REPORT

OF

FRANK H. BRADLEY,

GEOLOGIST OF THE SNAKE RIVER DIVISION.

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WASHINGTON, D. C., *April* 5, 1873.

SIR: I hand you herewith my report upon the region examined by me during the past season, while accompanying the Snake River division of your party.

After working for about a month at Ogden, while our outfitting was being completed, we followed well-marked roads to Fort Hall, Idaho, and thence to Market Lake Station. Here we turned off into the almost unbroken wilderness, and spent some time in examining the Téton Mountains, from which region we passed up the valley of Henry's Fork to its head, and crossed by Tyghee Pass to the Upper Madison, which we also followed to its source, in Madison Lake, after stopping by the way to examine the geysers and hot springs of the Fire-Hole Basins. Thence we crossed the divide to Shoshone Lake, examined all the head-waters of the main Snake River, and descended that stream, via Jackson's Lake and the Grand Cañon, to its emergence into the Great Basin, reaching the latter at a point only a few miles from Fort Hall.

From Ogden to Fort Hall, we were able to examine but a narrow strip of country; but, beyond the latter point, frequent side trips enabled us to understand the general features of quite wide areas, though, at several points, we were so much hurried as to neglect certain small spaces, which are now seen to have been essential to absolute certainty regarding the connections of different parts of our work. Upon the whole, however, though much yet remains to be done by subsequent explorers in that region, I am satisfied that they will find but few errors in our results.

I am indebted to Mr. Bechler, our chief topographer, for many distances and bearings, as well as for the very accurate map which he has now nearly completed, and upon which I expect to color the outcrops of the various formations. I am also indebted to Mr. Hering, astronomer and meteorologist, for the determination of most of the levels indicated in this report. Mr. Gannett, of your own party, has also aided me in this matter. As Mr. Nicholson remained at Fort Hall during our absence, taking hourly observations, while previous barometric comparisons of Fort Hall and Ogden had been made by Messrs. Gannett and Hering, I place much reliance on the determinations of elevations throughout the region examined.

The skillful pencil of Mr. Holmes has supplied the sketches which accompany this report, the materials being mostly obtained from the photographs of Mr. Jackson, who accompanied us as far as to the Fire-Hole, and from Mr. Bechler's field-notes.

Mr. Taggart acted as my assistant during most of the trip; and his work was satisfactory.

I have to thank our surgeon, Dr. Curtis, for information on certain microscopical points, as well as for much personal kindness.

Yours, very respectfully,

FRANK H. BRADLEY,
Chief Assistant Geologist.

Dr. F. V. HAYDEN,
In charge of the United States Geological Survey of the Territories.

CHAPTER I.

WAHSATCH MOUNTAINS—OGDEN TO FORT HALL.

The first installment of the party reached Ogden, Utah, which had been determined on as our rendezvous, upon the evening of Friday, May 24; and the work of the season was commenced on the following day, by the ascent of a peak of the Wahsatch Range, which stands directly back of the town, and has been called Ogden Peak. This is the culminating point of that block of mountains which is separated from the northerly and southerly continuations of the range by the cañons of Weber and Ogden Rivers. No mercurial barometer was taken to the summit; but its height was twice measured with aneroid barometers, and once, roughly, with a pocket-level. The elevation was thus approximately determined at 5,298 feet above the railroad at Ogden Station, or 9,638 feet above the sea-level.

The mountain was originally pretty well covered with a tolerably thick growth of small-sized pine and spruce, with some cedar along the limestone outcrops, except on the steepest slopes, which, where not entirely bare of soil, had, and still have, very dense, low growths of a form of "Jersey tea," (*Ceanothus velutinus*,) and of small "mountain mahogany," (*Cercocarpus ledifolius*,) mostly so depressed by the winter's snows as to have taken a permanent downward slope, which greatly increases the difficulty of the steep ascent, but often renders the descent altogether too easy. The timber has mostly been cut, except on the highest parts of the mountain; and, along the small cañons and lower slopes, the places of the pine and spruce have been taken by a small growth of scrub-oak (*Quercus alba*) and maples, (*Acer glabrum* and *A. grandidentatum*.) This oak also abounds along most of the small streams which flow from all the cañons, and extends in small groves far out upon the terraces. I think that we may reasonably expect these and other "hard woods" to increase and take the place of the pines which have so nearly disappeared, and which have here but very few descendants.

Upon our first ascent of the mountain, we reached the lower edge of the snow, upon a spur, at about 2,000 feet below the summit, and, on our return, descended to nearly the same level, in a ravine, by "sitting glissades," over the soft surface.

At the time of our arrival, the streams issuing from the cañons were pretty full, though variable, by reason of the daily meltings and nightly freezes; but, before our departure for the northward, the snow-drifts were so greatly reduced that their flow had nearly ceased; and the irrigation of the lower ground immediately about the town, until then depending on these streams, was supplied entirely from Ogden River, by a ditch starting at the mouth of Ogden Cañon. This failure during the summer will render the cultivation of the higher terraces impossible, or at least extremely precarious, until ditches are run up the Ogden or the Weber River far enough to take water at quite a high level.

Except along the immediate banks of the streams, these terraces are mostly overgrown with sage-brush, though the scrub-oaks before mentioned also spread out over considerable areas, and there are some patches of almost barren sand and gravel. Along most of the mountain, there are only three prominent terraces, marking old lake-levels, the highest reaching the level of about 876 feet above the railroad, or 966 feet above the present lake-level; but they are much more numerous near the mouths of the streams, where the stream-currents have dis-

tributed their sediment, when the lake-waters were at these higher levels. Thirteen of these terraces were observed on a line between the center of the town and the mouth of Ogden Cañon, the highest of which was less than 400 feet above the railroad. Above this point, the foot of the mountain has been swept so bare of rubbish as to show no terrace until we reach the highest, which was slightly outlined on the upper slopes.

Most of the material of these terraces is entirely uncompacted, and the edges expose beds of drifting sand and loose gravel; but, at two or three levels, there are layers, a few feet in thickness, in which a calcareous cement has more or less consolidated the gravel into still rather loose and porous conglomerates.

The *débris* thus deposited along the base of the mountain has so covered the solid strata as to make it difficult to determine their exact positions at this low level; but the upper slopes show so much bare rock as to make the general structure very evident. The beds form, as was stated in last year's report, a huge anticlinal, whose axis makes a small angle with the general trend of the range; but it proves to be much more complicated than was then supposed. While its eastern slope is nearly regular, its western is quite irregular, including at least two subordinate folds, large portions of which have been eroded, so that one must study closely, to be able to supply the missing links.

The accompanying sketch (Fig. 44) shows, in a general way, the actual and theoretical section through the range, at Ogden Peak.

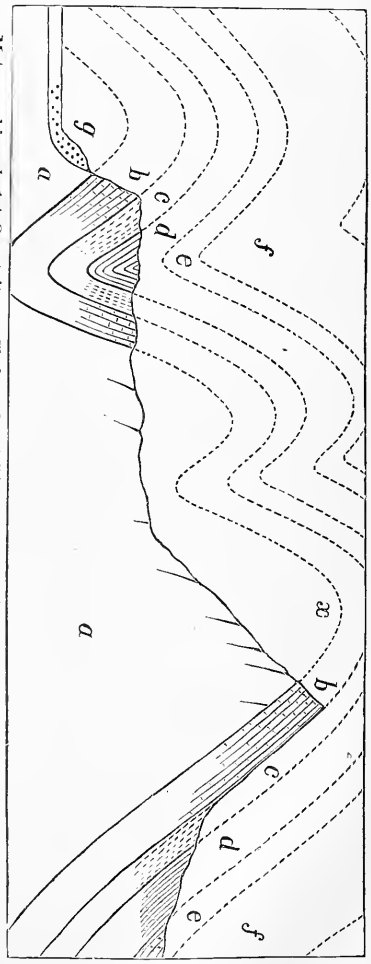


Fig. 44.

a, Metamorphics; *b*, 1st Quartzite; *c*, Shales; *d*, 1st Limestone; *e*, 2d Quartzite; *f*, 2d Limestone; *x*, Axis of main anticlinal; *g*, Terraces.

In the more northern portion of this block of mountain, both of the folds of the western slope make considerable outcrops; but their axes are so much inclined to the horizon that the bottoms of the folds rise rapidly as we go southward, until they pass above the present surface, leaving the western slope here entirely composed of metamorphic rocks, in which no continuation of these particular folds can be traced. The southern portion of the eastern slope was not examined; so that I cannot say just at what point of the eastern base the unmetamorphosed rocks disappear from it; but they certainly show no outcrop in the section displayed along Weber Cañon. At two or three points, the metamorphic rocks show some slight easterly dips; but most of their dips are strong westerly, and the overlying beds are *plainly unconformable*. The metamorphics are mostly hornblendic

gneisses, with some granites and occasionally chloritic and talco-mica schists, all more or less penetrated by quartz-veins. One of these veins, near the summit, contains considerable quantities of translucent semi-crystalline masses of hematite. These veins have been opened at various places by prospectors; but nothing of any value has yet been reported. Several of these openings were examined; but a few small scattered crystals of pyrite were the only metallic indications seen. The so-called "tin-mine" was not visited. Samples of its "ore" appeared to be merely massive hornblende, whose high specific gravity, due to the presence of iron, probably originated the idea of its metallic character. A "graphite mine," about twelve miles north of Ogden, near the Hot Springs, was examined, in company with its owners, and found to be a small opening in an irregular quartz-vein which contains a few small flakes of graphite, but gives no indication of the presence of any valuable bodies of that mineral. On the whole, it appears probable that no valuable mines will be found in the metamorphic rocks of this neighborhood.

Immediately upon the metamorphics we find about 1,500 feet of heavy-bedded quartzite, partly white, but mostly quite ferruginous. Its lowest layers consist of a coarse conglomerate of large, red, gray, and white quartz, and jasper pebbles. The upper portions are mostly finer grained, with occasional streaks of very small pebbles. The lines of false bedding are rather irregular, but mostly face the west or southwest, indicating open sea in that direction at the time of their deposition. The only fossils found in these beds are indistinct fucoidal markings, resembling in general appearance the *Arthrophycus Harlani* of the Medina sandstone, but plainly not identical with it. From the character of the overlying strata, I am inclined to refer this bed to the age of the Potsdam sandstone. It forms the grand arch figured in the report for 1871. Just to the south of this arch, the horizontal edges of its outcrop, in the continuation of the axis of the arch, form a high cliff, over which the waters of one of the small mountain-streams falls, first in a steep cascade 52 feet, and then in one leap 263—in all, 315 feet—to the bottom of a narrow ravine. The tumbling rocks under the spray of the fall were covered with numerous snails, (*Helix.* sp.)

These quartzites are overlaid by something over 1,000 feet of gray calcareous shales, without fossils so far as seen, and these by nearly 2,000 feet of compact blue and gray dolomitic limestone, partly oolitic in structure, partly silicious and even cherty, partly filled with irregular streaks and patches of ferruginous clay. In this immediate neighborhood, this bed of limestone is exposed only where the strata have been much disturbed, and it has consequently been mostly thoroughly shivered in every direction, though afterward recemented by the thin sheets of calcite which fill all the crevices. No fossils were found in it hereabout, but a single specimen of *Halysites catenulata*, the characteristic coral of the Niagara group, was obtained by the survey, in 1871, from the upper part of what was supposed to be this bed, in Box-Elder Cañon, some twenty-five miles north of Ogden. From the character of the rock, however, I judge that at least the larger part of the bed, together with the underlying calcareous shale, belongs to the Quebec Group of the Lower Silurian age, which is so largely developed along the Malade Valley farther north. It is not impossible that here, as in the neighborhood of the Téton Mountains, nearly two hundred miles farther north, the deposition of limestone might have been continuous from the Quebec epoch onward to the Niagara epoch or even later.

This limestone is followed by a second heavy bed of quartzite, mostly

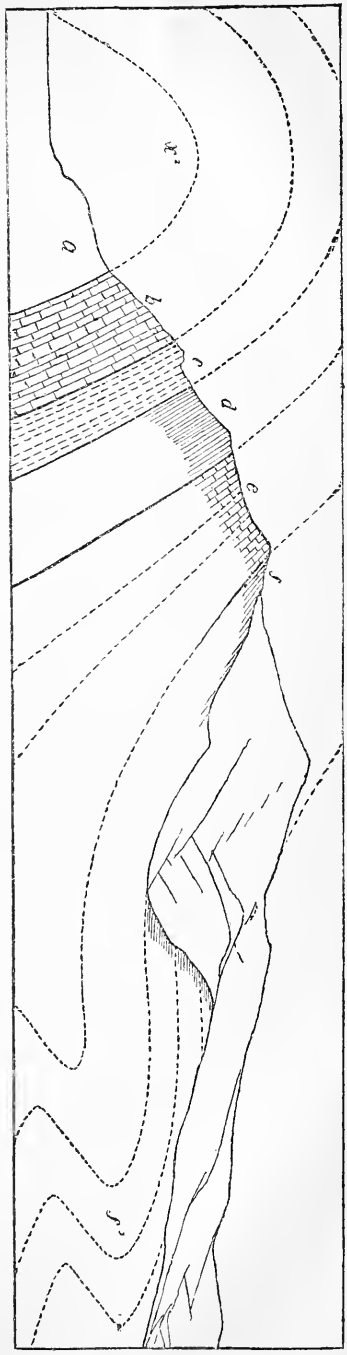
ferruginous, from 2,000 to 2,500 feet in thickness. No fossils were seen in it, and I know of nothing which would give any grounds for judging as to its age.

This is followed by probably 3,000 feet of quite compact, mostly thin-bedded gray and drab limestone, largely silicious, the lower part even cherty and somewhat geodiferous. These beds contain a few fossils, *Zaphrentis*, &c., which are plainly of Carboniferous age.

These higher beds make no appearance upon the western slope of this mountain-block, except in the immediate neighborhood of Ogden Cañon. The crest of the mountain consists of the lower quartzites, as shown in the section previously given. The upper of the two subordinate folds on the western slope has its eastern side much steeper than its western, and at some points almost pinched out. The lower and more westerly one has both sides quite steep, and the two edges of the thin plate of limestone which forms its central portion are folded so closely together as to appear, at first sight, when seen from below, near the limekiln, like a single outcrop; higher on the spur, where they perhaps spread a little more than they do below, the eastern edge has a dip of only from 50° to 53°, and the western one of 75°.

The following is a section of the strata as they are exposed in Ogden Cañon. (Fig. 45.) The two subordinate folds of the western slope of the anticlinal, having more westerly trends than the mountain-range itself, pass under the valley before reaching Ogden Cañon, and, accordingly, are not seen in this section.

In ascending the stream the first grand fold of the upper limestone is so much concealed by the *débris* as to be unnoticed until we pass the second bridge and come to the "wedge" figured in the report of 1871, and even then it is difficult to trace the outlines of the fold on the upper slopes. The second fold, however, is very prominent, forming an immense tilted "Z" upon the mountain-side, a half mile long and at least 1,000 feet high. The



SECTION, OGDEN CANON.

a, Metamorphics; *b*, 1st Quartzite; *c*, Shales; *d*, 1st Limestone; *e*, 2d Quartzite; *f*, 2d Limestone; *x*, Axis of main anticlinal.

Fig. 45.

upper bar of the "Z" dips 16° and the lower one 11° to the eastward, while the connecting stroke has a dip of 49° in the opposite direction. The angles are very sharp, and the rocks, correspondingly, so much broken that they have yielded readily to water-action on the south side of the cañon, known as Walker's Cañon, which gives passage to a large stream supplied by the melting snows of the great hollows on the northeast side of Ogden Peak. Small cold springs, depositing calcareous tufa, were noticed along the rocky sides of this cañon. At Dr. Cannon's, half way down Ogden Cañon, a strong sulphur spring flows from the second quartzite on the north side of the river. The foot-bridge, which generally makes this accessible, had recently been washed away, and this stream was not fordable at the time of our visit, so that we could not measure its temperature. The water was said to be warm but drinkable. The escape of gas was strong enough to be noticeable as we passed along the road on the opposite side of the stream. Near the mouth of the cañon there are two small clusters of hot springs, both of which are saline and ferruginous. The upper cluster, just below the lower bridge, and within the mouth of the cañon, flow from the granites, make but little deposit, and have a temperature of 136°. The lower ones, just outside the mouth of the cañon, have formed a considerable mound of calcareous tufa, and, for that reason, are supposed to come up through the lower limestones, one of the folds of which should be in place beneath the terrace about at this point. The thermometer used here was too short, and simply indicated a temperature of 125° or *higher*.

The lower part of the cañon through all its length, but especially near its mouth, is more or less lined with heavy beds of coarse gravel, thoroughly consolidated by a ferruginous cement. In some places, this forms the bed as well as the banks of the stream; but, at others, it is cut through, and the original well-worn rock-bottom of the old channel is exposed beneath the gravel by the side of the road. It is evident that, when this cañon was originally excavated, the Great Salt Lake was not far, if at all, above its present level; so that the rushing torrent which wore out this old rounded bottom met no check until it had passed entirely beyond the mouth of the cañon. There followed a time when the lake filled nearly or quite to its highest terrace; and, meanwhile, the Ogden River continued to bring down the sand and pebbles which it had before been accustomed to sweep out upon the lower terrace, but now, checked by the rising lake, deposited them in the lower parts of its old channel, until they accumulated to a very high level, not yet accurately located. Again, the lake retired, and the stream again cut down its channel, sometimes reaching its old level and sometimes not. It is evident that there were some pretty good sized cascades, at least, if not large falls, in the old river where it passed over the more solid limestones and quartzites, and wore away the softer underlying shales and schists. The conglomerated gravel has worn more evenly, though it is far from homogeneous.

The lower bed of limestone was formerly burned in small kilns, about a mile above the mouth of the cañon; but the local supply of wood is now nearly exhausted, and the kilns are deserted. The same bed is used in a kiln at the mouth of Taylor's Cañon, just back of Ogden, where it is burned with coal from Evanston, which is delivered at the Ogden station for $5 per ton. Hauling to the kiln, on the return trips of teams which haul down the lime, costs $2.66 per ton. Three tons burn 100 bushels of lime, which sells readily at 50 cents per bushel, delivered in Ogden. The kiln burns about 60 bushels per day.

In order to examine briefly the southern continuation of this range,

and to get some idea as to the uniformity of character of its formations, I accompanied Messrs. Jackson (our photographer) and Peale (mineralogist) to Salt Lake City and Little Cottonwood Cañon, the latter being about fifty miles south of Ogden. At that time, June 20, immense snow-drifts still remained in all the upper parts of the cañon, and made it impossible to obtain more than a very general idea of the section. The outer (western) part of the cañon is walled solely by the almost white granite, which is extensively quarried, near its mouth, for the Mormon temple, as well as for other uses about Salt Lake City. This is entirely different from anything seen near Ogden. From the strike of the bedding, it is evident that the line of outcrop would pass considerably to the eastward of the crest of the mountain, in making only a few miles of northing. The dip is westward, as is the case with most of the metamorphic rocks near Ogden. Several of the large faces of granite exposed in the quarry showed angular and rounded patches of darker material, which were evidently sections of what had been more or less rounded pebbles in the conglomerated mass, before its metamorphism. Unconformably upon this granite lies a heavy mass of ferriginous quartzites, whose northern continuation forms the Twin Peaks, said to be the highest points of the range. Upon this, apparently conformably, lies a series of limestones, the lower part rather thin bedded, the upper part in heavier layers. The lowest beds could not conveniently be visited. A short distance south of the Flagstaff mine, a small mass of rock was found to be full of small fossils, including some characteristic forms of the Sub carboniferous. A few others were found scattered about in such condition as to satisfy me that the whole cluster of mines surrounding the Emma and the Flagstaff is in Carboniferous and Sub carboniferous rocks, so far as yet developed. While the age of the lower part of the series was not determined, yet it was evident that there is nothing in the character of these beds which should cause us to anticipate any considerable decrease in the metallic deposits before reaching the underlying quartzites. At that level, however, they are likely to be greatly diminished, if not entirely wanting.*

Even on the comparatively moderate slopes of the head of the valley, climbing is very wearisome; and the lower part of the cañon is hemmed in by immense nearly vertical walls of granite, standing up out of steepest slopes of *débris*. From these bare walls and steep slopes descend, in winter, the avalanches which have buried so many teamsters and others, and which will continue to thus destroy life and property until the mining companies shall unite in constructing either a covered or an elevated road for the transmission of ore and supplies as well as of passengers. The inexhaustible supply of granite, already broken by nature to manageable size, would seem to make the construction of a covered way extremely feasible.

The limestones which form the base of the high-terrace shoulder of the mountain, at the Warm Springs, just north of Salt Lake City, show at one point a dip of 25° S. 38° E. They apparently belong to a subordinate fold of the western slope of the main anticlinal, similar to those already described.

On June 24 we started from Ogden on our northward journey, and camped at the Hot Springs, about ten miles from that city. After crossing Ogden River, about two miles below the mouth of its cañon,

* As this report is passing through the press, I find that, in the Engineering and Mining Journal of March 11, 1873, Mr. Henry Engelman states that a second quartzite is in place in the Cottonwood section. The lower limestones must therefore be referred to the Silurian age, as at Ogden.

we saw the village of North Ogden, some four or five miles to the right of our route, at the foot of the mountain, in an angle of the lower terrace, at the mouth of the pass which afforded communication with Ogden Hole before the construction of the road through the previously impassable cañon. The mountain between this pass and the cañon has a base of metamorphics, a precipitous face of the lower quartzite, an upper moderate slope of the calcareous shales and lower limestone, and a crest of the upper quartzite. In the portion trending back toward the pass, the shales and limestones descend somewhat, and have been weathered out into an immense amphitheater, reported as being very grand by Dr. Peale, who examined it.

The hot springs are located immediately at the foot of a high shoulder of the mountain, consisting of the upper terrace, preserved from wear and upheld by a mass of quartzites, shales, and limestones, which form the continuation of the uppermost of the subordinate folds on the west flank of Ogden Peak. Though the connecting portion is gone, so far as can be seen, yet some portions of these beds are doubtless in place beneath the plain which stretches past North Ogden to near the mouth of Ogden Cañon. The terrace at the hot springs exposes both sides of the fold very plainly; and here we find, as on Ogden Peak, that the eastern side of the fold is much the steepest, and has been pinched out, so as to show but a thin outcrop. The portion of the terrace next to the mountain consists of metamorphic rocks, as does also far the larger part of the mountain-face. The rocks are mainly hornblendic gneiss and syenite, with quartz-veins. The crest of the mountain here consists of the second quartzite, and reaches an elevation so nearly identical with that of Ogden Peak that I am in doubt which is the higher.

The hot springs flow from the quartzites of the west side of the fold at the end of the terrace, practically on the same line of crack as those just outside the mouth of Ogden Cañon.

Just beyond the springs, several of the high spurs of the mountain form very prominent pinnacles, being capped with masses of the first quartzite, from above which the overlying calcareous shales, by reason of their softness and the easterly dip, have been readily eroded. This structure, as well as the general bedding before described, can be plainly seen by those who may pass on the cars between Ogden and Corinne. A fine fall leaps over this quartzite in Willow Creek Cañon, opposite Willard City.

As we pass northward, the mountain bears farther to the east, the axis of upheaval passes out under the plain, and the quartzites and limestones decline from high dips to nearly level positions, the second quartzite passing from the very crest to the very bottom of the mountain just north of Box Elder Cañon, back of Brigham City, and about twelve miles from the hot springs. The high monoclinal dips seen by Dr. Hayden along this cañon in 1871 probably represent the continuation of the axis of either the "wedge" or the "Z" of the upper limestones in Ogden Cañon, but show greater disturbance than was there experienced. For about six miles north of Brigham City, the upper quartzite forms the base of the mountain, but then disappears, and the upper limestone alone outcrops, though a thin local bed of quartzite appears about the middle of its section for a short distance. At Mr. Barnard's place, about five miles above Brigham City, I was shown a fragment of galena in calcite, with some green carbonate of copper, from an opening in the limestone about a thousand feet up the mount-

ain. The lode was said to be about four feet thick. The ore is reported to be rich in silver, and arrangements have since been made for working it.

Some of the limestone along here is quite compact and furnishes good building-stone, which dresses well, and has been extensively used in this neighborhood for houses and barns, the supply being mostly obtained from the piles of large masses swept down along the channels of the small but rapid mountain-streams. While passing down this road, upon my return in November, I saw a dozen or more medium-sized two-story stone dwellings in process of building or just completed, in as many miles, evincing a much higher degree of general prosperity and thrift than one would have expected from a view of the small adobe cottages previously occupied. The soil is evidently fertile, wherever irrigated. Stacks of wheat and corn and huge piles of pumpkins were constant features along this road at the close of the season.

About twelve miles north of Brigham City we came to another small cluster of hot springs, of temperatures varying from 121° to 128°. These are strongly chalybeate and saline. By the side of them is another cluster of springs only feebly saline, free from iron, and of much lower temperature, mostly about 68°. Upon my return in November these reached 72°, but had a much smaller supply of water. The hot springs were also weaker, and reached 132°. Frémont reports them at 134° in 1843. The water of these springs supplies a long narrow pond, hemmed in by portions of the lower terrace upon which the road runs at this point. Cool springs are said to break out along this pond; but we did not succeed in finding them, and so made our camp on the bank of Bear River, about two miles farther on. This stream is here sluggish, having nearly reached the level of the lake, though yet some miles distant from it.

Passing up the road about seven miles farther, we approached Hampton's Bridge, where the stream is much more rapid. The channel of the river here makes a sharp turn to the eastward, passing through the front range of the Wahsatch Mountains on our right, while the northern continuation of the valley in front of the range is occupied by a tributary now known only by the name of Malade River, though sometimes referred to in old publications as Roseaux or Red Creek.

The immediate channel of Bear River, where it breaks through the mountain, at the point known as "The Gates," is narrow, with high precipitous walls of light-drab, compact limestone, partly siliceous, from which I could obtain no fossils; but, from its position, it must be Carboniferous. The strata show a westerly dip of about 25°, and evidently belong to the west side of the anticlinal upheaval, whose southern continuation has been mentioned as crossing Box Elder and Ogden Cañons. The cliffs of this narrow channel reach nearly to the level of the top of the second principal terrace. On the north side of "The Gates," a short distance back from the edge of this channel, there is another considerable break in the upper terrace, showing a second channel to have existed when the stream was at this level; and, as seen from this north side, the appearance of the surface on the south side indicated the probable existence of still a third old channel, along the line now occupied by the Utah Northern Railroad, (narrow gauge,) which there crosses the range into Cache Valley. At the level of the upper terrace, the old valley of Bear River spreads out to a width of about five miles. The upper terrace itself consists almost entirely of a grayish-white limestone, partly fine grained and compact, partly coarse and porous, and mostly pebbly. All of it is more or less oolitic. The compact layers are entirely destitute of fossils; but the more pebbly

portions contain very numerous individuals of a few species of fresh-water shells, which are sufficient to mark the bed as of late Tertiary (Pliocene?) age. (Dr. Curtis, of our party, afterward obtained from the shore at the southern end of Salt Lake specimens of oolitic sand, which show that this kind of calcareous deposit is still forming abundantly in this basin.) The beds exposed are about 200 feet thick. They show, at this point, a dip of about 25° south, 68° west. As no corresponding disturbance of the surface of the terraces is apparent, it is evident that the upheaval antedates the Terrace epoch. The lower terraces show extensive deposits of coarse gravel, which is well exposed in the cuts of the Utah Northern Railroad, and supplies that road with an abundance of superior ballast.

After crossing Bear River, the Tertiary limestones are found covering the entire foot of the mountain, for two or three miles, though the mountain itself is still plainly composed of the older limestone, which appears on its summit. Then the Tertiary disappears altogether, and the upper quartzite rises so as to form the face of the ridge, for four or five miles. Then the Tertiary comes in again, in a heavy body of compact flinty limestones and siliceous shales, running to the very tops of the hills, which are here much depressed. The strata are mainly nearly level, only the portion nearest the valley having a westerly dip, which at some points reaches 40°. About nineteen miles above Hampton's Bridge, the mountain rises again, and the Tertiaries disappear again, exposing the face of the lower limestone, which has now risen so as to form the entire mass of the mountain. At the junction of the two series of strata, it is evident that the Tertiaries lie unconformably upon the older limestones, many layers of which are here crowded with fragments of trilobites and other fossils, which are plainly of the age of the Quebec group. Among the specimens from this locality which have already been worked up, there are at least fifteen trilobites of the genera *Conocoryphe*, *Bathyurus*, *Dicellocephalus*, *Agnostus*, &c., five brachiopods, two gasteropods, and one pteropod. As we approach Malade City the mountain becomes higher and more precipitous, a point about three miles south of that place being found to be about 2,500 feet above the river. Of this total, about 2,000 feet are exposed in the face of the mountain, the terraces being mostly washed away. All the strata exposed belong to the Quebec Group, and consist mainly of limestones, though including perhaps 200 feet in all of sandstones, partly shaly, but mostly thick-bedded and quartzitic, as well as an indeterminate amount of interlaminated greenish calcareous shales. The uppermost limestones are compact and full of nodules and layers of chert; the lower ones vary greatly, from pure compact to coarsely fragmentary, to fine-grained silicious, and to oolitic and coarsely concretionary forms. The colors vary from drab to blue, gray, buff, flesh-color, and pale red, sometimes uniform, sometimes mottled and streaked. Some of the beds, of both the limestones and the sandstones, would make good building-stone; but these are rather too high in the section to be conveniently quarried on the face of the mountain; though they could probably be easily reached by ascending some of the numerous cañons which break through the range in this neighborhood. The fossils occur at various levels, from bottom to to of the section, though some portions of considerable thickness are entirely barren. They can be most easlly obtained from the tumbled masses of the different beds which lie numerously along the foot of the mountain. As Malade City is only one day's ride, by stage, from Corinne, the locality can easily be visited by collectors who may be passing over the Central Pacific Railroad. The section should be more care-

fully examined, so as to determine the positions of any special horizons which may be marked by special groups of fossils. Time did not permit me to make so thorough examinations of the different beds as such determinations would require.

The finding of distinctively Quebec Group fossils, in such abundance and through so great a thickness of strata, was a matter of considerable interest, since this was, I believe, the first identification of this horizon on the western side of the Rocky Mountain divide; and, indeed, but few specimens from that or any other part of the Silurian, had ever been obtained from any part of the country west of Minnesota, Missouri, and Texas. As no fossils were found in the lower limestones at Ogden, the age of those beds was in doubt until the identity of stratigraphical position and of lithological character showed that they must be of the same age. The first examination of these Malade rocks was made at a point where the section terminated below in a very quartzitic sandstone, which occupied the relative position of the Potsdam, and was accordingly referred with doubt to that group in a letter-extract which was published in the August number of the American Journal of Science. Later examinations have shown that this was really a part of the true Quebec, whose base is not here exposed.

The valley of the Malade is broad and flat; the stream itself is sluggish and mostly deep, with steep banks and muddy bed. At a few points there is rock or gravel bottom, but crossings are few. The bordering flats are rich, and considerable portions are well cultivated, producing heavy crops of wheat and some corn. They are well watered by numerous large springs, which burst up at various points, doubtless being supplied by subterranean streams flowing through and escaping from the limestones of the mountain. These are mostly pure and cold springs; but at one point near the stage-road, about a mile south of Malade City, there is a low mound of calcareous tufa, surrounding a small spring which is rather warm, but still drinkable. Only a small amount of land has yet been irrigated about here. The ridge which forms the western boundary of the valley is lower and more rounded in outline than that upon the east. It was not visited, but the apparent structure and color of its bare slopes render it probable that it also consists of Quebec Group rocks.

The old route across the divide, to the Snake River Valley, passed on to the head of the Malade, and thence to the left and down Bannock Creek. The stage-route now turns a little to the right at Malade City, and crosses to Marsh Creek. Following it, we camped at Keeney's Station, four miles above Malade City, and stopped over one day, June 28, to examine the neighborhood. The side valley, which the road follows, makes a broad break through the eastern mountain, up which the terraces extend, and connects with a narrower valley lying between this and the next range. Messrs. Taggart and Coulter accompanied Mr. Jackson to the summit of the mountain north of the gap, found it to be the regular continuation of that to the southward, and brought in a few characteristic fossils. Mr. Adams accompanied me to the southward, where we found the back-slopes of the mountain covered with Tertiary beds, consisting mostly of thin-bedded, light-drab, clinking limestones, partly pure, partly earthy, with some silicious shales. Some of these beds would probably make good hydraulic cement. A few minute ostracoids and small, indistinct fresh-water gasteropods were the only fossils found. From the summit of the mountain, it became evident that these Tertiary beds extend up this back valley to that of Bear River, and that this crest formed two long, narrow islands in the old Tertiary lake. The beds have a slight easterly dip.

The next range east was also examined in a hasty reconnaissance up New Cañon, which opens into the valley about four miles east of Keeney's Station. The lower portion of the cañon is walled with heavy beds of ferruginous quartzite, belonging with the lower beds at Ogden, and, like them, referred with little doubt to the Potsdam. Some small excavations have been made by mining prospectors in some of the more thinly-bedded portions, but without any success. Their rubbish gave no indication of anything which should have encouraged such excavations. Above the quartzite lie heavy-bedded, dark-blue and ferruginous, impure limestones, which belong to the Quebec group; but no fossils were found. The dips are all easterly and reach 50°. The upper part of the cañon is heavily timbered with pine and spruce; and residents of Malade City have combined to make a good wagon-road up it, for the purpose of more readily obtaining a supply of timber for building purposes and for fuel. The sharp dips of the cañon are much flattened, a little farther south, so that in the course of a few miles the quartzite and the lower portion of the limestone disappear beneath the upper edge of the abutting Tertiaries of the valley. A cañon on the east side of the mountain north of Keeney's Station has yielded a considerable amount of maple-timber, a foot or more through at the butt, and 30 to 40 feet long.

The small stream-valley which the stage-road follows runs over to the east side of the main valley between the ridges, and leaves the Tertiaries exposed in white banks upon the slopes of the western ridge. Mr. Stevenson reported having examined these for fossils without success.

About eight miles from Malade City, we reached the divide between the waters of the Great Basin and those of the Columbia. The upper lake-terrace, which has been a marked feature of the country thus far upon our journey, with small exceptions, here becomes a little irregular and much washed, but apparently reaches to the very summit, as if this might have been a point of dribbling outflow for the waters of the great lake when at its highest level. This is also true of the point in the upper course of Bear River, where the Port Neuf most nearly approaches that stream in the same broad valley, with only remnants of the old terraces forming the divide between them. The level of the divide between the head of Marsh Creek and the Bear River drainage, at Red Rock Pass, as ascertained by the party of 1871, indicates that this was probably another point of outflow; and the divide between the head of the Malade and Bannock Creek may very probably have been a fourth, since Captain Mullan reports that as "prairie-surface of clear gravel formation." (See Wagon-road Report, 1863, p. 76.) Time forbade our working out the details of these points by the way, and I can, therefore, only offer these suggestions as to points worthy of more deliberate examination. Without any very accurate determinations of levels, I am yet inclined to believe that the terrace-levels rise somewhat as we pass to this northern rim of the basin, implying a moderate upheaval of the whole country in that region, which may have taken place while the lake was yet full, and so have been the first means of separating the Great Basin from the Columbia drainage. I agree, however, with those who hold that the decline of the lake from these old terrace-levels has been due mainly to a climatal change, which decreased precipitation, but either left the evaporation constant or increased it. These variations in the lake-level are still going on, as is shown in the recorded rise of the surface for about twelve years, until, two years ago, it began to decline again. I have questioned, in my own mind, whether this latter decline does not really represent the result of dimin-

ished rain-fall theoretically consequent upon the largely-increased consumption of timber in the building and since the completion of the Pacific Railroad. On the other hand, upon the same theory, we may refer the previous rise to the results of cultivation of land and planting of trees, and may expect that, as these increase, the lake will again begin to rise and to spread over larger areas.

As we pass down from the Malade divide into Marsh Valley, the Quebec Group limestone and underlying (Potsdam ?) quartzite outcrop on our right, until the valley spreads, and they disappear beneath the level of the lower terrace. These terraces are very strongly marked through the whole length of this valley; and an upper one is readily identified, though not so prominent, at the level of about 1,000 feet above the stream. They are on too large a scale, and the valley is too wide, to have resulted from merely the drainage of the small area of mountains about the head of the stream; and I am strongly of the opinion that this must have been at one time the channel for a large outflow from the Great Basin.

Rain caused us a day's delay at Watson's ranch, (formerly Carpenter's,) but on the next day (July 1) we moved onward, though showers still continued. At Watson's, a road turns off to the upper cañon of the Port Neuf,* through which it passes to the head-waters of that stream, where it meets the Soda Springs road, and then crosses the divide to Fort Hall. We had proposed to follow this, but found that the river was still high and the fords bad, so that we decided to continue on the stage-road. The distances by the two routes are almost identical.

The face of the high terrace at Watson's consists of Quebec Group limestone, partly quite cherty, with abundant characteristic fossils, though mostly in fragmentary condition. This is overlaid by heavy beds of white quartzite, followed by Carboniferous limestones. The dips are all easterly, varying from 20° to 40°.

A short distance above the junction of Marsh Creek with the Port Neuf, we met with the first appearance of the basalt-rock which fills the Great Snake River Basin. It makes its first appearance as a narrow stream, which forms the floor of the upper cañon of the Port Neuf through its whole length, having had its source in one of the old craters still standing near Soda Springs, though their fires have long been extinct. A short distance up the stream from the point where the stage-road strikes it, we found the lowest of a long series of calcareous spring-deposits, which form a prominent feature of the cañon for several miles, damming the stream at numerous points, so as to make small but pretty waterfalls. This lower dam is about 20 feet high, but with a perpendicular fall of only about 12 feet. In the cañon, the river is sometimes one side of the basalt and sometimes on the other. Where it strikes the wider level of the continuation of Marsh Valley, it has basalt on both sides at first, but soon passes to the right, where it has dug out a channel in the upturned edges of the bordering limestones, leaving the basalt as a perpendicular barrier on the left, which rapidly increases in height as the stream descends. The surface of the basalt has, of course, some slope, corresponding with that of the valley at the time of the volcanic outflow; but it is here much more moderate than that of the present stream, which rushes along rapidly, with occasional leaps of a few feet. The foot and face of the hill on the east side of the valley consist of mostly thin-bedded limestones of the Quebec Group, dipping

* So named after an old French-Canadian trapper.

about 20° N. 51° E., and containing a few fossils. These beds are overlaid by the quartzites before mentioned, which here form a lofty mountain-crest running northward for many miles. As they show here great thickness and only moderate disturbance, I consider this a very favorable locality at which to examine them for fossil remains; but none were found, and the precise age of the formation is uncertain. At the angle of the cañon, a large knob of the limestones, perhaps 500 feet in height, gives a fine view of the whole cañon. From this point, the basalt appears as a high flat-topped ridge, occupying the center of the valley, on the west side of which the narrow valley of Goose Creek has been hollowed out of the edges of the lower quartzites. A small stream also comes in from the right, and has changed its channel once or twice, so that a considerable knob of limestone and some small ones of basalt stand out in the valley; but the streams finally cross to the left side of the valley, leaving the basalt entirely on the right. The road crosses this for some distance, passing among walls and piles of the columnar rock, and then descends to the lower level near Black Rock Station, where the basalt abruptly terminates.

At the angle of the cañon, we had turned sharply to the west, so that, instead of following the strike of the strata, as heretofore, we were now traveling directly across the edges of the outcrops. Soon after we turn, we meet the outcrop of the lower quartzites, upturned at various high angles and strongly metamorphosed. The continuation of this cross-section is confused: one anticlinal is plain and others probably exist; but quartzites, limestones, calcareous schists, all highly metamorphosed, are exposed with various dips; and time and mosquitoes forbade the working out of the details. These, however, though of local interest, have no general importance, since they are not in the direct line of our northern connection.

Though we encountered mosquitoes and gnats in very troublesome quantities at several other points on our trip, yet they nowhere equalled the *mass* which met us between Black Rock Station and the lower angle of the cañon. Hundreds of thousands, at least, perished at our hands, as we hastened through; and such passages are of daily occurrence at this season, but with no perceptible decrease in their numbers. My impression is that this, being a somewhat sheltered point, is a sort of general rendezvous for those of them who are tired of facing the strong winds which so frequently sweep over the unobstructed levels of the broad Snake River plain, into which the cañon now opens, upon turning northward again, after making five or six miles of westing.

Here, again, we encounter basalt; but it seems to belong to a lower layer than that we left at Black Rock. All over the great plain, indeed, we find two or more layers of basalt, separated by greater or less thicknesses of sand and gravel, partly loose, partly consolidated by ferruginous, silicious, or calcareous cement. If two layers should be found superimposed, at any point in the upper part of the cañon, I should believe that they had resulted from two distinct eruptions from the volcanic source before mentioned. As it is, it is not impossible that these layers in the outer plain have been ejected from some central source, have overflowed the plain, and so have run up into the mouths of the valleys opening upon it. It seems hardly possible that, after flowing seventy or eighty miles, the lava should still have retained sufficient fluidity to spread out in a solid layer over the plain. Whatever the source, the material had evidently become quite viscid; for, at some points, where it ran over small inequalities of the surface beneath, it now stands in low mounds, which would not have been the case if

it had been very fluid. That these mounds were not all formed by an undermining and sinking of the surrounding mass, to which some of them have very properly been referred, is proved by the tapering shape of the closely-fitting blocks which form the arch. But there is still room for study on all these points.

As the cañon opens toward the plain, white and drab friable sandstones, probably of Pliocene age, make their appearance on the flanks of the bordering hills. As nothing of the kind was apparent within the cañon, it would seem either that the whole width of the cañon has been thoroughly scoured out since the deposition of the Pliocene beds, or else that the stream carried so much and so rapidly-flowing water during the Pliocene epoch as to prevent the deposition of such beds. These sandstones dip about 30° N. 11° W., showing that the disturbances, of which we have such abundant evidence, continued to a very late period. The terraces themselves show no evidence of any local disturbances; their levels were not determined, however, with sufficient accuracy to enable us to judge whether or not any general upheaval, such as has already been suggested, might have affected this region.

Leaving the Snake River plain at Ross's Fork, we followed up the valley of that stream some six or eight miles, and then crossed a dividing ridge to Lincoln Valley and Fort Hall, which post we reached about noon on July 3. Thus far we had followed well-traveled roads, and had transported our baggage and provisions in wagons; but now we were soon to leave roads entirely, and accordingly turned in our wagons and fitted out a train of pack-mules. During the week thus occupied, we were enabled to examine a considerable territory in the neighborhood of the post.

At Ross's Fork we had struck the line of the old emigrant-road across the mountains to Oregon. This road crossed from Green River to the head of Bear River, down that stream to Soda Springs, thence across the head of Port Neuf, and through a low gap to the head of Ross's Fork. Near the mouth of Ross's Fork it crossed Snake River, and thence ran in almost a direct line past the westernmost of the Three Buttes to the foot of the Salmon River Mountains.

Lincoln Valley, as a whole, is broad and flat, with mostly gentle slopes rising to the crests of the bounding ridges. On the wet bottoms, large quantities of a coarse grass are cut for the stables at the post. The slopes are covered with various grasses, sedges, and other forage-plants, which make fine grazing for nearly the whole year. In this excessively dry atmosphere, these plants, which are ripe and have stopped growing by midsummer, lose their moisture so rapidly as to escape the decay common in the damp air of the Eastern States, and so become natural hay while still standing, and mostly retain their nutritious qualities until the melting of the snow and the setting in of the spring-rains, which start the new growth while occasioning the decay of the old. Here in the foot-hills, the snows sometimes lie deep enough to prevent the stock from reaching the standing grass, and so a supply of hay is essential to their wintering. Only a few miles westward, however, the snows are generally so light and melt so rapidly that, in an ordinary winter, no hay is needed; and stock range through the whole winter, never even coming to the ranches of their own accord. This neighborhood was formerly one of the favorite winter-rendezvous of the trappers and fur-traders; and the plains and foot-hills then supported vast herds of buffalo, as well as many antelope, deer, elk, and bears. The region is now so much frequented that none of these animals are

often seen, except when the deep snows drive them out of the mountains, and the buffalo is here entirely exterminated.

Hollows on the northern slopes, where the snow lies late in the spring, and so furnishes the requisite moisture, are mostly filled with little copses of scrubby cottonwood. The higher and more rocky parts of the hills bear large numbers of stunted cedars, (*Juniperus occidentalis.*) One of these was seen, a half mile east of the fort, which measured 41 inches in diameter, while only 12 feet high, a form probably resulting from the great dryness of the atmosphere. Large pines are brought from the cañons in the north slopes of Mount Putnam, (formerly known as Sublett's Peak.)

The spur which divides Ross's Fork from Lincoln Valley seems to be the final termination of the limestone ridge which formed the eastern boundary of Marsh Valley and of the upper part of the lower cañon of the Port Neuf, and is mainly a monoclinal ridge with strong easterly dips. Its culminating point is a lofty peak, now called Mount Putnam, standing about twelve miles south of Fort Hall. Its western base was not examined; but it is evident that the lower quartzite forms a large portion of its lower face, followed above by from 200 to 300 feet of drab, thin-bedded limestone, in which no fossils were seen; then, from 100 to 150 feet of compact, coarse, pebbly sandstone, nearly pure white; then several hundred feet of dark drab, pebbly limestone, evidently of Quebec Group age, though only fragmentary fossils could be found, with the exception of a single *Ophileta*. A covered space follows, apparently underlaid by the continuation of the last-named limestone, and then comes an outcrop of about 50 feet of compact, fine-grained, white sandstone, overlaid by from 200 to 300 feet of a light-drab vesicular limestone, much resembling in texture the Niagara limestone of Indiana and Illinois, and probably representing either the Upper Silurian or the Devonian. Neither of these beds showed fossils. Immediately above come heavy beds of Carboniferous limestones, 300 feet or more in thickness. Their lowest layers include some pretty pure limestones, some of which are partly oolitic and contain great numbers of minute fossils, the mass looking much like the layers of the Saint Louis limestone at the famous locality of Spergen Hill, Indiana, except that the color is a dark-bluish drab. From masses collected here, over forty species of brachiopods, conchifers, gasteropods, pentremites, corals, and bryozoans have been separated, of which Mr. Meek has already identified fourteen with well-known Spergen Hill forms. Mr. Meek informs me that these are the first distinctively Spergen Hill forms yet brought from the Rocky Mountains. It will be remembered that a few allied forms from Little Cottonwood Cañon, Utah, have already been mentioned in this report. These beds are followed by several hundred feet of very cherty limestone, rarely containing any fossils, except a large *Zaphrentis* (*Z. Stansburyi*,) which is very abundant in some layers. The upper part of the series consists of mostly pure limestones, from which a few specimens of *Spirifer*, *Productus*, &c., were obtained. The rocks of this series form the upper part of the western face as well as the summit and eastern slope of Mount Putnam.

Passing northward along the line of this ridge we find it much eroded and, in two places, cut entirely through by small tributaries of Ross's Fork. In these gaps, the lower quartzites outcrop clear through the ridge, while the intermediate knobs are capped with the Quebec group limestone. The strike of the beds runs a little to the east of the line of the ridge, so that the Carboniferous limestones pass out from the main spur and form the high knob which stands at the south end of the main

part of Lincoln Valley. On the eastern slope of this knob appear the overlying beds, consisting of a few hundred feet of thin-bedded ferruginous sandstone, with few fossils, apparently Carboniferous, with a hundred feet or more of bright-red sandstones, possibly Triassic, followed by brown and drab thin-bedded limestones, crowded with *Pseudomonotis, Lingula, Aviculopecten* (*?*,) &c., which are evidently of Jurassic age. The dip of these latter beds is here 15°, N. 44° E.; and no unconformability is evident from the very base of the lower quartzite to the top of the exposed beds. At other points in the neighborhood, however, certain distortions and displacements led me to suspect a partial unconformability between the Carboniferous and the Jurassic.

Passing farther out on the main spur, nearly to the road running from Fort Hall to Ross's Fork the, older beds mostly disappear, only a thin outcrop of the shelly Jurassic limestones being located by loose blocks in the soil on the west slopes, while the crest and eastern slopes of the spur consist of white and light-gray Pliocene sandstones and limestones, interlaminated with trachytic porphyries and coarse volcanic sandstones, all dipping about north 54° east, at angles varying from 15° to 30°. These dips, which gave renewed evidence of late disturbance, even later than the commencement of volcanic eruptions in this region, continue with little change to the very extremity of the spur, where the opposite side of the anticlinal fold is also apparent in the basalts, which dip 72°, S. 34° W. The examination was not carried far enough to ascertain certainly whether these tilted basalts are, or are not, continuous with either of the beds which floor the great plain.

On the east side of Lincoln Valley there is either a small fault or a very sharp double fold. About five miles south of the fort, on the east side of the road to Soda Springs, the Jurassic shaly limestones lie at the foot of the ridge, with a dip of about 35°, N. 19° E., while its higher portions include sandstones and interlaminated limestones, probably of Carboniferous age, dipping 65°, N. 45° E. A more eastern portion of this same ridge shows the other side of a synclinal in these same Carboniferous sandstones, dipping 46°, S. 58° W. In the axis of the synclinal the Triassic red sandstone shows a thickness of 100 feet or more, at a point about one and a half miles east of Fort Hall, and visible from that post. The most easterly portion of this ridge, approaching the valley of Blackfoot Fork, exhibits another anticlinal and another synclinal, the eastern edge of the latter culminating in the highest point of the outer end of the spur, which received from our topographers the name of Higham's Peak, in honor of the proprietor of the nearest ranch. From this high point it becomes evident that the valley of Blackfoot Fork occupies, for a considerable distance, the axis of a broad anticlinal; and considerable thicknesses, of Carboniferous limestones are exposed on both sides. The immediate mouth of this valley is rather wide and flat, though the channel of the stream itself is comparatively deep and narrow, but, from a point above five miles up, the stream is for many miles deeply cañoned in basalt which floors the valley as a corresponding stream does that of Port Neuf; and it is probable that, here as there, the valley has given exit to the overflow of some volcano near its head, which is very near to the head of Port Neuf and the Soda Springs. The extremity of the dividing ridge beyond Higham's Peak consists of the Carboniferous sandstones, nearly or quite to the level of the plain. If any volcanic rocks have ever rested upon it, they have been so thoroughly eroded as to leave no trace; but the ridge next east of Blackfoot Fork terminates in a mass of porphyries.

CHAPTER II.

MARKET LAKE—CRATER BUTTES—TÉTON MOUNTAINS—HENRY'S FORK—HENRY'S LAKE—MADISON RIVER—GEYSER BASIN—REUNION.

Having completed our outfit, through the kind assistance of Captain Putnam and his aids, who did all in their power to forward our plans, though at the same time showing such courteous hospitality that we were loth to leave them, we started again, on the 12th of July, and camped at Higham's ranch, on Blackfoot Fork, after a drive of only seven miles. This stream was named after the well-known Indian tribe, whose warriors once infested this region to the great discomfort and danger and frequently loss of the trappers and traders passing through or wintering near here. At present members of the tribe are rarely, if ever, seen on this side of the mountains, and the generally peaceable tribes of Shoshones, Bannocks, and Boisés, whose reservation reaches to the southern bank of the stream, were the only ones seen by our party on the entire trip.

Either westerly winds or the waves of the old lake, which is supposed to have covered this broad plain, have accumulated in this neighborhood considerable bodies of fine sand. As we approach the mouth of Lincoln Valley we encountered broad stretches of this sand, partly covered with a scattered vegetation, partly bare and drifting. On one of these drifting patches lies the bleached trunk of a large cottonwood, though no such trees are now to be found for miles around. Has the gradual drying up of the country only recently permitted the sands to drift and accumulate here? And did its accumulation kill off a formerly extensive growth of trees at this point? Here also appears the first of a long range of sand-knobs, which are seen at short intervals for some miles, until they finally are lost in the irregular sand-plain along the lower course of Sand Creek.

The road we are now following, between Ross's Fork and Taylor's bridge, is much used by drovers and freighters, when they are going south with empty wagons. Being less traveled than the stage-road, which follows directly up the river, the grazing is generally better, while the distance is about the same, and the grades over the ridge west of Fort Hall are not very steep, being only about 88 feet to the mile.

A fine young greyhound had accompanied us from the post, but the march of thirteen miles, from Blackfoot Creek to Sand Creek crossing, under a scorching sun and without water, was too much for her endurance, and she died of thirst, about a mile from our camp on the latter stream. This creek is said to have been entirely dry on June 24, 1871, when crossed by Dr. Hayden's party, and we accordingly attributed its fullness at the time of our arrival solely to the unusually large supply of water furnished by the immense snow-fall of the previous winter; but, upon our return in October, we found its channel still carrying from 12 to 15 feet of water, and were obliged to look to some other source for the change. Our guide, Richard Leigh, generally known as "Beaver Dick," who has long lived in this region, informed us that for many years this channel had carried no water except during rains, when it gathered small amounts from its immediate banks, but that, two or three years since, Willow Creek, which had previously emptied its waters into Snake River by two mouths, one about a half-mile and the other about two miles above Taylor's Bridge, broke over its banks in time of flood and poured part of its surplus into Sand Creek. Since

then, the latter stream has, during the spring, carried more or less water, which, however, has all sunk into the sands of the lower part of the channel before reaching Blackfoot, to which it should naturally be tributary, if we may judge by the shape of the country as seen from Higham's Peak. Indeed, from that point, certain water-courses were seen which lead me to suspect that, after once sinking, it again escapes from the sand and renews its individuality, at least for a short space. At present, it is evident that the connecting channel has been so deeply cut that Sand Creek carries far more water than does the original channel of Willow Creek below the separation; and, if this continues to be the case, it is not improbable that it may succeed in clearing away the sand-obstructions from its lower channel and in establishing complete surface-connection with Blackfoot. The tracing of these old channels—and of others which doubtless exist in this broad flat plain—and the determination of the relative dates of their occupation will be of much local interest to geologists who may, in the future, make their homes hereabout. On the upper course of Sand Creek, later in the season, we found many shells in the soil of the banks, giving further proof of the lateral movements of the old channels, while yet the general course of the drainage was unchanged.

Crossing Snake River at Taylor's or Eagle Rock Bridge, we encamped on its west bank, about seven miles above. The stream was very full, carrying an immense body of water, whose surface was constantly broken by the eddying whirls characteristic of irregular bottoms. After a long, hot day, the temperature of the stream, at 6.20 p. m., was 62°, the air being at 78°. At 4.20, on the next morning, with the air at 47°, (the minimum thermometer marking 44°,) the river was still at 62°. Only a very large and much-disturbed flow of water could thus escape all effects of so great an atmospheric change of temperature.

At medium and low stages of water, the river is confined, at the bridge, to a single narrow and deep channel, worn in the basalt; but, in times of flood, it here occupies two bridged channels, and elsewhere spreads considerably upon its banks. On either side there are old channels, more or less plainly marked, which were occupied by the stream at times before it had worn its present channel so deep into the rock. In passing northward, we found many of these, mostly dry, though some of them are occupied, during the rainy season, by the drainage of the neighboring plain and retain some pools through most of the year. The road here follows the bottoms, without anywhere rising to the level of the surrounding plain.

On the morning of July 16, we left the stage-road at Market Lake Station, and turned eastward toward the Tétons, whose highest peak had been visible at intervals, just above the horizon, ever since we crossed the river. The basalt-terrace, which here stands from 50 to 60 feet above the stream, is much broken near its borders, the edge being more or less undermined and sunken. At short distances within the borders are many depressed areas, occupying a few acres each, whose walls appear to have once inclosed small ponds; but these have long since been drained through the underlying sand and gravel, when the river cut its channel to this lower level. Here, again, we see many of the unbroken knolls of basalt, evidently consequent upon the shape of the underlying surface at the time of the overflow.

Since leaving Sand Creek, we had had constantly in view two rounded buttes of moderate elevation, which were now immediately in front of us. As we approached, we found that they stood in the lower angle between

retains no wind-marks. At the angle of 38° the sand will rest for an instant, but apparently holds no permanent position when the angle of slope is greater than 33°. The upper and lower edges of the dunes are marked by dense thickets of sage-brush. Above the dunes the base of the mountain shows solid foundations of trachytes, covered with considerable groves of cedar, from 12 to 15 feet high. Then follow covered slopes, thickly beset with Jersey tea (*Ceanothus velutinus*) and sumac, (*Rhus glaber*,) and spotted with blossoms of *Geranium Richardsonii*, and various Compositæ and Umbelliferæ, and, finally, irregular masses of coarsely-porous trachyte cap the crests at the height of about 1,200 feet above the valley. The range is a double one, the southern portion being the longer and larger, which runs about northeast and southwest for perhaps ten miles, with a moderate southern slope, much broken into long spurs, and a steep northern one, descending almost unbroken into a valley perhaps 200 feet above the plain, and about a mile wide, which opens westward, and has thence been filled with the barren drifting sands. These have been blown into drifts reaching to the very crest of the more northern ridge, which attains the same elevation as the other, with generally steep southern slopes, but apparently somewhat spurred on the northern, where it descends to the plain. The range, as a whole, has no apparent connection with any other, the rocks have no definite bedding, and I am inclined to believe that the two main ridges, facing each other with steep slopes, may be fragments of the bounding walls of a huge crater, whose fires were extinguished long before the eruption at the Crater Buttes commenced, and even before the eruption of at least the later of the basalt-layers which floor the plain.

Looking southwestward from these crests, we see the rough, almost impassable, basalt-plain, thickly overgrown with sage-brush, stretching away toward Market Lake. To the west and northwest spread the barren sands of the dunes, which are several miles in width where crossed by the stage-road, near Sand-Holes Station. These also extend northward, and their eastern edge forms a ridge from 100 to 150 feet high, joining the Sand-Hill Mountains to the main divide of the Rocky Mountains near Camas Creek, and forming the western border of the valley of Henry's Fork. These absorbent sands, and the cracked and cavernous basalt with sand and gravel foundations together, may well account for the fact that, from near the head of Henry's Fork to the Malade River, which enters below the Great Shoshone Falls, a distance of fully three hundred miles by the river, no stream joins the Snake by a surface channel, though several good-sized ones reach the plain from the Salmon River Mountains. Along the bank of the Snake, however, at several points, there are large cold springs escaping from the basalt; and, in the lower part of the region named, several large streams are said to leap boldly from the walls of the cañon, thus escaping from the subterranean channels to which they have been confined for many miles.

The low plain bordering Henry's Fork on the west is from two to eight or ten miles in width, partly well grassed, though with many dense patches of sage-brush. About half way between the Sand-Hill Mountains and the river, there is a low hill, in the shape of a horseshoe, opening to the south, which apparently was once a crater; but it has now been so much worn away and covered with soil that no rock is visible.

Nearly opposite the Sand-Hill Mountains we crossed Henry's Fork, at Eagle-Nest Ford. The river is here, perhaps, three hundred yards wide, with from one to three feet of water, with pebbly bottom, a bluff bank on the west side and a low one on the east, which is overflowed during the spring freshets, so as to double the width of the stream. At that

then, the latter stream has, during the spring, carried more or less water, which, however, has all sunk into the sands of the lower part of the channel before reaching Blackfoot, to which it should naturally be tributary, if we may judge by the shape of the country as seen from Higham's Peak. Indeed, from that point, certain water-courses were seen which lead me to suspect that, after once sinking, it again escapes from the sand and renews its individuality, at least for a short space. At present, it is evident that the connecting channel has been so deeply cut that Sand Creek carries far more water than does the original channel of Willow Creek below the separation; and, if this continues to be the case, it is not improbable that it may succeed in clearing away the sand-obstructions from its lower channel and in establishing complete surface-connection with Blackfoot. The tracing of these old channels—and of others which doubtless exist in this broad flat plain—and the determination of the relative dates of their occupation will be of much local interest to geologists who may, in the future, make their homes hereabout. On the upper course of Sand Creek, later in the season, we found many shells in the soil of the banks, giving further proof of the lateral movements of the old channels, while yet the general course of the drainage was unchanged.

Crossing Snake River at Taylor's or Eagle Rock Bridge, we encamped on its west bank, about seven miles above. The stream was very full, carrying an immense body of water, whose surface was constantly broken by the eddying whirls characteristic of irregular bottoms. After a long, hot day, the temperature of the stream, at 6.20 p. m., was 62°, the air being at 78°. At 4.20, on the next morning, with the air at 47°, (the minimum thermometer marking 44°,) the river was still at 62°. Only a very large and much-disturbed flow of water could thus escape all effects of so great an atmospheric change of temperature.

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Thus far, we had been accompanied by a large wagon from Fort Hall, which carried some of our heaviest supplies, so that our pack-animals might become accustomed to light loads before receiving heavy ones. Having now reached the limit of convenient wagoning, though it would have been *possible* to take vehicles even to the very base of the Téton range, we sent the wagon back, and spent one day in re-arranging packs and in examining the proposed route up Téton River, or Pierre's River, as it is more properly called, since this latter name was long since commonly applied to it among traders and trappers, as well as upon maps of the region. The trappers of the present day, having little or no knowledge of the names used by their predecessors, have, of course, applied their own terms to the landmarks with which they are familiar; but the adoption of these by geographers would be contrary to all rules.

Upon examining Pierre's River about six miles south of our camp, at a point not far above its junction with Henry's Fork, Mr. Stevenson reported it as occupying a deep though narrow channel, walled on either side by perpendicular cliffs of basalt, 60 feet in height, which frequently come to the water's edge, so as to make travel along the bottoms impossible. Our guide, Beaver Dick, stated that these cliffs increased rapidly to several hundred feet in height, rendering the stream unapproachable by stock for over thirty miles. As we were not in condition, being so heavily loaded, to make so long a march without water, we turned northward for a few miles, to pass up the valley of the next tributary, which Beaver Dick called the middle fork of the Snake. Since neither by position nor by size is this stream entitled to be considered a fork of the main Snake, we have applied to it another name, Falls River, for reasons which will appear later in this report. Camping just above where we struck the stream, we found it about 3 feet deep and from 50 to 60 feet wide. On the opposite bank, a bluff of basalt, about 30 feet high, showed a distinct prismatic structure through the upper 10 feet, while the central portion was amorphous and the lower 5 feet, again prismatic, the whole looking as if the upper and lower portions had been affected by rapid cooling and consequent contraction of the surfaces of the sheet of lava, while the central portion, cooling much more slowly, did not reach the same state of tension. Just above camp, on the south side of the stream, there is a considerable bluff of light-pink porous porphyry, with an indistinct bedding, apparently upturned nearly to verticality, with a nearly north and south strike. The upheaval evidently occurred before the flow of the basalt.

As we leave the valley of Henry's Fork, July 20, the country rises, and becomes more broken and rolling. The abundant growth of grasses, sedges, and other flowering herbs shows plainly that only slight irrigation would be necessary to make this valuable farming-land; and some crops would succeed without that. Most of it would be fine land for stock-raising, the only exceptions being those portions along deeply-cañoned streams, where water is difficult of access. We bore a little to the southward to-day, toward the upper waters of Pierre's River. About eight miles from camp, two rocky knolls, rising about 50 feet above their connecting saddle, and perhaps 350 or 400 feet above the nearest creek, mark two points of the rim of an old, broken-down crater, which faces nearly due east. The lava is a laminated mixture of quartz, obsidian, and feldspar; but no mass seemed to be *in situ*, so that direction of structure could not be determined.

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Where these lower limestones are first encountered, near the mouth of the cañon, they are nearly horizontal; but, as we pass in toward the center of the mountain, we find them rising considerably, until they reach angles of 15°, 20°, and even 30°, dipping westerly and southwesterly, and resting unconformably upon the edges of granites which dip in various directions. At the forks of West Téton Creek, where the granites are first seen, their bedding dips 35° N. 78° E. Up the left-hand fork they rise rapidly, causing beautiful cascades a hundred feet or more in height, and finally occupying the whole upper basin of that stream and reaching the very crest of the ridge. They also occupy the valley of the right-hand fork for a considerable distance, forming smooth, bare cliffs on the left as we ascend, and finally are exposed in broad surfaces on its floor. The right-hand wall of the cañon is abrupt for 1,200 feet or more, reaching well up into the Carboniferous limestones, the upper parts of which form crests here reaching more than 3,000 feet above the cañon and about 10,000 feet above the sea.

The granites, gneisses, and schists, which form the central nucleus of the mountain, vary greatly in character and position. They are partly micaceous, partly hornblendic, and partly talcose and chloritic. No regular succession was ascertained. The granites are mostly white or tinged with pink, and occur in thick, solid beds. The other rocks are much broken up and tilted in various ways, and are crossed in every

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direction by innumerable large and small veins, mostly of quartz, but a few granitic. None of these are metalliferous, so far as I could ascertain. At two or three points there are beds of trap-rock from 50 to 70 feet thick, which appeared at first sight to be dikes; but, upon further examination, it became evident that they lay conformably between regularly-bedded members of the granitic series, and it seemed as if they might have been deposited as broad sheets of lava, like those which we have seen flooring the Snake River plain, but deposited ages ago in the bed of the ocean, where were then accumulating the sedimentary sandstones which were metamorphosed into these granites before the Silurian age began. But, again, the trap shows no columnar structure, but is indistinctly laminated parallel to its walling planes; and this would seem to indicate that it might, when quite viscid, have been forced with difficulty between the solid granites after their upheaval, and so have received its laminated structure, while between walls of such slow-conducting power it did not take on the columnar structure. Or it is possible that, having been deposited horizontally among the sediments, as aforesaid, it may have lost a columnar structure, originally possessed, during the metamorphism of the surrounding beds. The trap weathers much more rapidly than the granite; so that its outcrops are plainly marked and readily traced from a distance by a sharp notch on the crests as well as by its *débris* on the slopes of the mountain. One of these beds, which crosses the saddle just south of the Grand Téton, was thus traced across the Great Cañon, and up the side of its perpendicular western wall, where at least 2,000 feet high; and its termination was then capped by the Potsdam quartzite, showing that it is at least older than that rock. Both this trap and its inclosing granites contain much epidote, partly compact, partly crystalline, and some pyrite. Near to this bed of trap are two very noticeable beds of granite, one being of the deepest flesh-red, the other almost pure white; both contain very little mica. The white bed has its constituent minerals much segregated; so that we find in some places large masses of pure feldspar, (orthoclase,) cleaving with broad surfaces, and again fine specimens of graphic granite, (pegmatite.) From a neighboring bed come large masses of mica (muscovite) tolerably well crystallized. A few small garnets were seen, but we found no large or particularly good crystals either of this or of any other mineral.

While the beds are generally so much disturbed as to prevent the accurate determination of any regular or prevailing dip, yet the general strike is approximately east and west; and this has determined, to some extent, the structure of the range. The spurs running east and west from each crest-peak are each dotted with three or four subordinate peaks, which would be thought large, if they were not belittled by their larger neighbors. The sharp dips cause the north and south sides to be extremely sharp—even sharper than the natural weathering of the granites, if level, would have made them. The highest of them all are visible from great distances in every direction, both on account of their great elevation and by reason of the sharp depressions on either side of them. From whatever point they may be seen, there is little danger of mistaking their identity, their abrupt, pointed outlines being markedly different from those of any other peaks of the region. From their prominence, affording good landmarks for travelers, they have sometimes been called the Pilot Knobs, (see Irving's Astoria, chap. xxix;) but the name commonly applied, from the earliest times, is that of Tétons, or Paps. As only three of the peaks are usually seen at a distance, they have been called the Three Tétons. There are really ten or more dis-

right, we found ourselves on the divide between the head of the Great Cañon and that of a smaller one, which opened directly out toward Jackson's Hole. In the head of this latter, perhaps 200 feet below us, lay a small ice-covered lake, with no surface-outflow, but probably draining through the slopes of *débris* which hemmed it in on either side. The accompanying outline-sketch of our route beyond this point has been made up by Mr. Holmes from Mr. Jackson's photographs, which were taken from the top of the western wall of the Great Cañon. (Fig. 47.)

In the broad head of the Great Cañon, which we now crossed, there are three or four small and apparently shallow ponds, partly covered with ice, though partly clear. The outflow of one, buried in rubbish for some distance, finally appears on the edge of a cliff and makes a pretty little fall, perhaps 30 feet high, at the head of which, with a favorable wind, one can easily get a spray-bath at short notice. At the head of this pond, a slight depresion of the crest of the spur indicates probably the best point for crossing, though the slopes are of fine sliding rubbish, which makes climbing tedious. Those who preferred climbing over solid rock crossed a little farther out on the spur. Another short half-mile of snow brought us at length to the foot of the central peak. In neither of these two snow-basins was there any apparent consolidation of the snow into glacier-like bodies of ice, though small icy patches were seen, and the compacted snow was occasionally cracked as if by incipient crevasses. Apparently, the melting of the snow is very nearly complete every season, so that no glacier-like masses can be formed. We afterward saw abundant evidence that this valley, like others in the range, was once the scene of intense glacial action.

It is possible to climb directly up the steep slope of bare rock in front of the lowest part of the saddle south of the main peak. Those who prefer gentler slopes of *débris* and snow should pass about two hundred yards farther north, where such a slope reaches to a higher point of the saddle.

Several of the party had already turned back, and Mr. Bechler's injury, previously mentioned, made it imprudent for him to attempt these steeper slopes. Accordingly, he turned off and examined the cañon for a mile or so lower down. Five of us reached the saddle—Messrs. Stevenson, Langford, Hamp and Spencer, and myself. Here I stopped, at 12 o'clock, at the elevation of about 11,400 feet, to wait for a mercurial barometer, which Mr. West had undertaken to deliver to me at that point, so that I might take it to the summit. I afterward learned that he had already turned back from the high spur, without really attempting either to reach the saddle himself or to send forward the barometer by any other person. Meanwhile, I examined the rocks upon and east of the saddle. Climbing is here much hindered by steep slopes of snow, some of which consist wholly of hail-stones from a third to a half inch in diameter. A fierce west wind, blowing forty to fifty miles per hour, was sweeping across the saddle with such force that the loudest shouts were inaudible fifty yards to windward. I experienced no inconvenience from the rarity of the air at this elevation. My highest point was about 12,000 feet, about a half mile east of the main saddle, from which point I had a limited view out to the basin of Jackson's Hole. The mountain descended in bare rock-slopes over 4,000 feet, until, with gentler slopes, there appeared a belt of pines and spruces. In the upper edge of this belt, a small lake, partly iced over, occupied a notch in the base of the mountain immediately beneath me. The timber stretched in a heavy body down along a small stream flowing past the base of the mountain out to its junction with Snake River. In plain

direction by innumerable large and small veins, mostly of quartz, but a few granitic. None of these are metalliferous, so far as I could ascertain. At two or three points there are beds of trap-rock from 50 to 70 feet thick, which appeared at first sight to be dikes; but, upon further examination, it became evident that they lay conformably between regularly-bedded members of the granitic series, and it seemed as if they might have been deposited as broad sheets of lava, like those which we have seen flooring the Snake River plain, but deposited ages ago in the bed of the ocean, where were then accumulating the sedimentary sandstones which were metamorphosed into these granites before the Silurian age began. But, again, the trap shows no columnar structure, but is indistinctly laminated parallel to its walling planes; and this would seem to indicate that it might, when quite viscid, have been forced with difficulty between the solid granites after their upheaval, and so have received its laminated structure, while between walls of such slow-conducting power it did not take on the columnar structure. Or it is possible that, having been deposited horizontally among the sediments, as aforesaid, it may have lost a columnar structure, originally possessed, during the metamorphism of the surrounding beds. The trap weathers much more rapidly than the granite; so that its outcrops are plainly marked and readily traced from a distance by a sharp notch on the crests as well as by its *débris* on the slopes of the mountain. One of these beds, which crosses the saddle just south of the Grand Téton, was thus traced across the Great Cañon, and up the side of its perpendicular western wall, where at least 2,000 feet high; and its termination was then capped by the Potsdam quartzite, showing that it is at least older than that rock. Both this trap and its inclosing granites contain much epidote, partly compact, partly crystalline, and some pyrite. Near to this bed of trap are two very noticeable beds of granite, one being of the deepest flesh-red, the other almost pure white; both contain very little mica. The white bed has its constituent minerals much segregated; so that we find in some places large masses of pure feldspar, (orthoclase,) cleaving with broad surfaces, and again fine specimens of graphic granite, (pegmatite.) From a neighboring bed come large masses of mica (muscovite) tolerably well crystallized. A few small garnets were seen, but we found no large or particularly good crystals either of this or of any other mineral.

While the beds are generally so much disturbed as to prevent the accurate determination of any regular or prevailing dip, yet the general strike is approximately east and west; and this has determined, to some extent, the structure of the range. The spurs running east and west from each crest-peak are each dotted with three or four subordinate peaks, which would be thought large, if they were not belittled by their larger neighbors. The sharp dips cause the north and south sides to be extremely sharp—even sharper than the natural weathering of the granites, if level, would have made them. The highest of them all are visible from great distances in every direction, both on account of their great elevation and by reason of the sharp depressions on either side of them. From whatever point they may be seen, there is little danger of mistaking their identity, their abrupt, pointed outlines being markedly different from those of any other peaks of the region. From their prominence, affording good landmarks for travelers, they have sometimes been called the Pilot Knobs, (see Irving's Astoria, chap. xxix;) but the name commonly applied, from the earliest times, is that of Tétons, or Paps. As only three of the peaks are usually seen at a distance, they have been called the Three Tétons. There are really ten or more dis-

right, we found ourselves on the divide between the head of the Great Cañon and that of a smaller one, which opened directly out toward Jackson's Hole. In the head of this latter, perhaps 200 feet below us, lay a small ice-covered lake, with no surface-outflow, but probably draining through the slopes of *débris* which hemmed it in on either side. The accompanying outline-sketch of our route beyond this point has been made up by Mr. Holmes from Mr. Jackson's photographs, which were taken from the top of the western wall of the Great Cañon. (Fig. 47.)

In the broad head of the Great Cañon, which we now crossed, there are three or four small and apparently shallow ponds, partly covered with ice, though partly clear. The outflow of one, buried in rubbish for some distance, finally appears on the edge of a cliff and makes a pretty little fall, perhaps 30 feet high, at the head of which, with a favorable wind, one can easily get a spray-bath at short notice. At the head of this pond, a slight depresion of the crest of the spur indicates probably the best point for crossing, though the slopes are of fine sliding rubbish, which makes climbing tedious. Those who preferred climbing over solid rock crossed a little farther out on the spur. Another short half-mile of snow brought us at length to the foot of the central peak. In neither of these two snow-basins was there any apparent consolidation of the snow into glacier-like bodies of ice, though small icy patches were seen, and the compacted snow was occasionally cracked as if by incipient crevasses. Apparently, the melting of the snow is very nearly complete every season, so that no glacier-like masses can be formed. We afterward saw abundant evidence that this valley, like others in the range, was once the scene of intense glacial action.

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sight were the butte above the mouth of Gros Ventre Fork and the



Fig. 47

"THREE TETONS," LOOKING EAST.

a, Mount Hayden; *b*, Lake; *c*, Quebec Group limestone; *d*, Quartzite; *e*, Granite; *ff*, Trap dykes; *g*, "Saddle;" *h*, Timber line, 9,000 feet; Dotted line, course of ascent; *ss*, Snow.

valley of that stream running far into the eastern mountains, with

large stream, flowing directly from the broad depression north of the Tétons. No sedimentary rocks were seen in this region. Only scattering groves of aspens, pines, and spruces had been seen thus far; but, after crossing, we at once passed into dense bodies of pines and spruces, large areas of which had long since been burned over and were mostly grown up again with dense young pines, from one to six years old, and smaller numbers of quaking aspens. The country is much cut up by precipitous cañons, from 50 to 200 feet deep, with flat bottoms and broad shallow streams, the smaller ones being dammed by the beavers at short intervals. A few purple-nacred unios occur in these streams.

Approaching the Spring Fork of Henry's River, two buttes are prominent, consisting of porphyries and loose-textured volcanic sandstone. Their tops are much cut by ravines, with flat, grassy hollows at their heads, which at first remind one of craters; but closer examination shows that these are not distinct volcanic cones, but are merely fragments of the terrace-like mountain to the northeastward, which have been cut off from it and left behind in the general erosion of the valleys. On the slopes of one of these buttes we found a profusion of large, blue huckleberries, growing on rather small bushes a foot or so high; but these were not again seen on the whole trip. A smaller trailing species, however, forming a perfect carpet in the open groves of pine and spruce, and bearing a very small, deep-crimson berry, with a pleasant acid flavor, now began to appear, and was afterward found abundantly, through all the pine-country, until we reached Jackson's Lake, late in September.

Spring Fork, where we crossed it, is about 100 feet wide, and was then carrying about 150 feet of water. Its banks are very steep, consisting mainly of the drab and pink porphyries so common in this region, which are here well laminated and nearly or quite horizontal. If Raynolds's distances and ours are both correct, our camp must have been about two miles below the immense spring, described by him as leaping over a 30-foot fall into the stream, and furnishing to it fully two-thirds of its water as well as its name. This sudden increase would explain the evident inconsistency between the size of the stream and the apparent extent of its upper basin. We did not at the time understand our relation to Raynolds's route, or we should have tried to reach this spring. Starting from this camp the next morning, August 5, the steep bank proved too exciting for one of the usually most obstreperous of our mules, and, in attempting to kick herself free from her pack, she lost her footing and rolled down hill, turning five complete somersaults before reaching the bottom, where she quietly went to grazing, with only one or two slight scratches. For want of any other name, at the time, we called this, among ourselves, the Mormon Mule's Creek.

Shortly after leaving this stream, we found the soil becoming noticeably thinner, and masses of basalt began to appear upon the surface. The loosely-jointed character of the basalt seems to have given to the soil, as fast as it formed, a ready passage downward with the water of rains and melting snows; so that, in many places, broad surfaces of the rock appear, with barely enough soil upon them to support a few small herbs and grasses. The basalt is doubtless underlaid here, as it is elsewhere, by sands and gravels, which not only readily absorb all waters percolating through the crevices of the basalt, but also furnishes covered passage-ways for the large streams which supply large springs, of which there are many examples in this region besides the one just mentioned. Timber is here more scattered and has suffered less from fire than in the tracts we had recently crossed. The basalt is much bulged up into

low domes, like those before encountered and described. Many of these are broken away at the top, and the basins are often occupied by ponds; these being the exact equivalent of the pond-holes already described as having been seen near Market Lake, only these are at a less advanced stage. By the dribbling outlet of one of these ponds, whose water was, during the middle of the day at least, too warm to be agreeable for drinking, we found a small flow of quite cold chalybeate water, of medium strength. By one of these ponds, on the slopes toward Henry's Fork, we camped on the evening of the 5th.

Next morning, a few of us turned southwestward, to try to find the reported falls of Henry's Fork. About two miles from camp we struck the bank of the river, at a point where it was just entering a basalt-cañon. Following down stream for several miles, we found the walls gradually increasing to 50 feet or more in height, but finally turned back without reaching the falls, after having gone nearly twice the reported distance. The falls are said to be below the end of this cañon and about 80 feet in height, the upper 40 feet consisting of rapids and the lower 40 being a clear leap. For about ten miles above the cañon the country is open, with gently-sloping, broad grassy bottoms and scattered groves. At several points, large cold springs break out from beneath the basalt, evidently being the outflow of streams which have been swallowed bodily, higher up, by this cavernous bed. These are full of delicious trout. For the next ten miles, dense timber runs to the river, which is again walled by low outcrops of basalt. At first, fallen timber was very troublesome and delayed the train badly. Since the second day out from our Téton camp, we had been obliged to make our own road, but now, on the banks of Fishing Creek, we found a trail which had, at some recent time, been used by wagons, following our general course, though it led us up Fishing Creek instead of the valley of Henry's Fork, which here makes a large bend to the westward. Before long, the trail became less marked and finally disappeared; but we kept on to the head of the stream, which proved to be one of the large springs so common here, and then bore a little westward to regain the main stream, though guided mainly by the summit of a peak which was said to stand on the south side of Henry's Lake. Here we encountered excessively dense growths of young pine, through which we forced our way with very great difficulty, the packs continually requiring replacement. At length we reached Henry's Fork and a trail almost simultaneously, and soon rejoiced in a good road and a camp. We were now done with bad timber for some time.

The season was now so far advanced that we began to find that mingling of spring and fall flowers which is characteristic of regions where the summers are short. In the same field we often found violets, strawberry blossoms and fruit, monk's-hood, geraniums, everlastings, and fringed gentians, (*G. crinita.*) This last was first seen on August 4. Strawberries were found in considerable numbers as late as September 9.

August 8.—Mr. Bechler examined the stream below our camp, and found that it ran for several miles through a deep basalt cañon. At and above camp, its bottoms are broad and flat, including some beaver-dams, and the valley continues of that general character to the lake, which is only a few miles distant. The groves are somewhat open, yet nearly all the comparatively bare spots are well set with seedling pines, which plainly need only protection from fire to soon make good all previous losses. Passing these, we soon enter the open grassy basin which surrounds Henry's Lake.

This is a broad, shallow sheet of water, said to average not more than

8 feet in depth, which is practically the head of Henry's Fork, though several small streams flow into it from various directions. Though the shore is very winding, and numerous points project into the lake, yet, as a whole, it is a pretty regular body of water, about three miles long by from one and a half to two miles wide. Several small islands are scattered over its surface. From its borders, which are mostly marshy, the plain rises very gradually to the gravelly terrace of an old lake-shore, from 80 to 90 feet above the present water-level. When at that level, the lake would have been some eight or ten miles in diameter. No higher terraces were apparent. The upper level is covered with sage-brush, but the lower flat supports luxuriant growths of grasses, sedges, and other rich forage-plants. Near Sawtelle's ranch, at the head of the lake, large amounts of hay were curing in the hot sun; while a mowing-machine was still in active operation on the meadows. Messrs. Sawtelle and Wurtz here conduct a large trade in fresh fish, caught in the lake and its outlet, which they pack in ice and haul fifty miles to Virginia City. They at first attempted raising stock on these rich meadows; but the immense numbers of horse-flies and gnats which breed in the swampy borders of the lake soon compelled them to abandon that business. They report that game is still abundant in the neighborhood—antelope, deer, elk, moose, bear, and mountain-sheep, as well as smaller animals.

In approaching this basin, the trail passed with the river to the west side of the valley, leaving the main mountain two or three miles to the right. This consists of coarse volcanic sandstone, mostly composed of obsidian. Two or three deep cañons here reach the valley, showing that water once worked powerfully in them, but these are now dry, except where springs burst out of the sandstone at their very mouths, and apparently have carried no water for many years past, except during the times of most rapid melting of the snow in the spring. In examinations made later by Mr. Bechler, when crossing westward from the Fire-Hole Basin, the upper course of these cañons proved to be of the same character; here and there large springs burst out, but soon disappear again in the porous sandstones, which, in that direction, form the surface of the entire mountain. Passing a little to the northward, older rocks appear on the higher slopes of the mountain and soon form its entire face, the volcanic rocks disappearing beneath the valley.

On the opposite side, these appear again in the high mountain lying directly south of Henry's Lake, known to us as Sawtelle's Peak, whose lower spurs run down nearly to the lake-shore. The rugged precipitous sides of the peak, without well-marked stratification, led to the suspicion that it might be of volcanic origin, and it was accordingly visited by Mr. Taggart and myself. It was found to constitute the eastern and northeastern wall of a great crater, some 1,200 or 1,500 feet deep, whose east and west diameter is about a mile and a half, with a transverse diameter of about a half mile. The sides are much washed down and the bottom filled up; but, from the position of the portions of what was apparently the original wall which are still standing, it is probable that the original crater had very nearly the dimensions above given. The walls consist of ragged, cellular, largely amygdaloidal porhpyry, containing crystals of quartz, calcite, &c., partly weathering with a very rough surface, partly decomposing into a coarse brittle sand, and making very treacherous footing. Lower down, the slopes consist of very dense, nearly black, basalt. The western and northwestern walls were not visited; but their style of weathering indicates much softer material than was found on the part visited. Considerable portions of the crater, as well

as the outer slopes of the mountain, were well covered with tall pines and spruces; while the higher portions had only scattered and stunted trees and the crests were entirely bare, though enough dead stems of small pines or cedars were found even there to make a small signal-fire. The small plants of the summit are mostly of Alpine forms. Trails of mountain-sheep were abundant, but the only vertebrate seen was a large gopher, (?) very distinct from any species of which I have been able to find a description, or figure, or mounted skin; unfortunately, he escaped my bullet. The elevation of the peak, as indicated by two readings of my aneroid barometer, is about 10,600 feet.

No lines of outflow were traced down to the plain; but, from the size and position of the crater, and the character of the lava of its lower portion, it is evident that this was a prolific source of the basalt which so many times filled the great plain stretching off to the south and west. The isolated cluster of mountains, about half way between this peak and the Sand-Hill Mountains, has apparently the same structure, and may have been another source of outflow. The lowest gap in the crater-wall of Sawtelle's Peak faces northward; and the principal outflow of lava was probably from that point, escaping thence down the valley of Henry's Fork, though other portions may very probably have escaped through subterranean passages and cracks in other directions, as is frequently the case in those volcanoes whose modern eruptions have given opportunities for the observation of their phenomena. The portions of the lava next to the mountain and out to the center of the valley are all pretty solid basalt, while the farther side of the valley-deposits, and those which form the slopes of the eastern mountain, consist of the older porphyries and volcanic sandstones.

The peaks of the westward continuation of the range of which Sawtelle's Peak forms the eastern termination show such structure, as seen from a distance, as to indicate that they also are of volcanic origin, and may have been other sources of the basaltic outflow. It is not known to any of the present inhabitants of the region that any of these volcanoes have been active in modern times; but Irving, in his Astoria, states that Mr. Robert Stuart, a partner of Mr. Astor in the Pacific Fur Company, when crossing the mountain-range west of Pierre's Hole, in the fall of 1812, "observed to the northwest, between Henry's Fort and the source of the Missouri, several very high peaks covered with snow, from two of which smoke ascended in considerable volumes, apparently from craters in a state of eruption." The location indicated would apply well to peaks of the range now under consideration. It is hardly to be supposed that so experienced a mountaineer should have been deceived by timber-fires, or that such fires should occur near the summits of peaks covered with snow.

The ranges on the north and south sides of Henry's Lake are nearly parallel, while the cross-range west of it is nearly at right angles with them, thus giving a quadrangular form to the plain, which here terminates the broad valley of Henry's Fork. From three points it has easy passages to the neighboring valleys and the region beyond. From our camp on the east side of the valley, Tyghee Pass, named for an old Shoshone chief who was wont to use it, gives a smooth road, with very gentle grades, into the valley of the Upper Madison. From the north end of the lake, a broad, grassy plain, with scarcely a perceptible rise to the divide, about four miles distant, shows a clear road to Virginia City and the Lower Madison. This is called Raynolds's Pass, from having been used by that officer in his expedition of 1859–'60, and described in his report. Tyghee Pass is also mentioned and mapped in that report

as having been examined by Dr. Hayden. From the southwest angle of the valley, Red Rock Pass affords a broad, flat, grassy opening to Red Rock Lake, one of the ultimate sources of Beaver-Head Fork of the Jefferson. This was not visited by us, though seen from a distance. It was afterward examined by Messrs. Peale and Holmes, of Dr. Hayden's branch of the expedition. The levels, as decided by the observations of both parties, are as follows: Henry's Lake, 6,492 feet; Tyghee Pass, 7,063 feet; Raynolds's Pass, 6,911 feet; Red Rock Pass, 7,271 feet. The most favorable route for a railroad from Montana to Corinne, which is now talked of, is apparently *via* Raynolds's Pass and the valley of Henry's Fork. Down this valley the grades would be very easy, averaging only about 25 feet per mile from the pass to Taylor's Bridge, on Snake River, and the cost of grading very slight, while the large valleys which open on the east, containing large areas of valuable grazing and farming land, would be opened to settlement, and would very soon furnish considerable local business.

The short range on the west side of Henry's Lake shows at base, near Sawtelle's ranch, a considerable body of dark hornblendic, slaty schist; but the mass of the ridge consists of much-folded metamorphic limestone, which, in its lower portions, shows a considerable thickness of light drab, almost white, rock, which would make very fine building-material. Its higher portions, however, contain very numerous thick and thin bands of white, often transparent, quartz, corresponding, in general appearance and relations, with the bands of chert which accompany certain portions of the Carboniferous limestones in this region. From this character, in the absence of any opportunity to determine its age by tracing the bed to its unmetamorphosed portion, I have referred it, with very little doubt, to the Carboniferous. Upon the crest of the ridge, we found the outcrop of a dike of trap, about 60 feet wide, standing conformably between the layers of the limestone, and therefore supposed to have been deposited in that relative position before the beds were upheaved into their present nearly vertical position. The subsequent metamorphism of the whole series has obliterated any marks of alteration of the adjoining beds of limestone, which we might otherwise have looked for. From the crest of the ridge it was evident that the back spurs were of the same general structure and composition at the main ridge, at least for two or three miles.

On the east side of Raynolds's Pass, metamorphic rocks form the base and lower slopes of the mountain, while quartzites and limestones appear near its summit. This structure continues nearly to Tyghee Pass, where the upper rocks come down to the level of the plain, for two or three miles, and then rise again, exposing the granites, gneisses, hornblende schists, &c., until we reach the outcrop of volcanic sandstone before described. Just west of our camp, at the mouth of Tyghee Pass, the lowest of the quartzites is exposed on the bank of a small creek. The bedding is nearly vertical, with a *strike* trending about N. 53° E. Unconformably upon the edges of this bed lie about 200 feet of a light-drab, impure limestone, of Quebec Group age, from which we obtained with difficulty three fragments of characteristic trilobites. The *dip* is about 45° N. 54° E. As we have elsewhere found quartzites of supposable Potsdam age lying conformably beneath the Quebec Group, we are led to question whether *this* quartzite may not possibly be of still earlier age; but, in the absence of fossils, there are no means of deciding the question. But this may very well be Potsdam, as I presume it really is, without making it necessary that it should everywhere else lie, as here, unconformably beneath the Quebec.

At the quartzite-outcrop, about a fourth of a mile west of our camp on Pass Creek, another small creek comes out of the hills by an entirely distinct cañon. But, on going up the pass about a half mile, the two cañons unite into one valley, with barely enough divide to separate the streams; yet these continue distinct and come from very different directions. At this point, a stream-terrace of about 30 feet elevation is very prominent; but it is not continued out to the main valley. What could have been the conditions under which these two cañons were thus formed? Porphyry appears in place high on the mountain-side at several points, and in the stream-bottoms in this junction-valley, but only in the more eastern cañon, so far as I observed; so that I inferred that the outflow of the porphyry had stopped up the original eastern cañon, and filled up all the upper valley; that, in subsequent erosion, the new cañon had first been worn through the limestones and quartzites to the westward, a terrace-like deposit of sand being meanwhile formed at the head of it by the partially-checked stream; and that afterward, when the new channel had been cut low enough to reach the old-stream gravel, and the porphyry had been eroded from the main valley outside, the percolation of water through the gravel of the old channel undermined the overlying porphyry and opened the cañon anew for the more eastern stream.

The porphyry is now so much worn away from the pass that the outcrops of the older rocks can be traced. Above the Quebec group, as in the cañons of the Téton range, we see the limestones continuous to the highest summits. At one point, the castellated ruins of the Niagara (?) limestone, with their intermediate pine-clad hollows, make a prominent show upon the hill-sides. The Carboniferous limestones, from which a few characteristic fossils were brought by Mr. West, are mainly thin-bedded; but one heavy bed caps some of the highest points. The pass has very little timber and affords a good road. Yet, the largest trees seen during the whole season stood near the summit of the pass. No notes of their size were taken at the time, but I remember them as about four feet through. They all seemed to be dying.

On the Madison side of the range, the porphyry, which appears at intervals all through the pass, is replaced by basalt. The broad bottoms are covered with basaltic sand, bearing a thin growth of pines. The streams have in many places bluff banks from 30 to 40 feet high, of volcanic sand, partially cemented into a loose sandstone. As we pass up the valley the timber becomes more open, and, where not burned over, resembles the artificial grouping of parks, with avenues opening in every direction. There is, however, no turf, the volcanic sand being only sparsely covered with a growth of coarse plants, often including much sage-brush. Through a broad bottom, occupied by numerous beaver-dams, a large stream, carrying perhaps 80 feet of water, comes in from the south, which was afterward traced by Mr. Bechler to its source in the mountains, where it grows rapidly from the large springs characteristic of the porous volcanic sandstone. The Madison itself was carrying possibly 200 feet of water, sometimes thinly spread out in a broad channel, sometimes narrow and deep, with dangerous holes. Trout were shy and appeared to be few. Antelope and black-tailed deer were seen in considerable numbers in this park-like region, which continued up to the mouth of the upper cañon of the Madison.

The cañon is narrow, with lofty cliffs on either hand, running up to 800, 1,000, and 1,200 feet at different points. Passing up the north bank, our trail lay for much of the distance along the edge of the river, on the steep *debris*-slopes of the mountain. The cliffs consist mainly of

columnar porphyry, which disintegrates rapidly, forming pretty solid but very porous slopes, and so yield numerous springs and form many small bogs along the river's edge. Ripe red raspberries were abundant along these slopes, but were not seen elsewhere, I believe, on the whole trip. The springy character of these *débris* is apparently the only serious obstacle to the building of a railroad through the cañon, which has been suggested by parties who desire to facilitate access to the geyser-basins; but the disintegrated rock reconsolidates so well that I should anticipate no trouble from the springs. A noticeable feature of the river along here is its apparent freedom from freshets; the vegetation runs down to the water's edge, and no accumulations of drift-wood were observed. Does the heat which escapes so freely in these upper basins remove the snows so constantly and steadily throughout the winter that no accumulations are left to cause freshets by rapid melting in spring?

The cliffs along the cañon at various points are both beautiful and grand; but we resisted the temptation to give names to all the different points, which is said to have overcome others who have passed this way; though Mr. Raymond has not yet seen fit to publish the names for which he would claim priority. (See Christian Union, New York, May, 1872, p. 437.)

We had supposed ourselves the only travelers in this region, when suddenly we encountered a party of officers and soldiers from Fort Ellis and other northern posts, under the leadership of General Gibbon, who had been visiting the wonders of the Yellowstone and geyser regions. After a brief exchange of courtesies and information, both parties were again on the march, and we soon emerged from the cañon and camped at the forks of the river. While the main stream came from the southward, yet the real continuation of the valley we had been following was occupied by the stream coming from the eastward with perhaps 40 feet of water. As this stream had been partially explored by General Gibbon, who gave us some useful information concerning it, we have called it Gibbon's Fork of the Madison. Its valley continues eastward for some eight or ten miles, when the depression terminates, the stream entering it from the north, where its sources evidently lie high up on the divide toward Gardiner's River. Following directions given by General Gibbon, we found, about half a mile above our camp, the first indication of our approach to the geyser region, in a cluster of hot springs, which have formed a terrace a little back from the north bank of the stream, and from 60 to 80 feet above its level. The water flows from a dozen or more different openings, of which the principal one is a pit from 2 to 3 feet in diameter and 15 feet or more in depth, from which water is ejected with constant ebullition to a height of from 1 foot to 3 feet above the level of the surrounding pool. The pool itself is of an irregular form, something like the outline of a goat-skin bottle, with the spring in the mouth of it, about 200 feet long by from 50 to 90 feet wide in its main part, while the narrowest part of the neck is from 10 to 15 feet wide. The temperature, at the point of nearest safe approach to the center of ebullition, was 146°; 100 feet distant, the water escaping from the pool gave 126°; while the farthest point of the pool gave 120°. The exit flow was rapid, along a channel averaging about 3 feet wide by 9 inches deep. This had built up its banks a few inches above the surrounding level, and at two or three points the deposit had even bridged the stream. The second pool in size was quadrangular in form and measured about 50 feet on a side. The center of ebullition could not be approached; and the water along the edges of the pool gave

only 113°. The smaller flows varied from 110° up to 134°, and in one case up to 150°. Several old openings along the outer edge of the terrace were long since deserted; and the flow is now only from higher levels farther back. The deposit thus appears to stop up the channels and so to force the water back until it finds or makes new openings in the disintegrating jointed masses of the porphyry which form the underlying stratum and the hill behind the terrace. At only one point is there a strong flow from below: this is on the immediate bank of the stream, and the temperature, being only 92°, indicates a mingling of cold and hot springs.

The other fork of the Madison has from this point been called the Fire-Hole River; but it is hardly a distinct stream, and should more properly be called the Fire-Hole Fork of the Madison. For about five miles above its mouth it passes through a succession of small cañons with precipitous walls, which render the stream inaccessible in most places. At one point there is a fine fall of about 30 feet. There are also two long successions of rapids, with many points of artistic beauty. After emerging from the cañon, and getting far enough out in the bottoms to clear the timber and look back, we found that we had risen so rapidly as to be now on the level of the top of the cliffs on the south side of the great cañon through which we had passed on the previous day, while those on the north side are seen to rise rapidly from the borders of the cañon into a lofty mountain-mass, whose northern slopes must give rise to some of the head-waters of Gallatin River.

We now come to the stream which Dr. Hayden descended in coming from the Yellowstone in 1871, and which was named to him, by his guides, as the east fork of the Madison. That name has been applied to at least three different streams. If such a point-of-compass title is ever proper, this should most properly belong to that part of the stream which comes out of the Gallatin Mountains and joins the Madison nearly opposite Tyghee Pass. We now propose to call the stream which joins the Madison at the lower end of the geyser-basins Hayden's Fork, after its first known explorer. Here we first met with the hot springs of the lower geyser-basin. One of the first, directly on the bank of the river, had a temperature of 197°. In the mucilaginous deposit upon its sides, Dr. Curtis found skeletons of diatoms, but no living ones; but, for further statements of these microscopical observations, I must refer to his detailed report. About a quarter mile farther up the stream, above the first bend, a strong spring, boiling intermittently, but rarely over a foot in height, with a pool about 25 feet long by from 6 to 12 feet in width, gave a temperature of 200°, the highest found in the whole region, and a fraction above the boiling-point theoretically due to that elevation. And now we were in the midst of hot springs and geysers, and shortly camped on a wooded knoll which overlooks a considerable part of the Lower Basin. We had expected to meet Dr. Hayden's party in this neighborhood, and soon learned that they had reached the Basin, coming from Bozeman, *via* the Yellowstone valley, a few hours before us, and had pitched camp about a mile farther east. Next morning, therefore, we moved over and joined them. The collections of both parties were now packed up; specimens were gathered from the geysers; and Mr. Stevenson started with them, on August 17, for Virginia City, both to ship the specimens and to procure provisions for our return trip. Dr. Hayden's party also started down the Madison, on the 20th, and we were again nearly alone, though a few visitors from Montana were also in the Basin and camped near us part of the time. Among them was probably the first lady who ever saw the geysers—Mrs. Stone, of Bozeman.

CHAPTER III.

YELLOWSTONE FALLS—GEYSER BASINS—MADISON LAKE—SHOSHONE LAKE—MOUNT SHERIDAN—HEAD OF SNAKE RIVER—JACKSON'S LAKE—RETURN TO FORT HALL.

During Mr. Stevenson's absence, seven of us made a short trip to the Yellowstone Falls and Lake, starting on the morning of the 21st. As far as to the forks of Hayden's Fork, we had no difficulty in following the trail; but here, among the swampy ground, it spread out so as to be very blind, and we finally decided to make one for ourselves, following a northeasterly course. The slopes of the dividing ridge are heavily timbered; and, at some points, we found difficulty in forcing our way, though much twisting about was generally the extent of our trouble. The pack-mule, however, was continually running against trees and loosening the rope; so that either "tightening up" or "re-packing" was necessary at least twenty-five times, in making not over five miles. Upon reaching the crest, we found that this was the highest point of the ridge for several miles, being about 8,893 feet above the sea; but this we did not regret, when we came to view the surrounding scenery; for we not only enjoyed the sight of a broad expanse of beautiful country, but were able to select a route which saved us some miles of travel. From the summit, we descended directly to the head of a stream-valley which shortly opened out into broad, grassy areas, along which we traveled rapidly toward the main valley. Near the head-waters of this little stream, we passed several mud-pots and warm springs, some of the latter showing considerable deposits of sulphur. Emerging from the foot-hills, we found that this stream joined the Yellowstone south of the Crater Hills; we therefore crossed the rolling prairie to the northward, and camped near the mouth of a large creek which joins the river just north of the Crater Hills, having traveled, as we judged, about twenty-seven miles. Next morning we struck the trail near the mouth of the creek, and reached the falls in about eight miles.

Here, there is little to add to the descriptions already published. We examined and admired the cañon and falls from all the customary points; but those of us who descended to the red knob which stands out in the middle of the cañon, in front of the lower fall and slightly above its level, agreed that this was by far the best point from which to view it. Mr. Jackson's best photographs of the fall were taken from this point. Descents to the bottom of the cañon below the fall have heretofore been made on the east side, the slopes on the west side having been held impracticable. But, with considerable difficulty, I made a way down, often reaching ahead with my hammer to cut holes for the next steps, and stood at the foot of the fall. The water is mostly broken into drops before reaching the bottom, and the air is filled with spray, driven violently down the cañon by the strong wind created by the rush of the fall. The slopes which are thus kept wet are well covered with grasses and flowers, of which several species were gathered. This is evidently

a favorite grazing-ground of deer and elk, whose tracks abounded, even on the steepest slopes. I was here the victim of a curious delusion. Looking up toward the fall, I saw what appeared to be patches of small flowers, of a rich, blue color, closely resembling the patches of brilliant blue "forget-me-nots," which ornament the higher crests above us. In pursuit of them, I pressed on until the spray became a drenching rain, when suddenly I saw at my feet patches of the same blue; but they were only sky reflections from the wet rocks! The walls of the cañon are largely composed of soft volcanic ashes, hardly cemented, which disintegrate rapidly; and the slopes are largely covered with sliding masses of the sand thus formed. Where this is reached by the spray of the fall, it is partly further disintegrated into a bluish-gray mud, and subsequently partially cemented into a fine-grained argillaceous sandstone, stratified parallel to the slopes. These slopes descend directly into the river, so that, even at the bottom, the utmost care must be used in walking. Along the edge of the river, several small hot springs occur, which steam moderately, but rarely to such an extent as to be visible from the top of the cañon. I was able to reach but one of these, which had a temperature of 150°. On the opposite bank, a miniature geyser was in operation; from the top of a steep cone, about a foot high, a half-inch stream was constantly spirting about a foot from the orifice. In ascending, I followed the track of an elk, part of the way, and found much less difficulty than in the descent. On the east slope, regular game-trails are numerous; and I think that most of the animals which graze on the western spray-slope approach and leave it by fording or swimming the river.

The upper fall, though less than one-third the height of the lower, appears far grander, by reason of the momentum of the mass of water, gained while rushing down the rapids which extend about a half mile up stream.

About 11 a. m. on the 23d, we started southward, passing the Crater Hills and the Mud Geysers, and camped on the shore of the lake, near its outlet, about 5 p. m., the distance being eighteen miles. The trails were distinct and tolerably level. The soil here is very loose and washes easily; so that, in many places, the trails made in 1870 and 1871 are already badly gullied. This should be considered, in laying out roads and trails through the park.

On most of the early maps of this region, a large lake is represented at the head of the Yellowstone, under the name of Eustis's Lake, a name supposed to have been given in honor of General Eustis, of the Engineer Bureau. Later, it appears as Sublette's Lake; and now, for several years, it has been called by the general name of Yellowstone Lake. If any law of "priority" is to hold in geography, it would appear that the name of Eustis should be again and permanently applied to it, unless the original Indian name be ascertained and substituted for all later ones. Aside from this general principle of priority, there is no doubt that the present name is the best; and it has become so generally known that it is likely to hold. The first map which, so far as known, represents the lake with anything like its true form is a manuscript one by Jedediah S. Smith, who hunted through the mountains from California to the British Possessions, during the years from 1821 to 1830. The original was purchased in Oregon for the War Department, but is supposed to have never reached Washington. A copy, taken in 1853, exists in the hands of Mr. George Gibbs, of New Haven, Connecticut.

When we arrived at the lake, in the afternoon, the usual daily wind was blowing, and considerable waves were dashing upon the beach; but

both wind and waves subsided during the night, and both air and water were perfectly calm at sunrise next morning. While getting breakfast, we heard every few moments a curious sound, between a whistle and a hoarse whine, whose locality and character we could not at first determine, though we were inclined to refer it to water-fowl on the other side of the lake. As the sun got higher, the sound increased in force, and it now became evident that gusts of wind were passing through the air above us, though the pines did not as yet indicate the least motion in the lower atmosphere. We started before the almost daily westerly wind, of which these gusts were evidently the forerunners, had began to ruffle the lake.

Grasshoppers were so scarce that we did not succeed in catching a single one of the wormy trout for which the lake is famous.

Reaching the mud-geysers about 10 o'clock, we found the principal spring just ready to erupt, and so were detained only a few minutes.

Having thus briefly inspected the wonders of the Yellowstone, we turned back along the regular trail toward the geyser-basins, and got to camp that night by a rather hard march of about thirty-seven miles. Considering the characters of ground and timber along this trail, we were satisfied that we lost nothing by leaving it on our outward trip.

During this time, Mr. Bechler had gone, with his assistants, to examine the divide to the west of the Fire-Hole, and to locate a stream supposed to exist in that direction and which had been mapped as the south fork of the Madison. But no such stream exists, unless it be the short one before described as forming in the north face of the mountain, just east of Tyghee Pass. The divide is high and largely covered with dense timber, mostly young, the old growth having been burned off. Only volcanic rocks were found, being mostly obsidian sandstones, which are very porous. Accordingly, he found but little water. Springs and pools occasionally appeared in the cañons, but soon sank again. From what I saw elsewhere in this neighborhood, I judge that he would probably have found more open timber and more water along the spurs than he did along the cañons. Hollows among and upon the spurs become partially puddled, and so frequently hold water; while the flow of springs, constantly wearing their channels, however slightly, is quickly absorbed by porous soils. At two points the party found small clusters of hot springs, some of which spouted a little, but no considerable geysers. The cañons, running westward, finally lead out to the basin of Henry's Lake, whence the party returned by our old trail through Tyghee Pass.

Concerning the geysers, springs, and pools of the main geyser-basins on Fire-Hole Fork, so much has already been written that I propose to merely note a few of the more prominent points which especially attracted my attention, and which have to do rather with generalities than with details, except in case of localities not visited by those who have published descriptions. In this latter case I think it best to be pretty full, in order that we may reach as far toward a complete description of this interesting region as is possible for those who only make brief visits to it. It is to be hoped that means will be found, ere long, to locate two or three persons here for an entire season, so that, by protracted detailed observations, we may obtain something like an approximate idea of the laws which govern the wonderful phenomena here displayed on so grand a scale.

At one point in the lower basin, near the Architectural Geyser, we found masses of volcanic sandstone, perforated by numerous irregular holes from a quarter inch to an inch in diameter, which had evidently been dissolved out by the hot waters, in their escape to the surface.

Here, I think, we have an example, on a small scale, of the process by which the large cavernous pools, of which so many examples occur all about us, have been excavated. It would appear that, in many cases at least, the hot alkaline (?) water, as it reaches the surface, is not thoroughly saturated with silica, and accordingly dissolves away the walls of its orifices, so as to undermine the surrounding area, the surface of which falls in, until, in many cases, large caverns are excavated. This action appears to be limited in two ways: first, the pool may reach such dimensions that the quantity of water constantly supplied bears so small a ratio to the whole contents that the whole pool becomes partially cooled as well as somewhat concentrated by evaporation, and so the excavation is checked, if not stopped; and, secondly, the supply-pipe may become almost entirely stopped up, so that barely enough water is supplied to make good the loss by evaporation, in which case the solution of silica would become supersaturated, and the silica itself be deposited on the walls and bottom of the pool until it be ultimately closed again, unless the stoppage of the tube be removed, and the succession of conditions thus begun again. If, however, the stoppage of the tube be complete, the silica will soon all be deposited by reason of the evaporation of the water, and the pool will become a dry cavern, except in positions where it may be kept full by the drainage of surface-waters. The large deep pools, however, are generally very hot, showing a constant supply from beneath, and many of them are in constant ebullition, though rarely true geysers; indeed, I believe that the Giantess, in the Upper Basin, is the sole exception to the rule, so far as yet observed; and this is probably in its last stages and near extinction, if we may judge by the length and irregularity of its intervals.

The smaller vents vary greatly in temperature, depending apparently upon the greater or less freedom of their connection with the heat-centers below. In some cases they are few and solitary, with little or no deposit about them, as if they had been but recently opened. Again, they are in large clusters, of which the more elevated vents are generally, though not always, the hottest. It would appear that the comparatively compact deposit of nearly pure silica, formed by the flowing water, is much less readily dissolved and disintegrated, by the hot flow beneath, than is the silica of the more porous and partly argillaceous volcanic rock which forms the slopes of the hills; so that, when a vent is once stopped, it is very rarely re-opened, unless by earthquake-cracking, and the checked water is forced backward and escapes at higher and higher points on the hill-sides. In the geysers, the tube, being exposed to the air at frequent intervals, while it is yet dripping with the rapidly evaporating water of previous eruptions, receives constantly new layers of silica, which are but slightly, if at all, re-dissolved by the next eruption; and so its size is constantly decreased, until the tube becomes entirely closed and a new vent is opened elsewhere.

In the clusters of small vents, there is generally more or less sympathetic action, showing that they open into some common chamber below, but that the connecting passages are more or less contracted, so that the flow of steam and water is far from being controlled by the ordinary laws of hydrostatics. Frequently a large vent, whether a geyser or simply a boiling pool, is surrounded by a number of small ones, which are active while it is quiet and quiet while it is active. I stood, one morning, upon the mound of Fountain Geyser, in the Lower Basin, whose pool was filled to overflowing, and was watching a vehement steam-jet, a hundred yards away, on the lower slopes of the terrace.

Suddenly this ceased, and, at the same instant, Fountain commenced playing, throwing a body of water, some 10 feet in diameter, though mostly broken into drops, to constantly varying heights of from 5 to over 40 feet. This continued for about thirty minutes, and then ceased rather abruptly; as suddenly, the steam-jet commenced again. About twenty minutes later it ceased again, and a small pool, a few yards from Fountain, which had been empty before the latter's eruption, but partially filled by its overflow, immediately began to boil and to spit water from 5 to 10 feet high, and continued intermittently for a half hour or more. During its periods of moderate boiling, the steam-jet opened again, but ceased when the boiling became more violent. Other vents in the neighborhood seemed to have some slight sympathy with these. Similar facts were noted elsewhere. Thus, in the Upper Basin, Grand Geyser has only a small pool, and erupts only at long intervals. Close by its side, Turban Geyser is almost constantly disturbed, and has frequent small jettings of from 5 to 20 feet; but, when Grand, without giving any warning, sprang suddenly into its magnificent eruption, nearly 200 feet in height, Turban seemed startled into more violent action, reaching 70 or 80 feet, and rising and falling synchronously with Grand. Giant stands, with another good-sized mound, upon a broad platform on the river-bank. As I first saw it, water was spirting, intermittently, to heights varying from 6 inches to 20 feet, from some fifteen or twenty small vents on various parts of this platform. When the two large vents began to show activity, though boiling to only small elevations, these little ones became quiet. When Fan Geyser was in full eruption, its partner, 30 yards off, was steaming gently. Fan stopped for a moment, and its partner fairly roared with a rush of steam, which stopped as soon as Fan opened again. Yet they are not in full sympathy; for, on another occasion, Fan was steaming or boiling very gently, while its partner was boiling furiously, and throwing water 5 or 10 feet high, but with quiet intervals, during which Fan showed no access of force. (Under such circumstances, one is inclined to question whether Fan's partner may not possibly serve as the vent for two distinct geyser-tubes.) The three pools which surround Giantess lost much water by her eruption, but were not drained as low as the bottom of her pit when that was empty.

In many cases, however, vents almost side by side show not the least sympathy. About 200 feet east of the Steady Geyser, in the Lower Basin, which constantly spouts from 5 to 20 feet, Young Hopeful spirts from 2 to 10 feet high for from sixty-five to eighty seconds, with quiet intervals of about the same length. About 60 feet from it, another small vent spirts from 6 inches to 2 feet, for from thirty to forty seconds, with intervals of from forty-five to sixty seconds. Here is evidently no sympathy.

The deposits made by the springs and geysers vary greatly. Where the flow is gentle, the deposition generally takes place in thin laminæ, of thickness varying from that of a sheet of paper to a quarter inch. Though, as previously stated, this is so compact as to be dissolved with difficulty from below, yet its thin laminæ are readily separated and broken by frost, and form a very peculiar fine gravel, immediately recognized after having been once seen, which has served to indicate the former location of hot springs over broad areas which give no other evidence of such vents ever having existed. In the small pools which surround many of the geysers, we frequently find great numbers of apparently water-worn pebbles; but, upon breaking them, we find their structure concentric, and it becomes evident that they have grown by constant surface-accretions, while the frequent agitation of the pools,

by water falling from the geyser-jets, has prevented their being cemented to the bottom, and has at the same time aided in keeping them smooth. Where these are few, so as to have plenty of room for rolling, they are commonly quite regular, and often nearly spherical; but, where they are numerous and crowded, they wear each other quite irregularly, so that polyhedral forms abound. Often, while the lower portions are thus polyhedral, the exposed upper surfaces are quite regularly spheroidal. The original centers of concretion seem to have been very minute fragments, broken from the surfaces of the geyser-cones, probably by the rush of the eruption. In some cases, the upper surfaces of these concretions are pearly, in others they are beaded; occasionally the whole surface is beaded, or is covered with prickly points. These surfaces are also frequently deposited upon fragments of the laminated material which may have by any means found their way into these crystallizing baths. These pearly and beaded and prickly surfaces are also individual characteristics of the deposits of different geysers, and vary greatly in detail. The immediate orifice of a geyser is almost universally beaded, and this character extends to greater or less distances from it, according to the distribution of the falling water, surfaces frequently thus washed or sprinkled being almost universally of this character. Such surfaces, on the contrary, as are frequently bathed in steam, without much spray, are nearly always pearly, as if the steam itself carried enough silica to form the extremely thin layers which are essential to pearly luster. This is commonly the character of the upper surfaces of those coral-like growths which form along the borders of many of the quiet hot pools, while their lower surfaces are covered with prickly points. In nearly every pool, except where ebullition is so strong as to break up such tender tissues, we see gelatinous vegetable forms allied to *mycelium*, or the "mother" of vinegar, sometimes in broad, thick sheets, sometimes in thick branching forms, resembling sponges, sometimes in long waving fibers. The former kinds are generally either green or rusty brown; the fibrous forms are generally pure white. These are very common in the rapidly-flowing outlets of the hot pools, and are continually reproduced as these channels fill up with newly-deposited silica; so that, in breaking through the crust, we often find laminæ filled with molds of those fibers, and sometimes to such an extent as to closely resemble silicified wood.

From our camp on the east side of the lower basin we saw on several occasions tall columns of steam rising from near the foot of the ridge on the extreme western side of the basin, but at first referred them to the cluster among which we had camped on the evening of our arrival. But upon examination we found a considerable stream coming from west of the Twin Buttes, which had not been seen by previous explorers, and whose valley included a cluster of large geyser-mounds, from which these columns of steam must have escaped. Though this group was visited on three different occasions, none of us were so fortunate as to witness any eruption from these vents. On entering the valley from below, we see before us a range of four large mounds running diagonally across it. The two central ones are the highest, and appear so much as if they were guarding the upper valley that this was called Sentinel Branch. Approaching this row from the east, the first spring observed is upon a low mound, near the foot of the spur which separates this valley from the main one. It is a deep oval pool, whose two diameters are about 12 and 15 feet, with a beautifully-scalloped edge, not raised above the general surface of the mound. The temperature is 198°, and this is probably a geyser. Several small vents also appear on this mound, but

no other is important. A little to the left, as we advance across the valley, upon a very flat mound, we find a cluster of four large and several small vents. The beady deposit about them is very pretty. One of the larger vents apparently spouts moderately, though not frequently. The temperatures vary from 191° to 193°. A few rods farther on, we come to a truncated conical mound, rising about 22 feet above the creek, on whose bank it stands. Upon the summit is a shallow, nearly circular, pool, about nine feet across, bordered with an exquisite frilled edging, from four to six inches high from the surface of the mound. From this, three or four small streams flow over the edge and down the side of the mound through deeply-imbedded channels. This appears to be a strong spouter, and is probably the source of the tall column of steam before mentioned. The creek cuts into the base of the mound on the north and west sides, and will probably before many years cut into the central tube and cause the eruptions to take a horizontal direction, as well as, or instead of, a vertical one. The temperature is 198°. A few rods farther, on the west side of the creek, stands another mound of the same form, but from two to three feet lower, and its pool is a little less regular. It has also a small conical vent just outside the pool. This has probably been a strong spouter, but I think that it does not now erupt; temperature, 197°. The ornamentation about these two pools appeared to me, as well as to others, to be the most beautiful of any in the whole basin. Still going westward, we find, in the extreme edge of the valley, on the top of a low mound, a cluster of four vents, from one to two and a half feet across, quite irregular in shape, and all boiling too violently to allow one to take the temperatures. All were surrounded by bead-like incrustations. I judge that they all spout moderately. Along this western side of the valley, the base of the hill is thoroughly saturated by the flow of very numerous cold and slightly warm springs. About a quarter-mile above the mounds, we found the creek flowing rapidly in a narrow deep channel with muddy banks, and not easily crossed. Its temperature of 52°, and the entire absence of the siliceous fragments elsewhere so abundant, satisfied us that no hot springs exist in the upper part of its valley. Returning to our former crossing, between the high mounds, we turned south along the east side of the valley. Here is a low mound on the foot of the spur, which had shown only the smallest whiffs of steam, and had been supposed to be nearly extinct; but, upon approaching the vent, we found a deep basin, apparently hollowed out of dark basalt, but really lined with a smooth-surfaced dark reddish-brown siliceous deposit, made by the spring itself. This is very different in color from any other known in the whole Fire-Hole Valley, and was called the Iron Pot. It was boiling moderately at about six feet below the surface, when first seen, but afterward filled nearly to the surface. Its temperature could not be obtained. The form of the pool is ovate, about 7 feet by 5 at the lowest level seen, and expanding above to about 10 feet by 7. Though it may often fill its pool, it probably does not spout much. A hundred yards farther south, along the foot of the spur, there is an irregularly-oblong, steaming pool, about 100 feet by 30, and from 15 to 20 feet deep, with two or three deeper pits. At the east end it boils constantly and sends off dense clouds of steam. Along the edge at this end, the ordinary pearly-beaded deposits are abundant, while a few inches within the rim, and sometimes attached to it, were numerous coral or mushroom-like forms with broad tops expanding from a slender base. The portions of these forms which are toward the steam, and so are constantly moist, are covered with small points, reminding one of the polyp-cells of the Madrepores, while the oppo-

site sides, which must be alternately wetted by the steam and spray and dried by the wind, have the beautiful pearly luster, partly due to the thin lamination of its structure and partly to the opaline composition of the material. The west end of the pool is shallow, and the water flows from it to the foot of the slope over broad and shallow terraced steps, resembling the deposits of the calcareous springs of Gardiner's River, though on a much smaller scale. The main pool nowhere showed a higher temperature than 187°, but a little vent two feet from its rim gave 199°. Several small pools and vents were noticed in the adjoining timber, but none that deserve special mention.

Though this whole valley is more or less miry, yet its luxuriant growth of grasses and other forage-plants attracts the game, whose trails abound in every direction; and this is probably the best location for a ranch that can be found in the Lower Basin. The camping-ground on the east side of the valley is low and damp, so as to be unhealthy for a prolonged stay. If a hotel were to be located in the region, the best place would probably be on the foot-hills on the east side of the river, between the Lower and Upper Basins, since cold springs and abundant forage within easy reach would there be combined with dry locations for building, while the wonders and beauties of either basin would be but a short distance off.

Most of the cold ponds found at intervals throughout the valley are plainly extinct hot springs; but, among the timbered hills about a half mile southwest of the White Dome Geyser, there is a large one which is not of this character. It has no outlet. Just south of it is another hollow, once occupied by a still larger pond, of which only a small pool now remains, while the old bottom is covered with a very luxuriant growth of grasses and sedges.

Between the two basins, Rabbit Branch enters the river from the east, with a strong flow of hot water. The whole of its short valley is filled with warm and hot springs. The principal one, at the head of the northern fork, a large steaming pool, reaches 148°, and is not surpassed by any of its neighbors. About the forks of the stream, a considerable cluster of steam-vents, pools, and mud-pots give various temperatures up to 186° and 192°; yet, as a whole, the group shows but little activity. Steam-vents and small pools run far up the side of the mountain. At the head of the southern fork, separated from the last group by from 200 to 300 yards of timber, is a cluster of mostly small springs, which shows rather greater activity. The principal vent is situated under the precipitous bank, and is apparently working backward by undermining the overhanging rock. Large masses have already slipped off and fallen into the narrow pool, so as to greatly interfere with the free motion of the water; and, accordingly, though steaming and boiling furiously, it spatters only a short distance. It was impossible to reach the boiling center; the nearest accessible part of the pool gave a temperature of 192°. Crossing the spur to the southward, we found, instead of a broad, flat valley, like the one we had just left, a narrow, steep ravine, partly with precipitous sides, at only one point of which did we see slight indications of warm springs. There was, however, an abundant flow of cold springs, fully equal in volume to that of the hot springs of Rabbit Branch. As no difference was noticed in the rocks of the two hollows, we could refer their difference in form of erosion only to the solvent power of the hot waters.

As we approach the Upper Basin, we find considerable stretches of swampy flats, now nearly destitute of any signs of hot-spring action, but probably occupied by such springs in former times. In the Upper

Basin, we find fewer of the mire-holes which render travel difficult and even dangerous in some parts of the Lower Basin. The surface is made up largely of the thinly-laminated sinter, broken up by frost and sun, and partly of the clay left behind in the disintegration of the volcanic rocks and the removal of the silica by the hot waters.

The larger geysers, so far as yet known, are clustered within a rather limited area, so that one can generally watch three or four at once. The different ones have very different periods of eruption; and, in many, the successive intervals of any one vary considerably. The violence of eruptions also varies greatly; but no law of connection between relative violence and length of interval has yet been determined. Many of the geysers erupt without any noise, other than the mere rush of water and steam; but the eruptions of several of the larger ones are constantly accompanied by violent regular pulsations, audible to a considerable distance, and shaking the earth for many rods, as if a fifty-thousand-horse-power steam-pump were in full action down below. In one eruption of Giantess, five or six pulsations were heard before the water began to rise. Their rate was at first seventy-three per minute, but slightly decreased toward the close of the eruption. One eruption of Grand started with seventy-two pulsations per minute, which decreased to seventy, in the course of twenty minutes, and became fainter and fainter. Another, of the same geyser, started at seventy-three per minute, slowing gradually. In most instances, these pulsations cease when the flow of water ceases; but they were once observed to continue for some minutes after the opening of the final rush of steam. This escape of steam often comes with greater velocity and noise than that of the water, and is really a part of the eruption, though generally not so considered.

The erosion effected by the erupted water is generally very slight, being confined, even in case of the most abundant flow, to the channels by which the water escapes and to the space immediately about the vent, where, however, the sinter is generally very compact, and is increased by deposition from evaporation rather than eroded by the falling jet. In the case of Fan Geyser, the main jet, instead of being vertical or nearly so, escapes at an angle of about 60° with the horizon, and the falling water has hollowed out the disintegrating sinter quite deeply for a space of about 115 feet from the vent.

In some of the shallower hot pools, we find beautiful rosettes of sinter, of variable thickness, slightly attached to the bottom. In their earliest stages, these are extremely thin, and from the lower side small spiny processes fall to the bottom, much like the rooting-processes of the bryozoans, or the roots which depend from the branches of the mangrove and the banyan. Judging by their general appearance and conditions, these probably originate as fragments of very thin pellicles formed by evaporation upon the very surface of the pool, and, broken up by the wind, each fragment tends to sink; but some of them escape that fate, and more material accumulates by evaporation upon their wet edges, so that they become basin-shaped and float securely. I cannot account for the basal spires, about which a solid pedestal finally accumulates, except by supposing that they have central nuclei of the small fibers of *myeelium*, which are floating in all these pools in greater or less abundance.

With the exception of these low-grade vegetables, and the larves of *Helicopsyche*, found by Mr. Taggart in water of temperature of 180°, we saw no evidence of the existence of living forms in these very hot pools.

A small stream, carrying, perhaps, 15 feet of water, enters the river from the west, just below the mouth of Iron Spring Creek. It rises far up on the western divide. About a half mile up from the river, we enter a sharp, narrow cañon, along which small hot springs still occur, and arrive, in about a half mile farther, at a fine fall and cascade, some 80 or 90 feet high. The chief interest of the spot is in the inclined bedding of the volcanic sandstone, which dips strongly to the southwest. So far as I could judge, this was not consequent upon disturbance and upheaval of the beds, but upon the slope of the surface upon which the materials were originally deposited. Upon the west side of Sentinel Branch, I found westerly dips, and upon the divide, toward the Yellowstone, northeasterly dips. Though the question cannot positively be decided without many more detailed observations, yet I am strongly inclined to believe that we have at these points remnants of the outward slopes of a huge crater, whose central area was large enough to include most if not all of the heat-vents of the two geyser-basins. Possibly there was a central cross-division between the two basins; but I noticed no decisive dips thereabout. On the foot-hills of the eastern ridge, perhaps a hundred and fifty yards southeast of Giantess, westerly dips occur, which, according to the above supposition, must represent the internal slope of the crater.

Mr. Stevenson returned from Virginia City with supplies on the last day of August, and we started upon our return-trip the next day. Stopping one day in the upper basin, to make our final observations upon the geysers, whose like we expected to see no more for years, we again moved southward on September 3.

Above Old Faithful, which is recognized as the last large geyser of the upper basin, there are only a few hot springs, mostly small, including one small geyser. The valley soon narrows to a deep, impassable cañon, with perpendicular walls of trachyte, with nearly vertical dips and east and west strike. The trail is here forced to the top of the bank, following the east side of the cañon, and, in the next half mile, passes close by a set of beautiful cascades at the head of long rapids. The principal fall is 30 feet high and 40 feet wide, with a side jet about 5 feet wide, like a mill-tail. The water was about 1 foot deep on the crest of the fall. Fifty yards below, all this water is forced through a passage only about 5 feet wide, and rushes with great violence into a deep, still pool below. From a rocky point directly in front of the fall, there are fine views up and down the ravine; and it is well worthy of a visit from all who would see the beauties as well as the wonders of the geyser-basins. The main fall much resembles the Middle Fall at Trenton, New York. From this point, the parties of 1871 turned across the divide toward Yellowstone Lake. The rapids above the fall are moderate, and the banks spread out into a flat bottom, much of which is swampy. To avoid this swampy ground, the trail, which here crosses the river, turns up over the bounding range of hills on the west. In the hollows, we now find many small ponds covered with lily-pods; but only a few of the yellow blossoms appeared. A few of these ponds have small outlets, and small but apparently constant supplies of water, but most of them are entirely inclosed by hills. The surface is here densely timbered, but mostly with young growth.

These hills soon approach the river again, which has here a very narrow valley. This, however, suddenly widens again into a third geyser basin. The first intimation of hot springs, if we follow up the river-bank, is a strong column of steam appearing among the timber on the east side of the valley, just as we enter the basin. Mr. Taggart

visited this vent and reported a boiling pool, temperature 190°, overhung by rocky banks, which showed no signs of spouting. As we emerge from the timber on the west side, we find the lower angle of the basin occupied by an area of hot springs, perhaps 500 feet long by 250 feet wide, with the usual floor of disintegrating silicious sinter, and containing numerous vents, mostly active. Near the center of this area stands the chimney of a single geyser. This is a dome-shaped mound, averaging 15 feet in diameter and from 11 to 14 feet high, completely covered with most elegant varieties of the pearly beads before described. It is striped vertically with bands of white, dark-green, brownish black, and various shades of yellow and orange, the white being ordinary geyserite, while the other colors are apparently of purely vegetable origin. On the north side of the dome, where the main flow from the eruptions is now generally scattered, the geyserite has also a beautiful, delicate pink tinge. The summit of the northwest side, as seen from the northeast, is ornamented with a fine profile of a mild-featured human face done in the bead-work. The top of the mound is perforated with numerous small three, four, and five-angled apertures, and a single larger one between 2 and 3 inches in diameter. In eruption, this larger opening throws a stream from 20 to 50, and even to 70, feet in height, mostly in drops with much steam. Though the amount of water ejected is small, yet the force is very great; and, in this respect, the eruptions much reminded us of those of the Castle Geyser. Its highest jets are generally about the middle of the period of eruption. Eruptions take place at somewhat irregular intervals, but generally are about two hours apart. During such as were carefully observed, there was first a period of violent activity, continuing from three to four minutes and ceasing suddenly; then, a quiet interval of from eleven to twenty-four minutes; then, a second active period of from twenty-three to twenty-six minutes, closing gradually with a rush of steam and occasional water-jets. The small vents spit furiously all through the eruption, their jets reaching 3 feet or more in height when the main jet was at its culmination. About 10 yards off, on the platform, a small vent is in sympathy, but is so nearly stopped up as to be generally overlooked. I think it probable that this was wider in the younger days of the geyser, and has become stopped up equally with the latter. It is evident that eruption at this point must soon cease, unless the great force developed beneath shall be able to break away the upper part of the dome. It is more probable, however, from facts observed in the other basins, that a new vent will be opened and a new mound built. I could not obtain the temperature of the water of the geyser, since the water, except just before and during the eruption, retired below the surface-openings; and we had no self-registering thermometers with which to measure its heat from a safe distance. The surrounding springs, which are nearly all boiling, gave temperatures varying from 185° to 192°. The general elevation of the basin is about 7,770 feet, at which the theoretical boiling-point is about 198°. The single geyser of the basin was called the Solitary.

This small basin spreads perhaps a half mile from the stream, and includes, near its northwest corner, another cluster of hot springs, some of which reach 186°, surrounded by variously-colored deposits, including some sulphur. The trail of our main train entered the basin at this point. The central part of the basin shows the vents and deposits of numerous scattered springs, most of which are nearly or quite extinct, only a few of them still boiling.

A small stream, which comes in from the west near our camp, has a fine cascade, 130 feet high, about a quarter mile from the river. Its

supply apparently comes from the flow of the numerous small ponds among the hills before mentioned.

Showers for two days had softened the soil so much that portions of ground immediately about the springs, which are perfectly safe in dry weather, were now too soft for passage, often letting one down a foot or so, and that, too, in places where at that depth one was likely to find scalding-hot mud. Fortunately, no serious accidents occurred.

After a short interval of timber, another small meadow-like basin opens to view, occupied by a few small warm springs of no importance. Again the mountains close in; so that the stream flows for nearly a mile through a narrow rocky cañon, with sharp ridges rising from 1,000 to 1,200 feet high on either side, down whose almost precipitous slopes beautiful cascades rushed to the river. The banks are mostly composed of obsidian sandstone in tumbling masses; so that I had great difficulty in leading my horse through it, while the train was obliged to climb over the bounding ridge on the east. The strata are mostly upturned at various angles through the cañon, but become more nearly horizontal at its upper end, where we approach the level of the last flat basin about the head of the river. Mr. Bechler reports a large amphitheater, resembling a crater, passed by the train as it reached the top of the ridge on the east side of the cañon.

The basin surrounding the head of the river is occupied by quite a large meadow, tolerably dry in the middle, where the stream winds along, but very swampy all around its borders, where numerous cold springs escape from the rocky hills. The sites of a few old hot springs, long since extinct, are marked by patches of the much-disintegrated white geyserite, now mostly buried under the tall grasses and sedges which cover the meadow. A small lake, covering perhaps sixty acres, occupies the southern end of the valley, where it bends to the eastward; and, as the ultimate lake-source of the Madison River, is the only proper possessor of the name Madison Lake, which has heretofore been applied by the hunters to a large sheet of water upon the other side of the divide, under the mistaken idea that it was the head of this river. The lake once occupied the entire extent of the basin, having then covered a curving area about two miles long by about a half mile wide, but has been mostly drained by the erosion of the last cañon. The terrace-borders of the old lake are faintly indicated at some points, but not so plainly that their elevation could be definitely determined. The present border of the timber, from 20 to 30 feet above the stream, in the lower part of the basin, marks the lowest level at which the lake stood for any considerable time. Though the basin receives only three small brooks, supplied by the banks of snow which constantly rest upon portions of the divide, yet the main stream, where it leaves the basin, carries a good body of water, mostly supplied by the large springs already mentioned. Some of these are large pools, from 10 to 20 feet across, with a strong flow of water boiling up from beneath, sometimes through quicksand, sometimes through numerous large openings in the stiff clay bottom.

A storm of mingled snow, sleet, and rain detained us here for one day, September 5; but next morning it cleared, the snow rapidly melted, and we went on. Our hunter, Frank Mounts, had reported a valley about two miles south of us, through which a stream flowed westward. Accordingly, while the train moved about three miles nearly due east, to a new camp on Shoshone Lake, Mr. Bechler and I crossed the southern divide to the head of the newly-reported river. We found it to be a large stream, formed, within a short distance, from the abundant flow of

numerous large springs bursting from low down in the sides of a high plateau of very porous volcanic sandstones, which we afterward found to extend for several miles to the southward. This was evidently the head of one branch of the stream crossed and camped on by us on the evening of August 3, as we were ascending the valley of Henry's Fork. In the absence of any prior designation, I have called this Beehler's River. Its upper course is among deep ravines, with sharp slopes, but well timbered, for some six or eight miles. It then passes through a rather narrow cañon, with bare, precipitous walls, whose extent was not determined, and emerges into a broad, grassy basin, which reaches nearly to our lower crossing-place.

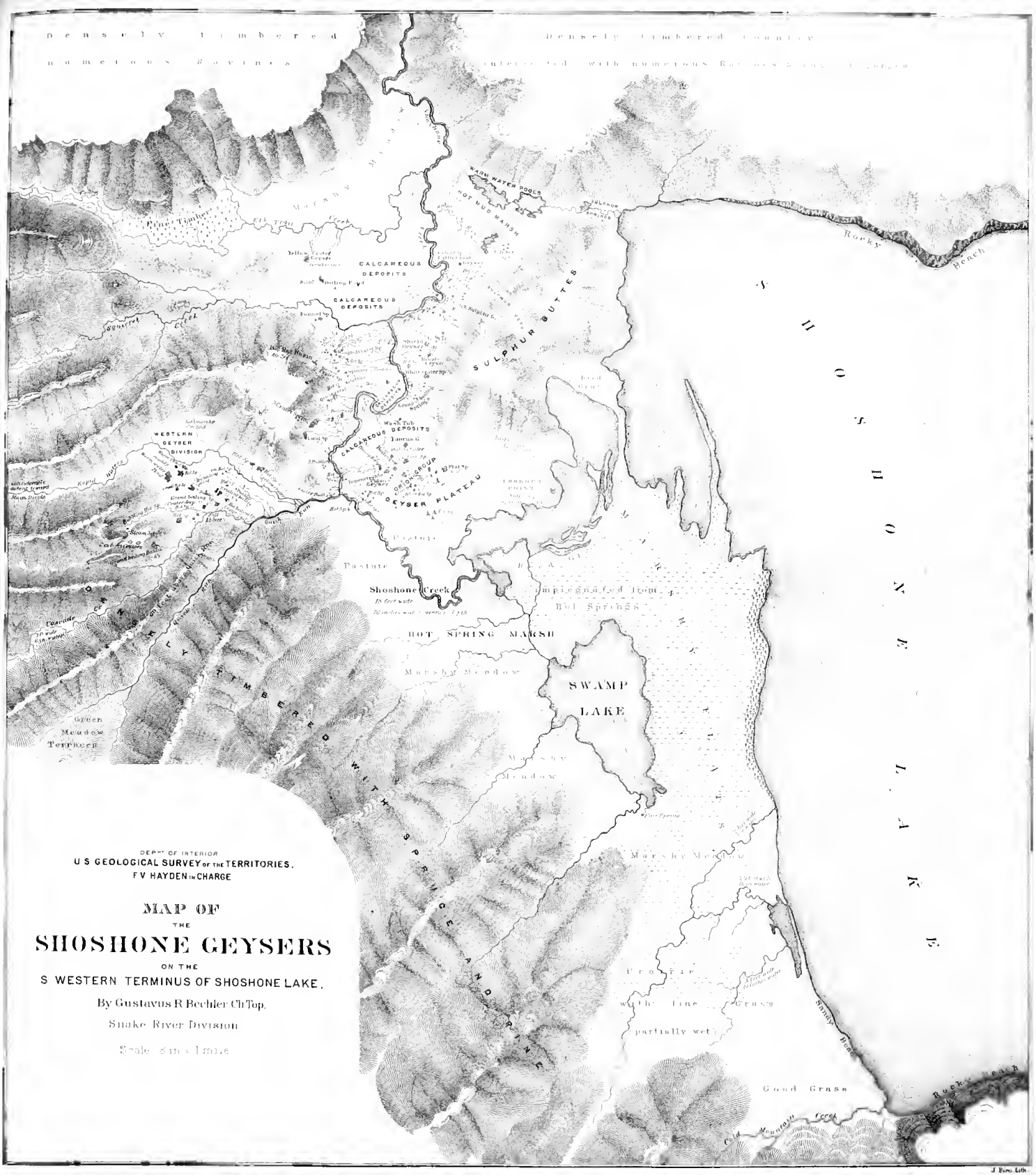
The snow lying among the timber gave us an opportunity of observing the game-trails; and we were surprised at seeing so few. A few miles farther east, game is very abundant.

In crossing the divide eastward from Madison Lake, the western slopes are quite steep, and porphyritic obsidian sandstone appears in heavy rounded masses, but slightly disintegrated. On the eastern face the slopes are much more easy, and the rock is much disintegrated into a very loose, spongy soil, which, where the timber has been burned from the upper spurs, makes very slumpy traveling, at least in wet weather.

Descending the valley of a small but rapid stream, the principal affluent of this part of the lake, the trail crosses a considerable area of hot springs and geysers, to a good camping-ground on the edge of the marsh, which here prevents easy access to the immediate shore of Shoshone Lake.*

If we had not been fresh from the wonders of the Great Geyser-Basins of the Fire-Hole Fork, we should have considered the phenomena now about us as extremely grand and beautiful. In beauty, indeed, these springs are probably unsurpassed; but the geyser-eruptions exhibit much less force than those we had just left. Still, I consider it desirable to make the recorded descriptions of all these phenomena pretty full, and will therefore give a general description of the vents of the Shoshone Lake Geyser-Basin. The area occupied by active springs

* This lake was seen by Dr. Hayden in 1871, while he was returning, with a small party, from the Fire-Hole Basins to Yellowstone Lake, but at a point some miles east of this camp. His guides informed him that the name Madison Lake had been applied to it by the hunters, and that it was considered the head of a fork of the Madison River. On the strength of this information, in the absence of an opportunity of exploring it sufficiently to verify or disprove the statements, the maps of last year's report give the name as Madison Lake and show a stream which was supposed to connect it with the Madison River. Its connection proving not to be with the Madison and Missouri, but with the Snake and the Columbia, it became at once a question whether the old name should any longer be used for this body of water or should be transferred to the true lake-source of the Madison. This latter course was unanimously decided on. The latest published map of this region, for many localities the best, and supposably the best for this particular neighborhood, since the author claims to have traveled here, is one recently compiled by W. W. DeLacey, of Helena, and published by G. W. & C. B. Colton, of New York, (edition of 1872.) This shows a so-called Madison Lake, a so-called DeLacey's Lake, located some miles west of the head of the Madison and about fifteen miles long, and still a third, called Lake Bessie, all three of which we were ultimately obliged to identify with the body of water now before us. It has, therefore, been considered whether we should adopt either of the two latter names. The last, Lake Bessie, was at once rejected, as having been originally proposed for the lake long known to the hunters of the region as Heart Lake, for changing whose name there was and is no valid reason. The numerous and outrageous errors of the map show that neither as discoverer nor as mapper of this lake has Mr. DeLacey any claim to a perpetuation of his name; and, since the lake occupies a position entirely different from that assigned to DeLacey's Lake, we have decided to drop that title, and to call this, in our maps and reports, Shoshone Lake, as being the head of one of the principal forks of the Shoshone or Snake River.


densely timbered
numerous Ravines
densely timbered country
intersected with numerous Ravines
WARM WATER POOLS
HOT MUD MARSH
Fine Timber
Fir Trees
CALCAREOUS DEPOSITS
CALCAREOUS DEPOSITS
Squirrel Creek
SULPHUR BUTTES
Rocky Beach
WESTERN GEYSER DIVISION
CALCAREOUS DEPOSITS
OBSIDIAN GROUP
GEYSER PLATEAU
Pasture
Shoshone Creek
Impregnated from Hot Springs
HOT SPRING MARSH
Marshy Meadow
SWAMP LAKE
Green Meadow Terrace
DENSELY TIMBERED WITH SPRUCE AND PINE
Marshy Meadow
Pasture
with fine Grass
partially wet
Sandy Beach
Good Grass
Rocky Point
Cold Mountain Creek
DEPT OF INTERIOR
U S GEOLOGICAL SURVEY OF THE TERRITORIES.
F V HAYDEN IN CHARGE
MAP OF
THE
SHOSHONE GEYSERS
ON THE
S WESTERN TERMINUS OF SHOSHONE LAKE.
By Gustavus R Bechler Ch Top.
Snake River Division
Scale 4 in = 1 mile
J Bien. Lith.

extends up the stream on both sides about a half mile. In the upper edge of the narrow belt of timber which separates the spring-area from the lake-shore, is a small mud-pot, whose borders were ornamented with exquisite cock'scomb-like deposits of a bluish-gray geyserite, containing sufficient clay to give their pointed tips far more toughness than their form would lead one to expect. These forms have not been seen at any other point.

About fifty yards west from this point stands the most important geyser of the basin. It has now three vents, standing closely in a row, each of which has built up a small mound, beautifully beaded without and pointed within. The eastern vent has an irregularly-oblong opening, about 2 feet long and from 8 to 12 inches wide; its mound is about a foot high, and stands upon a base of about 3 feet by 4. The central mound is about 5 feet in diameter at the base, and about 3 feet high, with a deep central, triangular opening, measuring about 30 inches on a side. The western one is about 1 foot high, on a base of about 20 by 30 inches, with two small openings about 2 or 3 inches in diameter. These stand in the mouth of an old geyser, once probably of great power, though now nearly inactive, of which there remains a deep pool about 8 feet wide by 12 feet long, in which the surface of the water during our stay at this camp was about 3 feet below the top; but it evidently overflows at times, and it is possible that it still spouts occasionally. It showed no sympathy with the present vents during their eruptions. The section of the layers constituting the old mound is well shown in the walls of this pit. During eruptions, the west vent spouts a little water, 2 or 3 feet high, for from 1 to 2 minutes, and then yields a moderate flow of steam. Meanwhile, the center vent is throwing a very powerful jet from 70 to 90 feet into the air, which, after about 5 minutes, gradually gives place to steam, the mingled steam and water giving the highest jets. The east vent, spouting from 10 to 50 feet, throws a solid body of water for about 10 minutes, when the whole supply of water seems to be exhausted, and the rush of steam from all the vents becomes more violent and continues some 40 to 50 minutes longer, gradually declining, however, though with many spasmodic renewals. A small flat opening in the space between the central and western vents gives exit to a little water while the geyser is preparing for eruption, but takes no part in the eruption itself. We called this Union Geyser, because of its combination of the various forms of geyseric action. Its temperature, immediately before eruption, was 198°. Its periods of eruption are irregular, and no law of irregularity was ascertained. An eruption was heard by the men on guard on the night after our arrival, but the time was not noted. The first recorded one began at 10.28 a. m., and continued, steam and all, 47 minutes. Its highest jet reached the elevation of 92 feet. The next began at 1.55 p. m. on the same day, reached 70 feet in height, and lasted 56 minutes. Still another was heard at 10.25 p. m., but no further time observations were recorded.

About this spot, there are several quiet and boiling springs; but none of the latter spout more than from 1 to 3 feet. Passing up this side of the stream, however, for about a hundred yards, we find, just above the point of the hill upon our right, the first of a group of larger vents, of which several seemed to us to deserve names. This, which was called the Minute Man, has built up a mound about 4 feet high and from 12 to 15 feet across, beautifully ornamented with bead-work and with the sharp points which usually accompany the more frequent and abundant flows of water. This ornamental work spreads far beyond

the mound, covering an area at least 40 feet across. Just behind the mound, and at its immediate base, there is a large ornamented opening, which partly fills before eruptions, but is emptied by them. Much of the ejected water falls in such a way as to flow back to this reservoir, so as to keep up the supply necessary to the eruptions. These occur pretty regularly for some hours, at intervals of from 2 to 3 minutes, but gradually decline in force, until the supply of water becomes exhausted. Then the geyser is silent for several hours, until all the crevices, as well as the surface-pools, are again filled with water, when its eruptions recommence with much violence, the jets then reaching altitudes of from 30 to 40 feet. These again decline, and the series of phenomena is repeated. As water gets low, the back pool sometimes receives some of the steam-pressure and spouts from 5 to 8 feet. At one point on the top of the mound, there are some small sulphur-vents, which seem to be entirely disconnected with the water-pipes, but maintain communications of their own with the volcanic laboratory beneath.

About 50 feet farther on, Shield Geyser has an ornamented mound about 15 inches high, which incloses a shield-shaped opening, measuring about 8 feet on each of two sides and 7 feet on the third, at the top, but narrowing to 4 feet on each of the two sides and 3 feet on the third, a little lower, at what was water-level when I measured it. This spouts moderately at intervals of a few hours, but no special notes of its eruptions were taken. By its side its partner has an irregular opening about 8 feet long and varying from 10 inches to 3 feet in width. These vents exhibited no sympathy with Minute Man. Their temperature is 190°.

Between Shield Geyser and the foot of the hill, Rosette Spring has a triangular basin with sides of about 15, 20, and 25 feet, in whose shallow waters form many most perfect specimens of the beautiful thin-leaved rosettes already described as occurring in the Fire-Hole Basin. The muddy bottom of this spring contains much sulphur.

A little rocky knoll intervenes between this and the Bulging Spring, which every few moments gives vent to large bubbles of steam, which raise a considerable part of its surface from 1 foot to 3 feet, with a bulging sound like that of liquid escaping from the bung of an overturned barrel.

Forty feet beyond, the Soap-Kettle keeps up a furious boiling of colored water, more or less covered with foam, looking like dirty soap-suds. Its basin is lined with a yellowish-brown deposit. This has probably been a strong spouter, but now erupts only at long intervals, if at all. Its mound is about 8 feet across, and is still 1 foot high, though disintegrating.

Forty yards farther, the Black Sulphur Geyser has three vents, in small dark-colored mounds, which almost constantly spit, but do not spout much. An abundant black sulphurous deposit is formed along the run from these vents.

The Twins are two small symmetrical vents, from 4 to 6 inches across, in a small mound which stands back against the foot of the hill. They spout rarely and to but small elevations.

Several boiling springs occur at short intervals along the bottom. About seventy yards farther on, a flat mound includes two large flat openings which spout to the height of from 20 to 30 feet at short intervals; temperature, 192°. Above this point, the springs are of little importance, though a few vents and old deposits occur at intervals for a mile or two up the valley. One, near those last described, is a nar-

row fissure, along which for 6 or 8 feet the water boils constantly. Near this is a small geyser-mound strongly colored with iron.

On the opposite side of the creek is a broad terrace of the siliceous spring-deposits, upon which stand several small mounds very prettily ornamented, from 1 foot to 2 feet high, whose pools boil considerably, and evidently spout occasionally, though no one of them was seen in eruption. One of these, near the creek and nearly opposite to Minute Man, is shaped like a conch-shell and strongly colored with iron, and was called Iron-Conch Geyser.

Nearer the base of the hills, there are several large hot pools. One of them was so well furnished with coralliform masses, standing in the shallow water near its edge, as to be called the Coral Pool. This measured about 40 feet by 50, with a shallow border, and a deep central pit about 10 feet across, from which numerous bubbles of gas were escaping. There is a strong flow of water of the temperature of 160°. A little to the west of this, a valley runs well up into the hills and contains several large boiling pools, but no geysers. One boils with great violence, with a very large escape of steam. The pools and old deserted basins extend up the slopes of the hills to elevations of from 100 to 150 feet above the creek.

As a whole, these springs and geysers show far greater amounts of sulphur, and especially of iron, in their deposits than any of those on the Madison. The geysers also show much greater irregularities of eruptions. The group seems to me, as a whole, younger than those in the Fire-Hole Basins. The little geysers on the west side of the creek are plainly young, and are just beginning mounds which promise to attain considerable size.

On the east side of the creek, between it and the lakes, we find a cluster of ragged hills, separated by crateriform hollows and valleys, which are occupied more or less completely by mud-springs and sulphur-vents. Upon breaking up the surface-crust about these latter, we find all its hollows lined with sulphur, either in distinct crystals or in moss-like aggregations of imperfect ones. Upon first observing the shape and contents of these hollows, one would naturally suppose them to be old volcanic craters, whose connections with the interior fires were becoming nearly stopped up; but, upon more careful examination, it becomes evident that they have been hollowed out of the surrounding sandstone by the action of the hot springs themselves, which have disintegrated and removed portions of the sandstone and conglomerate of the old lake-terrace. Worn bits of rocks, penetrated by numerous small irregular holes, are abundant on all the lower parts of the slopes, as well as about the existing vents, showing that the process is still going on. These springs are evidently much affected by variations in the supply of water. Many which were entirely dry gave abundant evidence that they sometimes give forth considerable streams. The effects of these variable supplies upon the activity of the different springs and geysers are probably very different in different cases. Since a full basin seems to be essential to an eruption, a greater supply of water to fill the place of that ejected would, in many cases, cause more frequent and powerful eruptions. On the other hand, it is probable that too large a supply, causing a continuous stream to pass through and escape from the basin of a geyser, would cool down its contents below the temperature essential to an eruption.

The springs extend eastward along the shore of the lake for several miles near its present level, and some were seen boiling up from its bottom, several yards from shore. Many occur also in the marsh about

the mouth of the creek, which is constantly extending itself into the lake. Some large lagoons are here inclosed by narrow sand-bars, some of which are scantily covered with pines. On this marsh, a little back from its present border and a foot or so above its level, an old shore-line is faintly marked. The only plainly-marked terrace is about 112 feet above the lake. It consists of thick beds of sand and gravel, which form the hills just described. The gravel has formed a loose conglomerate, but the sand has been compacted into a pretty solid quartzite by the siliceous deposits of the springs which filled it when it was beneath the lake-waters. This consolidation, so diametrically opposed to the disintegration just now described, was probably consequent upon the pressure of the overlying lake, which caused a very slow percolation of the spring-waters through the sand, except at the points of more active ebullition.

The present level of the lake is about 7,792 feet, at which the theoretical boiling-point of water is about 198.1°. Springs were observed in active ebullition at various temperatures, from 198° to 182°, and one even at 160°; in this latter case the ebullition was probably due to an escape of gas, though that was not apparent. Quiet springs were of all temperatures, up to 186°. Certain sulphur-vents gave 190°.

For some six or eight miles north, along the divide, the ridges consist mainly of obsidian-sandstone, inclosing heavy bands of reddish-brown and variegated obsidian, having a nearly east and west strike. Most of the subordinate ridges had about the same course. All of this district is heavily timbered, with few openings, so that it became necessary to climb trees when we wished to get any idea of the surrounding country, even upon the highest crests.

On September 9th we moved to the outlet. The lake is of a very irregular form, something like that of a well-filled purse, contracted in the middle to quite a narrow passage. Besides the Geyser Creek, it receives only one stream of any size, which enters at the southern end of its more eastern pocket, coming from the high plateau on the south, before mentioned. The northern and eastern shores and the central part of the southern ones are mostly precipitous, with deep water near them, but along the western and parts of the southern shores one can ride most of the way in the edge of the water, thus avoiding the swampy ground and fallen timber of the steep hill-sides. The center of the lake was apparently deep, though, as we did not put the boat together here, we were not able to take any soundings. The water was clear, and the shore sand and gravel quite clean, even from diatomaceous growth, except at the mouths of the streams. At the entrance of the southeastern tributary, a considerable marsh has formed, on the eastern side of which small spring-deposits were noticed; but no springs were seen here except cold ones.

Near the outlet, the rocks are mainly mottled black and red spherulitic obsidian-porphyry.

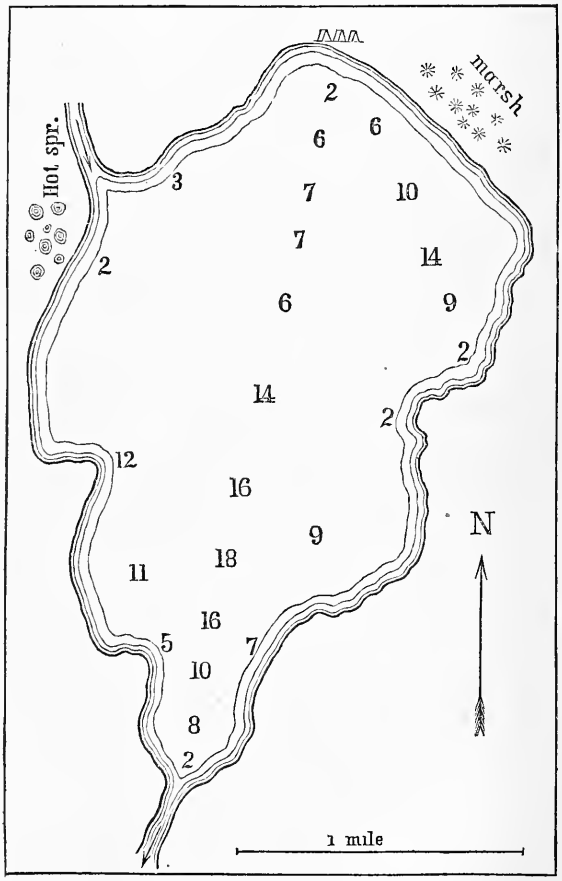
At 6.33 p. m., (9th,) just as we were camping, we felt three slight earthquake shocks.

On the 10th we moved about five miles, to a camp at the north end of Lewis's Lake. In leaving Shoshone Lake, the river has at first wide bottoms, but the valley soon becomes quite narrow, with steep banks. About one and a half miles below the lake, the stream widens to between 600 and 700 feet, and becomes very shallow, with muddy bottom. Then it narrows suddenly, and rushes through a rocky gateway, perhaps 75 feet across, formed by the projection into the stream of a mass consisting of two layers of obsidian-sandstone, with a rapidly disintegrating

central layer of pink porphyry. There was evidently a fine fall here at one time, and the valley which comes to the river on the north bank, just below the gate, was then a second channel of the stream. Below, the stream continues deep, with steep banks, gradually widening until it reaches Lewis's Lake.*

This is a much more regular and symmetrical body of water than Shoshone Lake. It is about two and a half miles long and from one to one and a half miles wide, tapering southward, and is surrounded by mostly gently-sloping shores. These are steepest on the west side, where a few bluffs run out into deep water. Our canvass-boat being put together, Mr. Adams took a series of soundings, with the results indicated upon the accompanying sketch, (Fig. 48,) in which the depths are given in fathoms. The deepest part found is seen to be 108 feet, somewhat south of the center of the lake. The deepest sounding yet obtained in Yellowstone Lake, 300 feet, was made also by Mr. Adams in 1871.

Fig. 48.



From our camp at the north end of the lake, the valley of its outlet at the south end lay directly in a line toward the Tétons; and, early in the morning, before the lake was stirred by the wind, those snow-patched peaks, though forty miles away, were most perfectly reflected by its mirror-like surface. In its setting of the deep-green foliage of the pine and spruce forests which cover the surrounding slopes, this seems to us one of the most beautiful of the many fine views seen upon our trip.

*This lake was seen from a distance, in 1871, by Mr. Schönborn, and was located, from his notes, by Mr. Hergesheimer, but its connections were not known. It was also seen on two occasions, and once visited, in the same year, by Captain Barlow; but its connections were wrongly determined, and the lake itself is represented on his map by two bodies of water, some miles apart, and of very different outlines. As it had no name, so far as we could ascertain, we decided to call it Lewis's Lake, in memory of that gallant explorer, Captain Merriwether Lewis. The south fork of the Columbia, which was to have perpetuated his name, has reverted to its Indian title, Shoshone, and is commonly known by that name, or by its translation, Snake River. As this lake lies near the head of one of the principal forks of that stream, it may not inappropriately be called Lewis's Lake.

The accompanying panoramic view, (Fig. 49,) taken from Mr. Bechler's field-notes, will give a general idea of the relative positions of the Tétons, the lake, and the slopes of the Red Mountain group, of which Mount Sheridan is the culminating point.

On the west shore of the lake, near its northern end, numerous hot springs occur, over a considerable area, a few being seen far up on the western ridge. Those near the lake were examined by Mr. Taggart, who reports as follows:

The hot springs found on the west bank of Lewis's Lake occur mostly in two groups, separated by a low ridge. In the first group examined, all of the springs issued from the sides of a marsh, and were mostly covered either with masses of leafy vegetation or with the soft, thick, pulpy masses of fungoid growth so common about the hot springs of the Fire-Hole basins. Some of the springs were constantly bubbling with an escaping gas, whose character was not ascertained. The temperatures of all the springs are low. A few of them are as follows: 112°, 122°, 124°, 126°, 128°, 130°, 138°, 140°, 148°. As an interesting fact, I noted that all the springs whose temperatures reached or exceeded 120° had the growth of fungoid pulp or a deposit of gray geyserite, while those cooler than 120° were covered with leafty vegetation. This cluster of springs is evidently the last remnant of a much more active group, since, all along the shore of the lake at this point, there are large deposits of old geyserite. At some points, this extends far out into the lake.

The second group of springs differs from the one just described, in that its vents are larger and the water hotter. The springs are surrounded by solid ground, and, in their general features, resemble the hot springs of the Fire-Hole basins, so that they need no general description. The following are the temperatures and sizes of a few of the principal ones: 1, 152°, 2 feet in diameter; 2, 156°, 10 feet by 6; 3, 176°, elliptical, about 40 feet by 20.

Both Mr. Stevenson and Mr. Taggart brought specimens of the geyserite, including many vegetable fragments, apparently some of the coarse sedges common along the lake-shore.

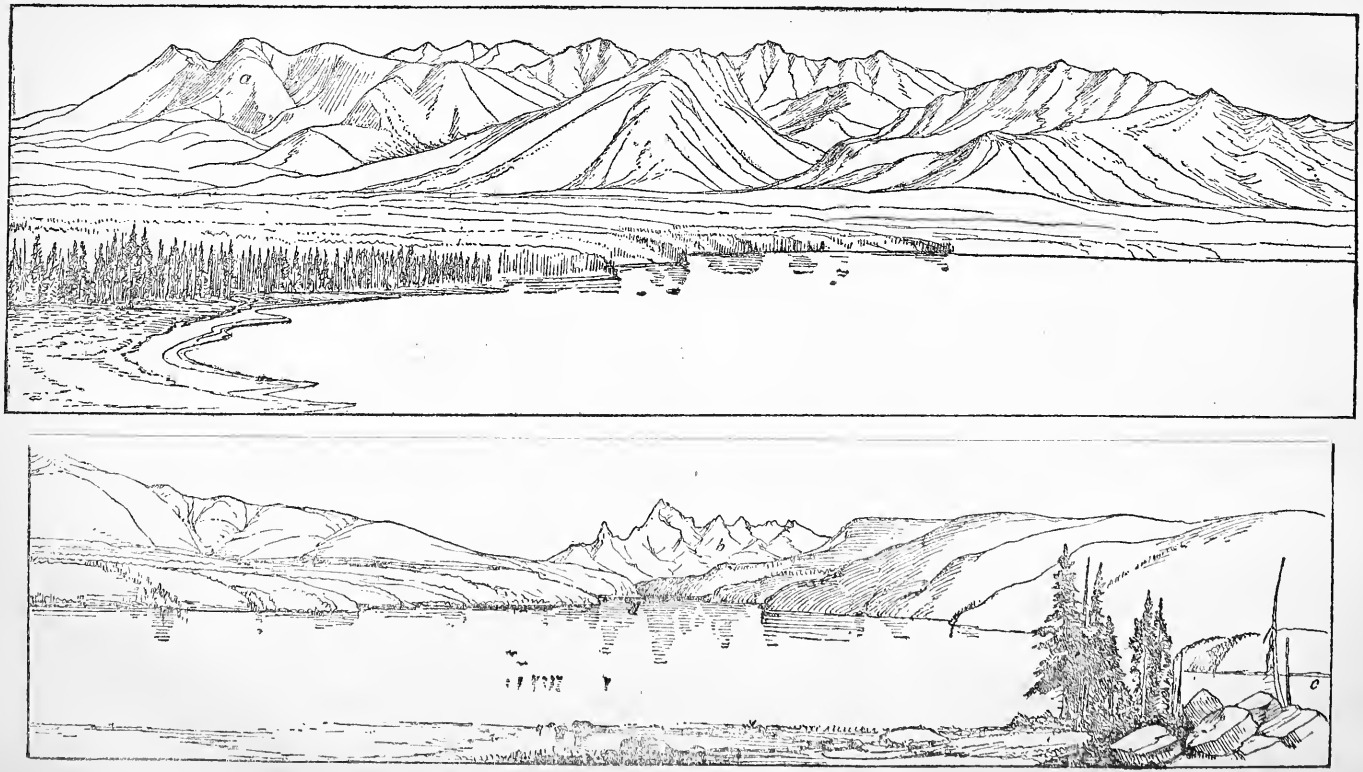
CHAPTER IV.

MOUNT SHERIDAN—HEADS OF SNAKE RIVER—FALLS RIVER PASS—JACKSON LAKE—GLACIER LAKES—GRAND CAÑON OF SNAKE RIVER—FORT HALL.

Leaving the main train to find its way southward to the stream which flows from Heart Lake, a small party of us started, on the morning of the 11th, for Mount Sheridan and the country beyond. At the north end of the lake, there is a considerable marsh and a lagoon, which, when full, throws good streams into the lake; but its outlets were now choked up with beach-sand. Its water comes from the drainage of the broad, flat area, partly in meadow, partly in timber, which stretches across to Yellowstone Lake. Our course, holding to the left of the main peak, led us over moderate slopes, for some miles, until, passing one or two small ponds, with no outlets, we struck the foot of the spur which, running out from the second crest of the Red Mountain range, counting from the north end, forms the divide between Lewis's and Yellowstone Lakes. Upon that divide lies the small lake, without outlet, called Lake Riddle,* visited by Dr. Hayden's party on their return from the Fire-

* "Lake Riddle" is a fugitive name, which has been located at several places, but nowhere permanently. It is supposed to have been used originally to designate the mythical lake, among the mountains, whence, according to the hunters, water flowed to both oceans. I have agreed to Mr. Hering's proposal to attach the name to this lake, which is directly upon the divide at a point where the waters of the two oceans start so nearly together, and thus to solve the insolvable "riddle" of the "two-ocean water."

Fig. 49.



A, Red Mountain Range—slopes toward Yellowstone Lake; B, Téton Mountains—forty miles distant; C, Inlet; D, Outlet; E, Mount Sheridan.

Hole basins in 1871. Mr. Hering visited this lake, and found it to be 7,999 feet above the sea, while Lewis's Lake is 7,750 feet and Yellowstone Lake is 7,788 feet. A high terrace is faintly indicated on the east side of Lewis's Lake, but its level was not determined. This region should be more carefully examined, with a view to ascertain whether there is not some continuous terrace higher than the divide just described, which shall prove that the whole of this broad comparatively flat area was, as its general form suggests, covered by a large lake, which was really tributary to both oceans. The lowest point of the actual divide was determined to be 25 feet above Lake Riddle, or 8,024 feet above the sea.

In ascending the mountain, we found the easiest slopes very steep, so as to make much zigzagging necessary in getting our animals to the summit. As we occasionally looked back, we saw beneath us, on our left, the large cluster of hot springs which occupies the head of the valley of the longest tributary of Heart Lake, and, beyond, caught glimpses of Yellowstone Lake. Upon reaching the first crest, both lakes lay spread out before us, while, to the westward, Lewis's Lake and Shoshone Lake were also in full view. Between us and Heart Lake lay a great hollow of the mountain, looking much like a broken-down crater, and very probably it may once have been one. The highest peak was still beyond us, and we made but little delay, except to shoot grouse for supper, in riding to its crest. This range was called Red Mountain by Dr. Hayden's party of the previous year; but its highest peak lacked a name, until Captain Barlow visited its summit and dubbed it Mount Sheridan.* It is one of the most sightly points in the whole region. Surrounded by deep valleys on all sides, and itself standing 10,420 feet above the sea, it gives one a range of vision over an immense area. Sweeping round the horizon, I counted four hundred and seventy-five distinct mountain-summits, at distances varying from thirty to two-hundred miles. The Tétons on the west loomed up grandly, while, through the broad depression just north of them, the Crater Buttes, the Three Buttes, the Salmon River Mountains, and Sawtelle's Peak, were in full sight. To the north, the Gallatin Mountains, the Belt Mountains, and Crazy Woman Mountains appeared close at hand, while along the eastern horizon stood the high walls of the Yellowstone Range and of the Big Horn Mountains, and far to the southeast stood what we supposed to be Frémont's Peak and other crests of the Wind River range. There appeared to be a considerable depression in the Big Horn Mountains nearly due east from the head of Yellowstone Lake, as if there might be a practicable pass through the range at that point. This should be examined. Throughout all this wide area, with its numerous lofty crests, there were *no* "snow-*covered*" peaks, though many large bodies of snow appeared near the summits in every direction.

The lower slopes of the mountain are heavily timbered; but, as we approach the summit, the trees become scattered and stunted, consisting mostly of *Pinus flexilis* and a small spruce, *Abies Douglasii*, both characteristic of high levels. The coarse, yellow lichen (*Ever(?)nia vulpina*,) often called "Montana moss," which is somewhat abundant at lower levels, but is there rarely found well fruited, grows here in immense quantities, magnificently fruited, the spore-disks (apothecia) being fre-

*Mount Everts had been used for it, but that name was already in use for a peak farther north, and duplication of names is as objectionable in geography as in the other sciences. It is not improbable that this may have been the peak to which the name Mount Madison of the old maps was intended to apply, but the location of that peak was so many miles distant from the position of this, and had so different relations to surrounding ranges, that we cannot consider the identification at all certain, and therefore must reject the name.

quently an inch or more in diameter. At the very crest, vegetation is reduced to a few grasses and Alpine plants, and the gray, red, and yellow rock-lichens which so commonly make these high levels brilliant.

The extreme crest consists of a dark, breeciated porphyry; but, only a few feet lower, we find an abundance of the purplish-pink laminated porphyry, which forms a large part of the mountain. All the rock is quite ferruginous, so that, on weathering, it attains the dark-red tint so characteristic of the mountain as seen from a distance.

In the south slope of the mountain there is another huge crater-like hollow, but I doubt its being really an old crater. Its slopes are steep, with loose rubbish, on which we could hardly stand, while at the same time we could with difficulty *drag* our horses down it to our chosen camping-spot in a grassy opening by the side of the small stream formed from the snow-banks, which probably never entirely disappear from the head of this hollow. A snow-fed pond lies on a small flat near the head of the stream. A large dike of very compact trap crosses this ravine just above camp, running about north 44° west. Mr. Hering, with his assistants, remained upon the summit until after dark, for star-observations, but succeeded in bringing his instruments safely to camp.

Next morning (12th) Mr. Hering and Mr. Stevenson returned to the main party, while the rest of us went on to examine the head-waters of the Snake, whose general position we had seen from the summit of the mountain. About a mile below our camp, we came to a curious little spring-pool, standing on a marshy bottom. Around its edge there was a dam-like border of roots, grass, and moss, by which the water was held at perhaps a foot above the surrounding marsh. Apparently the spring had burst up through an old turf, which had turned up at the edges, and through which the water had never been able to break down an open passage, though escaping through its mass and over its edges.

Our descent continued to be quite rapid for nearly two miles farther, when we reached the meadow-like bottom of a stream coming in from the left, which apparently gathers the water from the springs which escape from the foot of the mountain, nearly round to the basin of Heart Lake. From the junction of the two streams we held our course southeasterly, over a spur about 500 feet high, until we struck Heart River not far above its junction with Barlow's River. As the stream leaves Heart Lake, it flows for some miles through dense forests of pine and spruce, and then through a deep, narrow cañon, apparently of volcanic rock, from which it issues just above where we struck it. This river is evidently not subject to the great freshets which are common on many of the streams hereabout, and it is therefore probable that Heart Lake acts as a retaining reservoir for the waters of the melting snows, while the melting itself goes on more slowly in this densely-timbered basin than on the barer slopes.

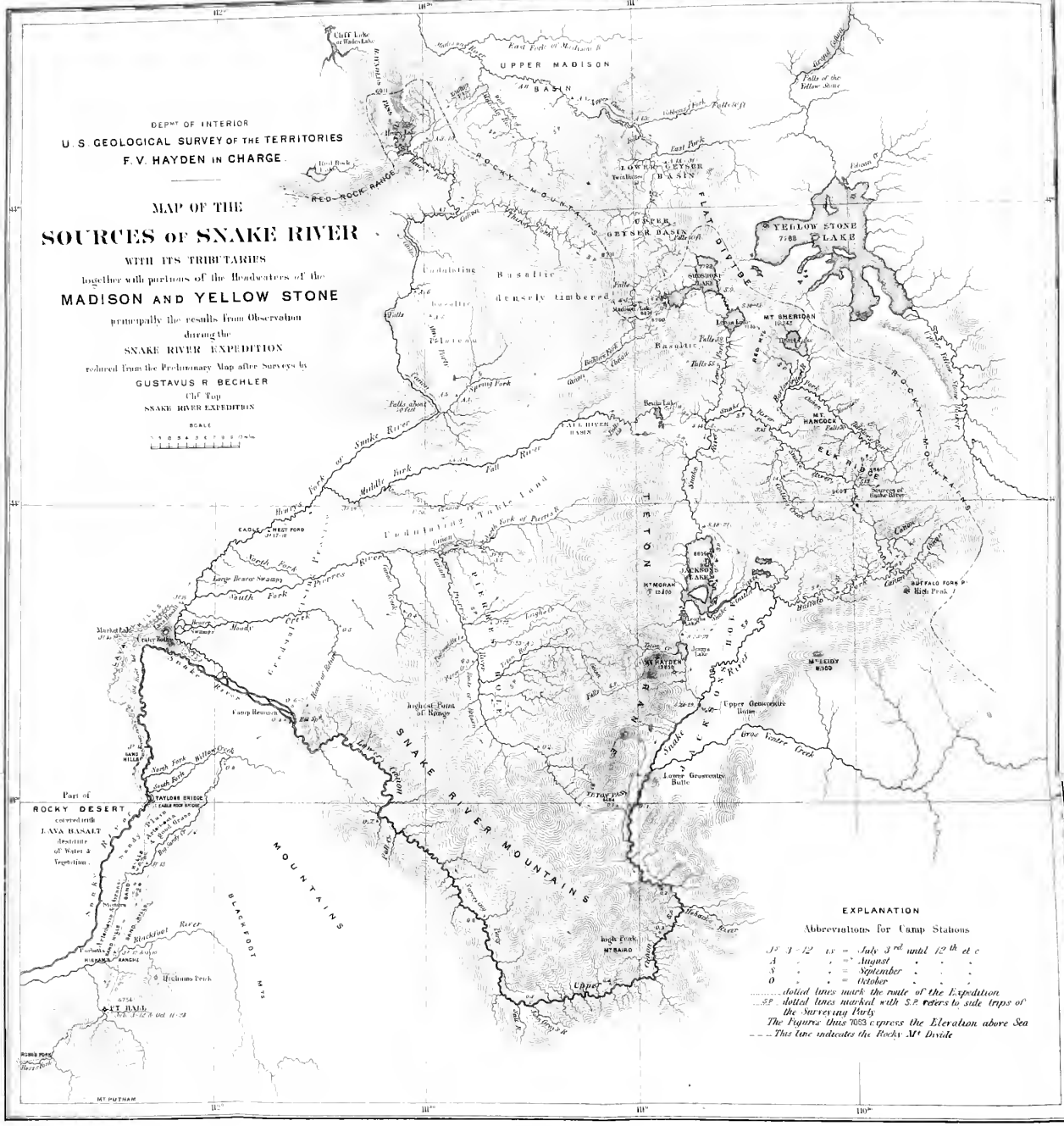
The valley about the junction of the two streams contains a considerable area of beaver-ponds. Continuing southward, up the valley of Barlow's River, we rode for two or three miles over a level, sage-covered prairie, but little above high-water mark. The stream has a very wide, gravelly channel, in contrast with which its present flow seemed very small, though really of pretty good size. The lower slopes of Mount Hancock on the west, and those of an unnamed peak of nearly equal height on the east, soon close in upon the stream, forming a deep and narrow cañon. To avoid traveling in the bed of the stream, we followed some of the numerous game-trails, which led us to from 300 to 400 feet above its level, but finally brought us down again about ten miles from Heart River, and just below some small falls and rapids, where the

stream descends about 30 feet in about 200. About two miles below this we began to find outcrops of a fine-grained, ferruginous, laminated sandstone, destitute of fossils, but probably of Tertiary age. Some of the layers showed abundant ripple-marks. At the falls, the rock is heavy-bedded. The dips are mostly about 22°, varying somewhat on either side of due east. Just above the falls, and opposite to our camp, four thin layers of coal, varying from 1 inch to 6 inches in thickness, and two layers of clay ironstone, (iron carbonate,) varying from 6 inches to 1 foot in thickness, are all included within 10 feet of shales. About three miles above this point, the cañon opens out into a broad valley, with rather narrow bottoms, but with broad, gentle, grassy slopes, topped with gently-rounded hills, partly timbered, partly grassy. The huge rocks which lower down had encumbered both bottoms and slopes gave place to cobble-stones, pebbles, and sand. From this point Captain Barlow turned eastward, in 1871, after following up the cañon, as we had now done; and here we turned eastward to climb the hills. From a higher point, we saw that the rest of the valley is mainly a broad basin. There appears to be no pond at the head of the stream, which is apparently near the summit of a flat divide, from the other side of which the waters run to Buffalo Fork. This is mostly fine grazing-ground, and the numerous game-trails give evidence that it is frequented by deer and elk; indeed, we found two herds of elk, of about twenty each, among the groves on the top of the ridge. The mountains shut off the winds on all sides, and the valley lies so well to the sun that the snows must melt rapidly here, thus causing the great freshets of which the broad, gravelly bottom of the river below had already given so abundant evidence. The upper slopes of the ridge on either side are mostly bare of timber, and many parts of them are badly washed. Those on the east are composed of mostly thin-bedded sandstones, probably of Tertiary age, at least 2,000 feet thick, with variable south-easterly dips. A few red layers appear, but the majority of them are gray. No fossils were found, though careful search was made for them.

From the summit of this ridge, we again saw Yellowstone and Heart Lakes, and had a fine view of the rugged Tertiary (?) crests of the Big Horn Mountains to the east, running down to Union Pass.

The scattered groves of spruces, with occasional pines, which are so constantly characteristic of the upper edge of the timber, occur scattered over these upper slopes, and nearly every cluster contains some young trees; but we nowhere encounter the patches of dense young growth which at a lower level so constantly start up, in a short time, whenever a body of old timber has been burned over and has fallen, and often even before the dead trees have fallen. The idea has been advanced that the burned patches are *not* thus renewed in these mountains; and, *under some circumstances*, this seems to be true; but the *rule* is just the opposite, as those of us who have had occasion to penetrate the vigorous growth of this dense young pine, whether alone or with a pack-train, will most vividly remember while memory lasts.

Crossing this ridge, we came to the valley of a stream which we afterward ascertained to be the head of the main stream of Snake River. At its upper extremity we found a flat valley-divide, upon which are two small ponds, near together, covering from eight to ten acres each, one of which is the ultimate source of Snake River, while the flow from the other joins Buffalo Fork, and so reaches the Snake just below Jackson's Lake. Ascending the high, sharp ridge on the west side of this valley, at least 500 feet high, we find its slopes to consist entirely of large and small well-rounded pebbles of variously-colored quartzites,


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U. S. GEOLOGICAL SURVEY OF THE TERRITORIES
F. V. HAYDEN IN CHARGE.
MAP OF THE
SOURCES of SNAKE RIVER
WITH ITS TRIBUTARIES
together with portions of the Headwaters of the
MADISON AND YELLOW STONE
principally the results from Observation
during the
SNAKE RIVER EXPEDITION
reduced from the Preliminary Map after Surveys by
GUSTAVUS R BECHLER
Chf Top
SNAKE RIVER EXPEDITION
SCALE
UPPER MADISON LAKE
UPPER MADISON BASIN
LOWER GEYSER BASIN
UPPER GEYSER BASIN
YELLOW STONE LAKE
MT SHERIDAN
MT HANCOCK
MT MORAN
MT LEIDY
MT PUTNAM
RED ROCK RANGE
ROCKY MOUNTAINS
SNAKE RIVER MOUNTAINS
BLACKFOOT MTS
Undulating Basaltic densely timbered
Undulating Basaltic Plateau
Part of ROCKY DESERT covered with LAVA BASALT destitute of Water & Vegetation.
EXPLANATION
Abbreviations for Camp Stations
J. Bien. Lith

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up to the very summit, where this deposit is just pierced by an outcrop of the gray trachytic lavas and red basalt, partly vesicular, though mostly compact, which form the nucleus of the ridge. We here stood upon one of the highest points in that neighborhood, about 8,654 feet above the sea; so that we were entirely at a loss as to the source from which had flowed the large river which had distributed such immense amounts of gravel and sand. We could obtain no local data which should enable us to judge whether the stream had flowed northward or southward, but the general levels of the country would imply a northerly drainage. The deposit is evidently very ancient, but no considerable consolidation had taken place.

Looking westward, a heavy mass of mountains, broken by very few water-courses, at least on their eastern face, lies between us and the basin of Jackson's Lake, and I believe that this is here properly the "main range" of the Rocky Mountains. It is certainly part of the *highest mass-connection* between the Wind River and Big Horn Mountains, on the east, which really form the northern termination of what is the main range farther south, and the range west of the Three Forks of the Missouri, which there bears the name of Rocky Mountains, and the continuation of which really appears to be the main range farther north, so far as the best maps indicate.

Above this mountain-mass the Tétons loom up grandly. A peak of that range, some fifteen or twenty miles north of Mount Hayden, is second only to that peak in elevation.

Passing westward the quartzite-gravel continues for several miles, though the mass of all the ridges is composed of a coarse volcanic breccia. The slopes are here much flatter and more rounded, with heavy growths of fine spruce, of which large areas have been burned and have fallen, so that we found some large patches absolutely impassable with animals, and were obliged to make considerable *détours* to avoid them. The small streams heading here have flat valleys, with some good meadows.

Descending the valley of Coulter's Creek, we found that the high divide between the head of this creek and the head of Snake River consisted of rapidly-disintegrating volcanic rocks, mostly conglomerates of trachytic porphyry, obsidian, &c., like those which form the very precipitous banks of the streams. Many bare spots on the slopes indicate old land-slides, some of them of large size. The main valley is narrow and in some parts deeply cañoned, so that, with both steep, rocky slopes and badly-interlocked fallen timber, we had great difficulty in making a passage out to the valley of the main Snake. This stream, we found, after a course of about twelve miles from its ultimate sources, running through a broad graveled channel, 200 feet or more in width, with three considerable terraces on either bank, along which we rode to the junction, of Barlow's River. The gravel is in some places washed away by the stream, so as to expose a solid river-bed of volcanic rocks. Near the junction, the terraces are at the levels of about 25, 80, and 140 feet above the present level of the bottoms. These are also developed to some extent along Barlow's River, which enters the Snake at a sharp, reversed angle, through a narrow cañoned valley, from the upper slopes of which we could see the broad flats about the mouth of Heart River. Though this fork brings at this season the most water to the united stream, and has the longest course, draining the largest area, yet the relative forms of the valleys at once decided that this could not properly be called the main Snake River.

On the broad lower terrace, about a mile west of the mouth of Barlow's

River, stands a large conical mound, about 65 or 70 feet high and perhaps 250 feet in diameter at the base. Though circumstances prevented me from making the desired examination of it, yet, from the regularity of its outline, I feel quite certain that it is a structure of the age of the Mound-builders. No other relics of that interesting people were seen upon the entire trip, unless the rude rock-wall reported by Mr. Stevenson as existing upon the summit of Mount Hayden should prove to be such.

The broad valley soon narrows again to a deep cañon, walled by red shaly sandstones, containing no fossils beyond indistinct fucoidal markings, which are referred with doubt to the Triassic period. The gray beds of the lower part of the series make their appearance in the lower end of the cañon. The stream is here broad and shallow and easily forded, so that the cañon can be easily traversed at this season. From this point the valley is wide and terraced, the bordering ridges being a mile or more apart; and this continues, gradually widening, to the basin of Jackson's Lake. Just at the mouth of the narrow cañon, the river bends sharply to the right and then to the left, so that the form of the slopes gives the descending traveler reason to expect here a large affluent; but none exists. About a mile lower, we came suddenly upon a small basin of hot springs, most of which are now nearly extinct, though some large mounds on the river-bank give evidence of great activity in former times. The active vents seen were all in the bed or on the bottoms of the river, so that their flow was more or less mingled with river-water; and no temperatures were taken. The deposits are siliceous. Mr. Taggart found, near here, at the foot of the second terrace, several conical depressions, from 30 to 40 feet deep and from 75 to 100 feet in diameter, which *might* have been old spring-basins, though their origin is by no means certain. At the bottom of one of these lay two dead rabbits, upon which there were no signs of violence. No other signs of escaping gas were noticed.

This hot-spring basin occurs at the upper edge of a belt of basalt, which forms, a little farther on, lofty vertical walls, from 300 to 500 feet high, through which a small stream, coming in from the north, has worn a deep, narrow cañon. About two miles below this, high walls of nearly white limestone appear on either hand, though the fading light of evening prevented a clear understanding of the relative position of the beds at the junction. It is probable that the basalt, escaping from some vent in the volcanic range of Red Mountain, filled a large north and south valley, of which the limestone had previously formed the western wall; and semi-metamorphism should be found in the limestones near the line of contact.

About three miles more brought us to the camp of the main party, at the mouth of Lake Fork, where the broad valley of the Snake makes a sweeping curve into its future southerly course, while Lake Fork itself joins it from the north through the narrow cañon which it has worn down through a high barrier of volcanic rock.

In descending from Lake Lewis, the main party found the river-banks low and rocky for a short distance, before the stream enters a cañon with walls from 150 to 200 feet high, in which were encountered sharp rapids and a vertical fall of about 30 feet. Then, for a mile or two, the slopes are gradual, with narrow, swampy bottoms along the river. About three miles below the lake, high, rocky banks indicate the approach to a deep cañon, which really commences at about three and a half miles, with perpendicular walls on both sides, inclosing a narrow channel with a rapidly-sloping rocky floor, in some places partially obstructed by huge

tumbling masses of rock, but apparently without any accumulation of gravel. Considerable rapids occur through nearly the whole cañon, and one fall of nearly 50 feet was noticed. The cañon deepens rapidly to from 700 to 800 feet, with widths of less than half the depths at the deepest precipitous portions, though in some places widening above, so as to have sloping banks of about 50° from the horizon. About three miles down, it reaches its culmination, and is truly grand. It has none of the brilliancy of coloring so characteristic of the Yellowstone Cañon, but the somber tints of its gray, brown, and dark-red lichen-covered rocks, occasionally variegated with smaller patches of green and yellow, constitute a peculiar style of beauty and add greatly to the effect of its narrow dark depths. The only deficiency is in the supply of water, which is small at this season. The rocks are all volcanic, mostly porphyries and trachytes, with some porphyritic obsidian. Some two miles below the end of the main cañon, the cliffs close in again to the river, for a few hundred feet, to a width of about 200 feet, with a height of 400 feet or more, forming a suitable gateway to the cañon from below. The valley below this is still narrow, but opens enough to give room for a few beaver-dams in its swampy bayou-banks before it rushes out into the valley of the Snake.

The high ridges which form the slopes about Lake Lewis bear back from the river and form no part of its lofty cañon-walls. Between the river and this upper slope, on the west side, a large stream gathers its waters from the abundant springs of the mountains and occupies a broad flat valley on the lower level, filled with beaver-dams, whence it rushes, through a narrow, winding cañon and over a 30-foot fall, to meet the river about a mile above its junction with the Snake. On the foot-slopes of the mountain, along the west side of the beaver-dam flat, there are considerable numbers of warm springs oozing out, and considerable accumulations of siliceous deposits are indicated by the soil. A small run, formed from a number of these springs, gave a temperature of 101°. It is possible that active springs of some size exist in this neighborhood, but the contrary is indicated by the extensive bodies of dense timber, which also hinder exploration. From the south end of the cluster of beaver-dams aforesaid, a stream flows southward, which attains a pretty good size before it joins the Snake, about three miles below the camp at the forks. Its source is probably in strong springs on the flat divide, which have been dammed up by the beavers so high that the ponded waters can escape in both directions.

The mountain which bears off westward from the head of the cañon forms the steep northern wall, while the extreme slopes of the Téton Range form the more gently-sloping southern boundary of a flat valley, from five to eight miles wide, which breaks through to the basin of Henry's Fork, and is occupied by the sources and main stream of Falls River. The extreme source of this river is in the great water shed of the northern mountain, from whose southern face it bursts in four immense springs, which leap from its steep rocky sides as full-grown streams, and rush in beautiful cascades, from 75 to 100 feet high, down a slope of about 40°, to form two large branches, which, a mile below, unite in a stream carrying about 20 feet of water. After a winding course of two or three miles, from several points of which it could with very little difficulty be turned eastward into the main Snake, it flows with a still rapid current into the more northern of two small lakes, known to us as Beulah Lakes, which lie upon the lowest part of the divide and are each from 600 to 800 feet across. The southern one has now no surface-outlet, but marshy grounds extend to the more northern one, over which

outflow must pass when the surface of the lake is from four to six feet higher. The divide toward the east is only 8 feet above the lake. From the west end of the more northern lake, about 30 feet of water flow out rapidly, soon jumping over a fall of 12 feet. Strong branches soon join the stream from the north and one from the south, and double its supply of water. Five other falls succeed, of 6, 12, 40, 20, and 30 feet, before we reach the Great Falls. These show a total descent of 141 feet, consisting of three larger falls above, the third being 47 feet high, with three small ones at the bottom. The upper two are somewhat of horse-shoe form, while the third and highest has a nearly straight edge. The amount of water in the stream is fully 80 feet. The porphyritic trachyte of its walls forms perpendicular cliffs, with rounded tops. A stream of some size comes in about a half mile above there, on the south side, with fine cascades on its upper course, while its sources lie in a basin of the mountain whose form indicates that it may inclose a small lake; the left-hand branch of this stream comes from two small lakes on the divide, as hereinafter described.

From the lakes downward, we find laminated porphyries, succeeded by trachytes and red and black porphyritic obsidian. Below the falls, a high knob consists of a fine-grained, compact, white trachyte, which contains disseminated plates of black mica, (muscovite?) and which, with but a slight change of texture, might readily be mistaken for granite. From this knob we have a fine view westward to the lower basin of this river and its tributaries. The largest of these, Bechler's River, comes out of the plateau of the great water-shed, about ten miles to the northward, into a large basin apparently containing extensive grassy meadows, and then passes among rounded timbered hills to join Falls River, apparently but a few miles above our lower crossing of that stream. Large grassy meadows, some miles farther north, indicate another large stream, probably tributary to Bechler's River; but it was impossible to trace its course with any certainty at that distance. Some miles down Falls River our guides report another fall, about 40 feet high; so that it will be seen that the stream deserves its name. The slopes near the river are mainly well-rounded and fairly timbered, though, at a few points, steep and even precipitous and bare. The stream presents the utmost variety of water-scenery within a short distance; from the still, deep pools, which accompany a short stretch of beaver-dams, to short, sharp rushes over steep rock-slopes, to successions of steps, forming various styles of rapids, and to vertical falls of various forms and sizes—a perfect treasury of artistic bits.

The elevation of this divide and the moderate character of the slopes, averaging about 54 feet to the mile from Henry's Fork to the summit, indicate this to be a favorable line for railroad-access from the south to the region of Yellowstone Lake, if such should be thought desirable. From the main line up Henry's Fork to Montana, of which this would doubtless be a branch, the road would follow up the ridge on the south side of Falls River to the divide, thence keep around the foot of the northern mountain to Lake Lewis, cross Lake Fork, and, passing along the eastern shore of the lake, cross the flat divide, striking Yellowstone Lake about the middle of its western side, and thence follow down the valley. It is probable that a route could be located from Lewis's Lake, past the north end of Shoshone Lake, to the Fire-Hole basins; but the most easy access to the Fire-Hole is by way of Henry's Lake Valley, Tyghee Pass, and the Upper Madison Cañon. Between the Fire-Hole and Yellowstone Lake, the ridges are too sharp to be passed by railroads, unless by very winding routes or by long tunnels.

A short distance southwest of Beulah Lakes, over a divide about 300 feet high, and at a level about 100 feet lower, Mr. Bechler found two other small lakes, at the head of a branch of the stream which enters Falls River from the south, just above the Great Falls. The upper one has an area of something over one hundred acres, with rocky banks, and flows to the lower, which occupies about 40 acres in the center of a marshy basin of perhaps a hundred and forty acres.

Southeast of these latter lakes, over a divide about 350 feet high, we reach the head of a valley running eastward to the main Snake. Its upper portion is a flat basin, about one and a half miles long by a mile wide, bounded on the east and north by from 400 to 500 feet of volcanic rocks, of which the upper 200 feet present a vertical front, while the remainder is mainly covered by a slope of tumbling rubbish down to the stream. The other slopes are rounded, as are also most of those along the lower course of the stream down to its junction with the Snake.

All this wide area, from these northern slopes of the Téton Range nearly to the Tyghee Pass and to the mountains on the north side of the Upper Madison, though actually quite elevated, is relatively much depressed below the summits of the limestone, quartzite, and granite mountains on either side. From the general distribution of the volcanic rocks, as well as from facts observed elsewhere, I am inclined to believe that, before the ejection of these immense bodies of lavas, there was here a broad valley, through which the drainage of the upper mountain-region to the eastward found its way out to the great basin of the Snake, while the cañon by which it now escapes through the high mountain-mass south of the Tétons had not been cut down.

Immediately opposite the camp at the mouth of Lake Fork, there is a considerable cluster of dead and dying hot springs. Several mounds indicate the former positions of geysers of considerable size. The temperatures of ten springs were taken by Mr. Taggart, varying from 102° to 158°. Three were above 150°. The deposits are now rapidly disintegrating. Upon one large conical mound this process had developed a columnar or fibrous condition of the geyserite. Similar spring-deposits also occur on the west side of the river, from one to four miles below this camp, and some of the mire-holes so common in the Fire-Hole basins were also encountered. Upon looking back from below, two large columns of steam were seen, about a mile up the Beaver-Dam Creek, which seemed to indicate the possibility of geysers still existing there. The lower part of that stream was full of purple-nacred *unios*, apparently like, or closely allied to, those found in the branches of Henry's Fork.

Along the east side of the river, the face of the high ridge shows the following rocks, according to notes taken and specimens brought in by Mr. Taggart:—At the base lie about 200 feet of white and light-gray quartzites, overlaid by from 500 to 600 feet of light-drab and dark-gray limestones, and about 100 feet of gray sandstones, followed by heavy beds of red, shaly sandstones, apparently the same as those seen higher up the river. I am not satisfied as to the age of either the limestone or the quartzite. The ridge is capped with beds of porphyritic trachytes, having a dip of about 30° to the southeast, while the limestones beneath dip about 40° in the same direction, showing that their tilting commenced before the deposition of the trachytes.

The main trail crosses the Snake about a mile below camp, and passes over the hills so as to cut off a considerable bend of the river. From six to eight miles below the forks, a spur, which runs nearly to the west bank of the river, shows a high bluff face of porphyritic

trachyte. The valley is here wide and flat, mostly marshy, with some large bayous. There are considerable areas of fine grazing-ground and many large patches of willows. One island-like, rocky knob, with part of the first terrace, which has been protected by it from erosion, stands out in the middle of the valley, about a mile below the cliffs. The river is here of moderate depth, with a bottom of small pebbles and muddy sand, but good fords are few and mostly difficult of access by reason of the marshes bordering the stream, so that the necessary crossing to the east bank should be made near where our train crossed, unless special reasons take one down the west side. As we approach the lake, the stream gets deeper and more sluggish, being somewhat checked by the back-water of the lake. Broad marshy flats stretch back from the shore of the lake on both sides of the river. On all these flats we find an abundance of "bitter cottonwood," which had formed, higher up, only a very small part of the timber-growth, though its young plants had, for the last fifteen or twenty miles, furnished rapidly-increasing patches of yellow and pale-red along the slopes, thus replacing, in some degree, the autumn-tints of the hickories, chestnuts, and maples of more eastern regions, while a small mountain-ash was doing its best to replace the deeper crimsons of the oaks and of some of the maples. The development of these tints did not seem to be at all connected with any special increase of cold; and, indeed, we had been having frequent freezes all the summer, without any apparent effect upon the vegetation, which seemed to be accustomed, as the grasshoppers are, to being frozen up every night and thawed out every morning.

The Téton Range had been before us for many days as a prominent feature of the landscape, but now its peaks stood up as the features of main interest, bounding the valley on the west with a series of roof-like ridges and pointed peaks, well besprinkled with patches of snow. Farther north and east, we had been having pleasant weather, while this portion of the valley had several successive days of cloud and rain, as reported from our guide, Beaver Dick, who met us again here, having crossed from the valley of Henry's Fork. When these storms reached the higher portions of the mountains, their deposit took the form of snow, so that the drifts were now much larger than when we struck the range on the other side, in July.

On September 21, the minimum thermometer recorded 41½°; and a clear sky, with cool weather, gave us unusually fine views. The peaks stood out sharply, while the gaps and cañons were full of a deep-blue, smoky light, which would touch the heart of the least artistic.

On the northeastern slopes of the range, several hundred feet of limestones represent the Lower and Upper Silurian and the Carboniferous, as on the other side of the range. Their area here is limited, and has not been traced to its abutment against the volcanic rocks, which fill the depression to the northward. The range is much flattened and rounded off at this extremity; and I am inclined to believe that the granitoid nucleus declines so much as to allow of the connection of the limestones of the east and west slopes being exposed between it and the volcanic rocks. At least, the dips indicate that such a warped connection once existed; and I shall not be very far wrong in coloring the map according to that supposition. The underlying quartzite (Potsdam?) was not seen here, but is probably in place, as it appears a few miles farther south. The most northern large cañon of the range exposes, beneath the limestones, a heavy body of dark micaceous gneiss, with both granite and quartz veins. The local dip is northeasterly; but the main dip of the metamorphic rocks here is southerly.

Along the shores of Jackson's Lake there are no outcrops which would enable one to decide where the different strata lie; but, at its southern end, there are high knobs of porphyries and trachytes, which indicate, by their position, at least a former connection with the more northern beds, which we traced to within five miles of the northern end of the lake.

Jackson's Lake is a very irregular body of water, much cut up along its borders by long, narrow promontories jutting out into it from both sides, and containing one large island, which nearly separates the lake into two. The main lake is from two and a half to three miles wide, and the total length is about eight miles. In the soundings taken by Mr. Adams, the greatest depth found, 258 feet, was about a mile from the western shore. The series of soundings was far from complete, by reason of a squall coming down from the Tétons and raising dangerous waves, so that they had to give up the rest of the work. The lower slopes of the more northern Tétons come sharply down to the lake on the west, and these steep slopes, together with the tangled undergrowth of willow, cottonwood, mountain-ash, and iron-weed, with occasional box-elder and maple and some tracts of fallen timber, make passage along there difficult for a train; but its other shores are surrounded by low hills and by broad meadows, largely occupied by beaver-dam and other swamps. These flats are much cut up by bayous, and include several ponds of considerable size. Others are found among the rounded hills of gravel, which remain from the upper terrace of the old river-border. Two of these, lying from two to three miles east of the outlet, toward the valley of Buffalo Fork, are each about two miles long by a half mile wide. They apparently occupy portions of ancient river-channels. A stream of about the size of Barlow's River, with broad gravel-bottom and rapid current, comes out of the hills opposite the lower end of the lake and joins the Snake just after it has escaped from the lake.

The views from the east shore of the lake are wonderfully grand. The Tétons rise majestically from its western shore to the height of 7,000 feet above its surface, with sharp slopes and walls of bare rock above, and their bases buried in a dark mass of pine and spruce, while at this season (September 24) their snow-covered summits give the beholder a strong sense of sublimity. At times they are wrapped in heavy masses of cloud; but even then they are grand. The accompanying sketch of the face of the range, as seen from near the North Gros Ventre Butte, has been copied from Mr. Bechler's field-notes. (Fig. 50.)

A few miles below the lake, Buffalo Fork enters from the east through a broad valley with grassy and willowy bottoms, bringing a very large body of water. These bottoms contain some large groves of Menzies's spruce, (*Abies Menziesii*,) whose peculiar cones were seldom seen elsewhere by us. Near the mouth of the stream gray and buff, fine-grained, shaly sandstones of indeterminate age dip sharply to the southeast, and similar rocks appear in the bed of Snake River, at the ford just above the mouth of Buffalo, but the dips are here much confused. Mr. Bechler followed the Buffalo nearly to its head, and reports that, for about twelve miles from its mouth, its broad, open valley shows no rock, but has rounded slopes covered with "quaking asp," (*Populus tremuloides*,) and bottoms full of beaver-dams. About twelve miles up, the valley narrows to a cañon from 350 to 400 feet deep by from 50 to 200 feet wide, for about three miles, with coarse, gray sandstone walls. About one and a half miles of a rounded basin, with beaver-dams, then intervenes before reaching the second cañon, which has nearly the same character as the first and is about two miles long. A broad basin

succeeds, from five to seven miles across, reaching up to the foot of the high vertical limestone-walls of the main divide (?), whose ragged crest shows plainly from the mouth of the valley, and from whose many gorges come the numerous small spring-branches which form the main stream. Besides the main fork, seven or eight large creeks come in from either side, showing that the basin as a whole occupies a large area, and its amount of water makes this one of the most important tributaries of the Upper Snake. At this season, indeed, it carried fully two-thirds as much water as the Snake itself. About the mouth of the valley, the slopes are covered with partially-cemented Post-Tertiary sands and gravels, with occasional exposures of white marly clays, supposed to be of the same age, though no fossils were seen. The gray sand-stones of the cañons are plainly the continuation of the Tertiary (?) beds of Barlow's River directly to the northward; and the limestones of the high cliffs at the head of the valley are probably of Quebec Group age, perhaps capped with Carboniferous. A small bit of fine-grained, compact sandstone, found loose on the rubbish-slope near the top of the mountain by Mr. Brown, contains fragments of some thirty trilobites of the genera *Conocoryphe* and *Dicellocephalus* (?).

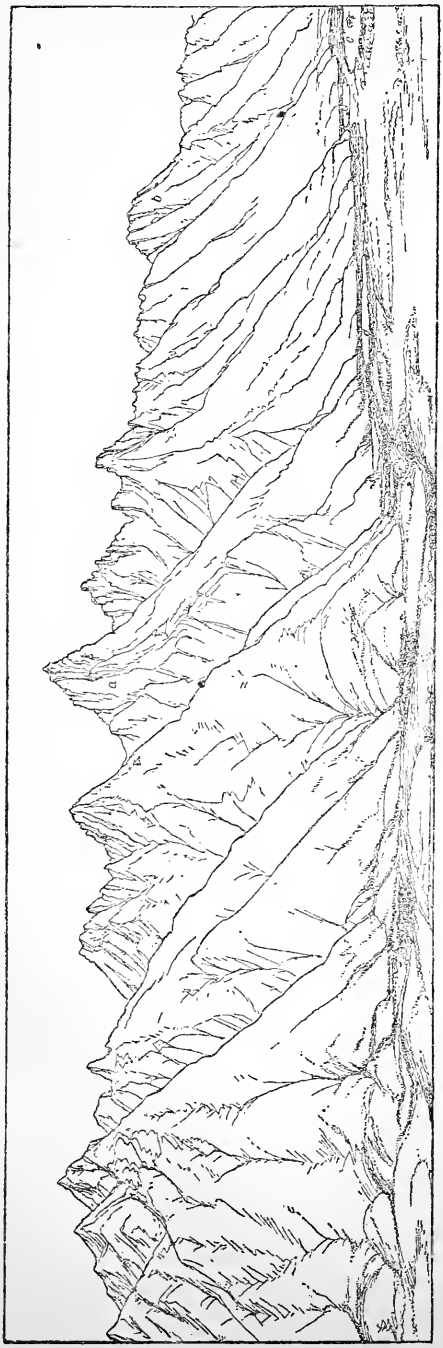


Fig. 50.

a, Mount Hayden; *b*, Mount Leidy; *c*, Jackson's Lake; *d*, *d*, *d*, small lakes.

Snake River escapes from Jackson's Lake at its southeastern angle and runs off eastward to the valley of Buffalo Fork before renewing its southerly course. Yet, from the top of the butte at the mouth of the lake, it is plainly seen that a broad valley extends directly southward from the southern extremity of the lake; and it at once

becomes a question why the river has thus deserted its own proper valley and has turned off so far to the east to find another outlet. Four old terraces are strongly marked along the river, and the third, above its present level, forms broad plains, on both sides of the river, below the mouth of Buffalo. Moreover, the old river-gravel, consisting mostly of quartzites, runs to the top of the island-like knobs in the center of the valley as well as of some of the hills which border it. Crossing westward over these broad plains, which are mostly covered with sage-brush, except about the isolated ponds, which seem to give evidence that much of this third terrace has been worked over by the river and cut up by bayous, we cross a narrow belt of spruces covering the surface of the fourth terrace, and then descend to the old deserted channel of the river, which is nearly on a level with the third terrace. Crossing this valley directly toward the mountain, we come at once to a series of high, steep, narrow ridges, covered with immense masses of granite and heavily timbered. Within the last of these concentric ridges, we come to a small lake, lying at the mouth of a deep cañon which runs far back into the mountain; and here at last we have the clew to the mystery. This cañon, like all the other large ones of this range, was occupied by a glacier, whose terminal moraines now hem in this lake; and, though the old river-valley seems to have been not fully blocked up by the flow of silt which passed beyond the moraines, so that its general features are still plainly marked, yet it is evident that the deposition which caused its bottom to slope from west to east so much as we now find it to, was sufficient to considerably delay the wearing down of this channel. The cañon next north of this was also occupied by a glacier—a moraine-dammed pond will probably be found in the mouth of it—and doubtless its *débris* aided in checking the erosion. At that time, the flow of water through all this region was much greater than at present, and the duplicating of channels in the broad bottom was far from being uncommon. If a channel had then joined the eastern streams, though only as a bayou in time of flood, there was reason for its being ultimately cut down, so as to drain the western channel, which is the true valley of the Snake. The summit of the highest and outermost moraine is partly covered with river-gravel, as if the stream had at least once reached this height after the glacier began to recede. This crest is 122 feet above the bottom of the adjoining part of the old river-channel, 222 feet above the present level of the included lake, and 366 feet above Jackson's Lake. These and other levels across the valley were taken at my request by Mr. Hering, who has furnished the data for the accompanying section from the lake, across the old channel and the present one of Snake River, to the eastern hills. The length of the section is so great that it became necessary to distort it by increasing the elevations considerably beyond their proportional size. (Fig. 51.) We have called this lake, which is about two miles long by a half mile wide, Leigh's Lake, after our guide, Richard Leigh, (Beaver Dick.) It appears to be mostly shallow, and has a small island near its center. Can it be possible that the glacier, which was formed by the flow from two cañons whose junction is only a very short distance above the lake, split again after it emerged, so as to leave this island uneroded? No special depression of the moraines opposite the island was noticed; but examinations just at that point were not carefully made. On the other hand, if we pass to the north end of the lake, we find a flat divide, not 5 feet above its level, and less than a hundred yards across, which separates it from a large beaver-pond, whose waters escape through two or three other ponds and marshes to the head of Jackson's Lake. A very trifling cut would thus give the lake a second

outlet; and it appears not improbable that the glacier did split, as suggested, during at least a part of its existence, and flow out at this end as well as at the southern one. These waters come so near together that, without any connected examinations, and without recognition of the rise of 144 feet from Jackson's Lake to Leigh's Lake, water-communication between the two had been inferred and reported; and Mr. Adams attempted to find a passage across in his canoe, but, failing in that, was obliged to make the long *détour* by the true outlet of Jackson's Lake.

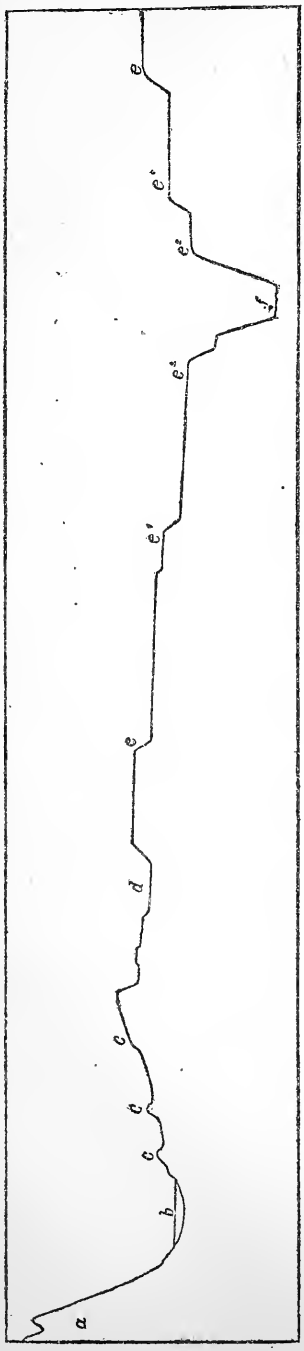


Fig. 51.

a, Téton Mountains; *b*, Leigh's Lake; *c*, *c*, *c*, Moraines; *d*, old-river channel; *e*, e^1, e^2, river terraces; *f*, present channel of Snake River.

About a mile south of Leigh's Lake, another, of about the same size, which we have called Jennie's Lake, after Mrs. Leigh, lies in the mouth of the Great Cañon of the Téton Range. Passing up this cañon for a short distance, Mr. Taggart found a cluster of falls and rapids about 250 feet high, with lofty, precipitous walls on either hand, which prevent ready access to the upper part of the cañon, which winds around to the western side of the peaks, where its lofty walls were seen by us in July. This cañon gathers the entire drainage of the western side of the three principal peaks, so long known as the Three Tétons. The water of these mountain-streams is so pure as to make it certain that not the least glacial erosion is now going on at any point on the range. Though many schists occur in the mountains, very few of them have contributed to the terminal moraines, nearly everything except the granites having been ground or weathered fine during the downward passage. The moraines about Jennie's Lake are not very largely developed; possibly, the more abundant flow of water from beneath this glacier, consequent upon the greater size of its basin, washed away the *débris* from here more thoroughly than was done elsewhere. At two other cañons, farther south, similar lakes occur. The more northern of the two, which we have called Taggart's Lake, is surrounded by five concentric moraines, the elevations of which above the old river-channel, which passes just outside of them, were taken by Mr. Taggart, as follows: The outer one, 162½ feet; second, 206 feet; third, 271 feet; fourth, 316 feet; fifth, 422 feet. The

present level of the included lake was found to be 249 feet above datum. The last of this series of lakes, which we have called Phelps's Lake, after a hunter of the region, who had seen and reported it, is hemmed in by three moraines, according to Mr. Taggart, the outer one 162 feet, the second 244 feet, and the third 287 feet above the lake itself, there being no special surface-feature near the moraines on their outer side to which to refer these levels, as to a recognizable base. In this last case, the cañon forks above, and the two arms extend in opposite directions along the line of separation between the granites and the flanking limestones. Each of the two glaciers, therefore, gathered, from the rocks overhanging it, granites on one side and limestones on the other, so that, after their junction, the central moraine of the united glacier consisted of limestone, and we find small fragments of limestone filling the low central portion of the terminal moraine, while its high flanks, which received the material of the lateral moraines, are composed of the granites, which are less easily disintegrated, and are therefore mostly in large bowlders. No remnants were anywhere seen of any lateral moraine deposits along the courses of the glaciers. It is possible that such may be found by more careful search, but the slopes are here so steep that most of their lower portions are buried in the tumbling rubbish, so that we can have little expectations of such a discovery being made.

A little south from the second large cañon south of Mount Hayden, the limestones come forward to the front of the mountain, above the granites, which shortly afterward disappear from sight altogether. The length of the exposure of the granitic nucleus of the range is about thirty miles.

About eight miles below Leigh's Lake, its outlet, which we have called East Téton River, enters the Snake. A hundred yards back from the opposite bank stands a high, rocky butte, known as North Gros Ventre Butte. Its northern end consists mainly of Carboniferous limestone, dipping about 70° N. 56° E., and containing many characteristic fossils. Along the west face of the butte, none of the lower rocks are visible, being buried under the Post-Tertiary whitish sandstones and marls, inclosing fragments of limestone and chert, but no fossils, of which all the southern part of the butte is composed; but, near the northeast corner, the lower part of the series of older limestones presents the conglomeratic texture so characteristic of the Quebec Group, on the west side of the Téton Range and elsewhere, and it is probable that they represent that group, though no fossils could be found. Beneath this we find gray quartzitic sandstones, which are probably of Potsdam age.

This butte stands near the middle of the broad basin which has long been known by the barbarous name of Jackson's Hole. This has a length of about twenty miles, and varies from five to ten miles in width. This includes portions of the different terraces, all of which are more or less covered with sage-brush. Near the butte, large areas of the sage had been burned off, and the grasses had grown up densely, forming fine pasturage; and on these we again encountered antelope, which had not before been seen by us since we entered the Upper Madison Cañon. It is said that, during the winter, when the grass is covered, they live upon the sage itself. This plant was now full of seeds, and the innumerable little chipmunks which burrow in the plains and hills were busy gathering them, biting off the long spikes and stripping them from end to end, passing them back and forth through the mouth, as one would an ear of corn.

The pebbles of the terrace-gravel have thus far been mainly quartzites,

and still continue such on the east side of the basin; but, nearer the western range, considerable proportions of granite and gneiss pebbles are now mingled with them. A considerable excitement was stirred up, a few years since, by reported discoveries of placer-gold in large quantities on the Upper Snake, and many prospectors visited this region. A small hydraulic operation was undertaken near this point; but the gold was too fine and in too small quantities to pay, and the whole region was entirely abandoned after a few months. The coarse gold, found on the lower part of the Snake, appears to have entered the river below the cañon, which is still to the southward of us.

The Gros Ventre Fork emerges from the eastern hills about opposite the North Butte, but runs off down the valley, some eight or ten miles, before joining the Snake. Passing up its cañon for a short distance, the following section was taken:

1. White, friable, false-bedded sandstones, 10 feet.
2. Covered space, about 100 feet.
3. Irregularly-bedded, pale-gray and buff, magnesian limestones, 50 to 60 feet.
4. Pale-red friable sandstones, darker and shaly below, 300 to 350 feet.
5. Compact, fine-grained, gray sandstone, 15 to 20 feet.
6. Brown, coarse, friable, false-bedded sandstone, 60 to 80 feet.
7. Coarse, friable, red sandstone, 40 to 50 feet.
8. Compact, dark-drab, fossiliferous limestones, 300 to 400 feet.

Near the mouth of the cañon, the Carboniferous limestones of No. 8 form the walls, capped, as we ascend, by Nos. 7 and 6. As these pass below the stream's level, No. 5, which forms the top of what I suppose to be Carboniferous, commences a new cliff, and is covered by the Triassic (?) beds of No. 4, which form prominent red bluffs along the stream for many miles. The compact to vesicular, variously-colored and partly bituminous limestones of No. 3 showed no fossils, and I am uncertain whether to refer them to the Triassic or to the Jurassic, but favor the latter reference. The covered space of No. 2 showed nothing from which one could even infer the character of the buried strata. The friable sandstones of No. 1, which cap the hills for some miles, are probably late Tertiary. The dips of their false bedding imply an open sea to the northward during their deposition, while those of No. 6 face eastward and southeastward. The lower beds, which should make their appearance along the face of the mountain to the south of the Gros Ventre, are so much covered with the partially-cemented Post-Tertiary sands and gravels as to be not readily recognized from the plain, and time did not permit a closer examination. Judging from the dips of the lowest beds seen, I should expect to find here the lowest Silurian, underlaid by metamorphic rocks, forming an axis which may connect the Tétons with the Wind River Range.

Just south of the mouth of the Gros Ventre, on the east side of the Snake, stands a cluster of buttes, known as the South Gros Ventre Buttes. The western one has a high, broad northern face of red, gray, black, brown, and variegated porphyritic breccias, including much jasper, but partly porous, loose-textured, and even ashy. The beds are much distorted, but have a general northwesterly dip. The lower end of the butte is tapering, long and low, and appears to consist mostly of Post-Tertiary sands and gravels. At its southern extremity it rises quickly into a sharp butte, composed of horizontal beds of gray limestone, unfossiliferous, but apparently of Carboniferous age. The same beds form the face of the mountain to the eastward. Three other

buttes lie east of the more northern part of this one, and evidently originally formed one with it.

These buttes greatly narrow the plain, which, immediately below them, expands into Jackson's Little Hole, whose flats are mainly upon the east side of the river and measure about four miles wide by perhaps ten miles long. Here, also, the sage has been burned off and replaced by grass. For several miles, from above the mouth of the Gros Ventre, the river has gravelly bottoms from half a mile to three-fourths of a mile wide, cut up by the several channels and partly occupied by beaver-dams. Of course, fords are numerous.

The only practicable pass across the Téton Range, so far as known, is about opposite to these South Buttes; and our main party left the river at this point. Mr. Taggart reports both slopes of the pass tolerably regular and gentle, except for a short distance just at the summit, but that the eastern is somewhat the steeper. The Carboniferous limestones, which were the only rocks noticed until the summit was passed, are nearly horizontal, have only a slight southerly or southeasterly dip; but, in descending the western slope, this dip increases to about 45°; and overlying, red, shaly sandstones, probably of Triassic age, appear at one point on the trail, while limestones, apparently those previously referred to the Upper Silurian, form considerable cliffs or spurs, a short distance to the northward. There would seem to be considerable displacement thereabout. The porphyries of Pierre's Hole appear at the mouth of the pass, at the elevation of about 7,000 feet, and form all the foot-hills of the mountains on the southwest side of that basin, until the actual bottoms of the Snake are approached, where the basalt appears. The track of the party lay so far out in the basin that there was little or no opportunity for examining the character of anything more than the foot-hills of the western mountains.

At the lower end of Jackson's Little Hole, the so-called Grand Cañon of the Snake commences. The river turns sharply to the eastward and cuts through the laminated sandstones which apparently overlie the Carboniferous limestones. Just at the mouth of the cañon, the upper terraces close in, and are capped by bastioned walls, 100 feet or more in height, of a pale-red sandstone, overlaid, as we see in looking back from lower down the cañon, after this turns south again, by heavy beds of dark-red, shaly sandstone, appearing like, and occupying nearly the relative position of, the Triassic (?) on the Gros Ventre, except that, below them, there come in several hundred feet of thick and thin bedded and shaly, gray and green sandstones, with interlaminated calcareous shales. These contain plant-remains, but so thoroughly comminuted that I was not able to find a single recognizable fragment. At the angle of the cañon, these dip strongly to about N. 78° E., and a long section of them is exposed on the east side of the stream; but in about a half mile they become horizontal, and, again, a mile lower, at the mouth of Hoback's River, dip 10° to about S. 63° W.

Hoback's, so named for a hunter of the Pacific Fur Company in 1812, by Mr. Wilson G. Hunt, as reported in Irving's Astoria, brings in a large volume of water from the eastward and plainly drains a large area upon the western slope of the Wind River Mountains. Its valley, though narrow near its mouth, was at one time the favorite route for the Indians in crossing to the Green River Valley; but, latterly, they have preferred the Gros Ventre route for some reason. The red beds hold a prominent place near the top of the high cliffs, for a half mile or more above the forks, but the valley is too winding to give much of a view. Just below here, a strong creek comes in from the west, appar-

ently draining a considerable area of the mountain. It approaches the river by a succession of cascades over successive layers of the sandstones. As we descend the river, these beds come up in two anticlinals, one low and flat and the second mountainous, with dips reaching 70°, and coming down steeply to the river on both sides. The axis of the second anticlinal is occupied by a narrow fold of limestone, through which escape several warm springs. A small cluster of these, escaping among the gravel in the edge of the river, on the south side, emit an abundance of sulphureted hydrogen. Though somewhat mixed with the river-water, they gave a temperature of 117°. About a hundred yards below this, a group of calcareous springs has built up a dam of tuff, so as to flood several acres about the vents, which are now inaccessible. The general flow from the pool gave a temperature of 94°. Just opposite these springs, in the lower part of the sandstones, as they re-appear on the west side of the anticlinal, there are exposures of two or three heavy beds of black, calcareous shale and friable clay, with some harder bituminous mud-stones, which appear, from short distances, precisely like coal outcrops. Fragments of teeth and bones, probably belonging to amphibians, occur in these layers. Above them there are some thick beds of chert.

Here the river turns south again, and runs for about two miles along the west side of the anticlinal, with sharp slopes on either banks. Turning west again, we cross three anticlinals, in the third of which considerable displacement has taken place, so that the Carboniferous comes boldly up, and, after this, forms the mass of the mountain clear through the cañon. The lower portion of these beds consists largely of sandstones and shales, though including heavy beds of limestone; higher up, the limestones form a heavy mass for several hundred feet, partly compact, partly fragmentary, overlaid finally by more shaly beds, making a total thickness of 2,000 feet or more. A few fossils of the genera *Spirifer*, *Macrocheilus*, and *Zaphrentis* were seen in the *débris*. The lower layers weather to nearly white, while the upper ones are strongly buff. All through this series, the cañon is narrow, with steep, often perpendicular, slopes and hardly any bottoms. The river mainly occupies a deep channel, with a broad shelf of rock on one or both sides, which is barely covered at this season. Crossing would be impossible without swimming the stock. Many of the steep slopes are covered with spruces, and their angular tops, lapping over each other, on the opposite side of the cañon, give the effect of diamond-slating on a roof, though with the angles reversed. Upon these limestones we begin to find again great numbers of the small maples seen farther south. These are said by the hunters to be somewhat on the increase in this region.

About ten miles through these limestones bring us to the mouth of the cañon. Through much of its upper course the stream is quite rapid, and almost deserves the name, Mad River, applied to this part of it by the early trappers; but there is little that would have proved troublesome to experienced *voyageurs*, and probably none that would prove really dangerous. (See Irving's Astoria, chapter xxxi.)

The terraces, though only fragmentary through the cañon, now spread out into broad sage-covered flats on either side of the river, and the higher slopes become much more rounded. Just at the mouth of the cañon, John Gray's River, which heads far to the south, on the divide toward Bear River, comes from the southeast, through the same mountain-mass, and with apparently just such a cañon as the one we have just left. At its mouth, a heavy mass of cemented bedded gravel shows

down-stream dips of 17°, apparently implying great rapidity of current over a rapid into a deep pool at some former period.

About two miles below, Salt River also enters the Snake, through a broad-terraced valley, which looks as if it were really the continuation of the lower valley of the Snake. But for misinformation as to distances, we should have explored this valley up to the salt-works before descending the Snake. It seems to afford an easy passage through a valuable region. The cañon through which we had just come, though having a reputation for very difficult traveling, was passed by us with ease, and really presents but very slight obstacles to building a railroad, if one were desired from this point to Yellowstone Lake or beyond, or merely to give convenient access to the rich basins of Jackson's Hole and Little Hole. Furthermore, a road, reaching this point from either the lower or the upper Bear River Valley, would have then the alternation of passing down the Snake with easy grades to the east side of the valley of Henry's Fork, with the advantage of crossing the river where its channel is narrow and its banks far above any floods.

The Snake here turns sharply northward into the continuation of the valley of Salt River, with high mountains of Carboniferous limestones on the east, showing some castellated walls, and lower and more rounded ones on the west. Two or three miles below the mouth of Salt River, a small stream from the west was thick with mud from the Caribou gold-washings.

The valley is here located by an anticlinal fold; and the nearly vertical limestones of its axis are finely exposed along the foot of the western hills. Here, also, is located a cluster of warm springs, making calcareous, sulphurous, and saline deposits. The largest spring, the Wash-tub, has built up a flaring table, 1 foot high, of an oval form, measuring about 4½ by 7½ feet, upon a mound consisting of calcareous mud, scarcely solidified, of from 5 to 7 feet above the creek-bottom in which it stands. The central table has contracted so as to crack across diagonally, and the flow now escapes at its western base, depositing a fine mud tinged in the full pools with a faint sulphur-yellow, but pure white in the dry ones. These pools cover the mound in descending steps of great beauty. The present flow is southward, though it has been on all sides in succession. The deposit on the surface of the mound is still very soft, and showed at the time of our visit (October 6) the tracks of a small bear, who had recently investigated the wonders of the mound, even setting his foot on the central table. One mound, no longer active, is 5 feet high, with a circular base of about 5 feet diameter and an oval summit of about 1 foot by 6 inches. Many small springs escape along the bank for a hundred yards or more. The deposits vary greatly in color. At some points, the odors of sulphurous acid and of sulphureted hydrogen were quite noticeable. The older deposits have built up a bank 10 feet high, along the base of the terrace; and the beavers have taken possession and have dammed up on it the waters of the cold springs which flow from the second terrace at short intervals along this plain. On the opposite shore, two considerable springs have built up their deposits against the foot of the mountain, one of which appears to be nearly dead. The highest temperature observed here was 144°. The Wash-tub gave 142° and others 142°, 140°, 90°, 88°, &c.

The deep channel, seen through all the lower part of the cañon, continues for several miles down the valley, and fords are at all points much rarer than in the upper valley. The stream is narrower on the average, and the amount of water has been much increased.

As the valley turns westward, it becomes somewhat narrower; and laminated porphyritic trachytes appear on the northeastern side, at first capping the spurs like isolated forts, and then forming, as it were, a row of casemates just below the crests of the hills. At two points this rock descends nearly to the water's edge; but the valley soon opens out again, with broad bottoms on the east for several miles, to opposite the mouth of Fall Creek, where basalt appears upon the eastern side as it had done on the western some miles higher up. The upper part of this valley-flat is covered with sage-brush, but the lower half is full of the richest of pasturage, except only such portions as are occupied by beaver-dams and bayous. Along these water-courses, large thickets of black-haws were most thickly covered with ripe fruit, but the crop of service-berries was almost an entire failure in all this region. At several points we noticed the abundant rose-bushes covered with hips, which were so soft when ripe as to have the translucent appearance of berries and to be very pleasant eating. This did not appear to be a specific character, but was probably consequent upon the shortness of the season, which, after the fruit is well developed, prevents the secretion of the large amount of woody fiber which elsewhere commonly forms so hard a covering to the rose-hips. All through the cañon, as well as along this lower valley, we noticed innumerable young plants of the lupines, which abound in this region, prepared to make vigorous growth as soon as the short summer opens.

Fall Creek heads some miles to the southward, in John Gray's Lake, near the Caribou mines, and here leaps into the river over a terrace of basalt perhaps 30 feet high, forming a very pretty fall, which has given the local name to the stream. A short distance below, we forded with difficulty, the water coming over our saddles. From this point the basalt lines both sides of the river, with very slight exceptions, to the Great Snake River Basin, and, according to report, to the Columbia. About four miles below Fall River, these basalt-walls close in the river's edge and form the lower cañon. At this point, two distinct beds of basalt appear, separated and underlaid by beds of river-sand, partly loose and nearly white, partly dark greenish and rusty brown, and considerably cemented with iron. These sands include great numbers of pebbles of basalt partly rounded. At one point, the lower bed of basalt slopes eastward at an angle of about 15°, indicating a probable source of flow situated in the mountains to the southwestward, though possibly due rather to upheaval. At another point, the basalt is curved above beds of sand and gravel having a curved surface, which plainly formed a bar in the old river-bed. These deposits spread up against the edges of limestones and sandstones of the mountains on either side.

At the base of the mountain on the southwest side of the valley, just above the head of this lower cañon, calcareous deposits, from now extinct springs, form a heavy mass, reaching about 100 feet up the mountain side. A small butte, nearly separated from the mountain behind, divides from the main valley the basin of a small stream which goes by the name of Swan Valley. The base of these western mountains is composed of gray quartzites, followed by coarse and fine white sandstones, and a very fine-grained white dolomitic limestone, all of uncertain age, though older than the overlying limestones, which contain a few Carboniferous fossils. The dips are sharp to the southwest, and the wash of the stream brings down fragments of red sandstone, which indicate that the higher beds here occupy their regular position.

The lower cañon is walled with basalt for from 200 to 400 feet, in many places perpendicularly, though elsewhere the slopes are more mod-

erate. On the upper slopes, west of the broad plain which borders the top of these cliffs, there are two other beds of basalt and one of porphyritic trachyte, separated by only thin beds of sand and gravel, which reach to the top of the southern hills, about 6,700 feet above the sea. The cañon bends northward to the base of the northern mountains, and there winds for some fifteen or twenty miles before opening gradually to the broad plain of the Great Basin of the Snake River.

As we had descended from the mouth of Salt River, the timber had gradually disappeared from the hills, until we now found only the scattered groves of small cottonwoods which mark the hollows where the snow lies late, or mingle with the willows along the banks of the few small streams which escape from the hills into the sage-covered plain. From near the mouth of the cañon, a belt of cedars runs along the course of a high-water bayou on the south side of the river and forms a conspicuous feature of the otherwise featureless plain for many miles.

Some three or four miles below the mouth of this last cañon, a small hot spring, 4 or 5 feet across, stands on the north bank of the river, about 20 feet above the bottom. This was not visited by any of our party, but was reported by our guide to be too hot for one to hold his hand in it for more than a half minute. White spring-deposits were seen, from a distance, at several points on the north bank, but there is believed to be no flow at these points at the present time.

Joining the main party here on the evening of October 8, we passed over the sage-plain described in the record of our outward trip, crossed Willow, Sand, and Blackfoot Creeks, and reached Fort Hall on the 11th. The facts observed during that time, and during the following twelve days, while we awaited Dr. Hayden's arrival to pay off and discharge the party, have been incorporated in the earlier part of this report.