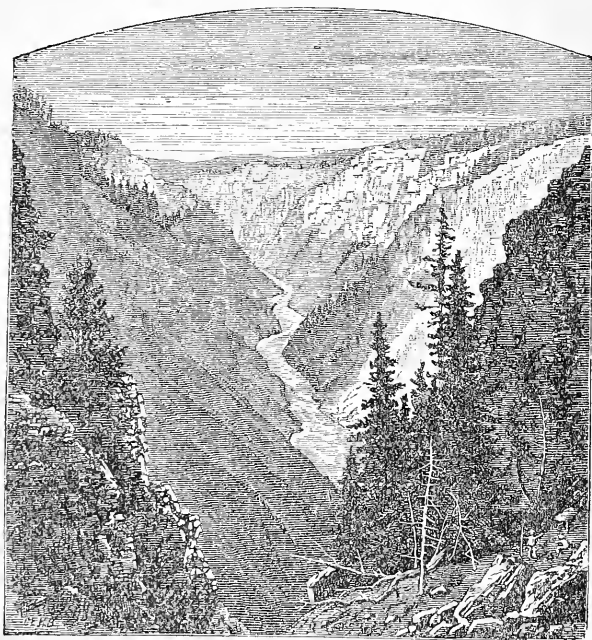
No. 5 is a blue-mud spring of about three feet in diameter, having a temperature of 190° F. Nos. 6, 7, 8, 9, and 10 form a small group distinguished by the abundance of sulphur surrounding them. The mud in them was very thick and varied in color from blue to black. The ground about them was too treacherous to allow of a near approach, but their temperature would probably average about 185° – 190° . Besides the springs I have described above there were numerous smaller ones and a great many steam vents. I have only mentioned the most important springs. Both the groups are situated in banks of clay, and the deposits consist mainly of clay, alum, and sulphur. All the springs are acid in reaction from the presence of sulphuric acid. The sulphur results from the decomposition of the sulphuretted hydrogen which is so abundant in this locality. The oxidation of the sulphur and its union with the alumina and iron gives us the alum which we find here.

Our next camp (No. 11) was on Cascade Creek, a few miles from the Lower Falls of the Yellowstone and the Grand Cañon. Cascade Creek, near our camp, flows through a valley covered with sedimentary rocks, into which it has cut a short distance. It is made up partly of sand and particles of volcanic material. It is probably Pliocene in its origin, and was deposited at the bottom of a lake which was very likely a prolongation of the ancient Yellowstone Lake, and existed here at a comparatively recent period. The strata are soft and contain particles of obsidian in abundance, and are also in part contributed to by volcanic ashes, for here we find ourselves in the midst of a volcanic country. This sedimentary deposit extends over the entire valley of the Yellowstone at

this point. The carving out of the Grand Cañon (Fig. 33) gives us an excellent opportunity to study the various rocks that underlie the valley.

At the head of the Grand Cañon is the lower fall of the Yellowstone, which was measured this year by triangulation and found to be 397 feet in height. At the

Fig. 33.



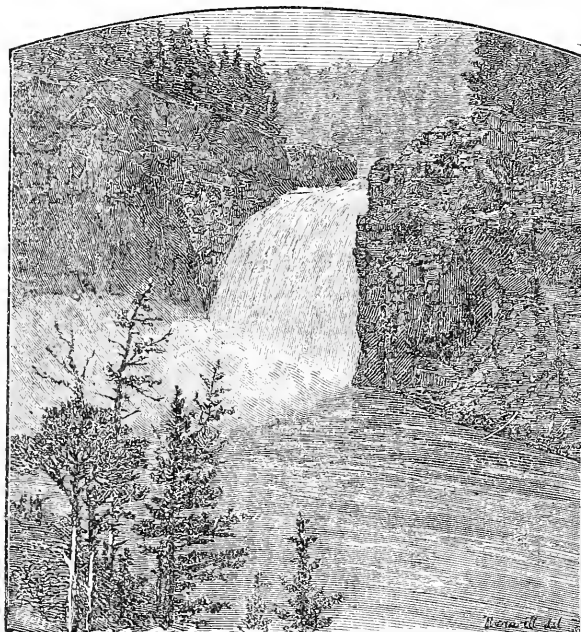
GRAND CAÑON OF THE YELLOWSTONE.

foot of the fall the depth of the cañon is 675 feet. This depth increases as we go down the river, and about half a mile below it is 1,000 feet, measured with an aneroid barometer. The fall of the river from the foot of the fall to the mouth of Tower Creek, a distance of twenty-two miles, averages 40 feet to the mile. On the western side of the cañon, some distance above the top of the lower fall, there is an exposure of a very fine soft sandstone having a light-yellow color. This must have been deposited in very quiet waters and is probably of Post-pliocene age. On the eastern side we find the rocks to be as follows: The top of the cañon above the falls is made up of obsidian, which is porphyritic, containing crystals of sanidine. The rock is very irregular in composition and color, the latter varying from black to brown. It passes into a perlite-like rock of a light-bluish color, in some places is white. This has in places perlite-like trachyte-porphry, containing small feldspathic balls with a radiated fibrous structure, (spherulites,) mixed with small bits of obsidian, the whole mass having a general color that resembles blue lead. A little farther down we find in this same rock jasper-geodes containing varieties of opal in the interior. They vary in size, some being only an inch in diameter, while others are half a foot. They are of a brown color on the exterior and botryoidal in shape, and are porphyritic, containing crystals of sanidine. Breaking them open we find that the mass often presents a beautiful appearance, some of the specimens having a rich-brown color, mingled with bright red and green, while the cavities are lined with pink, white, or blue semi-opal in some cases and in others by hyalite. The variety in the shades of color is almost infinite. Just above the fall there is a slide of rock reaching from the top of the cañon to the river's edge, and here we found many good specimens that had broken out of the more massive rock and fallen down.

At the brink of the fall the rock over which the water pours, and which extends some 50 or 75 feet above it, is a compact trachyte por-

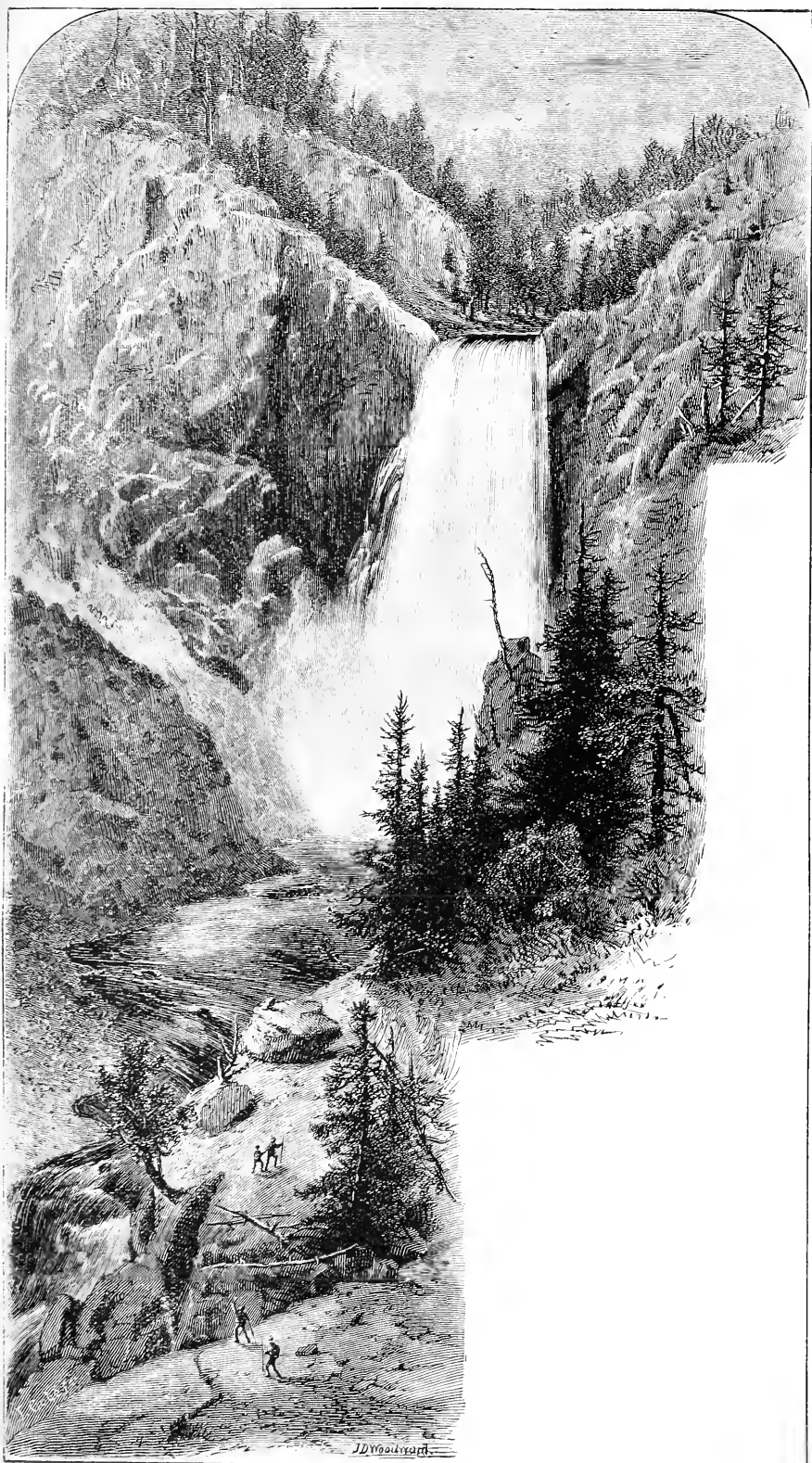
phyry of a light-violet color containing crystals of sanidine. As we proceed down the river we find that this rock is replaced by an argillo-trachyte-porphry, the white color of which contrasts strongly with the other colors seen on the sides of the cañon. The unequal hardness of the different rocks has allowed it to weather into curious and fantastic shapes, spires, towers, and minarets standing out on either side, adding to the picturesqueness of the scenery. There have once been many hot springs throughout this region, and it is to them that the greater portion of the coloring seen in the cañon is due, the iron deposits giving the reds and the sulphur the yellows. There still are a number of springs along the river's edge, although from the top of the cañon they cannot be distinguished. The center of attraction, however, is the lower fall, (Fig. 34). The river suddenly narrows to a width of only 100 feet and rushes over a ledge of trachyte, falling 397 feet to the bottom of the cañon. The water at the edge of the fall is very deep and of a deep-green color. Huge bowlders thrown in are carried by the force of the current far out from the edge of the fall. When we approach the brink and look over into the abyss we begin to realize the littleness of man when in the presence of nature's grand masterpieces. Down, down goes the whirling mass, battling and writhing as the water dashes against the rocks with a noise like the discharge of artillery. Here and there a resisting rock is met with and the water rebounds, broken into myriads of drops, which throw back to us the sunlight resolved into its

Fig. 35.



UPPER FALL OF YELLOWSTONE RIVER, 140 FEET.

primitive colors. The bottom of the cañon reached, the immense mass of water seems to dissolve itself into spray, and then recovering, it flows down the gorge an emerald-green stream, dashed with patches of white, beating with furious waves the rocky walls that imprison it. Taken in connection with the varied tints of the cañon itself, red, yellow, orange, white, the dark-green pines fringing the top, and the bright green of the spray-nourished moss on the sides of the fall, we have a picture of almost unequalled magnificence and grandeur. It is a scene of which one never tires and in the description of which language fails. As we stand above the lower fall and look toward the south we have a fine view of the upper fall, (Fig. 35,) which is distant about half a mile. This fall differs altogether from the lower one and does not so soon impress one with its height, which is 140 feet. The water pouring over the edge



LOWER FALL OF YELLOWSTONE RIVER,



strikes a number of ledges of rock, which churn it into a mass of foam. A portion of the water is projected out like a broad fan, and striking the water below makes a sort of ricochet, while the main mass of water reaches the base of the fall about 20 feet from the vertical line let fall from the top. The water has cut out of the solid rock a rounded basin, from which the course of the river is almost at right angles to the course above the fall. For some distance above the fall

Fig. 36.



CRYSTAL FALLS ON CASCADE CREEK, 129 FEET.

there is a series of rapids over which the current is very swift. The cañon between the two falls is about half a mile long and the fall of the river between these two points is 68 feet. The walls of this cañon vary in height from 100 to 200 feet.

Cascade Creek flows into the Yellowstone River on the west side between the falls. A short distance above its mouth we find a beautiful fall, (Fig. 36,) or rather cascade, for it is made up of three distinct falls, the

aggregate height of which is 129 feet. The stream, after passing through a deep, gloomy gorge, makes a leap of about 21 feet and then falls again in three streams a distance of over 50 feet into a beautiful, rounded basin, in which the water is perfectly clear and quiet. From this basin the final leap is taken and the water flows on to the Yellowstone River.

Leaving Cascade Creek our next camp (No. 13) was at Mud Volcanoes near the Yellowstone River, about eight miles below the lake. We spent three days here, waiting for a supply-train to join us from Fort Ellis. During this time I visited a number of the various hot-spring localities in this portion of the valley. The underlying rocks here are Pliocene and Post-pliocene, in horizontal strata, and presenting the same characters that were observed near the Grand Cañon, and probably resting, as those do, upon volcanic rocks. In some places I noticed iron as forming a prominent part of these sedimentary deposits, which, with the obsidian, makes very handsome specimens. The river flows quietly through the valley, the fall per mile, from Yellowstone Lake to the top of the upper fall, being only 8 feet, and almost all of this is in the rapids just above the upper fall. The first springs I visited were on a branch of Alum Creek about five miles northwest of camp. We named the small stream Violet Creek, from the profusion of violets growing upon its banks.

The first spring we met with was on the right bank of the creek, in a siliceous cone-like mound that rises six feet above the bed of the stream. Its temperature was 126° F., the air being at 70° F. The bed of the creek was filled with confervoidea, leading us to suspect that there were springs still farther up. After a further ride of about a quarter of a mile we came to quite a large group of hot springs lining both sides of the creek. The first spring I will describe is on the right bank of the creek, in the center of a white mound 20 feet in diameter and rising 10 feet above the bed of the creek. This mound is formed of the deposits from the water, which consist mainly of various carbonates and silica. The orifice of the spring is circular and about three inches in diameter and looks as though it had been artificially punched in the deposit, so mathematically exact is it. The water gives off carbonic-acid gas, leaving a deposit of iron. Its temperature was 190° F., the air being 70° F. Spring No. 2 is on the opposite side of the creek and has a basin measuring 4 feet by 2 feet; the temperature of the water was 160° F., the air remaining at 70° F. No. 3 has a circular basin two feet in diameter, which is lined with an abundant deposit of iron. Carbonic-acid gas bubbles through the water. Its temperature was 158° F. No. 4 is 6 feet deep and 1 foot by 3 feet in diameter, and has a temperature of 188° F. The next three springs had temperatures as follows: No. 5, 192° F.; No. 6, 194° F.; and No. 7, 188° F.; the air still remaining at 70° F. All these springs have circular orifices of about six inches diameter, and the water proceeding from them flows over a series of small terraces, resembling those of the Gardiner's River springs on a miniature scale. These basins are lined with a gelatinous form of silica, which has a leathery appearance and is coated with an iron deposit. The springs are about 10 feet above the level of the creek and all give off carbonic-acid gas. No. 8 is very irregular in shape and almost hid in the grass, about 40 feet from the creek. There is a slight bubbling in it and its temperature was 178° F. No. 9 is a small spring, 2 feet in diameter and 1 foot deep, lined with confervoidea and having a temperature of 140° F. No. 10 is a very pretty spring, about four feet above the creek, and has a beautiful scalloped edge, moss-lined on one side. Its temperature was 175° F. The boiling-point at this locality is 198° 3 F. None of the springs

reached this temperature, 194° F. being the nearest approach. The rocks exposed near these springs are sedimentary and contain a great deal of obsidian.

About three-fourths of a mile farther up-stream we came to the head of the creek and found that it originated in a most important group of springs. They are situated in a semicircular basin, bounded by a low hill wooded on the summit. The sides of this hill are perfectly bare and covered with glaring-white deposit, through which steam-jets force their way. Looking down into the basin from the top of the hill is like looking into a volcanic crater. The *fumaroles*, *solfataras* and mud-springs scattered through it give it a most peculiar appearance. The general color throughout the basin is a glaring white, relieved here and there by patches of brick-red iron deposits and the yellow of sulphur-masses that are scattered throughout the basin. The crust extending over the basin is lined with beautiful crystals of sulphur. On the left of this basin there is a ravine, covered with deposits of the same character but containing no springs. There are a few *fumaroles* remaining, the evidence that once the ravine was the site of active springs. A few yards on the opposite side of the basin there is a second ravine similar to the first, and in which also the springs are all dead, nothing remaining but the rust-colored deposits. I will give the different springs in this basin below in tabular form.

Springs at the head of Violet Creek.

August 10, 1872; time of observation, 12.30 a. m.; general elevation above sea-level, 8,059 feet; boiling-point, 198° 1 F.

No.	Character of spring.	Size.	Gas evolved.	Temperature of spring.	Temperature of air.
1	Siliceous	8 × 10 feet.....	Steam	185° F.	73° F.
2	do	3 feet diameter.....	do	172	72
3	do	2 feet diameter.....	do	194	72
4	do	do	do	194	72
5	Sulphur	20 feet diameter.....	Steam and sulphuretted hydrogen.	Not taken.	72
6	do	30 feet diameter.....	do	165	72
7	Mud-spring	2 × 4 feet.....	do	170	72
8	Sulphur	8 feet diameter.....	do	140	72
9	Blue-mud spring.....	6 × 10 feet.....	do	162	72
10	White-mud spring.....	1 × 3 feet.....	do	168	72
11	Blue-mud spring.....	3 feet long.....	do	188	72
12	Yellow-mud spring.....	4 feet diameter.....	do	180	72
13	Blue-mud spring.....	2 inches diameter.....	do	190	72

Besides the springs enumerated in the table there were many smaller ones and a few large pools through which the gases bubbled at various points. The ground near the majority of them was too treacherous to allow of our approach. There are also a great many steam-vents lined with sulphur-crystals. The hardened deposit about some of the mud-springs is an indurated clay, that has been deposited by the springs. The first four springs given in the table have clear water, and the first one was in violent ebullition, the water at times rising four feet above the ordinary surface. In No. 10 I found butterflies that had fallen into the water and been killed by the heat. The odor of sulphuretted hydrogen was not so strong at this locality as at the foot of Mount Washburne.

On the way back to camp we came across another group of springs, about a mile southeast of the group given above, and have an elevation about 200 feet lower. They are situated in a ravine bordering a small branch of Violet Creek. The following table will show them all at a glance:

Springs on branch of Violet Creek.

August 10, 1872; time, 2 p. m.; elevation above sea, 7,873 feet; boiling-point, 198°.5 F.

No.	Size.	Gas evolved.	Temperature of air.	Temperature of spring.
1	3 × 4 feet	Carbonic acid and steam.....	68° F.	160° F.
2	10 feet diameter	do	68	184
3	5 feet diameter	do	68	154
4	5 × 2 feet	do	68	188
5	3 feet diameter	do	68	180
6	5 × 3 feet	do	68	191
7	7 × 3 feet	do	68	186
8	3 feet diameter	do	68	192
9	8 × 1 feet	do	68	194

The amount of carbonic-acid gas given off from these springs is small, and, although there is considerable bubbling in some of the springs, it is caused mostly by the escape of steam. This in some is enough to cause the ground to tremble beneath. All the springs deposit iron. The first three springs given in the table are on the edge of a pool of water having a diameter of 100 feet by 50 feet, in which the thermometer stood at 120° F. There is also one spring in the midst of this pool which was beyond reach. The bottom of the pool is lined with gelatinous silica, which is coated with oxide of iron. The edge of the pool next the creek slopes to the level of the stream in a series of small basins over which the water flows. The creek itself is divided into a number of basins formed of the deposits, (mostly carbonates,) and the water flows from one basin to the other, they being at different levels. These basins are filled with a luxuriant growth of very bright green confervoides. The temperature of the water in the creek a short distance below the springs is 140° F.

The two groups of springs given above have never before been described, not being in our line of march last year. There are doubtless many more groups throughout the same valley that have never been studied yet, especially on the eastern side of the Yellowstone River, which here is not fordable, on account of quicksands.

The next group of springs to which I will refer is that at Crater Hills, near the Yellowstone River, about four miles below our camp. This place takes its name from the occurrence here of two high buttes or hills, one of which is 150 feet from top to base, and a second 140 feet. They are made up in part of a trachytic tuff and hot-spring deposits, the prevailing color of which is white, and a red, due to the weathering of the deposits, which contain iron. All of the springs are acidulous and contain sulphur as a prominent constituent. The principal spring is the boiling-sulphur spring near the base of the hills. The description of this spring was given in the report of last year, and I will not delay to redescribe it. I again took its temperature, which I found to be 178° F., the air being 58° F., at about 10 o'clock in the morning. The temperature given in last year's report is 183°.5 F., which was probably taken nearer the center of the spring than I was able to take it this year, the water being in violent agitation.

The next spring of importance is a large blue-mud spring near the large sulphur spring, the temperature of which (164° F.) this year varies only 1° from that taken last year, when it was 163° F. All the springs at this locality are noticeable, not only for the sulphur they contain, but also for their alum, which I take to be an iron alum. The small stream to which the springs give origin is a branch of Alum Creek, and in both the main creek and the branch the water is strongly astringent. A partial analysis of a piece of deposit from the edge of the boiling-sulphur spring, made by Mr. W. B. Platt, of the expedition, gives the following result:

	Per cent.
Water.....	23.48
Sulphur.....	3.23
Silica.....	.....
Sulphuric acid.....	.....
Chlorine.....	Trace.
Iron oxide.....	.....
Soda.....	.....
Magnesia.....	Trace.
Organic matter.....	.....
	26.71
	<u>26.71</u>
Specific gravity.....	1.800

The object of this analysis was to determine the percentage of sulphur. Silica is present in large amount.

The group of mud and sulphur springs just south of the two springs referred to above was mentioned in last year's report, but as the observations of this year are more complete, and include a large number of springs, I will present this group below.

Springs at Crater Hills.

General elevation above sea-level, 7,828 feet; boiling-point, 198° 2 F.

No.	Size of spring.	Temperature of spring.	Temperature of air.	Remarks.
1	A collection of springs covering an area of 600 square feet, and varying in size from one to three inches in diameter.	174° F.	50° F.	The water in this collection of springs has a milky hue, and the noise made by them resembles that made by a number of pots boiling simultaneously.
2		176	50	
3		182	50	
4		186	50	
5		144	50	
6		160	50	
7		168	50	
8		150	50	
9		160	50	
10	3 feet diameter.....	80	50	White-sulphur spring. Clear spring.
11	8 feet diameter.....	148	50	
12	.....	176	50	
13	2 feet diameter.....	180	50	Thick greenish-mud spring. Yellow-mud spring in active ebullition. A turbid pool bubbling at the edges.
14	8 × 2 feet.....	90	50	
15	.....	162	50	
16		166	50	A collection of greenish-sulphur springs, each a few inches in diameter.
17	.....	182	50	
18	.....	178	50	
19	.....	108	50	
20		180	50	This spring was called Foam Spring last year.
21	2 × 4 feet.....	170	50	
22	10 × 3 feet.....	188	50	Bluish muddy water. Both the sesprings have lavender-colored mud, and No. 2 is in active agitation.
23	2 feet diameter.....	180	50	
24	These springs occupy a space of about 1,200 square feet.	150	50	This collection of springs varies in size from a few inches to four feet. The water in the majority is of a milky hue. In others it is yellow or lavender colored, and in some it is transparent.
25		184	50	
26		130	50	
27		170	50	
28		168	50	
29		184	50	
30		106	50	
31		154	50	
32		188	50	
33		160	50	
34		130	50	
35		162	50	
36		174	50	
37		128	50	
38		120	50	
39		106	50	
40		176	50	
41		146	50	
42		186	50	
43		168	50	
44		174	50	
45		178	50	
46		172	50	
47		90	50	
48		158	50	
49		170	50	

Having completed observations on these springs, I devoted the remainder of my time to those near camp, which presented a great deal of interest. I was enabled to make more accurate observations than were made last year, and was greatly assisted by Mr. A. E. Brown, who determined the heights of the mud-geyser for me. The mud-geyser is the principal spring in the group at Mud Volcanoes, and was situated a few yards above our camp. It has a basin of about 60 feet diameter, surrounded by a rim that slopes inward, at an angle of 30° , to a funnel-shaped orifice in the center. This basin, which is the basin proper of the geyser, is made up principally of clay and silica, and is situated in another basin which measures 200 feet by 150 feet. The wall of this latter basin rises about 8 feet, on an average, above the level of the other basin, and between the two rims there is a deposit of clay which has been left by the water and has become hard, resembling a very fine clay slate. On one side of the outer basin there is a small ravine-like opening cut into the bank, through which water evidently flows sometimes, probably during the spring when there is more water in the basin. In several places on the banks I noticed small holes lined with sulphur from which the steam escapes. Besides the geyser there are two small springs at one end of the large basin. These springs are entirely independent of the geyser, and are constantly in action, bubbling quietly. They do not seem to be affected in the least by the eruptions of the geyser. The following is the description of an eruption: The water gradually rises until the inner basin is filled, when there is noticed a bubbling in the center. Suddenly, without any further warning, it becomes violently agitated and an immense mass of muddy water, mingled with clouds of steam, is thrown into the air. This action lasts a few minutes and is followed by a lull, the action not ceasing entirely. Then it recommences with renewed violence, and the water fills the entire outer basin, the water striking the banks in a succession of waves. The water is thrown up in a succession of impulses that follow each other rapidly, and sometimes the water is thrown obliquely and seems as though it would overwhelm one standing on the bank. The mass of water and mud is immense. After the maximum height is obtained the jets become smaller and smaller, and the eruption ends as suddenly as it began. It is a very impressive sight, and the stopping is like a calm after a storm. The water of the geyser is very muddy, and bluish in color, having an acid reaction, due to the presence of sulphuric acid.

I will transcribe my field-notes below and then give the result in tabular form, so that the whole may be placed before the eye at once.

August 11.

4.02 p. m.—The temperature of water in the basin is 140° F. and the air 50° F.

4.37 p. m.—The water is rising rapidly and there is considerable bubbling in the center of the basin, the temperature remaining the same.

4.42 p. m. to 4.52 p. m.—The water is still rising and flows in currents, giving it a variable temperature of 140° F. to 180° F.

5.02 p. m.—The temperature is still 180° F. at the edge, although in the center it must be considerably higher. It is still in ebullition.

5.04 p. m.—The eruption commences.

5.10 p. m.—There is a lull in the action.

5.14 p. m.—The maximum (40 feet) is attained.

5.17 p. m.—The eruption ends and the water at the edge of the basin has a temperature of 172° F.

5.52 p. m.—Temperature of water is 148° F. and the air 48° F. The water is four feet lower than it was during the eruption, and the sides of the basin are shown sloping inward. Several steam-vents, not seen before, are now made apparent. The surface of the water is quite placid, save in the center, where a slight bubbling takes place. The water seems to be rising slowly.

6.37 p. m.—The water has risen one foot since the last observation and is still rising.

7.37 p. m.—The water is now six inches above the level last observed.

9.35 p. m.—The eruption commences.

9.48 p. m.—The eruption ends. The maximum height was estimated at 20 feet, it being too dark to take any angles.

August 12.

6.19 a. m.—The geyser has evidently had an eruption during the night. The basin is full and the center in ebullition.

6.31 a. m.—The eruption commences.

6.35 a. m.—There is a lull.

6.42 a. m.—The eruption ends. The maximum height was 25 feet, and I noticed that the ground shook beneath me while the eruption was going on.

10.19 a. m.—The temperature of the water at the edge of the basin is 148° F. and the air is 60° F. The center is bubbling, and a black, oily substance floats on the surface.

10.29 a. m.—The temperature of the water is from 140° F. to 180° F., and it is rapidly filling the basin.

10.49 a. m.—The eruption commences.

10.55 a. m.—There is a lull.

10.58 a. m.—The maximum (18 feet) is attained.

11.02 a. m.—The eruption ends.

11.08 a. m.—The temperature at the edge of the basin is 170° F.; air, 60° F. The water has fallen a foot already.

11.15 a. m.—Water, 150° F.; air, 60° F. The water has fallen eighteen inches.

11.20 a. m.—The water has fallen five inches since the last measurement.

11.24 a. m. to 11.29 a. m.—The water still has a temperature of 150° F., and has fallen 2 feet 10 inches.

11.39 a. m.—The water has fallen 3 feet 2 inches since the eruption ceased, (lowest point.)

11.49 a. m.—The water is rising slowly.

2.39 p. m.—The water is within one foot of the top of the basin and bubbling in the center. Its temperature near the edge is 146° F., the air still being 60° F.

3.14 p. m.—Temperature outside the rim of the basin is 125° F.

3.15 p. m.—The eruption commences.

3.21 p. m.—There is a lull.

3.25 p. m.—The maximum (22 feet) is reached.

3.27 p. m.—The eruption ends. Temperature of water at edge of basin 170° F.

7.39 p. m.—The eruption commences.

7.44 p. m.—There is a lull.

7.48 p. m.—The maximum (19 feet) is reached.

7.51 p. m.—The eruption ends.

Mr. Sloane took observations of two eruptions on August 9, as follows:

12.40 p. m.—Eruption commences.

12.47 p. m.—Lull.

12.49 p. m.—Maximum estimated at 25 feet.

12.52.30. p. m.—Eruption ends.

4.58 p. m.—Eruption commences.

5.04 p. m.—Lull.

5.07 p. m.—Maximum estimated at 30 feet.

5.11 p. m.—Eruption ended.

The following table gives the result of these observations:

Date.	No. of eruption.	Length of eruption.	Interval between the eruptions.	Interval between commencement and lull.	Interval between lull and maximum.	Maximum height.
		<i>m. s.</i>	<i>h. m. s.</i>	<i>m.</i>	<i>m.</i>	<i>Feet.</i>
August 9.....	1st..	12 30		6	3	25
August 9.....	2d..	13 00	4 5 30	6	3	30
August 11.....	3d..	13 00		6	4	40
August 11.....	4th..	13 00	4 18 00			20
August 12.....	5th..	11 00		4		25
August 12.....	6th..	13 00	4 7 00	6	3	18
August 12.....	7th..	12 00	4 13 00	6	4	22
August 12.....	8th..	12 00	4 12 00	5	4	19

	<i>h.</i>	<i>m.</i>	<i>s.</i>
Average length of eruption.....	0	12	26.75
Average interval between eruptions.....	4	11	6
Average interval between commencement and lull.....		5	34.28
Average interval between lull and maximum.....		3	30

The remainder of the springs at Mud Volcanoes I will give in a table, as I did those of Crater Hills.

Last year, when at this locality, we noticed that the trees near the Giant's Caldron had their branches coated with mud, and the question was raised as to how the mud got there, we concluded that the geyser sometimes ejected its contents. This year, however, investigation seemed to prove that the mud is carried up mechanically, mixed with the steam that is constantly rising from the caldron, and that the spring never has any eruptions. We were led to this opinion first by noticing that it was only the under side of the branches that held the mud. Mr. Holmes then placed some dead branches in such a position that the steam came upon them and in a few hours they had a coating of mud. Again, some of the trees on which the branches are coated are living, which would hardly be the case had they received the mud from an eruption. Another reason also is found in the fact that the surface of the spring is constantly agitated, which is rarely or never the case with a true geyser. Still in the past it may have been a geyser and had regular eruptions.

Springs at Mud Volcanoes.

General elevation above sea-level, 7,775 feet; boiling-point 198° 5 F.

No.	Size of spring.	Temperature of spring.	Temperature of air.	Time of observation.	Remarks.
		° F.	° F.		
1	3 feet diameter.....	190	50	.....	Very thick mud spring.
2	10 feet diameter.....	163	50	} 3.35 p. m.	These springs are in the same basin with the mud-geyser but entirely distinct from it.
3	10 feet diameter.....	163	50		
4	6 feet diameter.....	126	48		
5	15 × 5 feet.....	156	48	5.00 p. m.	At head of ravine 250 yards above the mud-geyser.
6	75 feet diameter.....	134	58	11.20 a. m.	Thirty-five hundred feet from No. 4, in same ravine at the head. There are here some extinct basins and vents for stream.
7	3 feet diameter.....	136	58	11.23 a. m.	A large green-sulphur pool with many centers of ebullition, giving off sulphur, hydrogen.
8	12 × 20 feet.....	88	58	11.25 a. m.	Lavender-colored spring containing alum. Yellow-sulphur spring about fourteen feet from No. 7.
9	60 × 20 feet.....	140	58	11.30 a. m.	This group is in a ravine near the Giant's Caldron. No. 9 is on the edge of No. 8, and has clear water with confervoidea lining the stream.
10	2 feet diameter.....	124	58	11.30 a. m.	
11	3 × 1 feet.....	140	58	11.30 a. m.	
12	Grotto, 3 feet high, 8 feet wide, 20 feet deep.	182	58	11.45 a. m.	The grotto is an opening into a sandstone rock at the head of a small ravine. The top of the entrance resembles a gothic arch coated with moss and iron. Steam escapes in pulsations.
13	30 × 15 feet.....	94	58	11.46 a. m.	A greenish alum pool.
14	2 feet diameter.....	180	58	11.48 a. m.	A pool a few feet above No. 13.
15	20 feet diameter.....	163	58	11.50 a. m.	Light-gray mud spring 10 feet deep. There are others too deep to get temperature.
16	Pool, 500 × 60 feet.....	92	58	11.50 a. m.	Sulphur springs.
17	Small holes, 1 inch diameter.	148	58	11.51 a. m.	
18		172	58	11.52 a. m.	
19	.....	182	58	11.55 a. m.	Mud spring.

CHAPTER IV.

GEYSER-BASINS OF FIRE-HOLE RIVER.

We left Mud Volcanoes on the 13th of August and started for the lower geyser-basin of Fire-Hole River. Our course at first led us up an open valley that once formed part of the ancient bed of Yellowstone Lake. At the head of the valley we struck our old trail of last year, which we followed until we reached the east fork of the Fire-Hole River. The divide between the Yellowstone River and the Fire-Hole River at this point is 8,164 feet above sea-level. The summit seems to be made up mostly of obsidian, which is all porphyritic. The timber is so thick that it is difficult to trace the connection, but, as we descend, we come across trachytes that seem to underlie the obsidian. It is very compact and porphyritic, containing crystals of sanidine. The general color is a light blue, approaching violet. It is through these trachytes that the headwaters of the Madison cut their channels. Near the summit, on the Madison side of the divide, there is an old hot-spring basin in which the springs are now extinct, although there are a great many steam-vents from which steam still escapes; these vents are lined with sulphur. Besides sulphur the deposits consist mainly of silica and iron. The descent from the divide is very steep and rocky, and through thick timber, a great deal of which is dead and fallen. The valley of the east fork of the Madison or Fire-Hole at the point we reached it is very

marshy and full of springs, which cause the water in the stream to have a temperature of some degrees more warmth than the air. We followed the river to within some four miles of the lower geyser-basin, and camped at a level some 867 feet lower than the divide and 452 feet lower than our camp (No. 12) at Mud Volcanoes, having traveled nineteen miles. Some of the party who had preceded us a day came into camp in the evening and reported that they had met the advance-party of the Snake River division of the expedition, under Mr. Stevenson, so the following morning we moved down into the lower basin, and in the evening found that the main body of the Snake River division were encamped within a mile of us, having got in about the same time we did. The next day they moved their camp and joined us.

On the way from camp we passed a number of unimportant springs, which I will incorporate in the catalogue appended to my report. I shall devote but little space to the springs of the lower geyser-basin, as they were referred to at length in the report last year. During the three days and a half that I was in the lower geyser-basin this year, I was occupied most of the time in packing specimens to be sent to Virginia City, so that I was able to visit but one group of springs. As this, however, is a typical group, I will insert the description. They are situated just south of camp in an open space bounded on two sides by timber, while the front looks out into the main open basin. They occupy a space of a little over 3,000 square yards. The springs are as follows:

Gourd Spring.—This spring was named from its shape. It is in the center of a large, circular mound of siliceous material, and is 15 feet long by 10 feet wide and 12 feet in depth. The bed of the small stream, carrying away the overflow from the spring is coated with iron, and a short distance below we find the gelatinous material that we see in so many of the springs that have a low temperature. The temperature of the water in the spring was 171° F.; air, 62° F., at 9 a. m.

Thud Spring.—This spring is 375 feet southwest from the Gourd, and measures 18 feet by 16 feet. The depth varies from 8 to 13 feet. This of course refers only to the basin of the spring, as at the bottom there are orifices the depth of which cannot be ascertained by the line. There seem to be three centers of ebullition, two of which are very active. At intervals of a few minutes there seems to be an accumulation of steam, the escape of which shakes the ground, making a thud-like noise, whence its name. On looking into this spring the water seems to have an ink-green color, and had a temperature of 192° F.; air, 62° F., at 9.30 a. m.

Oak Leaf Spring.—This spring is 345 feet north of the spring next described. The deposit about it has a gray color, and the margin of the spring has the appearance of being fringed with oak-leaves. The spring is about 6 feet in diameter and 15 feet deep. The water appears of a greenish color and has a temperature of 194° F.; air, 64° F., at 10.35 a. m. About 7 feet from this spring there is a small cone of 2 feet diameter, rising five inches above the surrounding level. The temperature of the water in this cone was 190° F.

Fungoid Spring.—This spring is 140 feet west of the Thud Spring, and 345 feet south of the spring described above. The basin of this spring measures 13 feet by 17 feet and averages 6 inches in depth. The deposit is pure-white siliceous sinter, giving it the appearance of a marble basin. In the center of this basin there is another 5 feet in diameter and 7 feet deep. Here the water has a greenish tinge, which forms a pretty contrast with the white rim outside. The spring has a margin of the siliceous material that resembles a row of fungoid growths on short pedestals. There are two small streams proceeding from the spring, which

are lined with orange-colored deposit. Surrounding the spring, there is a large amount of siliceous sinter, forming a mound, as is the case with the other springs of the group. The temperature of the water in the spring is 162° F.; air, 64° F., at 11.05 a. m. Near the spring there are two small holes, in which the water is at 190° F. and 180° F.

Kidney Spring.—This spring is very irregular in shape, and consists of two arms that are almost at right angles to each other. The length one way is 19 feet and the other 15 feet, the average width being about 6 feet. The depth is about 1 foot. The spring is fringed with large scallops, each one of which is made up of smaller scallops. There are three fissure-like centers of ebullition in which the thermometer records 184° F., 190° F., 184° F.; air at 64° F. at 11.10 a. m. The spring is 180 feet northwest of the Oak Leaf.

Cliff Spring.—This spring is 240 feet southeast of the spring last described and 122 feet east of the Oak Leaf. It measures 4 feet by 8 feet and is 5 feet in depth. The deepest portion is at one end of the spring, where there is a cavernous opening, overhung by a scalloped edge. The water here is of a light-green color. At the other end there is a rugged fissure, to which the edge of the spring slopes from the surface, having the form in miniature of cliffs. These, above the water, have a brown color and below a deep purple. The temperature of the water is from 192° F. to 195° F.; air, 64° F., at 11.45 a. m. The overflow of water finds its way from the spring over an orange-colored bed.

Jug Spring is 123 feet southeast of the *Cliff* and 150 feet east of the *Oak Leaf*. It measures 4 feet by 5 feet and is 3 feet deep. Its temperature was 188° F.; air, 64° F., at 12.09 p. m.

Stirrup Spring is 8 feet by 9 feet and 5 feet deep. There are two holes in the bottom of this spring from which the steam escapes, and a fissure also, which makes the spring resemble the head of an old woman with a cap on, the scalloped edge of the spring representing the ruffles of the cap and the fissure the mouth, while the other steam-vents represent the eyes. The temperature of the water was 188° F.; air, 64° F., at 12.35 p. m. There are two small holes near this spring in which the thermometer records 182° F.

Lone Spring.—This spring is some distance northeast of the other springs of the group, and is on the side of a hill some 40 feet higher. It is $4\frac{1}{2}$ feet in depth and measures 9 feet by 16 feet. Its temperature at 8.30 a. m. was 186° F., the air being 62° F.

The general elevation of the group just described is 7,162 feet above sea-level, the boiling-point being about $199^{\circ}.3$ F. All the springs are somewhat globular in shape, widening below the surface, having overhanging edges, and narrowing below to fissures or tube-like orifices. They all belong to the class of springs that are constantly agitated, and, although this agitation is greater at some times than at others, I doubt if any of the springs in the group ever project a column of water into the air.

The area of the lower geyser-basin is about thirty square miles, and although it contains a far larger number of springs than the upper basin, there are not so many true geysers, and the water is not thrown as high into the air as in the upper basin. The geysers of the lower basin that have been seen to spout 30 feet or upwards are the "Great Fountain," "The Fountain," the "Steady Geyser," "The Jet," and two small geysers not named, which are a few yards below the Fountain. Having had no time while in the lower basin to visit these geysers, I will here insert the following excellent description, kindly furnished me by Mr. Holmes, artist to the survey:

During our somewhat protracted stay in the lower basin, I found time to observe pretty carefully all the geysers of any considerable importance. Among the six or eight which throw columns of water to the height, say, of 30 feet, there is only one that possesses the dignity and grandeur of the great geysers of the upper basin. Although, in some respects, it is much inferior to its more popular rivals, in others it is certainly superior. In approaching the crater of this geyser the observer is not at first impressed with its importance, as the outer rim of the basin or rather table—in the center of which the fissure is situated—is raised but two or three feet above the general level. This elevated part I should estimate to be upwards of 120 feet in diameter, and, with the exception of the crater, it is built up nearly to a level with the border. The surface, formed entirely of siliceous deposit, is diversified by an infinite number of forms and colors. The depressed parts in some places are so level and white and hard that a name could be engraved as easily and as well as upon the bark of a beech-tree. In others there are most exquisitely modeled basins and pockets, with ornamented rims and filled with perfectly transparent water, through which thousands of white pebbles of geyserite could be seen lying in the white, velvety bottoms. Rising above the general level are innumerable little masses and nodes of cauliflower-like and beaded silica, standing out of the shallow water like so many islands. Those near the crater swell into very large rounded masses. The whole surface is so solid that I walked, by stepping from one elevation to another, up to the very brink of the fissure, where I looked down with no little apprehension into the seething caldron, where, 12 or 15 feet below, was a mass of dark-green water in a state of constant agitation, threatening an eruption. The crater is about 10 feet in diameter, lined with an irregular coating of beaded silica. The water soon began to rise, plunging from side to side in great surges, sending up masses of steam and emitting angry, rumbling sounds. This demonstration caused a precipitate retreat, on my part, to the border of the basin, thinking that I could appreciate the beauties of a scalding shower-bath better from that point of view.

An irregular mass of water was thrown into the air in the utmost confusion, spreading out at every angle and whirling in every direction, some jets rising vertically to the height of 60 or 80 feet, then separating into large glistening drops and falling back into the whirling mass of water and steam; others shooting at an angle of 45° and falling upon the islands and pools 30 or 40 feet from the base. The eruptive force, for a moment, dies away and the water sinks back into the tube. Then, with another tremendous effort, a second body of water is driven into the air, but with a motion so much more simple than before that the whole mass assumes a more regular form and is like a great fountain with a thousand jets, describing curves almost equal on all sides and forming a symmetrical whole more varied and more grand than any similar work by man. The intermittent action continues for nearly an hour, but is so constantly changing that at no two moments during that time are the forms or movements the same. The eruptions are repeated at irregular intervals of a few hours and are not known to vary essentially from the manner of action here described; yet I have good reason to believe that at certain times there is a much greater exhibition of power. It must be borne in mind that all the elevations, such as the tubes, rims, and mounds about the crater of a geyser, are built by the evaporation of the water, and the portion of surface covered by the beaded silica indicates precisely the area over which the erupted water falls. In no case did I observe the water fall outside of a circle of 60 feet in diameter, and the additional force necessary to scatter it over twice that amount of surface must produce a display truly magnificent. That this display actually occurs is attested by one of our mountaineers and almost demonstrated by the extent of the beaded surface. During the earlier part of the eruption a considerable quantity of water flows over the rim and down the sides, where it has formed a series of basins somewhat similar in form and color to those at the springs on Gardiner's River. Falling from one to another of these it passes off down the slope and joins a large stream of hot water which issues from a steady spring not far away.

A few hundred yards farther up the ravine, and on the opposite side of the creek, I discovered a small spring that deserves in a quiet way to be one of the great attractions of this attractive region. It is isolated from the neighboring springs and nestled in against an abrupt bank, so obscured by tall pines that the visitor is liable to pass it by unnoticed. In approaching from the creek I passed up a gradually ascending slope down which the water flows, covering in its meanderings more than an acre of ground and leaving, wherever it touches, brilliant streams of color. About a hundred yards from the creek I came upon the spring, the waters of which stand nearly on a level with the surrounding surface. Approaching the border I looked down into the blue, mysterious depth and watched the large bubbles of steam slowly rising to the surface and passing off into the air. The larger of these bubbles would lift up a considerable quantity of water sometimes to the height of 3 or 4 feet, producing a kind of spasmodic boiling and dashing a succession of waves against the rim. The spring is surrounded by an irregular rim which stands a few inches above the general level of the water. The basin is 20 feet long and 10 feet wide, one end being narrower and partially separated from the main basin by an irregular row of beaded islands and projections.

Although the spring and basin are very chaste and delicate in form as well as color, there are other springs more beautiful in those respects. But when I ascended the bank and looked down upon the spring and its surroundings, I concluded, without the least hesitation, that I had never seen anything so uniquely beautiful. On the upper side of the spring, next to the bank, the water in overflowing ran into large shallow pools, painting whatever it touched with the colors of the rainbow. Beds of rich, creamy white and rich yellows were interlaid with patches of siennas and purples, and divided up and surrounded by the most fantastic patterns of delicate grays and rich browns. On the side next to the creek the running water has made a net-work of streams. In those where the water is still hot, the colors are bright, varying from a creamy white to the brightest yellows, but, as the water becomes cooler, farther down, the colors grow darker and richer, the siennas greatly predominating, while the basins of the larger pools are stained with still darker colors, frequently of a purple tint and reflecting the picturesque groups of pines on their dark surfaces. Scattered irregularly over the whole surface are numberless little areas of dry deposit, from which the brighter tints have faded but which still retain such a great variety of purple and blue grays that the harmony of the whole field of color is complete.

Mr. Holmes, in his description of the Great Fountain, refers to the pebbles of geyserite in the pocket-like depressions surrounding it. These pebbles vary in size from that of a pea to two or three inches in diameter. They are made up of concentric layers. The following analysis which I have made will give their composition:

	Per cent.
Loss at 100° C.....	3.75
Loss on ignition.....	5.25
Silica.....	88.60
Alumina and iron.....	1.60
Lime.....	0.95
Magnesia.....	Trace.
Soda*.....	Trace.
Potash*.....	Trace.
Lithia*.....	Trace.
	100.15

Farther up the ravine, at the mouth of which this geyser is situated, is a group of springs around which the deposit, instead of being white, as in the case of other springs, is black. These springs were referred to in the report of 1871, page 184. I have made an analysis of this deposit and find it to consist as follows:

	Per cent.
Loss at 110° C:.....	2.66
Loss on ignition.....	6.33
Silica.....	82.80
Alumina.....	5.64
Iron.....	1.49
Lime.....	2.13
Magnesia.....	Trace.
Soda*.....	Trace.
Potash*.....	Trace.
Manganese*.....	Trace.
	101.05

The color of the specimen I believe to be due to the large amount of organic matter included in the above analysis under the loss by ignition.

There was one quite large group of springs in the lower basin, during the summer, which escaped our notice during the season of 1871. For a

* By spectroscopic examination.

full description of it I refer to Professor Bradley's report. A specimen from this group was handed to me for analysis. Composition, irregular; color, rusty brown; fracture, conchoidal; luster, vitreous; hardness, 5.5-6.

Analysis.

	Per cent.
Loss at 110° C.....	4.00
Loss on ignition.....	5.75
Silica.....	85.85
Iron and alumina.....	1.94
Lime.....	1.85
Magnesia.....	0.30
Soda*.....	Trace.
Potassa*.....	Trace.
Lithia*.....	Trace.
	99.69

The Fountain Geyser is the second in importance in the lower basin, and is centrally situated. It is on a slight eminence, and from it the deposit slopes gradually toward the river, studded with innumerable springs. This geyser was fully described in the report for 1871, so I will pass it by here. Back of the Fountain are the Mud Puffs, which were also fully described last year. I wish to insert here an analysis, by Dr. Endlich, of a pink mud from this locality. A portion of the silica is doubtless combined with some of the alumina as a silicate.

Analysis.

	Per cent.
Loss on ignition.....	8.65
Silica.....	44.61
Alumina.....	45.09
Magnesia.....	2.66
Ferric oxide.....	1.86
Lime.....	Trace.
Soda*.....	Trace.
	102.87

Between the Fountain Geyser and the Mud Puffs, we find pieces of wood coated with geyserite, which assumed a beaded form, sometimes branching like certain forms of coral. Most of the specimens are translucent and have a vitreous luster. The color is generally a light pink. An analysis made by me of this form of geyserite gives the following result:

Analysis.

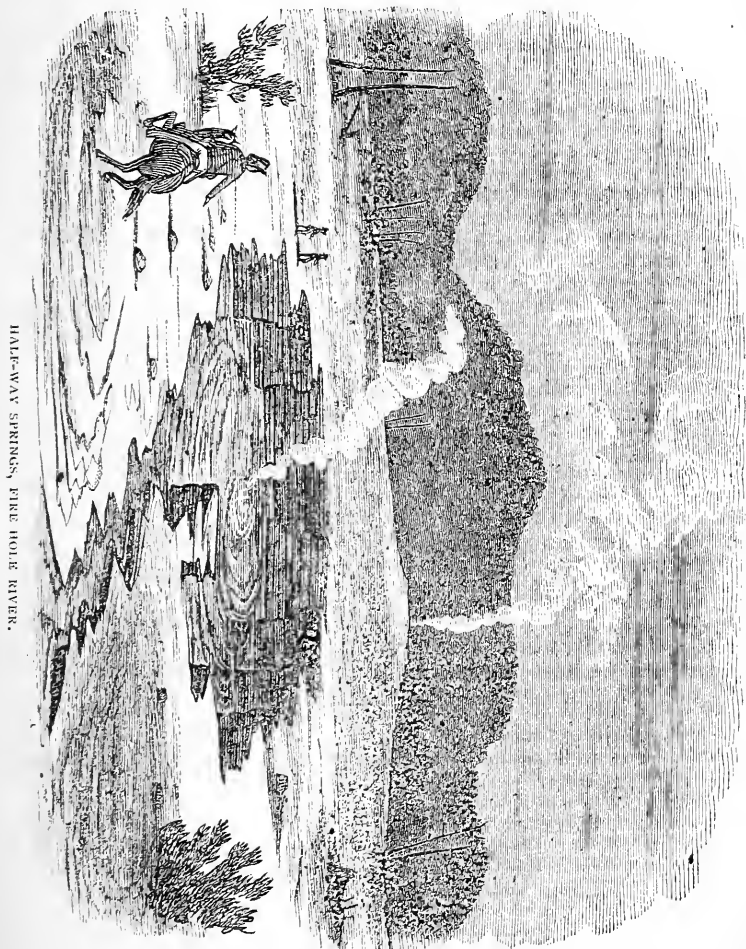
	Per cent.
Water.....	10.40
Silica.....	88.48
Alumina and iron.....	.88
Lime.....	.18
Magnesia.....	Trace.
Soda*.....	Trace.
Potassa*.....	Trace.
Lithia*.....	Trace.
	99.94

Wood may be found in various stages of silicification, and if the problem can ever be solved as to the process of silicification, I think a sojourn in the geyser-basins of Fire-Hole River will be of the highest importance

* By spectroscopic examination.

in assisting us to conclusions upon the subject. My space here is too limited to do more than refer to it.

The area of the lower geyser-basin is about thirty square miles, and the valley seems to be underlaid by a sedimentary, probably Post-pliocene, formation of which part is composed of broken bits of geyserite. The highest temperature that was recorded is 198° F., but there is no doubt that many of the springs are at the boiling-point, ($199^{\circ}.5$ F.,) it being impossible to determine it on account of the spouting of the water. The general elevation of the lower basin above sea-level is 7,275 feet.



HALF-WAY SPRINGS, FIRE-HOLE RIVER.

Fig. 36 a.

At the lower end of the basin the Fire-Hole River is joined by Fairy Fall Creek, at the head of which there is a beautiful fall called the Fairy Fall. This fall is 250 feet high, and the water falls into a beautiful basin at the foot of a cliff. From the mouth of this creek to the mouth of Iron Spring Creek, at the lower end of the upper geyser-basin, the distance is five and a half miles in a bee-line. Between the two there is a large group of springs that can be included in neither, and to which we gave the name of the Half-Way Springs; their general elevation is 7,296 feet. These springs were described at length in the report for 1871. The illustration (Fig. 36a) by Mr. Elliot shows one of the princi-

pal springs in the group. The peculiar lamination of the deposit at the edges is well shown. The elevation at the lower end of the upper basin is 7,321 feet, and at Old Faithful, at the upper end, 7,397 feet.

On the morning of August 17 all the specimens were sent to Virginia City by pack-train, and in the afternoon, in company with Messrs. Brown, Sloane, and Bingham, I proceeded to the upper basin to make observations on its principal geysers. These are named as follows: Old Faithful, Bee-Hive, Giantess, Castle, Grand, Turban, Saw-Mill, Giant, Grotto, the Riverside, the Fan, and the Soda Geyser. All of these, save the Giant and the Fan, were seen in action this year. Our stay being but three days in length necessarily renders the observations somewhat incomplete. There is but little doubt that a longer stay would develop many new geysers. We spent one day at Old Faithful, as it spouts more frequently than any of the others, and is also at the head of the valley, making a good starting-point. I will refer to them all separately below.

Old Faithful.—The mouth of this geyser slopes inward, measuring outside 8 feet by 4 feet and inside 6 feet by 2 feet. It is in a mound of geyserite that rises 11 feet 11 inches above the surrounding level, and measures at the base 145 feet by 215 feet and at the top 54 feet by 20 feet. The mound is arranged in a series of small basins, rising one above the other, in which the water, beautifully clear, stands after the eruptions. The edges of these basins, as well as the throat of the geyser-tube, are ornamented with bead-like silica. We tried to sound the depth of the geyser-tube, and after letting out the entire length of rope, 360 feet, and withdrawing it, we found the end completely tangled, which was the case in every attempt. It was impossible to get the temperature of the water, for immediately after the eruption the water sank out of sight, and at other times there was so much steam escaping that we could not even look into the tube. There are four conical mounds about Old Faithful that were probably geysers at some time in the past. The eruptions of the geyser commence with a few abortive attempts, followed by a rapid succession of jets, which soon reach the maximum, and then gradually subside and are followed by a slight escape of steam. We measured a base-line of 100 feet, and Mr. Brown was able to get the heights of five eruptions, although there were altogether seventeen witnessed during our stay, as follows:

No. of eruption.	Date.	Eruption began.	Eruption ended.	Time of maximum height.	Maximum height.	Average height.	Length of eruptions.	Intervals between eruptions.	Interval between commencement and maximum.
		<i>h. m. s.</i>	<i>h. m. s.</i>	<i>h. m. s.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>m.</i>	<i>h. m. s.</i>	<i>s.</i>
1	Aug. 17	3 22 00 p. m.	3 27 00 p. m.	.....	.....	.....	5	.....	.....
2	Aug. 18	7 27 30 a. m.	7 32 30 a. m.	.....	.....	.....	5	.....	.....
3	Aug. 18	8 35 30 a. m.	8 40 30 a. m.	.....	.....	.....	5	1 03 00	.....
4	Aug. 18	9 40 30 a. m.	9 46 30 a. m.	.....	.....	.....	6	.....	.....
5	Aug. 18	10 46 26 a. m.	10 51 13 a. m.	10 46 27 a. m.	106	49.4	4.47	59 56	1
6	Aug. 18	11 54 31 a. m.	11 59 10 a. m.	12 55 00 a. m.	130.3	45.0	4.39	1 03 18	29
7	Aug. 18	1 05 05 p. m.	1 09 46 p. m.	1 5 30 a. m.	125.5	52.2	4.41	1 05 55	15
8	Aug. 18	2 15 25 p. m.	2 20 15 p. m.	2 15 46 a. m.	125.5	49.9	4.50	1 05 39	21
9	Aug. 18	3 23 51 p. m.	3 28 22 p. m.	3 24 10 a. m.	120.8	31.9	4.31	1 03 36	19
10	Aug. 18	4 33 22 p. m.	4 38 22 p. m.	.....	.....	.....	5	1 05 00	.....
11	Aug. 18	5 41 00 p. m.	5 46 00 p. m.	.....	.....	.....	5	1 02 38	.....
12	Aug. 18	6 42 30 p. m.	.....	.....	.....	.....	4.45	.....	.....
13	Aug. 18	7 44 30 p. m.	.....	.....	.....	.....	4.50	.....	.....
14	Aug. 18	8 51 00 p. m.	.....	.....	.....	.....	4.20	.....	.....
15	Aug. 19	10 7 00 a. m.	10 11 45 a. m.	.....	.....	.....	.....	.....	.....
16	Aug. 19	11 12 30 a. m.	11 17 20 a. m.	.....	.....	.....	.....	1 00 45	.....
17	Aug. 20	11 54 00 a. m.	11 58 20 a. m.	.....	.....	.....	.....	.....	.....

The Bee Hive is on the opposite side of the river from Old Faithful, and about 300 yards distant in a northwesterly direction. It is on the bank of the river and recognizable at once by its cone, which is 3 feet in height and almost circular, measuring 3 feet by 4 feet at the top and 20 feet in circumference at the base. It is coated with beautifully beaded formations which, in some places, have a pearly aspect. The orifice at the top of the cone measures 3 feet by 2 feet, and the line dropped into the tube reaches a depth of 21 feet. The eruptions are very fine, and peculiar to this geyser. The water and steam escape from the orifice with great force in a steady stream. The average of the height of the column, which is fan-shaped, is very high, and, what is the curious, no water falls from it, but it seems to be entirely resolved into spray, which evaporates as soon as formed. Three eruptions were witnessed, but all from a distance, and we were able to get the height of but one, which was over 100 feet.

The following table gives the eruptions we saw:

No.	Date.	Eruption began.	Eruption ended.	Length of eruption.	Interval.
		<i>h. m.</i>	<i>h. m. s.</i>	<i>m. s.</i>	<i>h. m.</i>
1	August 18.....	1 39 p. m.	1 44 00 p. m.	5 00	.....
2	August 19.....	3 2 p. m.	3 17 00 p. m.	15 00	25 18
3	August 20.....	12 34 p. m.	12 38 30 p. m.	4 30	21 17

The duration and interval are both seen to vary, although a greater number of observations are necessary to deduce any conclusions, as there may be as it were a sort of regular irregularity.

Giantess.—This geyser is on the same side of the river as the Bee-Hive and only 200 yards from it. It has a large basin, measuring $23\frac{1}{2}$ feet by $32\frac{1}{2}$ feet, in which the water is 63 feet deep and appears of a green color. When I took its temperature, two days after the eruption, the water was level with the rim and perfectly quiet, the mercury recording 192° F.; air, 56° F., at 11.50 a. m. The only time we observed it in action was on the evening of August 18. The eruption commenced at 6.56.30 p. m., and lasted 17 minutes, starting again at 7.43.30 p. m. This lasted about the same length of time; at 8.48.30 p. m. it was followed by a third. The maximum height of the water was 39 feet; average, 30 feet; the steam reaching a height of 69 feet. The angles for height were taken from the end of a base-line 200 feet in length. There was an immense mass of water thrown up which surged and splashed in all directions, with seventy-three pulsations per minute. After the eruption the water sank 20 feet in the basin.

Around the Bee-Hive and Giantess there is a group of springs in which I took ten temperatures, ranging from 118° F. to 196° F., the average being $173^{\circ}.6$ F. Among them are a number of cones, which are probably geysers spouting at long intervals, although none of them were seen in action. On one of these I saw the bodies of about a dozen mice, that had the appearance of having been scalded to death.

Castle Geyser is farther down the river, 430 yards from the Giantess, on the opposite side. It has one of the most noticeable craters that is found in the basin. The cone is on a platform measuring 75 by 100 feet and 3 feet in height. Above this platform it rises 11 feet 11 inches. It is 120 feet in circumference at the base and 20 feet diameter

on top. The orifice of the geyser-tube is circular and 3 feet in diameter, and its throat is lined with large globular masses, of an orange-color, and beautifully beaded, as is seen so universally throughout both geyser-basins. An eruption is as follows: It commences with a succession of jets of water, in number about twenty per minute, which rise to various heights. These last about fifteen minutes and are succeeded by steam, mingled with spray, which escapes with a sort of pulsating movement. This soon changes to a steady escape. It seems as though the water were exhausted and the steam was being forced out as rapidly as possible. This again changes, and the steam escapes in cloud-like masses with a roaring sound, like the escape of steam from some vast escape-pipe, which in reality it is. This gradually dies away and the eruption is ended, having lasted about an hour and twenty minutes. We witnessed one full eruption and parts of two others, as follows:

First eruption, August 18.—Maximum height, 34 feet; mean height, 21 feet.

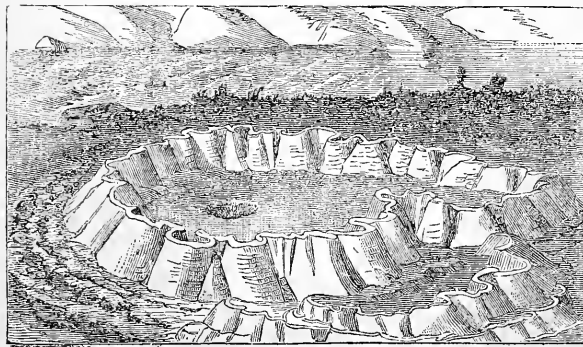
Second eruption, August 19.—10.30 a. m., commencement; 10.6.40 a. m., maximum of water-period, height 93 feet; 10.18 a. m., maximum of steam, height 115 feet; 11.25 a. m., end of eruption.

Mean height of water, 57 feet; of steam, 81 feet.

Third eruption, August 20.—7.24 a. m., eruption began; 7.40.20 a. m., eruption ended.

We did not see the beginning of the first eruption, and did not, therefore, wait until it was over. The angles for height were taken from the end of a base-line of 100 feet, measured from the center of the orifice, and the heights are above the end of the base-line. The third was witnessed from a distance, and the height was not ascertained. At the base of the Castle there is a spring, measuring 12 feet by 7 feet, which bubbles intermittently. The water was at the boiling-point, (199°;) air, 64° F., at 11.35 a. m. Twelve feet from this there is a second spring of the same character, measuring 6 feet by 3 feet and having a temperature of 192° F. The bed of the stream flowing from these springs is coated with bright-red oxide of iron. The water in these springs rose and fell repeatedly during the eruption of the Castle. While steam mingled with spray escaped from the Castle the water

Fig. 37.



RIM ABOUT A GEYSER-TUBE, UPPER FIRE-HOLE.

was out of sight in these springs, and when steam alone escaped they were active, spurting to the height of 3 feet. The principal spring near the Castle is a large blue spring, almost circular in shape, measuring 19 by 21 feet. It has a most regular and beautiful scalloped edge, and looks as though it were lined with white marble. This white basin slopes to a large funnel-shaped orifice, which is on the side next the Castle. This is 40 feet deep. The surface of the water is placid and appears of a most intense blue, especially over the orifice. The temperature of the water was 180° F.; air, 58° F., at 9.08 a. m. Fig. 37 is an illustration of one of the springs near the Castle, showing the ap-

pearance of the crater when the water has receded into the tube. A few hundred yards south of the Castle, separated from it by a small belt of timber, there is a group of quiet springs, ranging in temperature from 100° F. to 196° F., the average being 171°·3 F. A number of them are mud-springs, and it is the only place in the upper basin where I noticed any sulphur. The analysis of a specimen of blue clay from one of these springs, by Dr. Endlich, gives the following result :

	Per cent.
Loss by ignition.....	15.15
Silica.....	50.70
Alumina.....	20.27
Ferric oxide.....	3.25
Magnesia.....	11.55
Lime.....	Trace.
Sulphuric acid.....	Trace.
Chlorine.....	Trace.
	100.92

Grand Geyser is 460 yards from the Castle, across the river. It is situated at the base of a small hill, and, unlike the majority of the geysers, has no raised cone, but only a basin sunk below the general level. One would scarcely take it to be an important geyser, unless he witnessed one of its eruptions. The basin is 52 feet in diameter and 1 foot in depth. In the center is the mouth of the geyser-tube, measuring 4 feet by 2 feet. The depth was not ascertained. All the eruptions we saw took place early in the morning, and we were unable to get the height of but one, and in order to do this we camped immediately in front of it and kept guard by turns through the night. It did not spout, however, until daylight, but we succeeded in ascertaining the exact height of the column. The eruptions are as follows :

First eruption, August 18.—5.20 a. m., eruption began; 5.35 a. m., eruption ended.

Second eruption, August 19.—3.35 a. m., eruption began; 4.12 a. m., eruption ended.

Third eruption, August 20.—6.33 a. m., eruption began; 6.36 a. m., eruption suspended; maximum height, 122 feet; mean, 79 feet. 6.42 a. m., eruption began again; 6.46 a. m., eruption suspended; maximum height, 173 feet; mean, 149 feet. 6.56 a. m., action recommenced. 7.5 a. m., eruption ended; maximum height, 84 feet; mean, 53 feet.

As is shown above the eruption consists of three distinct periods of action, after each one of which the water sank completely out of sight, and water overflowed from the Turban, which is in close proximity, into the tube of the Grand. The water during the eruption is carried up in a succession of jets, the main mass of water being large. Through this a column will shoot at intervals to the greatest height. The shape of the entire column is, therefore, pyramidal, broad at the base and tapering to a point. Immense clouds of steam accompany the water, and the latter in falling back shakes the ground. The third eruption was not as high as some that were not measured. The height must sometimes exceed 200 feet. The interval between the first and second eruptions was 22 hours, and between the second and third 26 hours and 21 minutes. During the third eruption there were at first 73 pulsations per minute, which afterward were reduced to 71.

Turban Geyser.—Although this is one of the minor geysers of the upper basin, it has, perhaps, one of the most uniquely beautiful craters. It spouts very frequently, but as all our time was occupied with the more important ones, we ascertained the height of but one eruption and

obtained no data as to the interval. The crater is only a few feet from the Grand Geyser, above which it rises about 3 feet. It is 23 feet long and 11 feet wide and 6 feet in depth. The sides and bottom of this large basin are covered with globular masses that look like large squashes or pumpkins. (Fig. 38.) This resemblance is increased by their yellow

Fig. 38.



GLOBULAR MASSES IN THE CRATER OF THE TURBAN GEYSER.

color. We thought of naming it the Pumpkin Geyser, but, as the name Turban is perhaps more euphonious and some of the masses are turban-shaped, we called it the Turban Geyser.

The orifice through which the water rises is situated at one end of the basin and is irregular in shape, measuring 4 feet by 3 feet. After the

eruptions the water sinks into the tube very rapidly, leaving the entire basin empty. Preceding the eruption the basin fills, and the mass of water is so great that it cannot be projected to any great height. It is violently agitated and the escaping steam splashes it about in all directions.

The following is the eruption we witnessed :

August 20.—7.5.30 a. m. eruption began ; 7.5.45 a. m. eruption ended. Maximum height, 25 feet ; mean height, 19 feet.

Saw-Mill Geyser.—This also is one of the smaller geysers as well as one of the prettiest in the basin. The mass of water thrown up is not very great in quantity and is so broken into spray that it presents a most delicate fountain-like stream. I saw but one eruption closely, and before I had time to ascertain the height of the column, the Grand Geyser, which is quite near, began to spout, and I was obliged to leave the Saw-Mill. During its eruption there are noticed four distinct periods of action per minute, each one made up of fifteen impulses. The main body of water is carried up about 5 feet and then at intervals a stream is suddenly shot through this mass to the height of about 15 or 20 feet. I stood between the geyser and the sun, and on one side of the column there was the half-arch of a rainbow.

Giant Geyser.—This geyser was not seen in action by any member of the expedition this year, although last year it was one of the most active in the group. It is 500 yards northwest from the Grand Geyser, on the opposite side of the river, near the water's edge. It has a rough cone-like crater, 10 feet in height, measuring 24 by 25 feet at the base. The top is about 8 feet in diameter, the orifice from which the water is projected being about 5 feet in diameter. This cone is situated on a platform of geyserite, which rises 4 feet above the surrounding level and has a circumference of 342 yards. The sounding-line reached a depth of 25 feet in this cone. On the same platform there is a second cone, or rather a mound, 232 feet in diameter and 6 feet high, which has two orifices from which water spouts to the height of 12 to 15 feet at irregular intervals. The first orifice measures 6 feet by $2\frac{1}{2}$ feet, and at the bottom there are two holes from which the water is projected simultaneously. The greatest depth which the line reaches here is $17\frac{1}{2}$ feet.

Orifice No. 2 is 3 feet above the first. It is 1 foot in diameter and 12 feet deep. Besides these principal openings there is a large number of smaller orifices and springs scattered over the platform, some of which are quiet and some of which spout. Some of the temperatures are as follows: 194° F., 188° F., 182° F., 198° F., 196° F., 194° F., 186° F., 196° F., 194° F.; air, 68° F.; time, 4.25 p. m. The water in the Giant seemed to be considerably agitated, but never reached a greater height than about 3 feet above the top of the cone. The platform is made up of successive layers of geyserite, and on the side next the river the water has so cut into it that the layers are well exposed. They are very irregular in composition, but as a rule the lower we go the harder we find them. In one of the layers I obtained pieces that bore a remarkable resemblance to true opal, the color and specific gravity being that of semi-opal rather than geyserite. The colors are white, red, and green. Two of these specimens were submitted to Dr. F. Endlich, of the Smithsonian Institution, who has sent me the following communication in regard to them.

WASHINGTON, D. C.

DEAR SIR: I have examined the specimens from the Giant Geyser that you have kindly submitted to me, and give you herewith the results. From their position at the crater of the geyser, it may be deduced that they are older than the geyserite at the surface. The minerals form plates of about $\frac{1}{2}$ to 1 inch in thickness, lying horizontal when in position, and are also distributed in irregular nodules, bordered on all sides by geyserite. For particulars in regard to locality I refer to your report. The varieties obtained are two, as follows:

No. 1.—Structure, amorphous; hardness, 6-6.5; specific gravity, 2.4903; color, milky white; fracture, sub-conchoidal; luster, dull.

Analysis.

	Per cent.
Loss by ignition.....	1.50
Silica.....	95.84
Ferrie oxide.....	2.68
Soda*.....	Trace.
Lithium*.....	Trace.
Calcium*.....	Trace.
Alumina.....	Trace.
Total.....	100.02

No. 2.—Structure, amorphous; hardness, 6-6.5; specific gravity, 2.0316; color, light-greenish brown; fracture, conchoidal; luster, vitreous. Water, 6.3 per cent.

Comparing with quartz, opal, and geyserite, we find the position of this mineral as follows:

	Hardness.	Specific gravity.	Percentage of silica.	Percentage of water.
Quartz.....	7 0	2.5-2.8	99	0.3
Specimen No. 1.....	6.0-6.5	2.4	95	1.5
Specimen No. 2.....	6.0-6.5	2.08	.....	6.3
Opal.....	5.5-6.5	1.9-2.3	93	7.00
Geyserite.....	5.0	1.8-2.0	87	10.00

We therefore have a mineral resembling in some points semi-opal; in this case, however, having but little water, a comparatively high specific gravity, and an entirely new process of formation for any mineral, occupying, as it does, an intermediate position between quartz and opal. As the characteristic feature of opal is the presence of

* By spectroscopic examination.

water, it must, in a chemical system, be referred to that species; but, taking into consideration the specific gravity, the small percentage of water, and the circumstances under which the mineral is formed, I wish to distinguish it as a well-defined sub-species of opal, and propose to name it "*Pealite*," as you were the first to find and collect the mineral.

Very respectfully,

Dr. A. C. PEALE.

FREDERIC M. ENDLICH.

The following are analyses by Dr. Endlich of specimens from the same locality. The first is from the top of one of the cones, and is a typical specimen of geyserite. It is one of the latest formed and is covered with beautiful bead-like processes, having a pearly luster. The second specimen is also from the Giant Geyser, but is from one of the lower layers and is much older. It is opaloid and in layers some of which are white and others red. The latter have a flesh-color, like raw-beef.

Analysis of specimen No. 1.

	Per cent.
Loss on ignition.....	13.42
Silica.....	79.56
Lime.....	1.54
Alumina.....	.046
Magnesia.....	1.78
Iron.....	Trace.
Chlorine.....	Trace.
Soda*.....	Trace.
Total.....	97.76

Analysis of specimen No. 2.

	Per cent.
Loss by ignition.....	6.25
Silica.....	92.64
Lime.....	1.03
Ferric oxide.....	0.60
Alumina.....	Trace.
Magnesia.....	Trace.
Soda*.....	Trace.
Strontia*.....	Trace.
Total.....	100.52

Fig. 39 is an illustration of one of the minor geysers of the Upper Basin.

The *Grotto Geyser* is 400 feet northwest from the Giant, and separated from it by a line of trees. There are two cones which spout alternately during the eruption. The larger one, which we will call No. 1, is very irregular and is 8 feet in height. The tube from which the water is projected measures 6 feet by 2 feet and is 19 feet deep. The other cone, No. 2, is 19 feet in diameter at the base and 14 on top. It is 4 feet high, and the orifice on top is quadrangular in shape, measuring 5 feet by 3 feet. When not in action the water is from 10 to 15 feet below the top. The basin is 16 feet deep. The entire length, including both cones, is 53 feet and width 26 feet, the centers of the two being 30 feet apart. The plan shown in Fig. 40 gives the relation of the two. Between them there are two small geyser-tubes which spout whenever the main cones are in action. The eruptions consist of a series of jets averaging about 20 per minute.

* Spectroscopic examination.

First eruption, August 16.—2.45 p. m., eruption began; 3.23 p. m., eruption ended.

Cone No. 1. Maximum height, 32 feet; mean height, 13 feet.

Cone No. 2. Maximum height, 24 feet; mean height, 8 feet.

Second eruption, August 19.—1.27 p. m., eruption began; 2.40.30 p. m., maximum of No. 1, 31 feet; 2.42.30 p. m., maximum of No. 2, 41 feet; 4.0.0. p. m., eruption ended.

ON LONG GEYSER NEAR THE GIANT, UPPER BASIN, SHOWING THE ORNAMENTAL CHARACTER OF THE BORDERS OF THE SPRINGS.

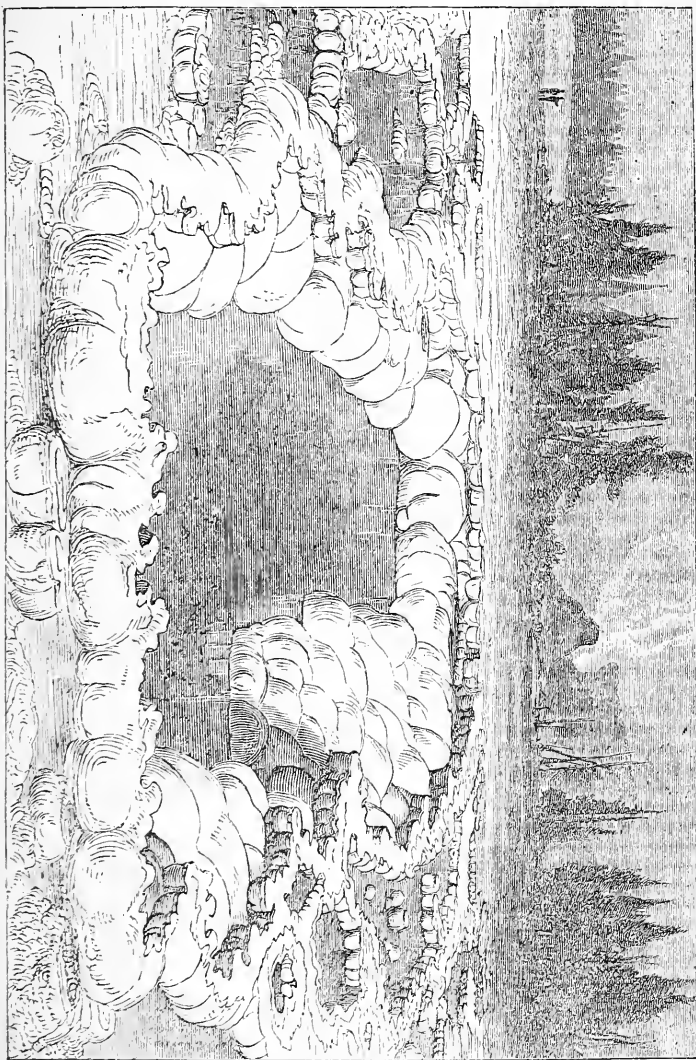


Fig. 39.

Mean height of No. 1, 16 feet; of No. 2, 13 feet.

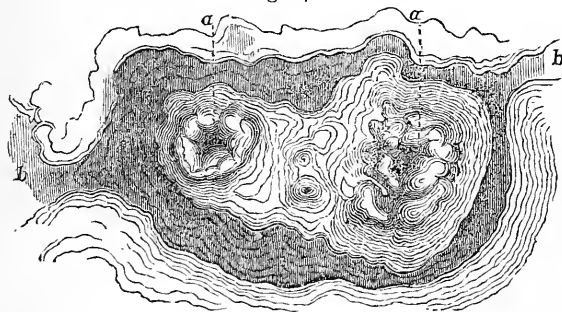
After the eruption the water sank rapidly to about 20 feet in No. 2 and 15 feet in No. 1.

The following table will present the results of the observations on the various geysers as made by myself. Other points of interest will be found in the various reports:

Name.	No of eruptions observed.	Average length of eruptions.	Average in- terval be- tween eruptions.	Maximum height.	Elevation of geyser above sea-level.
		<i>m. s.</i>	<i>h. m. s.</i>	<i>Feet.</i>	<i>Feet.</i>
Old Faithful	17	4 53.07	1 2 45	130	7,397
Bee-Hive	3	8 10	23 17 30	.....	7,402
Giantess	1	7 13	.....	39	7,408
Castle	3	15 30	.....	93	7,387
Grand	3	28 00	24 10 30	173	7,387
Turban	1	15 00	.....	25	7,387
Grotto	2	125 30	.....	41	7,324

As we go from the Grotto Geyser down the river on the oppsite side, we pass through the timber at the foot of a hill. Emerging from the

Fig. 40.



PLAN OF GROTTO GEYSER.

a a, Orifices of cones; *b b*, Outlets for water.

trees the first spring we meet with is situated at the top of the hill some distance above the level of the river. This spring is bordered by cauliflower-like forms of geyserite, which have a greenish tinge. The water flows from the spring in several small streams, the bed of each one being a bright orange color. The water flowing down the

hill becomes cool long before it reaches the river. An analysis of a specimen from the edge of this spring is as follows:

Color, greenish-gray; fracture, conchoidal; luster, dull; hardness outside 3, inside 6.

Analysis.

	Per cent.
Loss at 110° C	2.00
Loss on ignition	10.20
Silica	86.10
Alumina	1.96
Iron	.717
Lime	.28
Magnesia	Trace.
Soda	Trace.
Potassa	Trace.
Lithia	Trace.
	101.257

Thinking that the hot springs would have considerable influence on the temperature of the water in the river, I took the following temperatures in the Fire-Hole and Madison Rivers:

Position.	Time.	Temperature of air.	Temperature of river.
Above Old Faithful.....	12.00 m....	56	53
Below Old Faithful, opposite Bee-Hive.....	12.05 p.m....	58	56
Opposite Grand Geyser.....	12.30 p.m....	56	60
Above Giant.....	1.50 p.m....	58	60
Below Grotto.....	1.55 p.m....	58	60
East Fork of Fire-Hole River above its junction with the main river, but below springs.....	7.30 a.m....	44	56
Madison River, just below the junction of east fork of Fire-Hole River with the Fire-Hole River.....	7.40 a.m....	45	55
Madison River about twenty miles, below the junction of east fork of Fire- Hole River.....	6.00 p.m....	66	60.4
Madison River just after its junction with the Jefferson River, near Gallatin City, Montana Territory.....	6.00 a.m....	28	56
Gallatin River just above the junction with the Missouri River, near Gallatin City, Montana Territory.....	7.30 a.m....	45	52
	7.30 a.m....	45	50.5

These observations were all made in August, with the exception of the last two, which were made September 10, 1872.

The following analyses are of specimens collected by the Snake River division of the expedition:

No. 1.—Geyserite ball from geysers of Shoshone Lake. Composition, irregular; luster, dull; structure, amorphous; hardness, 5.5; color, grayish white.

Analysis.

	Per cent.
Loss at 110° C.....	5.75
Loss on ignition.....	6.25
Silica.....	85.75
Alumina and iron.....	2.20
Lime.....	85
Magnesia.....	Trace.
Soda*.....	Trace.
Potassa*.....	Trace.
Lithia*.....	Trace.
	100.89

No. 2.—Bluish-gray geyserite from geysers of Shoshone Lake. Amorphous; laminated; luster, dull; hardness, 5.

Analysis.

	Per cent.
Loss at 110° C.....	5.00
Loss on ignition.....	8.00
Silica.....	76.80
Alumina.....	9.46
Iron.....	Trace.
Lime.....	1.80
Magnesia.....	Trace.
Soda*.....	Trace.
	101.06

* By spectroscopic examination.

The following table gives the principal analyses of geyserite from all parts of the world.

Locality.	Analyst.	Year of analyses.	Specific gravity.	Si.	Li.	-Al-	-Fe-	Ca.	Na.	K.	Mg.	S.	Li.	Cl.	Si.	Mn.	Total.
Iceland.	Dumour.	.....	.....	87.67	10.40	0.71	.....	0.40	0.82	Trace	.....	.....	.....	.....	.....	.....	100.00
Do	do	.....	.....	93.50	7.41	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	100.00
Do	do	.....	.....	91.23	8.97	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	100.00
Do	Klaproth.	.....	.....	98.00	.....	1.50	0.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	100.00
Do	Kersten.	.....	.....	94.01	4.10	1.70	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	99.81
Do	Forchhammer.	.....	.....	84.43	7.88	3.07	1.91	0.70	0.92	1.06	.....	.....	.....	.....	.....	.....	99.97
Do	Bickel.	.....	.....	88.26	4.79	0.69	3.36	0.59	0.11	0.11	.....	2.49	.....	.....	.....	.....	100.00
Do	do	.....	.....	91.56	5.76	1.04	0.18	0.33	0.16	0.19	0.47	0.31	.....	.....	.....	.....	100.00
New Zealand.	Pattison.	1844.	1.968	77.35	7.66	9.70	3.72	1.74	.....	.....	.....	.....	.....	.....	.....	.....	100.17
Do	Mallet.	1844.	2.031	94.20	3.06	1.58	0.17	Trace	0.53	.....	.....	.....	.....	.....	.....	.....	99.86
Do	Mayer.	.....	.....	86.03	11.52	1.21	.....	0.45	0.38	0.40	.....	.....	.....	.....	.....	.....	99.99
Do	do	.....	.....	81.78	12.86	1.27	.....	0.27	1.09	.....	0.36	.....	.....	.....	.....	.....	100.00
Do	do	.....	.....	79.34	14.51	3.87	1.34	.....	0.42	.....	.....	.....	.....	.....	.....	.....	100.00
Do	do	.....	.....	83.02	7.99	2.99	.....	Trace	1.04	.....	.....	.....	.....	.....	.....	.....	100.04
Do	do	.....	.....	86.80	11.61	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	98.41
Yellowstone National Park, lower geyser-basin.	Peale	1872.	1.806	83.83	11.62	.....	.....	Trace	4.00	.....	.....	.....	.....	.....	.....	.....	98.35
Do	Hitchcock.	.....	.....	87.56	9.30	1.65	.....	0.55	0.48	0.46	.....	.....	.....	.....	.....	.....	100.00
Do	Austen.	1872.	1.97	87.14	9.79	1.67	.....	0.49	0.08	0.33	.....	.....	.....	.....	.....	.....	100.00
Do	Endlich.	1873.	.....	92.64	6.25	Trace	0.60	1.03	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	100.52
Yellowstone National Park, Giant Geyser.	do	.....	.....	95.84	1.50	Trace	2.68	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	100.02
Do	do	1873.	2.4903	79.56	13.42	0.46	0.71	1.54	Trace	1.78	.....	.....	.....	.....	.....	.....	97.76
Do	do	1873.	.....	86.10	12.20	1.96	0.71	0.29	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	101.25
Yellowstone National Park, lower end of upper geyser-basin.	Peale	1873.	.....	88.48	10.40	0.88	Trace	0.18	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	99.94
Yellowstone National Park, lower geyser-basin, near Mud Puffs.	do	.....	.....	83.60	9.00	1.60	.....	0.95	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	100.15
Yellowstone National Park, round ball from Great Fountain, lower geyser-basin.	do	1873.	.....	85.85	9.75	1.94	.....	1.85	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	99.69
Yellowstone National Park, brown specimen from back of Twin Buttes, lower geyser-basin.	do	1873.	.....	82.80	8.99	5.64	1.49	2.13	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	101.05
Yellowstone National Park, black specimen from ravine back of Great Fountain, lower geyser-basin.	do	1873.	.....	85.75	12.00	2.20	.....	0.85	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	100.80
Shoshone Lake geyser-basin, white irregular ball.	do	1873.	.....	76.80	13.00	9.46	Trace	1.80	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	101.06
Shoshone Lake geyser-basin, bluish specimen.	do	1873.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

* Na. cl.

CHAPTER V.

MADISON VALLEY GEYSER-BASINS TO GALLATIN CITY,
CHERRY CREEK MINES.

Late in the afternoon of August 20 we left the upper geyser-basin and proceeded to the lower, where we found Captain Stevenson's party still encamped, Dr. Hayden having moved down the river. As it was too late to follow we waited until morning, when we started at daylight, and joined the party just as they were about leaving camp on Gibbon's Fork, a branch of the Madison, which joins it five miles below the junction of the east fork. The rocks between these two points are all volcanic, trachyte-porphyrries, resembling those we saw at the Grand Cañon of the Yellowstone. In one place I noticed the same round geodic masses that I saw there, only here they were much larger, measuring as much as 6 inches in diameter.

Some of the trachytes are laminated, and seem to have been twisted after having been deposited. On the left bank of the river there is a high bluff-wall extending from below the east fork of the Fire Hole to Gibbon's Fork of the Madison. About three miles above Gibbon's Fork, in a gloomy gorge, is a very fine fall of about 40 feet in height. On reaching Gibbon's Fork I followed it up a few miles, to visit some hot springs which Dr. Hayden reported to me. These springs are on the right side of the river, in a valley about a mile in length and half a mile in width. The springs are situated at the foot of a ridge rising about 1,000 feet above them. This ridge is cut by numerous ravines, the divides between being rounded, thus giving to the top of the ridge the appearance of a range of conical peaks. On the opposite side of the Madison there are vertical walls of trachyte 1,500 feet in height. The springs are seven in number. The largest one is in reality a small lake, in which the water has a temperature of 140° F. It is supplied by two small streams, which have their origin each in two small springs a few feet above. One of these is a pulsating spring, the water rising about a foot above the basin. The temperatures are 135° F. to 150° F. A short distance to the east of this lake there are two other springs, having respectively the temperatures of 100° F. and 122° F. The temperature of the air during these observations was 61° F. About the center of the valley there is an old spring-basin composed of three terraces, rising about 18 inches one above the other, in much the same manner as the terraces of the Gardiner's River springs. Here the springs are extinct and the terraces are overgrown with grass. There is considerable lime, and a coating of iron lines all the channels of the streams, carrying away the overflow of these springs. They have all doubtless passed their most active period.

Messrs. Jackson and Coulter, with some other members of the survey who followed Gibbon's Fork some ten miles above its mouth, have given me the following notes in regard to a fall which they discovered:

About eight or nine miles above the mouth of Gibbon's Fork the valley gradually narrows into a deep cañon, the walls of rock rising with a steep slope on both sides from near the water's edge, leaving scarcely room enough for a rough trail. After following this cañon for about a mile, the slopes becoming steeper and the trail narrower, the river seems to issue from a perpendicular wall standing directly across the head of the cañon. On reaching this precipice, however, we found that the river makes a sharp bend to the right, forming nearly a right angle with its former course, and just at the bend makes a beautiful fall of nearly 100 feet in height. This fall is very simi-

lar to the upper fall of the Yellowstone. The stream does not leap sheer over the precipice in one unbroken fall, but after a few feet of perpendicular descent strikes upon a sloping ledge of rock and is shot out at an angle of about 45° . The scene is the more impressive from the fact that it bursts upon the view so unexpectedly, and without the least warning, the noise of the fall being shut off both by the intervening wall of rock and the rapids, into which the river is broken below. Above the fall the river runs with a smooth, slow current, no rapids breaking up its course until it reaches the very brink of the precipice, over which it plunges into the narrow gorge below.

Leaving Gibbon's Fork we find ourselves almost immediately in the upper cañon of the Madison, which averages about half a mile in width and is eight miles in length. The hills on either side rise from 1,200 to 1,500 feet above the river, those on the left side being almost vertical. The valley is partially timbered, and the hills also, wherever the trees can find a foot-hold. Near the lower end of the cañon there is a fine exposure of columns high up on the right-hand side. The rock is mostly a rough, purplish trachyte, with sanidine crystals. Emerging from the cañon we find ourselves in a wide valley, through which the east fork of the Madison flows to join the main river. Both cut their channels in serpentine manner through the modern beds, which are made up of Pliocene sands, containing a considerable amount of obsidian, which gives them a dark color. The valley is partially timbered, and must be nearly fifty miles in width. On the 22d we encamped near the junction of the east fork, just above the middle cañon, where we spent two days waiting for Dr. Hayden to join us from a side-trip through Taghee Pass to Henry's Lake. I made a trip up the valley of the east fork and ascended one of the hills bordering it on the north. The view from this point was one of the fairest that I have ever gazed upon. It seemed to unite all the elements of beauty—hill, grassy plains, and winding streams. Both forks of the Madison wind through the valley in a series of graceful curves. The rocks were not well exposed on this hill, but as far as I could judge the dip seems to be northeast at an angle of about 75° to 80° . Proceeding toward the river I came across limestones, the upper layers of which I take to be Carboniferous, although I could find no fossils to prove it. The lower layers are probably Silurian, and rest on chlorite-schists, which pass into mica-schists and gneisses. The angle of the dip of these limestones is still very great. At the head of the valley of the east fork there is a range of mountains that appear to be volcanic, and is probably part of the same range that I noticed from near the hot springs on Gardiner's River, which I referred to in a previous chapter. On one of the branches of the east fork I found on top of the modern beds layers of trachyte, which seem to have had their origin in these mountains.

On the 25th we moved camp down the river and camped in the midst of the middle cañon. In one of the gullies at the upper end of the cañon I found grains of glauconite in a quartzite-rock. The western side of the cañon seems to be composed entirely of metamorphic rocks, while the eastern side has outcrops of Silurian and Carboniferous limestones, which at the upper end incline northeast at a high angle.

On the 26th I visited a small side cañon on the eastern side of the river, through which a small creek flows to join the Madison, a short distance above camp. It was so narrow and rocky that we were obliged to leave our horses at the mouth. The first rocks we encountered were quartz-schists, followed by chlorite-schists, the strike seemingly at right angles to the course of the stream, the dip being southwest. The next rocks were very compact limestones, dipping underneath the chlorite-schists. The lines of junction could not be seen, but they seemed to be conformable. The angle of inclination was about 60° .

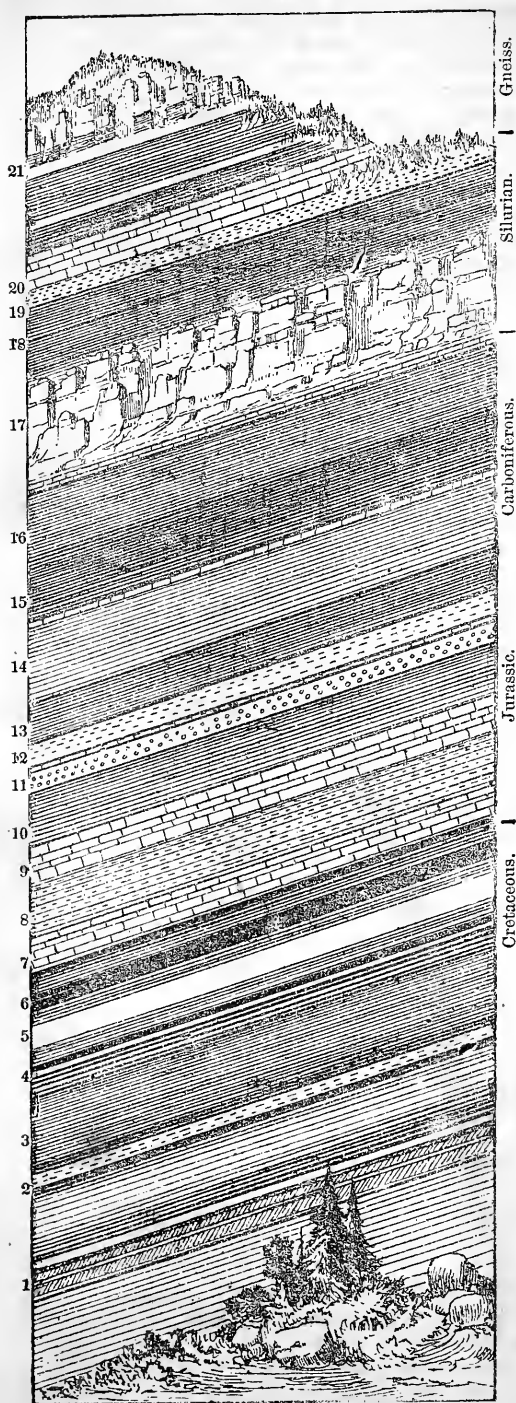
These beds I took to be Silurian, although I could find no fossils. They were followed by Carboniferous limestones, dipping unconformably beneath them at an angle of 50° . This unconformability was caused, most likely, by the force of upheaval. There appears to be a complete inversion of the strata, which a few miles farther up the river we saw almost vertical, but dipping northeast. On the opposite side of the river I found quartz-schists, but they were so covered by detritus and the timber that very little could be determined in regard to them. I will refer again to the inversion of the strata further on.

The middle cañon is seventeen miles long, and its direction from the upper end to the creek, where I found the inverted strata, is northwest. Here, however, it takes an abrupt turn toward the west, almost at right angles to its former direction, and is cut through chloritic and gneissic rocks.

On the 27th we camped just outside the cañon, and from this point, in company with Messrs. Gannett, Holmes, and Savage, I made a trip through Raynold's Pass to Henry's Lake, and thence across the divide, again to the valley of Red Rock Lake. The metamorphic strata still continued dipping southwest. At Taghee Pass, east of Henry's Lake, I believe they are capped with Carboniferous limestone. Raynold's Pass is low, only 6,911 feet in height. The ascent is very gradual, and it is difficult to determine exactly where the stream running into the Madison ends and that running into Henry's Lake begins. To the southwest of Henry's Lake I noticed in the distance a volcanic range. This section of country, however, will probably be fully treated of by Professor Bradley, and I therefore pass it. The divide between Henry's Lake and Red Rock Lake is 7,271 feet high, the distance between the lakes being about eight miles. On the Red Rock side of the divide I found in the valley of a small stream an excellent exposure of reddish quartz schists, the thickness of which I estimated at about 2,000 feet. I am of the opinion that they rest immediately on the granites. They dip southwest at an angle of 20° . Viewed from a short distance the out-crop has the appearance of a huge staircase. Between Red Rock Lake and the Madison Valley the formations are mostly modern, mingled with igneous rocks, the exact relations of which I had not time to determine carefully.

After leaving the middle cañon, the Madison River makes another turn of nearly 90° toward the north, and when we reach the point a short distance below, near Indian Creek, we find the limestones which we saw in the middle cañon again making their appearance. I made several trips into the Madison Range, one above Indian Creek, one at Bear Creek, and a third up Jackass Creek, at the lower end of the valley. Above Indian Creek I found the ridges and peaks made up of mica-schists, which were so covered with detritus that little could be determined in regard to them. We had a great deal of bad weather about this time, which also interfered much with my work. Among the specimens I obtained are aplite, micaceous gneiss, and quartz. Bear Creek is a small stream, joining the Madison on the right side, about forty-eight miles below the cañon. The rocks at the mouth are hard blue and yellow limestones, containing fragments of corals and crinoids. These I take to be either Upper Silurian or Devonian. The layers are very much contorted, but the dip is about west, or, perhaps, a little north of west; angle, 20° to 30° . These beds are followed by dark-blue Carboniferous limestones, containing *Strophomena*, *Spirifer*, *Productus*, and *Orthis*.

Fig. 41.



INVERTED BEDS OF JACKASS CREEK.

The entire exposure of limestones is about 800 feet in thickness. The upper, or rather lower, layers—for they are inverted as I found them in the middle cañon—are magnesian, and contain in places bladed crystals of tremolite. The limestones are followed by 430 feet of massive quartzites, which are at first white and then dark from the presence of iron. Beneath the quartzites, and dipping in the same direction at an angle of 20° , are alternate layers of sandy and calcareous shales, with interlaminated bands of coal-like slates, which break readily at right angles to the plane of deposition. They are followed by greenish-gray calcareous sandstones, breaking into lamina from $\frac{1}{2}$ inch to 2 or 3 inches in thickness. These contain *Trigonia*, *Modiola*, and other fossils, proving their undoubted Jurassic age. All of these rocks are conformable to each other.

Jackass Creek joins the Madison at the lower end of the valley, just above the lower cañon. This creek, like the others, cuts deeply into the range, affording an excellent chance to get at its structure. The range, however, is so long and so rugged, capped with so many sharp peaks, that to determine its geology with precision will require the work of several seasons, and I will be able, therefore, to give only a general idea of it. Still I think future research will modify but little my idea and only fill in the details that are wanting. There is no doubt but that it presents one of the most

interesting fields of study to be found in the West. Jackass Creek emerges from the mountains through a cañon, the mouth of which is very narrow and bordered by gneisses, which are very micaceous and of a black color. As we proceed up the stream they become lighter. The exposure on the right bank is very fine, the bedding being conspicuous, dipping northwest at an angle of 20° to 30° . About a mile inside the cañon we meet first with the limestones, which seem to dip underneath the gneissic rocks. On the left-hand side of the cañon, as we go up stream, there are two hills, on one of which the out-crop is gneiss and on the other limestone. Between is a deep gully, in which the line of junction is so obscured that even with the most careful investigation it could not be determined. Just above the limestones we find shales and quartzites, which probably represent the Potsdam group. Between there is a very compact porphyritic rock, which I take to be an old intrusion of igneous material. The limestones are very compact and brittle, and in layers of about 6 inches in thickness, dipping northwest at an angle of 30° , seemingly conformable with the gneisses. They are probably Silurian, and we found in them the fragment of a trilobite and lingulepis. Still farther up the cañon we find Carboniferous limestones, containing well-defined Carboniferous fossils, dipping northwest, conformably, with the Silurian beds. These layers above weather a blue color, those below yellow, and between them red. Then follows a porphyritic layer, resembling the one seen above the Silurian rocks. It is followed by what I take to be Jurassic beds. Although I found no fossils here, the rocks are precisely of the same character as those I found in Bear Creek, which contained *Trigonia*, &c. Then followed more modern beds, made up of soft, gray calcareous sandstones and clay-slates. The lowest layer observed was igneous material. The accompanying illustration, Fig. 41, corresponds with the following section :

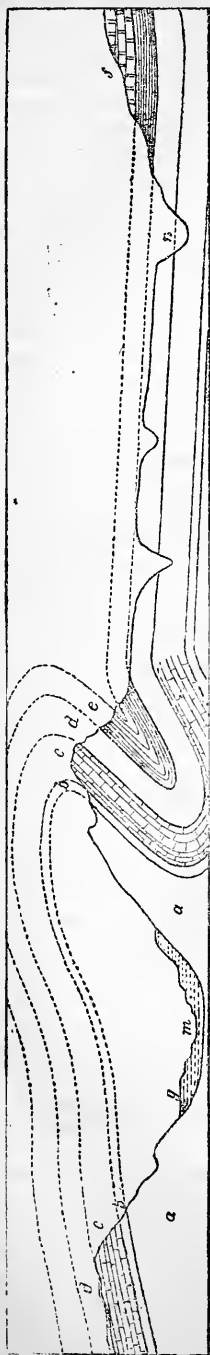
1. Igneous rock.
2. Clay-slates.
3. Soft, gray sandstone. Containing fragments of leaves.
4. Green and black shales.
5. Gray shales.
6. Green and black shales.
7. Quartzite.
8. Shales.
9. Quartzite.
10. Limestone.
11. Conglomerate.
12. Porphyritic, igneous rock.
13. Dark-blue limestone.
14. Reddish limestone.
15. Yellowish limestone. } *Spirifer*, *Productus*, and *Zaphrentis*.
16. Bluish limestone. }
17. Silurian limestones.—*Trilobite* and *Lingulepis*.
18. Shaly sandstones.
19. Porphyritic, igneous rock.
20. Quartzite.
21. Gneiss.

Toward the north the strike of these rocks seems to bend more and more toward the east, and probably extend across to the Gallatin, where I shall refer to them again further on.

The valley of the Madison from the middle cañon to the lower cañon is fifty miles long and averages six miles in width. It once formed

the bed of a lake, which was probably one arm of the lake to which I have referred before as covering the country about the Three Forks of the Missouri, and extending also into the valleys of the Gallatin and Jefferson Rivers. Since the subsidence of the waters the gradual elevation of the country at the head of the river has caused it to carve out of these deposits a beautiful set of terraces, the most perfect I have ever seen. At the head of the valley there are four of them, all well defined. Some are capped with basalt and trachyte, which is columnar above and laminated below. Opposite Virginia City there are two, the first of which, on the west side of the river, is 53 feet in height and on the eastern side is wanting. The top of the second terrace is 243.5 feet above the level of the river on the western side and 149 feet on the eastern side. These terraces are but the remnants of what once filled up the entire valley, and are composed above of very soft sandstones, containing fine grains of mica. These sandstones pass down into conglomerates. The beds are all calcareous and nearly horizontal in position. On the western side of the Madison Valley we find granites outcropping, upon which are limestones probably from the Silurian upward. The Carboniferous beds, at any rate, are present in considerable thickness. The underlying rocks in the valley, upon which the lake-deposits rest, I take to be granites. The accompanying illustration (Fig. 42) will show what I conceive to be the structure of the country. It represents a section across the country in a westerly direction from the east side of the Gallatin River to the west side of the Madison. The dotted lines represent the relation of the inverted beds, extending along the entire Madison Range to the beds resting on the granites on the west side of the Madison. The force which inverted the beds of the Madison range was probably oblique in its direction. The amount of erosion since the upheaval must have been enormous. I shall refer to this section again when speaking of the Gallatin Cañon.

Fig. 42.



SECTION FROM GALLATIN RIVER TO MADISON RIVER, M. T.

M, Madison River; N, Gallatin River; A, Granite; B, Silurian; C, Carboniferous; D, Jurassic; E, Cretaceous; F, Volcanic; G, Terraces Tertiary.

When I visited Jackass Creek with Mr. Holmes and one of our packers, we left the main party on the west side of the river, on which side they intended to proceed down stream some distance before crossing, while we were to go down on the east side skirting the lower cañon as closely as possible, and after visiting the Cherry Creek mines to join them as soon as we could overtake them.

We left Jackass Creek on the morning of the 8th and proceeded to the river,

which we followed until we reached the point where it enters the middle cañon. We then struck up on to the hills, which we found to be composed of granitoid rocks, mostly gneisses. We were unable to get very near the cañon, on account of the ruggedness of the country. We spent the day descending into deep ravines and crossing high ridges. The country is very rough and we had no trail to follow. Several times we thought we might be obliged to turn back. The highest point we reached had an elevation of 8,000 feet. This was on the divide between the Gallatin and the Madison, and we had a good view of the valleys of the Gallatin, Madison, and Jefferson, which lay spread out before us, the relations to each other of the different patches of lake-deposits between the rivers being beautifully shown. In the gneisses over which we were passing, which dip northwest, there are numerous veins of white quartz. In one place I noticed immense masses of it containing a green mica, *fuchsite* which was so abundant that it gave a green color to the entire mass. We camped late in the evening at the head of Pole Creek, which we mistook for Cherry Creek. In the morning we proceeded down stream, hoping to reach the mines. We found that the gneissic rocks continued for some distance and were succeeded by beds of massive quartzite resting conformably on them. These quartzites are succeeded by sandstones, shales, and shaly limestones, above which, we find a bed of jasper and flint containing a beautiful variety of specimens. Above this is a bed of limestone. All of these beds are probably Lower Silurian. Reaching the mouth of Pole Creek we found that it was a branch of Cherry Creek, and we were four miles below the mines. We then turned our horses' heads up stream and reached the mines about noon. We spent two hours examining them, during which time I obtained the following information: The mines are situated in gneissic rocks of distinct bedding, dipping northeast. All the openings have been made on the side of the hill, which faces toward the south. The first discovery was made at the Havana lode, near the Madison River, some four miles northwest of the present camp, in May, 1872. Next, the Devil's Gate lode was discovered, 3,000 feet southeast of the Havana. In June the discovery was made at the present camp. There has really very little been done, as yet, beyond the staking of claims and the beginning of shafts into them. I will give the names of the various lodes that I visited, with various points of interest concerning them:

Eberhardt lode.—This lode was discovered on the 5th of June, 1872. It is three feet in width and strikes north 75° west, dipping north 15° east; angle, 40° . The walls are gneissic. The gangue is quartz and jasper containing native silver. The assays of the ore are said to average \$600 per ton. There are two claims on the lode, one called the Eberhardt Discovery and the other the Eberhardt Extension. A shaft has been sunk in each to the depth of 15 feet. Not more than four or five tons of ore have been taken from these shafts. Several sales in this lode have been made since its discovery, averaging about \$150 per 100 feet.

The Heintzleman lode was also discovered on the 5th of June, 1872. It is above and parallel with the Eberhardt. The strike is north 80° west; dip, north 10° east; angle, 40° ; width, 3 feet. The walls are gneissic; the gangue is the same as in the Eberhardt, containing native silver and pyrites. There are two claims, and two tunnels are being driven into it. One has reached a depth of 25 feet and the other 30 feet. The ore is said to average \$900 to the ton, none of the assays ever having been less than \$300; the greatest (a picked specimen) gave a result of \$5,670 to the ton. One hundred and fifty feet of this lode

were sold for \$3,500, with the agreement that a shaft was to be sunk to the depth of 100 feet.

Clarke lode.—This lode was discovered June 11, 1872. The strike is northwest; dip, northeast; angle, 50° ; width, $2\frac{1}{2}$ feet.

Alabama lode.—This lode is below the others. Strike, north 70° west; dip, northeast; angle, 60° . It is only a few inches in width, and at present there is only a small opening into it.

Pennsylvania lode was discovered June 11, 1872. This is also quite narrow, not exceeding a foot in width. The strike is north 30° west; dip, northeast; angle, 65° . Assays are said to yield \$54 in gold and \$22.75 in silver.

G. W. Rea lode is $3\frac{1}{2}$ inches in width. The ore has never been assayed.

Valentine lode is supposed to be an extension of the Eberhardt. Very little work has been done on it yet.

Z. Daniel's lode.—This lode was discovered June 7, 1872. It has a shaft 10 feet in depth. The crevice is 2 feet in width. The strike is northwest; dip, northeast; angle, 50° .

Home lode.—This lode was discovered June 9, 1872, and is one of the richest in the district, the ore being said to have assayed \$3,200 per ton. The strike is north 30° west; dip, northeast; angle, 48° . The width is 3 feet. There have been two shafts sunk on it, one reaching 10 feet in depth, the other 15 feet. The strike seems to turn to the southwest, and the angle decreases to 45° . A three-fourths interest in this lode (1,125 feet) has been sold at \$900.

Parasol lode is above the Heintzleman, and parallel with it. It dips northeast at an angle of 60° . It is 4 feet in width, and has a shaft 10 feet in depth.

Emma lode is above the Parasol, and parallel with it. It is 2 feet in width.

New Haven lode is on top of the ridge above the Emma, and is 18 inches in width. Other lodes in this district are the *Claggett*, *Yankee Doodle*, *Merrimac*, *Davis*, *Silver Crown*, and *Monarch*.

The *Harper lode* is opposite the Cherry Creek district, on the opposite side of Cherry Creek, and is in limestones instead of gneisses. It is 25 feet wide, and the strike is nearly east and west; dip, south. It was discovered July 12, 1872. The ore is said to assay \$37 in gold and \$7 in silver per ton.

When I visited them there were fifty men working at the Cherry Creek mines, their wages being \$4 per day, or \$75 per month with board. This is the first important discovery of silver in the Territory, and there are no mills for the reduction of the ore at present. Whether the ore is in ore-beds or bedded veins cannot be determined without further investigation. Some of the lodes have been traced from the Madison River a distance of more than four miles. The country rock is all gneissic, and the lodes are parallel with each other. It will be noticed that they are all narrow, but it is claimed that they widen as we descend. The metallic silver is very apparent in the ore, having the form of arborescent crystals.

On the opposite side of the Madison we find the *Silver Shower district*, containing silver mines, which were discovered about the 28th of June, 1872. It is probable that they are merely extensions of the ledges we have described on the east side of the Madison, as the ore is said to be much the same and occurring in the same manner in gneissic rocks. The principal lodes in the Silver Shower district are the *Silver Shower*, the *Pilgrim*, the *Stonewall Jackson*, the *Chloride*, and the *Cross-Key*. The assays are said to vary from \$650 to \$900 per ton. Native silver is not

seen so abundantly as in the specimens from Cherry Creek. Specimens from the Stonewall Jackson lode contain galena, which is not seen at Cherry Creek.

Leaving Cherry Creek we crossed the hills to Elk Creek, which runs almost parallel to Cherry Creek. On the way we passed, on top of the ridge, several openings, none of which were developed to any great extent. Reaching Elk Creek we followed it to the Madison, where we learned at a ranch that the party had passed down the river the day previous. We camped for the night a few miles below the mouth of Elk Creek, and the next morning started down the Madison. The bluffs on either side of the river are made up of Pliocene marls and sandstones, the remnants of the lake-deposits. In some of the ravines, cut in these bluffs by the little streams, we find beautiful specimens of silicified wood. We reached Gallatin City at the Three Forks of the Missouri about noon, and learned that the party had camped there the night before and had left early in the morning on their way up the Gallatin River. We followed and joined them at night-fall. Above Gallatin City, on the north side of the river, there are several fine exposures of Carboniferous and Silurian rocks, the consideration of which I reserve for the next chapter. About four miles above Gallatin City, on the right-hand side of the stage-road leading to Bozeman, I noticed boulders of brown, flinty rock, resembling those I saw on Pole Creek, but was unable to determine whence they came. The following day, September 11, we reached Fort Ellis, and camped on our old camp-grounds, from which we had been absent almost two months.

CHAPTER VI.

GALLATIN VALLEY, BOZEMAN CREEK, MIDDLE CREEK, MOUNT BLACKMORE, AND WEST GALLATIN RIVER.

On the 14th of September, in company with Messrs. Gannett and Holmes, I left Fort Ellis to ascend Mount Blackmore and investigate the geology of the country south of the Gallatin Valley. The range in which the peak is situated gives origin to the branches of the East Gallatin, and once formed a portion of the southern shore-line of the lake which extended over the country about the Three Forks. Although the peak stands up prominently, and is in plain sight from Fort Ellis and Bozeman, it was difficult to determine exactly which stream would lead us to its base. We selected Bozeman Creek as the one to follow, hoping that if it did not lead us to the right point we would be able to cross the ridges and thus accomplish our purpose. We camped in the evening, just inside the mountains, in the cañon of Bozeman Creek, and the next day pushed on up stream. The timber along the creek was so thick that we ascended the hills, hoping to find traveling less difficult. We were obliged, however, to return to the bottom of the cañon. From the mouth of the cañon for about five miles the granites are the only rocks exposed. Succeeding them are the limestones to which I referred in the second chapter when speaking of Mystic Lake. The hills come down so abruptly to the edge of the creek and the cañon is so densely timbered that, in order to make any progress at all, we were often obliged to wade in the bed of the stream. On reaching Mystic Lake we found that it would be impossible to take our animals across the ridges which

separated us from Mount Blackmore, and that our best plan would be to try the next creek to the westward. So, joined by Mr. Jackson and his party, who had been at Mystic Lake several days photographing its fine scenery, we returned to the plain of the Gallatin Valley, and the next morning, skirting the edge of the mountains until we reached Middle Creek, we entered its cañon. We found the lower part of the cañon quite open and had very easy traveling for about two miles, when it began to narrow, and the granite rocks towered high above us on both sides of the stream, which here rushes furiously over its rocky bed. Immense slides of rock extend from the cliffs above to the water's edge, and, with the dense pine-forest through which we were obliged to cut our way with the ax, rendered our progress slow and difficult. The rocks are mostly gneissic, dipping northeast at an angle of about 70° . After five miles of this rough traveling we came out into a small open valley or park, bounded on either side by rather low rounded hills covered with sage-brush; here we camped. Shortly after getting out of the cañon we find limestones crossing the creek, the strike being almost at right angles to its course. On the left bank of the creek there is a bluff showing a fine exposure of the layers, which I take to be Silurian, although no fossils could be found. They dip south of east 45° to 50° . They are, probably, a prolongation of the layers below Mystic Lake. Between the two points there must be a rather abrupt turn in the strike. When at Mystic Lake, however, I noticed that the layers began to turn more and more toward the west as we followed them below the lake. A little farther up the valley of Middle Creek we found true Carboniferous beds containing *Orthis*, *Spirifer*, *Strophomena*, *Atrypa*, and other Carboniferous fossils. Still farther up the valley we find that the dip is reversed, and we have crossed a synclinal which is at right angles to the course of the stream. The occurrence of volcanic outbursts at the head of the stream has thrown the sedimentary beds into some confusion, so it is difficult to reduce them to any system. On the 17th we camped in one of the most picturesque valleys or parks that I have ever seen. It is about a quarter of a mile in length and almost oval in shape, bordered by a line of grand old pines. Through the center of the park Middle Creek flows. Back of the trees on the east side of the park, rising to the height of over 3,000 feet above the bed of the creek, is an almost bluff wall of volcanic rock, the prevailing color of which is black, relieved here and there by streaks of red and green, as though it had been painted. This wall is surmounted by dome and spire like points of rock, in whose crevices lay deep snow-banks. At some points on the wall we could distinguish groups of stunted pines. On the opposite side of the park is a similar wall, which has been more affected by the processes of weathering and presents many curious architectural forms. It does not require a very vivid imagination to trace on its front the forms of castles and fortress-walls. At the head of the park the wall makes a slight turn to the east, and here there are three monument-like piles of rock, dome-shaped masses surmounting perpendicular walls, on which we could see numerous waterfalls, looking like silver threads against the black background. To the most prominent of the three we gave the name of Palace Butte and the other two we called the Twin Buttes. The park in which we were camped we called Palace Park. From this point we concluded to strike out for the ascent of Mount Blackmore, which, although not in sight, we knew to be to the westward of us and not far off. The following morning we started, and, reaching the summit of the first ridge, saw the peak immediately before us and separated from us by a deep ravine which we were obliged to cross. On

this first ridge we passed over the upturned edges of limestones, dipping about northeast, and on the opposite side of the ravine, on the side of the ridge which culminates in Mount Blackmore, there is also an exposure of limestone, dipping in the same direction. The upper layers have an inclination of about 30° , while the lower ones incline only 10° . These limestones are capped with volcanic material, which seems at first to have tipped them up and afterward crushed them. Mount Blackmore itself is a volcanic peak, and the nearness of the sedimentary rocks to the center of volcanic action, which lies to the south or southeast, has affected them to a great extent and thrown them into great confusion. Taking our horses to the timber-line (9,550 feet) we finished the ascent on foot with comparative ease. The rock of which the peak is composed is basaltic in its character, of black and red colors. On the summit it is very compact and massive, while below we find it laminated and somewhat porphyritic. On the way up I found excellent specimens of *Hyalite* in globular concretions, as clear as glass, coating the rocks and making them look as though coated with ice. I also found *Chalcedony* and a yellow variety of opal resembling somewhat fire-opal. It varies in color from a honey-yellow with a greenish tinge to a brownish red. It is opaque; luster vitreous; hardness, 5; specific gravity, 2.172. Considering its physical properties it might be distinguished as a variety of opal between fire-opal and the ordinary semi-opal. I propose for it the name of *Blackmorite*, from its locality, Mount Blackmore. An analysis of it is as follows:

Analysis.

	Per cent.
Loss at 110° C.....	7.40
Loss on ignition.....	2.40
Silica.....	85.20
Iron oxide.....	2.68
Lime.....	1.48
Magnesia.....	0.37
Soda*.....	Trace.
	99.53

The view from the summit of Mount Blackmore is grand in the extreme. When we turn to the south we overlook an intensely rugged country, studded with numerous sharp volcanic peaks. Quite near the peak there is one point which looks as though it were once the center of volcanic action, the sloping sides bearing a striking resemblance to the sides of an old crater. To the north the field of vision is immense. The valley of the Gallatin, from its sources at our feet to the Three Forks, lies spread out before us, and beyond we could distinguish in the dim distance even the Missouri. Here we could trace the layers of limestone from Mystic Lake to Middle Creek, thence across the Cottonwood, the next stream to the west, and thence across to the West Gallatin. All these streams have cut their way directly across the strata at right angles to the strike. To the west we could see the Madison Range, and on the east the snowy range of the Yellowstone. The elevation of the peak above sea-level is 10,134 feet. The following morning we followed Middle Creek to its sources, and found that the valley abounded in most magnificent scenery, foliage, rocks, and numerous water-falls and cascades combining to form the most beautiful pic-

* By spectroscopic examination.

tures, and Mr. Jackson concluded to remain several days in the valley. We continued on our way, hoping to be able to cross the range and descend to the West Gallatin, where we expected to join the main party the next day. We reached an elevation of 9,000 feet, and found ourselves surrounded by a semicircular wall, which rose 600 feet in perpendicular height above us. At the base lay immense banks of snow. To cross was impossible, so we retraced our steps, and on reaching the first open space above the cañon where we had encamped three days before, we crossed the ridge to Cottonwood Creek, which we followed to the plain. We then proceeded along the edge of the mountains until we reached the mouth of the West Gallatin Cañon, and, striking the trail of the main party, we pushed up stream as rapidly as possible. The rocks at the mouth of the cañon are gneisses, which dip northwest at an angle of about 75° . They are followed by immense beds of limestone, which at first, I think, dip in a southerly direction, but soon change to the northeast. The angle varies from 20° to 30° . They are the direct prolongation of the layers which we observed on Middle and Cottonwood Creeks, and which we also noticed on Pole and Cherry Creeks when we were on our way down the Madison. The limestones are again succeeded by gneisses, probably the continuation of those through which the Madison cuts the Lower Cañon. Then follow limestones dipping southwest. These I believe to be the continuation of the layers in the Madison Range, which I referred to as making a turn toward the east near Jackass Creek. To the east of the Gallatin River it is difficult to trace them, for we find ourselves immediately in a volcanic region. That there is some connection between this ridge and the layers outcropping on Cinnabar Mountain is highly probable. Just above this last ridge of limestone we found the main party encamped. On the opposite side of the river there was a high bluff wall made up of Cretaceous and Jurassic rocks. Our camp on the western side was upon Jurassic rocks. These seem to continue to the westward in a gentle slope from the Gallatin to the Madison Range. The weather became so snowy and unfavorable for work that I was not able to follow the beds to the westward, as I desired, but the section shown in Fig. 42 which I referred to in the preceding chapter, will show what I believe to be the relation of the beds exposed on the Gallatin, opposite our camp, to those of the Madison Range. To definitely settle their relation, however, the western side of the Madison Range will have to be worked out in more detail than it has been up to the present time. The cañon of the West Gallatin is so fully treated of in other portions of the report that I have thought it best merely to refer to it. Leaving the Gallatin River we crossed the divide to the Yellowstone River. On the very summit I obtained specimens of silicified wood embedded in basaltic rock, which is here mingled with Tertiary sandstones, which have here been very much metamorphosed. The elevation of the divide at the point we crossed it is 9,317 feet. We struck the Yellowstone just below the second cañon, and followed it down to Bottler's ranch. While at this point I crossed the Yellowstone River and went up Emigrant Gulch, one of the regions in which gold-mining has been carried on to a somewhat limited extent. The gulch cuts into the mountain-range for some distance in a general southeasterly direction. The rocks near the mouth of the gulch are chlorite schists, which dip in a northerly direction, or perhaps a little west of north, at an angle of 40° to 45° . These chloritic rocks extend for about two miles and a half, and are followed by gneisses, which dip underneath them. These gneisses are probably a continuation of those exposed in the second cañon of the Yellowstone.

They extend for a short distance, when we find igneous rocks resting upon their upturned edges. These igneous rocks rise to a great height on either side of the gulch, and in fact form the crest of the entire range, as I noticed when on the summit of Emigrant Peak last year. The stream descends very rapidly as it flows down the gulch, and there are numerous cascades and waterfalls in its course. At the mouth of the gulch there was formerly quite a large settlement, but at present nothing remains save the stone chimneys of Yellowstone City. As we ascend the creek the gulch narrows very rapidly. There are two mining-camps, one at the head of the stream, the other at the mouth of the gulch. The mines are all placer-diggings, and at present there are only twenty or thirty men working here. The highest yield is \$15 per day, the average being about \$5 per day to each man. There are four claims worked at the lower camp and three at the upper, and since the discovery, in 1864, it is estimated that the gulch has yielded over \$100,000.

The chloritic rocks, which are exposed in Emigrant Gulch, extend along the range as far north as the Lower Cañon of the Yellowstone. Near the latter, in one of the smaller gulches, I obtained specimens of *Itacolumite* in lamina about an inch in thickness and having a greenish color. None of the specimens were flexible. Our next camp, after leaving Bottler's, was just above the Lower Cañon of the Yellowstone. Here the limestones extend across the river, which cuts through them almost at right angles to the strike. The dip of the beds is east of north. They are probably the continuation of one branch of the anticlinal, which we have referred to before in Spring Cañon. On the north side of the cañon we find Jurassic layers resting immediately on thick beds of quartzite, which lie between them and the Carboniferous limestones. The inclination of the beds is about 25° . The Jurassic beds consist of alternate layers of calcareous clay shales, which weather blue, and hard, yellow limestone. They contain great quantities of fossil, among which are *Trigonia*, *Ammonites*, *Ostrea*, and *Pinna*. These are succeeded by Cretaceous sandstones, which are in turn followed by Tertiary strata, which are from 1,500 to 2,000 feet in thickness. After passing through the Lower Cañon, we turned to the left and proceeded up Divide Creek, a small stream flowing into the Yellowstone from the western side. Its valley, for the most part, is a monoclinical valley, between Cretaceous and Tertiary strata. The Tertiary beds are composed of sandstones, which are generally quite soft and of a gray color. The lower layers are often quite hard, and of a somber brown color, seeming to have been somewhat changed. At several points I noticed the occurrence of dikes, to which this change may be attributed. The general dip is in a northerly or northeasterly direction, and the angle about 35° to 40° .

Reaching the head of the stream, we crossed the divide, and found ourselves at the head of the creek which flows through Spring Cañon. Here we turned toward the right and crossed to Bridger Creek, which we followed up around the eastern side of the Bridger Range to Flat-Head Pass, through which we went to the Gallatin Valley. The rocks on the eastern side of the range at Flat-Head Pass are Cretaceous sandstones, dipping a little north of east, angle, 30° to 50° , succeeded by Jurassic layers, which are for the most part covered with grass, concealing them. The center of the range is made up of Carboniferous limestones, which are almost vertical. As we pass toward the westward, however, they begin to dip in a westerly direction. They are followed by Silurian beds, which also dip in the same direction. The Silurian layers are composed of slaty limestones, pebbly conglomerate limestones, and compact brittle limestones, containing fragments of trilobites.

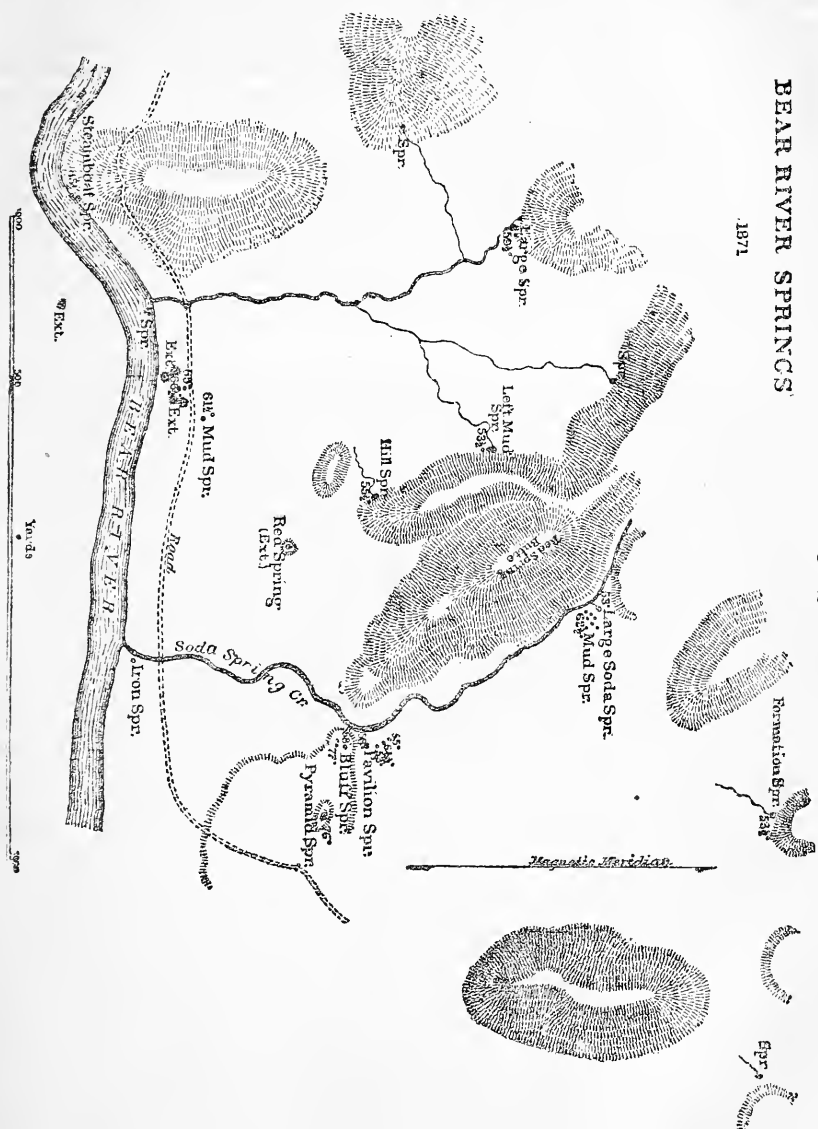
They are followed by very hard, compact, micaceous sandstones. During the upheaval of this range, the line of force seems at first to have been vertical, and tipped up the layers as we see them on the eastern side. Then the force seems to have acted in a line oblique to its former direction, and, breaking through the Silurian and partially through the Carboniferous layers, carried their lower edges to the westward; so that, while the Cretaceous, Jurassic, and a portion of the Carboniferous layers dip in an easterly direction, the remainder of the Carboniferous and all of the Silurian beds dip toward the west. This remarkable occurrence is fully treated of in Dr. Hayden's report, in which there is also a section showing the various beds.

From Flat-Head Pass we crossed the country in a northwesterly direction to the Missouri River, striking it at Horse-Shoe Bend, below the Three Forks. Between these two points there are a number of local synclinals and anticlinals. From Horse-Shoe Bend, we proceeded up the Missouri River to the junction of the Gallatin. About four miles above Gallatin City there is a magnificent exposure of strata on the east side of the river. The following section is in ascending order from the lowest exposure to the Jurassic beds.

	Feet.
1. Micaceous sandstones, interlaminated with blue, shaly limestones, weathering brownish, in bands, varying from a few inches to a foot or more in thickness. The upper layers of the sandstone are of a steel-gray color, breaking into cubical blocks, that give it the appearance, from a distance, of basalt. The general color of the sandstones is an olive-green. They contain fine grains of mica and small pebbles of quartz, mixed with a few opaque crystals of white feldspar. The rock is very hard, and has been little affected by the weather. It extends in high bluffs for considerable distance along the river. Some of the limestones contain flat, rounded concretions of about 6 inches in diameter and 3 inches in thickness. The sandstones vary in thickness from 2 to 4 feet. The general dip is northwest, inclination being 25° to 30°. The thickness of these beds is about.....	1,600
2. Pink sandstones, above which are heavy beds of quartzite. The general dip is about 30° northwest. Thickness, estimated at	100
3. Green and blackish shales, breaking into lamina of a few inches thickness. Low down we find layers that are of a deep purplish, red color. Short distance above these latter, we find a very hard calcareous sandstone, containing grains of a mineral resembling <i>glauconite</i> . In them we find also the remains of trilobites. A short distance above this layer we find sandstones of about 3 inches thickness, interlaminated with green argillaceous shales, containing trilobites, <i>Lingulepis</i> , <i>Conoceryphe</i> , &c. The estimated thickness of these beds is.....	300
4. Layers of very hard limestone, breaking into lamina of an inch or more in thickness and containing immense quantities of trilobites. Thickness.....	40
5. Black, shaly limestones, containing a small <i>Lingula</i> , <i>Acrovetula</i> , and <i>Obolella</i> , followed by rather thin layers of very compact, blue limestone. Thickness	50
6. Pebbly beds of limestone, containing trilobites, and <i>Lingulepis</i> . Thickness	60

7. Reddish and greenish calcareous shales, with interlaminated limestones, containing trilobites. Thickness	50
8. Limestones, weathering to a brownish color, shaly in many places.....	200
9. Alternate beds of pebbly and compact limestones.....	200

Feet.



10. Thick beds of limestone in which were found *Spirifer*, *Productus*, *Chonetes*, *Zaphrentis*. The lower layers weather yellow. The layer in which the fossils occur is of a blue color, and very compact. Thickness, estimated at..... 1,000
11. White quartzite.
12. Jurassic beds.

For a complete list of the fossils found at this locality I refer to Professor Meek's report.

Layers 10 and 11 probably represent the entire extent of the Carboniferous beds. No. 1 should probably be referred to the Huronian series, while No. 2, I believe, represents the Potsdam group, or at least a portion of it. From No. 3 to No. 9 includes the remainder of the Silurian beds. The section given above was made with all the care possible in the limited time afforded. More extended observation will no doubt result in the discovery of new organic forms and the more accurate determination of the age of the various beds. We followed up the East Gallatin River, reaching Bozeman on the 15th of October, when the expedition disbanded for the season.

Fig. 43 shows the relations of the various springs on Bear River, which were described in the report of 1871. These springs were described by Frémont in 1843, and called the Beer Springs, from the agreeable taste of the water.

No. 1.—CATALOGUE OF THERMAL SPRINGS.

Locality.	Number of springs.	Position.	Elevation above sea-level.	Time of observation.	Gases evolved.	Principal constituents.	Temperatures Fahrenheit.				Date of observation.	
							Highest.	Lowest.	Average.	Of air.		Boiling-point.
Near Colorado Springs on the Fontaine qui Bouille, Colorado Territory.	5	Granites	<i>Feet.</i> 6,529	Afternoon	Carbonic acid	Carbonates of lime, soda, potassa, magnesia.	60	48.5	54.06	70	201	May —, 1872
Do	2	do	.....	12 m	do	.....	67	63	65	68	.....	* July 13, 1880
Do	2	do	.....	11 a. m	do	.....	69	60.5	69	73	.....	July 18, 1883
Do	2	do	.....	Sunset	do	.....	61	58	66	66	.....	July 18, 1883
Do	2	do	.....	Sunrise	do	.....	57.8	54.3	57.5	57.5	.....	July 19, 1883
Month of Ogden Canon, near Ogden City, Utah Territory	1	Syenites	5,000	4 p. m	do	Iron and carbonates	121	.....	.....	73	204	May 30, 1872
Ten miles above Ogden City, Utah Territory, 4 miles from Salt Lake.	10	Quartzites	4,517	Evening	do	Chloride of sodium, iron, lime, and magnesia carbonates.	136	109	129	83	204	June 11, 1871
Do	12	do	.....	4 p. m	.....	.....	135	.....	129	.....	.....	May 29, 1872
Do	2	do	.....	.....	.....	.....	136	132½	.....	.....	.....	Sept. 5, 1843
Twelve miles north of Brigham City, Utah Territory.	3	Limestones, probably.	.....	4 p. m	Carbonic acid	Chloride of sodium and carbonates	128	68	72.33	78	.....	June 25, 1872
Do	5	do	.....	9 a. m	do	do	132	60	102.08	36	.....	Nov. 10, 1872
Do	1	do	.....	.....	do	Chloride of sodium, iron, carbonate of lime.	134	.....	.....	.....	.....	Sept. 13, 1843
Lincoln Valley, near Fort Hall, Idaho Territory.	5	Limestones	4,720	Morning†	.....	Alumina, lime, carbonic acid.	87	69	75.68	80	204	June 22, 1871
Hot Spring district, Madison County, Montana Territory.	3	Syenites	4,804	do	.....	Carbonates	76	64	70	48	204	July 8, 1871
Do	3	do	4,804	do	.....	do	.....	.....	.....	.....	.....	.....
Gardiner's River, Mammoth Hot Springs. First group level of river.	7	Limestones and igneous rocks.	5,750	8 35 a. m.	Sulphureted hydrogen.	Lime, iron, alumina, magnesia, silica, carbonic acid.	124	110	117	50	204	July 8, 1871
Second group, between river and main springs.	2	do	5,980	8 a. m	do	do	132	94	110.02	70	.....	July 29, 1872
Third group, 1st terrace.	4	do	6,278	8.40 a. m.	do	do	140	.....	.....	65	.....	July 29, 1872
Fourth group, 2d terrace.	3	do	6,304	9 a. m.	do	do	160	150	155	70	.....	July 28, 1872
Fifth group, 4th terrace.	1	do	6,412	9.25 a. m.	do	do	163	144	156	69	102	July 28, 1872
							152			72		July 28, 1872

* Long's expedition to the Rocky Mountains in 1819-20, vol. 2, page 24.

† Frémont's exploring expedition, 1842-43-44, page 118.

‡ Frémont, page 150.

§ Frémont, page 150.

|| Approximate.

Locality.	Number of springs.	Position.	Elevation above sea-level.	Time of observation.	Gases evolved.	Principal constituents.	Temperatures, Fahrenheit.				Date of observation.	
							Highest.	Lowest.	Average.	Of air.		Boiling-point.
Gardiner's River, sixth group, fifth terrace.	1	Limestones and igneous rocks.	<i>Feet.</i> 6,465	9.30 a. m.	Sulphureted hydrogen.	Lime, iron, alumina, magnesia, silica, carbonic acid.	° 152	°	°	74	°	July 28, 1872
Seventh group, 6th terrace.	8	do	6,491	12.30 p. m.	do	do	152	148	149	80.5		July 28, 1872
Eighth group, 7th terrace	2	do	6,551	10 a. m.	Sulphureted hydrogen and carbonic acid.	do	154	150	152	72		July 28, 1872
Ninth group, 8th terrace	1	do	6,556	9.45 a. m.	Sulphureted hydrogen.	do	122			72		July 28, 1872
Tenth group, 9th terrace.	6	do	6,591	10.14 a. m.	do	do	162	157	151.17	74		July 28, 1872
Eleventh group, 10th terrace.	2	do	6,596	10.30 a. m.	do	do	162	139	141	74		July 28, 1872
Twelfth group, 11th terrace.	3	do	6,603	10.35 a. m.	do	do	154	148	150.66	74.5		July 28, 1872
Eighteenth group, 12th terrace	8	do	6,681	12.20 p. m.	do	do	162	160	160.75	78.5		July 28, 1872
Fourteenth group, 13th terrace.	14	do	6,758	11.12 a. m.	do	do	148	108	138.43	78		July 28, 1872
Fifteenth group, 14th terrace.	14	do	6,779	11-11.50 a. m.	Sulphureted hydrogen and carbonic acid.	do	145	92	107.29	74		July 28, 1872
Near Lower Falls of Yellowstone River, Yellowstone National Park.	1	Trachytes	6,188	Morning	Sulphureted hydrogen & carbonic acid.	Iron, alumina, lime, magnesia, sulphuric acid.	127			70		Aug. —, 1871
South of Mount Washburne, near its base, 1st group.	8	Igneous rocks	8,117	7.30 a. m.	Sulphureted hydrogen.	Sulphur, alumina, iron, silica.	190	52	116.5	76	198.3	Aug. 5, 1872
South of Mount Washburne, near its base, 2d group.	4	Igneous rocks and clay.		9 a. m.	do	Sulphur, lime, iron, alumina, magnesia, sulphuric acid.	194	140	177	78	198	Aug. 5, 1872
South of Mount Washburne, near its base, 3d group.	3	do		9.30 a. m.	do	do	190	185	188.33	79	197.6	Aug. 5, 1872
East side of Yellowstone River, near lower falls.	33	do	8,000		do	do	190	88	134.5			Aug. 20, 1871
Crater Mills, Yellowstone Valley, 1st group.	3	Igneous rocks.	7,829		do	Sulphur, silica, magnesia, iron, sulphuric acid.	183.5	130	151.2	77.5	198.2	July 27, 1871
First group	2	do		10 a. m.	do	Sulphur, silica, magnesia, lime, iron, alumina, sulphuric acid.	178	164	171	58	198.2	Aug. 11, 1872
Second group	2	Igneous rocks and clay.			do	do	188.5	163	175.5	77.5	198.27	July 28, 1871

Second group, Violet Creek, Yellowstone Valley, near Crater Hills.	49	do	10 a.m.-12.00 m. Morning	Carbonic acid and sulphureted hydrogen.	do	188	89	157.62	59	198.3	Aug. 11, 1872
Head of Violet Creek, Yellowstone Valley.	11	do	12.30 p.m.	do	do	198	130	166.27	70	198.1	Aug. 10, 1872
Branch of Violet Creek, Yellowstone Valley.	12	do	2 p.m.	do	do	194	140	175.66	72	198.5	Aug. 10, 1872
Mid Volcanoes, Yellowstone Valley.	9	do	7, 873	Sulphureted hydrogen.	Sulphur, iron, alumina, silica.	194	160	181	68	198.5	Aug. 10, 1872
Shore of southwest arm of Yellowstone Lake.	19	Igneous rocks and clay.	7, 756	do	do	190	88	147.8	48.58	198.5	Aug. 1872
East Fork of Madison or Fire-Hole River, near head.	40	Shore of lake.	7, 098	Sulphureted hydrogen.	Silica, iron, alumina.	191	115	166.5	64	198.5	Aug. 8, 1871
East Fork of Fire-Hole River, above geyser-basin.	9	Igneous rocks.	7, 098	do	Sulphur, silica.	199	138	179.2	70	198.5	Aug. 1, 1871
Lower geyser-basin, 1st group on East Fork of Fire-Hole River.	4	do	8 a.m.	do	Silica.	180	164	158	64	198.5	Aug. 14, 1872
Second group, Thud Springs, &c.	67	do	Morning	do	do	198	106	158	50	198.5	Aug. 2, 1871
Third group, near Mud Puffs.	17	do	7, 162	do	do	195	171	185.35	*63.33	199.3	Aug. 15, 1872
Fourth group, ravine east of 3d group.	8	Igneous rocks and clay.	7, 357	do	Silica, alumina, iron, magnesia.	196	140	175.13	55	198.5	Aug. 3, 1871
Fifth group, ravine, south of 4th group.	20	Igneous rocks.	7, 357	do	Silica.	196	130	158.2	60	198.5	Aug. 3, 1871
Sixth group, on Fire-Hole River.	42	do	7, 296	do	do	198	112	178	60	198.5	Aug. 3, 1871
Seventh group, on Fairy Fall Creek.	95	do	7, 402	do	do	196	112	172.5	70	198.5	Aug. 4, 1871
Lower geyser-basin, 8th group, back of Twin Buttes.	34	do	7, 357	do	do	198	106	184	70	198.5	Aug. 4, 1871
Half-way Springs, between lower and upper geyser-basins.	7	do	7, 357	do	do	198	187	194.14	74	198.5	Aug. 15, 1872
Upper geyser-basin, 1st group, near Bee-Hive and Giants.	20	do	7, 357	do	Silica, iron.	196	132	184	74	198.5	Aug. 4, 1871
Second group, near Castle Geyser.	10	do	7, 357	do	Silica, iron, magnesia.	196	118	173.6	*67	199	Aug. 5, 1871
Third group, back of Castle Geyser.	11	do	7, 357	do	do	199	130	172.82	58	199	Aug. 19, 1872
Fourth group, on northern side of river about Grand Geyser.	23	do	7, 357	Sulphureted hydrogen.	Silica, alumina, iron, sulphur.	196	100	171.3	68	199	Aug. 18, 1872
Fifth group, from above Giant and Pyramid to below Grotto.	23	do	7, 357	do	Silica, alumina, iron, magnesia.	196	118	175.13	*67	199	Aug. 5, 1871
Sixth group, about Soda Geyser.	20	do	7, 354	do	do	192	150	167.1	*67	199	Aug. 5, 1871
	4	do	7, 351	do	do	184	140	167	*67	199	Aug. 5, 1871

* Average.

Locality.	Number of springs.	Position.	Elevation above sea-level.	Time of observation.	Gases evolved.	Principal constituents.	Temperatures Fahrenheit.				Date of observation.
							Highest.	Lowest.	Average.	Of a w.	Boiling-point.
Seventh group, opposite Soda Geyser, extending up the river.	19	do	<i>Feet.</i> 7,331	.....	.....	do	196	134	175	*67	.....
Eighth group, Iron Spring Creek.	4	do	.....	Morning	.....	do	184	152	172.35	*67	.....
Third Geyser Basin of Fire-Hill River.	5	do	7,772	.....	.....	Silica.	192	185	188	.....	198.5
Shoshone Lake geyser-basin, 1st group, agitated springs.	9	do	7,870	Middle of day.	.....	Silica, iron, alumina	198	160	187.44	.....	198.6
Shoshone Lake geyser-basin, 2d group, quiet springs.	7	do	.....	do	.....	do	196	156	175	.....	198.6
Third group, geysers.	4	do	.....	do	.....	Silica, sulphur, iron	198	190	192.5	.....	198.6
Lewis's Lake, 1st group.	10	do	7,828	do	.....	do	148	112	130.8	.....	198.6
Lewis's Lake, 2d group.	6	do	.....	do	.....	do	176	140	163.33	.....	198.6
Near mouth of Union River.	.....	do	.....	5 p. m.	.....	Silica	158	102	130	.....	198.6
Canyon of Snake River	2	Limestones	.....	3 p. m.	Sulphureted hydrogen.	Lime and other carbonates.	194	117	.....	*58	.....
Below cañon of Snake River.	6	do	5,050	11 a. m.	.....	do	144	88	124.33	.....	.....

*Average.

The boiling point at the Gardiner River Springs varies from 200.9 to 199.5.

No. 2.—CATALOGUE OF MINERALS.

Agate. (See *Quartz*.)

Amethyst. (See *Quartz*.)

Azurite, (blue carbonate of copper.) In Ogden Cañon, Utah Territory; near the head of Clarke's Fork of the Yellowstone River, Montana Territory; Little Cottonwood Cañon, Utah Territory; near Virginia City, Montana Territory.

Amphibole. *Tremolite* in Bear Creek Cañon, in Madison Range, Montana Territory. *Asbestus*, near Henry's Lake, Idaho Territory. *Hornblende* in syenites, near Ogden, Utah Territory; on the east side of the Madison River, in Middle Cañon, Montana Territory; in rocks of the Téton Range, Idaho Territory; on the east side of Henry's Lake, Idaho Territory; in slates, near Virginia City, Montana Territory; in gneissic rocks, in second cañon of Yellowstone, above Boteler's; in basaltic rocks, near Boteler's, in Yellowstone Valley; in acicular crystals, in rocks on the summit of Mount Washburne, Yellowstone National Park.

Asbestus. (See *Amphibole*.)

Aurichalcite. Little Cottonwood Cañon, Utah Territory.

Biotite, (black mica.) Granites of Little Cottonwood Cañon; in basalts of Emigrant Gulch, Montana Territory.

Calamine, (silicate of zinc.) Head of Little Cottonwood Cañon, Utah Territory.

Calcite, (carbonate of lime.) *Rhomb-spar* in blue limestones, near Ogden, Utah Territory; in sandstones, near Fort Ellis, Montana Territory; at Cinnabar Mountain and other points of the Yellowstone Valley, associated with agate and quartz in geodes; in geodes of agate from the East Fork of Yellowstone River; east side of Madison River, in the Middle Cañon, Montana Territory; bluff, opposite the Hot Springs, on Gardiner's River; cañon of Jackass Creek, in Madison Range, Montana Territory. *Crystals*, yellow, from Colorado Springs, Colorado Territory; Spring Cañon, near Fort Ellis, Montana Territory; Bridger's Peak, near Fort Ellis, Montana Territory; east side of Madison River, in Middle Cañon, Montana Territory; Sawtelle's Peak, Idaho Territory. *Stalactites*, from cañon on east side of Middle Cañon of Madison River, Montana Territory; from cave at Gardiner's River, Hot Springs, Yellowstone National Park.

Cerrussite, (carbonate of lead.) From head of Little Cottonwood Cañon, Utah Territory.

Cervantite, (oxide of antimony.) From head of Little Cottonwood Cañon, Utah Territory.

Chalcedony. (See *Quartz*.)

Chalcopyrite (copper pyrites.) Near Virginia City, Montana Territory; Clarke's Fork of Yellowstone River, Montana Territory.

Chlorite. (See *Ripidolite*.)

Chrysoprase. (See *Quartz*.)

Coal, (Tertiary.) Near Spring Cañon, Fort Ellis, Montana Territory; six miles above Spring Cañon, in hills head of Trail Creek, Montana Territory; (Cretaceous,) near Cinnabar Mountain, Montana Territory; poor quality opposite Gardiner's River Springs; on Hunter's River, near Mount Hancock, Yellowstone National Park.

Copper, (native.) Near Virginia City, Montana Territory.

Cuprite, (red oxide of copper.) Near Virginia City, Montana Territory.

Epidote. In crystals from the Téton Range, Idaho Territory.

Feldspar, (*Orthoclase*.) In syenites at Ogden, Utah Territory; in granites at Colorado Springs, Colorado Territory, in red masses; in granites throughout Idaho and Montana Territories. *Sanidine*, in trachytes, throughout the Yellowstone National Park and Montana and Idaho Territories. *Amazon stone*, near Colorado City, Colorado Territory.

Flint. (See *Quartz*.)

Garnets. In gneissic rocks near Golden City, Colorado Territory; in gneiss near Ogden, Utah Territory; in second cañon of the Yellowstone, above Boteler's, Montana Territory; in Emigrant Gulch, Montana Territory; in micaceous gneiss, on Black-Tail Deer Creek, near Gardiner's River; Hot Springs, near lower cañon of Madison River, in gneiss; in gneiss on Cherry Creek, Montana Territory; near Henry's Lake, Idaho Territory; in rocks of the Téton Range, Idaho Territory.

Galenite, (sulphide of lead,) (argentiferous.) Little Cottonwood Cañon, Utah Territory; Central City, Colorado Territory; Emigrant Gulch, Montana Territory; Clarke's Fork of the Yellowstone River; Yellowstone National Park; Hot Springs district, Silver Shower district, and other mining districts in Montana Territory.

Geyserite. (See *Opal*.)

Glauconite. East side of Madison River, in Middle Cañon, Montana Territory; near Gallatin City, Montana Territory; Téton Mountains, Idaho Territory.

Gold. Central City, Colorado Territory; Emigrant Gulch, Yellowstone Valley, Montana Territory; near Virginia City, Montana Territory; Hot Springs district, Madison County, Montana Territory; Upper waters of Snake River, Idaho Territory; near Taylor's Bridge, Idaho Territory.

Graphite. Twelve miles north of Ogden, Utah Territory.

Gypsum, (sulphate of lime.) Colorado Springs, Colorado Territory. *Selenite*, Colorado Springs, Colorado Territory; opposite Hot Springs, at Gardiner's River, Yellowstone National Park; in old hot-spring deposits, opposite Tower Creek, on Yellowstone River; Yellowstone National Park; in Grand Cañon of Snake River, Idaho Territory. *Satin-spar*, Colorado Springs, Colorado Territory.

Halite, (common salt.) In springs on Turbid Lake, near Yellowstone Lake, Yellowstone National Park; Great Salt Lake, Utah, in fine crystals coating wood; in springs in Idaho Territory; springs above Ogden, Utah Territory.

Hematite, (oxide of iron,) (micaceous.) Near Ogden, Utah Territory; near Brigham City, Utah Territory; near Madison Cañon, Montana Territory. *Iron-stone*, Emigrant Gulch, Montana Territory.

Hornblende. (See *Amphibole*.)

Jasper. (See *Quartz*.)

Limonite, (sesquioxide of iron.) Little Cottonwood Cañon, Utah Territory; near Fort Ellis, Montana Territory.

Lithomarge. Little Cottonwood Cañon, Utah Territory.

Magnetite, (magnetic-iron ore.) In gneissic rock, near Golden City, Colorado Territory; in gneisses near Ogden, Utah Territory.

Malachite, (green carbonate of copper.) Upper end of Ogden Cañon, near Ogden City, Utah Territory; near Virginia City, Montana Territory; Clarke's Fork of Yellowstone River, Montana Territory.

Massicot (lead-ocher.) Little Cottonwood Cañon, Utah Territory

Muscovite, (common mica.) Near second cañon of Yellowstone; near Black-Tail Deer Creek, Montana Territory; Téton Mountains, Idaho Territory; (var., *Fuchsite*,) from east side of Madison Cañon, Montana Territory.

Nephelite. In trachytes in Grand Cañon of Snake River, Idaho Territory. **Obsidian**, (volcanic glass.) On Trail Creek, near Yellowstone Valley; in chips throughout the Yellowstone Valley, from the lower cañon to Yellowstone Lake. *Spherulitic*, from Grand Cañon of Yellowstone River. *Porphyritic*, from Grand Cañon of the Yellowstone; divide between Yellowstone and Madison Rivers; Yellowstone National Park; east side of Snake River, Idaho Territory; in basin of Henry's Lake, Idaho Territory; head of Falls River, Idaho Territory; Lewis's Lake, Wyoming Territory; valley of Madison River, Montana Territory; West Gallatin Cañon, Montana Territory; near Missouri River, below Horseshoe Bend, Montana Territory.

Olivine. In basalts in Yellowstone Valley, opposite Boteler's Ranch, Montana Territory; in basalts on Snake River and Henry's Fork, Idaho Territory.

Opal. East Fork of Yellowstone River, Grand Cañon of Yellowstone; summit of Mount Blackmore, Montana Territory; Colorado Springs, Colorado Territory. *Hydrophane*, Grand Cañon of Yellowstone. *Wood-opal*, East Fork of Yellowstone River, near Gallatin City, Montana Territory; Jefferson County, Montana Territory. *Dendritic*, Hot Springs district, Montana Territory. *Hyalite*, Grand Cañon of Yellowstone River. Excellent specimens; clear, in colorless globular concretions, from summit of Mount Blackmore, Montana Territory; near Jackson's Lake, Wyoming Territory. *Geyserite*, (siliceous sinter,) geyser-basins of Fire-Hole River, presenting white, gray, greenish, pink, and red varieties, massive, porous, filamentous, compact, cauliflower-like, beaded, or pearly. The specimens vary from translucent to opaque, some being very friable while others are firm, even on drying; Hot Springs, on southwest arm of Yellowstone Lake; geyser-basin of Shoshone Lake, Yellowstone National Park.

Plasma. (See *Quartz*.)

Prase. (See *Quartz*.)

Pumice. Emigrant Gulch, Montana Territory.

Pyrite, (iron pyrites.) With galena, Central City, Colorado Territory; with serpentine and hematite, near Ogden, Utah Territory; in quartzite, in Emigrant Gulch, Montana Territory; Clarke's Fork of Yellowstone River, Montana Territory. *Pentagonal dodecahedral crystals*, from Téton Mountains, Idaho Territory; Little Cottonwood Cañon, Utah Territory.

Quartz. In granites throughout Rocky Mountains. *Rock-crystal*, Ogden, Utah Territory; in geodes, with chalcedony and calcite, from East Fork of Yellowstone River; from Sawtelle's Peak, near Henry's Lake, Idaho Territory; in granites of Téton Mountains, Idaho Territory; divide between Ross Fork and Fort Hall, Idaho Territory. *Amethystine* (*amethyst*), from the Colorado divide south of Denver, Colorado Territory; fine crystals in large geodes of chalcedony from East Fork of Yellowstone River, about ten miles above the junction of the Yellowstone. The specimens are found on the summit of a bold hill on the south side of the river. *Blue*, near second cañon of the Yellowstone. *Smoky* (*cairngorm stone*), Colorado divide, Colorado Territory. *Milky*, near second cañon of Yellowstone; East Fork of Yellowstone River. *Chalcedony*, Spring Cañon, near Fort Ellis, Montana Territory; in chips throughout the Yellowstone Valley; in geodes with calcite and quartz, above second cañon in Yellowstone Valley; associated with jasper from Elk Creek, near Yellowstone River, Montana Territory; forming the outside of geodes from East Fork of Yellowstone River; also associated with calcite at same locality, from Grand Cañon of Yellowstone River; in rounded pebbles on shores of Yellowstone Lake; from summit of

- Mount Blackmore, Montana Territory; beautiful blue specimens with jasper, in Hot Spring district, Montana Territory; from Jackson's Lake, Wyoming Territory. *Carnelian*, from Grand Cañon of Yellowstone. *Chrysoprase*, East Fork of Yellowstone River. *Prase*, East Fork of Yellowstone Lake, Montana Territory; Willow Cañon, Utah Territory; near lower cañon of Madison River, Montana Territory. *Agate*, banded, near Fort Ellis, Montana Territory; in Yellowstone Valley, above second cañon; East Fork of Yellowstone River, near Elk Creek, Yellowstone Valley, Colorado Springs, Colorado Territory. *Moostastone* (*moss-agate*), near Boteler's ranch, Yellowstone Valley, Montana Territory. *Flint*, (bluish variety,) in valley of Yellowstone; West Gallatin River; (brown variety,) Pole Creek near Madison River, Montana Territory; (black variety,) East Fork of Yellowstone River. *Jasper*, (red variety,) in conglomerates, near Ogden, Utah Territory; near Fort Ellis, Montana Territory; Yellowstone Valley, Montana Territory; back of Boteler's ranch, Montana Territory; East Fork of Yellowstone River; near Elk Creek, Montana Territory; east side of Middle Cañon of Madison River; (yellow variety,) Bridger Peak, near Fort Ellis, Montana Territory; East Fork of Yellowstone River; (gray variety,) East Fork of Yellowstone; (green variety,) East Fork of Yellowstone River; near Horseshoe Bend of Missouri River, below Gallatin City, Montana Territory; on Henry's Fork of Snake River; (black variety,) East Fork of Yellowstone River. *Silicified wood*, abundant throughout the valleys of Yellowstone, Madison, and Gallatin Rivers, and on the Yellowstone National Park. *Itacolumite*, (common inflexible variety,) near Mount Cowan, Yellowstone Valley.
- Ripidolite.** In metamorphic rocks, near Ogden, Utah Territory; east side of Middle Cañon of Madison River, Montana Territory; near Henry's Lake, Idaho Territory; Téton Mountains, Idaho Territory.
- Sanidine.** (See *Feldspar*.)
- Satin-spar.** (See *Gypsum*.)
- Selenite.** (See *Gypsum*.)
- Serpentine.** Near Ogden, Utah Territory; in Snowy Range of Yellowstone; divide between Madison and Gallatin Rivers; Alder Gulch, near Virginia City, Montana Territory; Cañon Creek, a branch of Téton River, Idaho Territory.
- Silicified wood.** (See *Quartz*.)
- Silver.** (Native.) Cherry Creek mines, Madison County, Montana Territory; in *galena*, from Little Cottonwood Cañon; Clarke's Fork mines.
- Sphalerite**, (zinc blend.) Little Cottonwood Cañon, Utah Territory.
- Strontianite**, (carbonate of strontia.) Sawtelle's Peak, near Henry's Lake, Idaho Territory.
- Sulphur.** In *crystals*, at Gardiner River Hot Springs; on bluffs opposite Tower Falls; in Mud Springs, near Mount Washburne, in small crystals; Crater Hills, Yellowstone Valley; geyser-basin of Fire-Hole River; Shoshone Lake geyser-basin; on divide between Yellowstone and Fire-Hole Rivers.
- Talc.** Near Ogden, Utah Territory; in Snowy Range of Yellowstone, Montana Territory; near Henry's Lake, Idaho Territory; Téton Mountains, Idaho Territory.
- Tremolite.** (See *Amphibole*.)
- Tufa**, (Calcareous.) At Hot Springs, Gardiner's River; Warm Springs, near Fort Hall, Idaho Territory; Grand Cañon of Snake River, Idaho Territory.
- Wulfenite.** Little Cottonwood Cañon, Utah Territory.

No. 3.—CATALOGUE OF ROCKS.

Catalogue of rocks collected by the Yellowstone division of the expedition, A. C. Peale.

No.	Name.	Locality.
1-7	Red porphyritic granite.....	Ute Pass, Colorado.
8-11	White gypsum.....	Near Colorado City, Colorado.
12-14	Pink gypsum.....	Do.
15-17	Light-red sandstone.....	Do.
18-19	Dark-red sandstone.....	Do.
20-26	Serpentine, with quartz and chlorite.....	Ogden, Utah.
27	Chlorite-schist.....	Do.
28	White quartzite.....	Do.
29	Quartzite, ferruginous.....	Do.
30	Siliceous conglomerate.....	Do.
31-32	Protoginic gneiss.....	Do.
33-35	Syenite.....	Do.
36-42	Quartz, with hematite.....	Do.
43	Quartz.....	Do.
44	Jasper-conglomerate.....	Do.
45	Pink quartzite.....	Do.
46	White quartzite.....	Do.
47	Blue limestone.....	Do.
48	Mica-schist.....	Do.
49	Syenitic gneiss.....	Do.
50-51	Aplite.....	Do.
52	Quartzite.....	Do.
53	Mica-schist.....	Do.
54	Syenitic gneiss.....	Do.
55-56	Protogine.....	Do.
57	Protogine, with pyrites.....	Do.
58-59	Syenitic gneiss.....	Near North Ogden, Utah.
60	Porphyry.....	Bingham Cañon, Utah.
61	do.....	Do.
62	Quartzite, with pyrites.....	Do.
63	Hematite.....	Do.
64-66	Granite, (white).....	Little Cottonwood Cañon, Utah.
67-68	Mica-schist.....	Do.
69-70	Quartzite.....	Do.
71	Crystalline limestone.....	Do.
72	Magnesium-limestone.....	Do.
73-74	Dendritic sandstone.....	Near Helena, Montana.
75-78	Purple quartzitic sandstone.....	Spring Cañon, near Ft. Ellis, Mont.
79	White quartzitic sandstone.....	Do.
80-83	Argillaceous sandstone, (metamorphosed).....	Do.
84	Sandstone-conglomerate.....	Do.
85-88	Brown limestone.....	Do.
89-91	Calcareous sandstone shale.....	Do.
92	Gray calcareous sandstone.....	Do.
93	Coarse reddish sandstone.....	Do.
94-95	Gray fossiliferous sandstone, (calcareous).....	Do.
96	Coarse brown limestone.....	Do.
97	Compact limestone.....	Do.
98	White quartzite.....	Do.
99	Calcareous sandstone.....	Do.
100	White quartzite.....	Do.
101	Grayish quartzite.....	Do.
102	Flinty conglomerate.....	Do.
103	White quartzite.....	Do.
104	Yellow limestone.....	Do.
105	White quartzite.....	Do.
106-07	Yellowish calcareous sandstone.....	Do.
108	Reddish sandstone.....	Do.
109	Purple sandstone.....	Do.
110	Pink sandstone, calcareous.....	Do.
111	Conglomerate.....	Do.
112	Purple spotted sandstone.....	Do.
113-14	Brick-red sandstone, (compact).....	Do.
115-16	Purple sandstone, (compact).....	Do.
117	Gray quartzite.....	Do.
118	Purple sandstone.....	Do.
119	Arenaceous limestone.....	Do.
120	Carboniferous limestone.....	Do.
121	Gray sandstone, (Eocene).....	Above Spring Cañon.
122	Soft, gray sandstone, (calcareous).....	Near Fort Ellis, Montana.
123	Gray sandstone.....	Do.
124-25	Brown sandstone, (Eocene).....	Do.
126	Calcite.....	Do.
127-29	Sandstone conglomerate, (Pliocene).....	Do.
130-37	Volcanic breccia.....	Mystic Lake, near Fort Ellis, Mont.
138-39	Limestone, (Carboniferous).....	Do.
140	White calcareous sandstone.....	Near Fort Ellis, Montana.
141	Red limestone.....	Do.

Catalogue of rocks collected, &c.—Continued.

No.	Name.	Locality.
142-46	Gray sandstone, (Cretaceous)	Bridger Peak, near Fort Ellis.
147-48	Hard, greenish sandstone, (Cretaceous)	Do.
149	Hard, gray sandstone	Head of Middle Creek, Montana.
150	Soft, gray sandstone	Do.
151	Basalt	Valley of Yellowstone River.
152	Volcanic breccia	Near Boteler's, Montana.
153-54	Trachyte	Do.
155	Rhyolite	Do.
156-57	Basalt, with olivine	Do.
158	Basalt-tuff	Do.
159	Dibase	Cinnabar Mountain, Montana.
160	Bl. ls. slate	Do.
161	Trachyte	Electric Peak, Yellowstone Valley.
162-63	Soft sandstone, (Cretaceous)	Do.
164	Clay slate, (Cretaceous)	Do.
165	Marl	Valley of Yellowstone River, near Boteler's.
166	Sandstone, (Tertiary)	Bluff opposite Gardiner's River. —
167	Quartzite, (Cretaceous)	Do.
168	Sandstone, (Cretaceous)	Do.
169	Purple sanidine trachyte	Do.
170	Micaceous gneiss	Mouth of Black-Tail Deer Creek, Montana.
171	Limestone, (Carboniferous)	Near mouth of Black-Tail Deer Creek, Montana.
172	Brown sandstone metamorphosed, (Tertiary)	Near Elk Creek, Montana.
173-74	Trachyte-breccia	Do.
175	Trachyte	Do.
176-77	Gneiss	Do.
178	White rhyolite	East Fork of Yellowstone River.
179	Volcanic sandstone	Near Tower Creek, Yellowstone Valley, Montana.
180	Gray sandstone	Near junction of East Fork of Yellowstone, Montana.
181	Micaceous gneiss	Do.
182	Quartz	Do.
183	Trachytic sandstone	Near Grand Cañon of Yellowstone.
184	Obsidian porphyry, (black)	Do.
185	Obsidian porphyry, (brown)	Do.
186	Obsidian porphyry, (perlite-like)	Do.
187	Porphyritic obsidian	Do.
188	Spherulitic obsidian	Do.
189	Vesicular trachyte-porphyry	Do.
190	White trachyte-porphyry	Do.
191-92	Rhyolite	Do.
193	Jasper	Do.
194	Perlite-like trachyte-porphyry	Do.
195	Green and brown jasper	Do.
196	Cavernous trachyte-porphyry	Do.
197-98	Common trachyte-porphyry	Do.
199	White trachyte	Do.
200	Vesicular trachyte	Grand Cañon of Yellowstone River.
201	Porphyritic trachyte	Do.
202	Obsidian porphyry	Do.
203	Vesicular trachyte	Do.
204-13	Argillo-trachyte porphyry	Do.
214	Hot-spring deposit	Violet Creek, valley of the Yellowstone.
215	Trachyte-conglomerate	Crater Hills, Yellowstone Valley.
216-18	Trachytic tuff	Do.
219	Vesicular trachyte	Near Mud Volcanoes, Yellowstone Valley.
220	Brown obsidian sandstone	Do.
221	Black obsidian sandstone	Do.
222	Purplish volcanic conglomerate	Do.
223	Red volcanic conglomerate	Do.
224	White trachyte	Do.
225	Trachyte porphyry	Do.
226	Geyserite sandstone	Fire-Hole Basins, Yellowstone National Park.
227	Trachyte porphyry	Upper Cañon of Madison River.
228	Rhyolite	Do.
229	Cavernous trachyte, (porphyritic)	Do.
230	Vesicular trachyte-porphyry	Do.
231	Siliceous limestone	East side of Madison River, near Middle Cañon.
232	Quartzite	Do.
233	Gray calcareous sandstone, (Jurassic)	Do.
234	White arenaceous limestone	Do.
235	Blue limestone, (Carboniferous)	Do.
236	Jaspery limestone-conglomerate	Do.

Catalogue of rocks collected, &c.—Continued.

No.	Name.	Locality.
237	Pebbly limestone, (Silurian)	East side of Madison River, near Middle Cañon.
238	Micaceous gneiss	Do.
239	Chlorite-schist	Do.
240	Gray gneiss	Do.
241	Mica-schist	Do.
242	Limestone, (Quebec)	East side Middle Cañon of Madison.
243	Quartzite	Do.
244	Glauconitic quartzite	Do.
245	Red calcareous sandstone	Do.
246-47	Chlorite-schist	Do.
248	Talcose-schist	Near Red Rock Lake, Montana.
249	Quartz-schist	Do.
250	White quartz	Wedge Peak, east side Madison River.
251	Mica-schist	Do.
252	Gneiss	Do.
253	Micaceous gneiss	Do.
254	Trachyte	Valley of Madison River.
255	Slaty trachyte	Do.
256	Purplish trachyte	Do.
257-58	Gneiss	Madison Range.
259	Red quartzite	Do.
260	Magnesian limestone, (Carboniferous)	Bear Creek, Madison Range.
261	Blac limestone, (Carboniferous)	Do.
262	Calcareous sandstone	Do.
263	Garnetiferous gneiss	West side Lower Cañon of Madison River.
265	Quartz	Do.
266	Fine-grained gneiss	Do.
267	Gray gneiss	Do.
268	Slaty gneiss	Do.
269	Micaceous gneiss	Do.
270	Sandstone	Jackass Creek, Montana.
271	Flint	Pole Creek, Montana.
272	Basalt, (black)	Mount Blackmore, Montana.
273	Basalt, (red)	Do.
275	Gabbro	West Gallatin Cañon, Montana.
276	Diorite	Do.
277	Brown sandstone, (Cretaceous)	Do.
278	Gray sandstone, (Cretaceous)	Do.
279	Blue limestone, (Carboniferous)	Do.
280	Crystalline limestone, (Carboniferous)	Do.
281	Oolitic limestone, (Carboniferous)	Do.
282	Brown fossiliferous limestone, (Jurassic)	Do.
283	Volcanic conglomerate	Divide between West Gallatin and Yellowstone River.
284	Metamorphosed sandstone, (Tertiary)	Do.
285	Amygdaloid	Valley of Yellowstone, above Boteler's.
286-87	Chlorite-schist	Emigrant Gulch, Montana.
288	Gneiss	Do.
289	Dolerite	Do.
290	Basalt	Do.
291-92	Basalt-tuff	Do.
293	Porphyritic basalt	Do.
294	Quartzite, with pyrites	Do.
295	Volcanic tufa	Near Boteler's, Yellowstone Valley.
296	Quartz	Mt. Cowan, Yellowstone Valley.
297	Itacolumite, (common)	Do.
298	Gneiss	Do.
299	Chloritic schist	Do.
300	Brown sandstone, (Tertiary)	Divide Creek, Montana.
301	Blue slaty limestone, (Carboniferous)	Flathead Pass, Montana.
302	Slaty limestone, (Silurian)	Do.
303	Pebbly limestone, (Silurian)	Do.
304	Coarse fossiliferous limestone, (Silurian)	Do.
305-06	Micaceous sandstone	Do.
307	Chlorite-rock	Near Horseshoe Bend, Missouri River, Montana.
308	Basalt	Do.
309-10	Brown-clay slate, (Silurian)	Do.
311	Sandstone	Do.
312-13	Blue argillaceous slate	Do.
314-15	Trap, (from dike in Jurassic)	Missouri River, below Gallatin City, Montana.
316	Trap, (from dike in Carboniferous)	Do.
317	Pebbly limestone, (Silurian)	Near Gallatin River, above Gallatin City, Montana.
318	Glauconitic limestone, (Silurian)	Do.
319	Hard-brown sandstone, (Silurian)	Do.

Catalogue of rocks collected, &c.—Continued.

No.	Name.	Locality.
320	Blue slaty limestone, (Silurian)	Near Gallatin River, above Gallatin City, Montana.
321	Green chloritic slates, (Silurian)	Do.
322	Purple calcareous sandstone	Do.
323	Glaucopitic sandstone, (calcareous)	Do.
324	Purplish sandstone	Do.
325	Pink quartzite	Do.
326	Steel-gray quartzite	Do.
327	Red sandstone	Do.
328	Micaceous sandstone, (fine-grained)	Do.
329	Micaceous sandstone, (pebbly)	Do.
330	Blue argillaceous slate, (calcareous)	Do.
331	Brownish argillaceous slate, (calcareous)	Do.
332	Trap-rock, (dike in Jurassic)	Do.

Rocks collected by the Snake River division of the expedition, Professor F. H. Bradley and W. R. Taggart.

No.	Name.	Locality.
1	Hematite	Near Brigham City, Utah.
2	Oolitic limestone, (Tertiary)	Bear River Bridge, Utah.
3-9	Fossiliferous limestone, (Quebec group)	Malade City, Utah.
10	Gray limestone, (Tertiary)	Do.
11	Gray trachyte	Near Fort Hall, Idaho.
12-14	Cellular trachyte	Sand Hill Mountain, Idaho.
15-17	Basalt	Falls River, Idaho.
18	Rose-colored trachytic tufa	Do.
19-20	Basalt	Pierre's River, Idaho.
21-22	Trachytic tufa	Do.
23	Trachyte-porphry	Do.
24	Serpentine	Do.
25-26	Conglomerate-limestone, (Quebec group)	Téton Cañon, Idaho.
27	Limestone, (Niagara group)	Téton Creek, Idaho.
28	Glaucopitic sandstone	Téton Mountains, Idaho.
29	Trap-rock	Do.
30	Slaty trachyte	Bechler's River, Idaho.
31	Granular trachyte	Do.
32	Trachytic tufa	Crater near Henry's Lake, Idaho.
33-35	Basalt	Sawtelle's Peak, Idaho.
36	Micaceous quartzite, (Potsdam)	Tyghee Pass, Idaho.
37-38	Sanidine trachyte	Upper Madison Cañon, Montana.
39	Hot-spring deposit, (calcareous)	Gibbon's Fork of Madison River, Montana.
40	Volcanic sandstone	Lower geyser-basin, Yellowstone National Park.
41-42	Volcanic sandstone, compact, metamorphosed	Shoshone Lake, Yellowstone National Park.
43-44	Volcanic sandstone, conglomerate	Do.
45-46	Brown porphyritic obsidian	Near Shoshone Lake, Yellowstone National Park.
47-48	Volcanic sandstone	Do.
49	Sanidine trachyte	Two miles south of Shoshone Lake, Yellowstone National Park.
50-51	Trachyte	Lewis's Lake, Wyoming.
52-64	Tufaceous geyserite	Do.
65	Tufaceous sandstone	Do.
66	Compact geyserite	Do.
67	Trachyte	Mt. Sheridan.
68-69	Trachyte-porphry	Do.
70	Compact sandstone, (Tertiary)	Hunter's River, Wyoming.
71-77	Rhyolitic	East side cañon of Union River, Wyoming.
78	White volcanic sandstone	Do.
79	Porphyritic obsidian, (black)	Do.
80-81	Spherulitic obsidian	Do.
82	Rhyolitic	Do.
83	Gray trachyte	West side cañon of Union River, Wyoming.
84	Brown trachyte	Do.
85	Trachyte	Ridge west of Coulter's Creek, Wyoming.
86	Red trachyte	Do.
87	Cellular trachyte	Do.

Rocks collected by the Snake River division of the expedition, &c.—Continued.

No.	Name.	Locality.
88-89	Red sandstone, (Triassic ?)	Third cañon of Snake River, Wyoming.
90	Pink sandstone, (Carboniferous ?)	Opposite mouth of Union River, Wyoming.
91	Sandstone, (Carboniferous ?)	Do.
92	Limestone, (Carboniferous ?)	Do.
93-94	White sandstone	Do.
95	Trachyte	Do.
96-98	Trachyte	Do.
99	Cellular trachyte	Do.
100	Porphyritic trachyte	Head of Fall River, Wyoming.
101	Sandstone, (metamorphosed)	West side outlet of Jackson's Lake, Wyoming.
102	Cavernous trachyte	Do.
103	Gray trachyte	Do.
104-05	Amygdaloidal trachyte	Do.
106	Volcanic tufa	Do.
107	Sandstone	Mouth of Buffalo Fork of Snake River, Wyoming.
108	Limestone, (laminated)	Head of Buffalo Fork of Snake River, Wyoming.
109	Green sandstone, (Pliocene)	Ridge east of Henry's Lake, Idaho.
110	Granite	East side Téton Mountains, Wyoming.
111	Micaceous gneiss	Do.
112	Granitoid gneiss	Do.
113	Quartz	Do.
114	Granite	Do.
115	Chert, (Carboniferous)	North Gros Ventre Butte, Wyoming.
116	Siliceous limestone, (Pliocene)	Do.
117	Calcareous sandstone	Do.
118	Quartzitic sandstone, (Potsdam ?)	Do.
119-21	Slaty trachyte	Do.
122	White sandstone, (Tertiary)	Gros Ventre River, Wyoming.
123	Limestone, (Triassic ?)	Do.
124-26	Red sandstone, (Triassic ?)	Do.
127	Limestone, (Carboniferous)	Do.
128-33	Rhyolite	South Gros Ventre Butte, Wyoming.
134	Slaty trachyte	Do.
135-36	White quartzitic sandstone, (Carboniferous)	West side Téton Pass, Wyoming.
137-39	Red sandstone, (Triassic ?)	Do.
140-41	Pink trachytic tuff	Do.
142-44	Compact basalt	Do.
145-48	Bituminous mud-stone	Snake River Cañon, Wyoming
149-51	Gypsiferous bituminous mud-stone, (fossiliferous)	Do.
152-53	Conglomerate sandstone	Do.
154-56	Fine-grained sandstone	Do.
157-60	Chert, (Carboniferous)	Do.
161	Hot-spring deposit	Do.
162-63	Slaty trachyte	Snake River, below mouth of Salt River, Wyoming.
164-65	Vesicular trachyte	Snake River, head of upper basalt-cañon, Wyoming.
166-68	Porphyritic trachyte	Do.
169-70	Magnesian limestone	Swan Valley, Idaho.
171-72	Quartzitic sandstone	Do.
173	Compact limestone	Do.
174	Brown quartzitic sandstone	Do.
175	Semi-metamorphosed sandstone	Do.
176	Sandstone	Do.
177-78	Pink siliceous limestone	Do.
179	Crinoidal limestone	Do.
180	Compact blue limestone	Do.
181	Fragmental limestone	Do.
182	Chert	Do.
183	Purple trachyte	South side of upper basalt-cañon Idaho.
184	Vesicular trachyte	Do.
185-86	Limestone, (Pliocene)	Near Fort Hall, Idaho.
187-89	Limestone, (Jurassic)	Lincoln Valley, near Fort Hall, Idaho.
191-92	Glaucconitic sandstone, (Quebec)	Near Fort Hall, Idaho.
193	Chert, (Carboniferous)	Lincoln Valley, Idaho.
194	Compact limestone, (Pliocene)	Do.
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