43D CONGRESS, 1st Session. } HOUSE OF REPRESENTATIVES. { MIS. DOC. No. 265.

PROFESSOR POWELL'S REPORT ON THE SURVEY OF THE COLORADO OF THE WEST.

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

TRANSMITTING

A report of Professor Powell on the survey of the Colorado River of the West and its tributaries, &c., &c.

MAY 2, 1874.—Referred to the Committee on Appropriations and ordered to be printed.

SMITHSONIAN INSTITUTION,
Washington, D. C., May 1, 1874.

SIR: I have the honor to present a third preliminary report, made in accordance with the acts of Congress, approved March 31, 1871, June 10, 1872, and March 3, 1873, "appropriations for sundry civil expenses of the Government," &c., for the survey of the Colorado River of the West, and its tributaries, by Prof. J. W. Powell.

This survey was placed under the direction of the Smithsonian Institution by Congress, without solicitation on the part of the Institution. It has, however, endeavored faithfully to discharge the duty imposed upon it; has given due attention to the plans and execution of the work intrusted to it, and has received and prepared for exhibition in the National Museum the valuable collections in ethnology and natural history which have been obtained by Professor Powell.

The region embraced in this survey, as I have stated in a previous report, is one of the most interesting, in a geological point of view, in this or in any other country. The Colorado of the West and its tributaries traverse a series of remarkable chasms, in some instances of more than a mile in depth below the general surface of the region, presenting in several places, at one view, sections of the greater number of the known geological formations of America.

In the report herewith submitted, a general summary is given of the entire work. It exhibits a great amount of labor, and a series of results, not only of importance to science, but also to a knowledge of the country in its relations to agriculture and mineralogy. The report embraces a statement of what has been accomplished in the way of, first, *Topography*, as based on triangulation, including a description of the arable valleys, the supply of water, the extent of timber and of pasture-land;

second, *Geology*, including economic mineralogical products, such as coal, salt, and other minerals; third, *Ethnology*, comprising tribes, political organization, languages, manners, customs, mythology, poetry, arts, &c.; fourth, *Natural History*, including mammals, birds, reptiles, insects, and plants.

Professor Powell in his last year's survey completed the work for which the appropriations by Congress have been made. He now suggests the propriety of a further appropriation for one year, to enable him to connect his surveys with those of Clarence King on the north, and those of Dr. Hayden on the east. I have no hesitation in saying that this additional work is of importance, and that an appropriation for the purpose would be well applied.

But whatever may be the determination of Congress on this point, in view of the valuable results already obtained at a comparatively small expense, I would respectfully and earnestly recommend that a sufficient appropriation be made to prepare a detailed report of the whole work. Unless this be done, the labor and money already expended will be of little or no avail to the Government or the public generally.

I have the honor to be, very respectfully, your obedient servant,

JOSEPH HENRY,
Secretary Smithsonian Institution.

Hon. J. G. BLAINE,
Speaker of the House of Representatives.

WASHINGTON, D. C., *April* 30, 1874.

SIR: I have the honor to submit the following statement of the progress made in the survey of the Colorado River of the West and its tributaries. It is a summary of all the work which has been performed from the date of beginning to the present time.

TOPOGRAPHY.

The Colorado River is formed by the junction of the Grand and Green. These streams unite in latitude 38° 11′ 21″ and longitude 110° 7′ 48″, approximately.

The mouth of the Colorado River, as determined by Lieutenant Ives, is in latitude 31° 53′ and longitude 115°. The course of the river from its head, the junction of the above-mentioned streams, to the mouth of the Colorado Chiquito, is south 40° west.

From the mouth of the Little Colorado to the junction of the Rio Virgen with the main stream, the general course of the river is to the west. From this point its course is to the south, until it empties into the Gulf of California. This lower part of the river was explored by Lieutenant Ives in the winter of 1857–'58; and the district of country to the east between the river and the Rio Grande del Norte, and to the west between the Colorado and the Pacific, has been crossed by various exploring parties and military expeditions.

The maps made by these several parties, when compiled, give a general map of the country of great value in determining many of the important features, but unreliable in details, contradictory, and confusing.

That portion of the Colorado between the mouth of the Rio Virgen and the junction of the Grand and Green had never been mapped until the one made by the parties under my charge was constructed. The

river had been seen at two points by Lieutenant Ives, and at another by Father Escalante, and such points approximately determined. Nor had that portion of the Green between its junction with the Grand and the crossing of the Union Pacific Railroad ever been mapped; but its position at three different points had been determined by Government explorers, viz, at the mouth of Henry's Fork, at the mouth of the Uintah, and at Gunnison's Crossing, on the old Spanish trail.

During the years 1867, 1868, and the first part of 1869, I was engaged with a small party of naturalists, volunteers like myself, in the exploration of the mountains of central and western Colorado about the sources of the Grand, White, and Yampa Rivers. After exploring a number of cañons through which these streams run, I determined to attempt the exploration of the great cañons of the Colorado. Boats were built in Chicago and shipped by the Union Pacific Railroad, which was then running construction-trains, to the point where that road crosses Green River, and from thence in our boats we descended Green River to the Colorado, and the Colorado through the series of great cañons to the mouth of the Rio Virgen.

On starting we expected to devote ten months to the work; but meeting with some disasters, by which our store of rations was greatly reduced, we were compelled to hasten the work, so that but three months were given to it.

On this trip astronomic stations about fifty miles apart were made, and observations taken for latitude with the sextant, and also for longitude by the method of lunar distances. The meandering course of the river was determined by compass-observations from point to point, with the intervening distances estimated, thus connecting the astronomic stations. For hypsometric data a series of tri-daily barometric observations were recorded taken at the water's edge, and using this as an ever-falling base-line, altitudes on the walls and such adjacent mountain-peaks as were visited were determined by synchronous observations. The results of this hypsometry were used in the construction of the geological sections made along the course of the river. The course of the river and the topographic features of the cañons only were mapped. It should be remarked here that a portion of the records of this trip were lost at a time when three men, who had them in charge, were killed by Indians.

Having demonstrated the practicability of descending the river in boats, it was determined to make a more thorough survey of the series of cañons along the Green and Colorado Rivers, and of the more important side cañons, and also to include as broad a belt of country as it was possible from the river, and application was made to Congress for the necessary funds to carry on the work. The assistance asked was granted, and the work has been in continuous progress from July, 1870, until the present time.

It had been determined that it would not be practicable to perform the elaborate work projected, depending on such supplies as it was possible to take with us on the boats from Green River Station, but that it would be necessary to establish depots for supplies at a number of points along the course.

Between Gunnison's Crossing, on Green River, and the foot of the Grand Cañon of the Colorado, a distance of five hundred and eighty-seven and one-half miles, it was not known that the river could be reached at more than two points. One of these, at the crossing known as El Vado de los Padres, where Father Escalante had crossed the river in 1776, by following an old Indian trail; the other but a short distance

below, at the mouth of the Paria River. This route had been discovered by Jacob Hamlin, a Mormon missionary. These were so near together that only one of them could be used as a depot for supplies.

The last part of the year 1870 was given to the exploration of routes from the settlements in Utah to the Green and Colorado on the east and Colorado on the south. These lines of travel were mapped by fixing astronomic stations with the sextant and connecting them by the methods usually adopted in a meandering reconnaissance.

Early in the spring of 1871 boats were provided at Green River Station. The latitude of this point was determined by observations with the zenith telescope, and the longitude by telegraphic signals, with an astronomic station at Salt Lake City, previously established by officers of the United States Coast Survey. The altitude of this point above the sea had also been determined by the railroad surveys, so that the altitude, latitude, and longitude of the initial point of the survey were fixed with a good degree of approximation.

In descending Green River, astronomic stations were established at distances averaging forty-five miles by river, or about twenty-five miles by direct lines, the instrument used being the sextant. At each of these stations the variation of the needle was determined. The river was again meandered by two observers, working independently, and their work compared.

The lines between stations on the river were used as a series of base-lines, the lengths, of course, only approximately determined, and an intricate net-work of triangles was projected to salient points on either side of the river. From a vast number of points thus fixed the surface contour of the country was sketched so as to include a belt from twenty to fifty miles wide, the parties making frequent trips from the river into the interior of the country. At each of these astronomic stations barometric readings were recorded in hourly series, and as we proceeded down the river tri-daily barometric readings were made, all referred to the water's edge. With the river as a base-line for hypsometric work, altitudes were determined by triangulation and by barometric methods, using both mercurial and aneroid instruments. Thus all of our altitudes in this region are related to the river.

Our time during the spring, summer, and fall of 1871 was thus occupied until we arrived at the mouth of the Paria, a stream entering the Colorado from the northwest, a little below the Arizona line.

Such was the character of the astronomic, topographic, and hypsometric work done up to this time, methods not absolutely correct, but giving valuable approximate results.

But the wonderful features of the Grand Cañon district had yet to be mapped, and it was determined to do the work in this region by more thorough methods. A general reconnaissance was made for the purpose of selecting a site for a base-line, and the valley of the Kanab was chosen. Then a point midway between the extremities of the proposed line was selected, and an astronomic transit mounted for the purpose of determining the meridian direction and fixing the extremities of the line. This accomplished, the alignments were made with a theodolite. The latitude of the northern extremity of the line was determined by an extended series of observations with the zenith telescope, and the longitude by telegraphic signals with the previously-mentioned astronomic station at Salt Lake City. The base-line was measured with wooden rods, leveled on trestles, and aligned by sighting on small steel pins in either extremity. The rods were trussed to prevent sagging and warping, thoroughly seasoned, oiled, and varnished, and the extremities were shod

with small metallic cones, for the purpose of securing accurate contact. The rods were measured with a standard steel tape, at a temperature of 52°. Three rods were used, two always remaining in position as a protection against accidental movement. The leveling instrument was a plummet, or an inverted T, the base of which was the same length as the rods. Every hundred feet of distance was marked off by a stake, in the top of which was inserted an iron wire sharpened to a point, and this point connected with the point at the end of the rod by a plummet, and each hundred feet of the distance was re-measured with the steel tape.

The ground selected for the site of the base-line was very good, being nearly level and quite smooth, and we found that the work could be done more rapidly than had been anticipated, the only delay being due to windy weather. When the wind was blowing briskly it gave a trembling motion to the rods, which rendered it impossible to make that correct alignment and accurate contact between the points which was desirable, and for that reason the work was carried on only during still weather. The line was found to be $48{,}099\frac{4}{10}$ feet in length. Then a system of triangles was expanded from the extremities of this line, so as to embrace all of the country from the Mar-ká-gunt and Pauns-á-gunt Plateaus on the north to salient points a few miles south of the Grand Cañon, and from the Beaver Dam and Pine Valley Mountains on the west to the Navajo Mountain beyond the Colorado on the east, and still farther to the northeast, so as to embrace the country from the Sevier River on the west to salient points immediately beyond the Colorado on the east, and as far north as the southern tributaries of the Dirty Devil River. The angles of these triangles were measured with a seven-inch theodolite. At the geodetic points mounds were built and flag-staffs erected, and in that clear atmosphere it was found that it was practicable to make the sides of the triangles from twenty-five to thirty miles long, and occasionally, when the artificial points were on very salient natural points, the sides of the triangle could be made much longer.

Six of the more distant and important geodetic points were used as astronomic stations, where observations were made with the zenith telescope for latitude, for the purpose of checking any serious error that might occur in the triangulation.

From the points thus established a number of observations made were with the theodolite or gradientor, and from these observations a vast net-work of secondary triangles was constructed. Thus the position of all the salient topographic features were determined, courses of streams and lines of cliffs were meandered, and the position of the observer constantly checked on the determined points, and *pari passu* with this the topographical features were sketched. The great features were Marble Cañon and the Grand Cañon of the Colorado, and many salient points on either side of the great chasm were fixed by triangulation.

The following summer we descended through these cañons in boats, and fixed the course of the river and the topographic features of the cañon wall by compass and gradientor observations on the points thus previously determined. The same system of barometric observations carried on in the cañons above was continued through these cañons, and occasionally hourly observations of eight-day series were made.

The parties engaged in geodetic and topographic work carried with them barometers, and made a vast number of observations over the country traversed. All of these and all of those in the cañons were synchronous, with a continnous series made at the northern extremity of the base-line in the valley of the Kanab, so that the altitudes along the river and on the walls of the cañons, and over all the country embraced in the triangulation, are referable to this hypsometric base. We

have compared this base of altitude with other points whose altitudes have been approximately determined by other observers, as at the mouth of the Rio Virgen, Saint George, Beaver, Salt Lake City, &c.; but it is hoped that before this work goes on permanent record the altitude of Kanab above the level of the sea will also be determined by the levels of the railroad survey, which is now in progress.

We have one unbroken series of observations at this point (Kanab) of three months' continuance, and another of ten months, and several shorter series. These were tri-daily, except that occasionally they were expanded into hourly series.

By the methods last described, an area of country has been surveyed embracing twenty-five thousand square miles, and by the less accurate methods first given, an area of country embracing twenty thousand square miles, making in all forty-five thousand square miles.

Preliminary maps have been constructed on a scale of two miles to the inch, but the final result of all this work will be shown in a series of maps on a scale of four miles to the inch, giving the topographic and geological features of the region surveyed.

RIVERS.

As before stated, the greater part of the country embraced in this survey was an unknown region in geographic science. An examination of the map prepared by the War Department from data collected up to 1868, being a compilation of all knowledge of this class concerning the territory of the United States west of the Mississippi River accessible to geographers, will show that this region is left an entire blank. We have filled this blank and completed the survey of the last unexplored region, mapping minutely the unknown portions of the Green and Colorado Rivers.

The junction of the Green and Yampa Rivers has been fixed, and the lower course of this latter stream, which was unknown, has been mapped. The junction of the San Rafael with the Green has also been fixed, and the lower course of this river mapped. It was also unknown. The junction of the Grand and Green has also been determined, and the lower course of the Grand mapped.

The Dirty Devil River, more than two hundred miles in length, was discovered and mapped. The Escalante, a river more than one hundred and fifty miles in length, was discovered and mapped. The junction of the San Juan with the Colorado has been determined, and the lower course of that stream, which was unknown, has been mapped. The Paria, a stream one hundred and twenty-five miles in length, which had been seen only at one point near its mouth, has been traced for its entire course. The junction of the Chiquito, or Little Colorado, with the Rio Colorado, or Colorado Grande, has been fixed, and the lower and previously unknown course of that stream has also been traced.

The lower part of the Kanab was seen by Lieutenant Ives, but was mistaken for the Colorado itself, and on his map the Colorado was turned to the northeast, conforming to the course of the Kanab. This stream is more than a hundred miles long. Its whole course has been traced. In some places it does not carry a great volume of water, and about midway of its length it is often lost in the sands, but through the greater part of its course it runs through a deep gorge, which makes a very important feature in the topography of the country. The Rio Virgen had been seen at points, but we have traced its entire course and that of all its tributaries. A great number of smaller streams have also been discovered and mapped.

CAÑONS.

The whole region embraced in the survey is a cañon country. At the very beginning we have a series through the Uintah Mountains, as the channel of Green River: Flaming Gorge, King-fisher Cañon, Red Cañon, the Cañon of Lodore, Whirlpool Cañon, and Split Mountain Cañon; then Yampa Cañon, the cañon along the lower course of the river of the same name, and many other tributary cañons; then below, still descending Green River, the Cañon of Desolation, Gray Cañon, Labyrinth Cañon, and Stillwater Cañon, with many lateral cañons; then Cataract Cañon, a profound chasm below the junction of the Grand and Green; then Narrow Cañon, which terminates at the mouth of the Dirty Devil River; then Glen Cañon, extending from the mouth of the Dirty Devil River to the mouth of the Paria, and Marble Cañon from the mouth of the Paria to the mouth of the Colorado Chiquito. Then we have the Grand Cañon, the most profound chasm known on the globe. Were a hundred mountains, each as large as Mount Washington, plucked up by the roots to the level of the sea and tumbled into the gorge, they would not fill it.

Along all of the streams mentioned we have series of cañons, and yet all of these represent but a part of the cañons explored and mapped, for there are many profound chasms, the channels of intermittent streams, dry during the greater portion of the season, that are hundreds of feet deep, and that never have a continuous stream for their entire length.

PLATEAUS.

To the knowledge of the geography of this country we have added a great number of plateaus. The streams cut through plateaus rather than through mountain-ranges.

Immediately south of the Uintah and White River Valleys, streams which unite with the Green at points almost opposite each other, the last-mentioned river enters a great table-land, and cuts through it by the deep gorge known as the Cañon of Desolation. We have called this Ta-va'-puts Plateau. The southern boundary of this plateau is an abrupt wall, and it slopes gently to the north until it is lost in the valleys of the White and Uintah Rivers; on the west it is lost in the Wasatch Mountains; its extension to the east is yet unknown. Still continuing to the south, Green River cuts through another plateau, which we have named, in honor of Captain Gunnison, Gunnison Plateau. The southeren boundary of this is a line of cliffs mapped by Captain Gunnison, and called by him Roan, or Book Mountains, east of Green River and Little Mountains on the west.

Between Sanpete Valley and the headwaters of Price and San Rafael Rivers there is an elevated district of country which has heretofore been mistaken as the extension of the Wasatch Mountains to the south; it is in fact a plateau. We propose to call this Wasatch Plateau.

Geographers and geologists have heretofore spoken of a great Colorado Plateau, referring to the district of country through which Marble and Grand Cañons are cut, for so it appeared to the observer standing on the southwest margin of this great district; but it has proved, in fact, to be a complex system of plateaus, bounded by walls of faults, escarpments, or cliffs of erosion, and cañon gorges.

The Mar-ka'-gunt Plateau is an extensive table-land, bounded by a line of precipitous cliffs on the south, and by cliffs or abrupt slopes, which have heretofore been mapped as mountains, on the west; to the north it

is lost in the Tu-shar Mountains; on the east it is bounded by the upper valley of the Sevier. Many of the western tributaries of this stream have their sources in this plateau; it is also the source of the Rio Virgen.

The Pauns-a′-gunt Plateau is on the eastern side of the upper course of the Sevier, and is bounded on the east, south, and west by lines of cliffs, and on the north by the cañon of the East Fork of the Sevier, and is the source of one of the upper branches of this stream; it is also the source of the Kanab and Paria.

The Aquarius Plateau lies still farther to the northeast; it is bounded on the south, east, and west by lines of cliffs and abrupt slopes, and on the north it is separated from the Wasatch Plateau by the cañon of Salina Creek. Thousands of little lakes are scattered over its surface. These are the sources of the Escalante and Dirty Devil Rivers and the southern tributaries of the San Rafael. On its western margin many little streams head that are tributaries to the Sevier. All three of the last-mentioned plateaus carry on their backs extensive beds of lava and volcanic cones developed to such an extent as to produce groups of mountains.

The Kai-par-o-wits Plateau is a table land extending from the southeast corner of the Aquarius Plateau nearly to the Colorado River opposite the mouth of the San Juan, and is bounded on all sides by lines of cliffs.

The Colob Plateau lies to the southwest of the Mar-ka′-gunt. It is an extensive table-land traversed by deep, narrow cañons through which the headwaters of the Rio Virgen find their way to a dosolate valley below.

South of the Pauns-a′-gunt, Aquarius, and Kai-par-o-wits Plateaus and east of the Colob, there are a great number of smaller plateaus of which I will make no farther mention, but their positions have been well fixed and will be represented on the map.

South of the Paria, and west of Marble Cañon, is the Paria Plateau bounded by lines of cliffs on the south, east, and west, but on the north by the cañon of the Paria River.

The Kai-bab Plateau lies west of the Paria Plateau and the lower end of Marble Cañon, and north of the Grand Cañon. It is about seventy miles in length, and varies from five to thirty in breadth, and is bounded on all sides by steep slopes or bold escarpments.

The Kanab Plateau is bounded on the east by the lower cañon of the Kanab, on the south by the Grand Cañon, on the west by the To-ro′-wîp cliffs, and on the north by a low escarpment of basalt. The U-in-kar-et Plateau lies to the west of this, and is bounded on the east by the To-ro′-wîp Valley and a basaltic escarpment, on the south by the Grand Cañon, and on the west by the Hurricane Ledge; it runs to a point on the north.

The Shi′-vwits Plateau is a terraced table-land; its southern extremity extends far into an angle of the Grand Cañon; on the west it is bounded by a line of cliffs, on the north it descends by abrupt slopes into the valley of the Virgen, and on the northeast by a gentle slope into the valley at the foot of Hurricane Ledge.

The Colorado Plateau lies to the south of the Grand Cañon; it is bounded on the north by this great gorge, on the east by an escarpment which faces the Little Colorado, and on the west and southwest by an escarpment which has received the name of Aubrey Cliffs; the southeastern extension is to me unknown. We confine this name to this single plateau, rather than to the more extended but undefined country to which it had been previously assigned. The outlines and altitudes of these plateaus have all been traced and mapped.

LINES OF CLIFFS.

Perhaps the most wonderful of the topographic features of this country are the lines of cliffs, escarpments of rock, separating upper from lower regions by bold, often vertical and impassable barriers, hundreds or thousands of feet high, and scores or hundreds of miles in length. These are of two classes, escarpments of erosion, presenting lines of cliffs, usually having an easterly and westerly trend, and walls standing along the lines of faults, having a northerly and southerly direction. Of the first class I will enumerate the following:

The Brown Cliffs, the southern escarpments of the Ta-va'-puts Plateau; the Book Cliffs bounding Gunnison Plateau on the south; the latter is a great escarpment of blue shales capped with gray and buff sandstones and limestones. Standing below, an extensive storm-carved façade is presented, with giant forms of rocks, elaborately sculptured by the rain, and colored in beautiful and delicate tints.

The Orange Cliffs are a broken escarpment which commences at the foot of the Sierra La Sal on the eastern side of Grand River, passes the Grand, then crosses Green River, and then turns to a southwesterly direction, and runs parallel to the Colorado River for fifty miles, and then turns again to the southeast and crosses the Colorado, terminating in the slope of the Sierra La Sal, scores of miles south of the initial point. Thus the head of the Colorado, the junction of the Grand and Green, is encompassed by a towering wall—the Sierra La Sal on the east, on the north, west, and south the Orange Cliffs. The Indian name for this basin is Tum'-pin-wu-neir'-tu-wîp, the Land of Standing Rocks.

Buttes, towers, pinnacles, thousands and tens of thousands strange forms of rocks, naked rock of many different colors, are here seen; so that before we had learned the Indian name, we thought of calling it the Stone Forest, or Painted Stone Forest; and these rocks are not fragments or piles or irregular masses, but standing forms, carved by the rain-drops from the solid, massive beds. Weird, strange, and grand is the Tum'-pin-wu-nier'-tu-wîp.

The Wasatch Cliffs form the eastern boundary of the Wasatch Plateau and separate it from the district of country about the headwaters of Price River and the San Rafael. This district is covered with buttes and many strangely carved rocks, and is known as Castle Valley.

Descending the river through Glen Cañon several great lines of cliffs are seen, which have not yet received names, as they have not yet been fully traced, nor their geological relations fully studied.

To the north of the Grand Cañon and facing it we see first a low line of irregular, broken cliffs, everywhere capped by a conglomerate which is covered with trunks and fragments of silicified wood, known to the Indians as Shin-ar'-ump, and we call these Shin-ar'-ump Cliffs. Still to the north and approximately parallel with this line, but sometimes coalescing with it, are the Vermillion Cliffs. These can be traced from the west side of Rio Virgen across the Kanab and around the northern extremity of the Kaibab Plateau, and across the Colorado, where they turn to the south and form the eastern wall of the valley of the Little Colorado for many miles. Above, and approximately parallel with these, we have the White Cliffs and many minor lines of cliffs due to erosion. The second class of cliffs are due to the displacement of the beds along the lines of faults; these have a northerly and southerly direction at right angles to the three great lines of cliffs last mentioned. We have the cliffs of the eastern Kaibab faults and the cliffs of the western Kaibab

faults; then the To-ro'-wîp Cliffs on the west side of the Kanab Plateau. There is a long line of cliffs known as the Hurricane Ledge forming the western escarpment of the U-in-kar'-et Plateau and extending far north across the Rio Virgen.

The Sevier Cliffs constitute the boundary of the Pauns-a-gunt Plateau, and are approximately parallel to the upper course of the Sevier River; these and many other subordinate lines of cliffs have been traced and mapped.

MOUNTAINS.

Many new mountains have been added to our geographic knowledge. To the north of the Escalante River there is a group of eruptive mountains, the three highest peaks of which attain an altitude of about 12,000 feet above the level of the sea. We have called these Henry Mountains, in honor of the secretary of the Smithsonian Institution. Then we have the Navajo Mountain a little to the south of the mouth of the San Juan River, the greatest single mountain mass known to me within all the territory of the United States; it is nearly 12,000 feet high. On the U-in-kar'-et Plateau there is a group of eruptive mountains which we have called U-in-kar'-et Mountains.

On New Year's day, 1854, Lieutenant Whipple, from an eminence on the western flank of San Francisco Mountain, descried the summit of a peak away to the north, and on the maps of the route of the expedition he indicated the position of the mountain and called it High Mountain.

In the year 1858, Lieutenant Ives, from a position farther west, saw what he calls a short range, and on his map indicates the supposed position of the mountains and calls them North-Side Mountains. This group of mountains we have found to be composed of three great mountain masses along which and standing about for a score of miles in every direction are volcanic cones, 118 in number. The position of every cone in the group has been determined in the secondary triangulation, and the data collected to make an elaborate map of this region on a scale of two inches to the mile. The Indian name for this group is U-in-kar'-ets, (the Mountains where the Pines stay) and this (U-in-kar'-ets) is the name by which they are known to the people of Southern Utah and Northern Arizona who live in sight of the mountains and who have daily use for some name. As the names given by Whipple and Ives were doubtless intended only as provisional, this Indian name has been adopted. Other mountains have been added to the general stock of geographic knowledge, and many which have been seen by other travelers have been located and their outlines defined on the maps.

VALLEYS.

One-third of the entire area of the United States is so arid that agriculture is dependent on irrigation, and within that same area it is not possible to redeem for agricultural purposes more than three per cent. of all this territory, probably much less. The deposits of precious metals, ores, and other minerals are the chief incentives to the settlement of this country. With a proportion of area fit for agricultural purposes so small that the probable demand for the products of the soil by those who follow other pursuits will be greater than can be supplied by the agriculturists, it is a matter of primary importance to determine the amount of water which can be used for irrigation, and the extent of the several districts to which these waters can be applied. Impressed

with the importance of this, we have carefully examined the facts to determine the several districts of country which can be used for agricultural purposes within the territory embraced in the survey. In the mountainous regions where is found the maximum precipitation of moisture in this country, there are small elevated valleys, but they are too cold for successful cultivation, and are only valuable for summer pasturage and hay-fields. On the more elevated plateaus we find extensive grass-lands; they are also too cold for general agricultural purposes. On the lower plateaus and hilly countries the lands are desert wastes, often covered with drifting sands or surfaces of naked rock. A few valleys nestling along the rivers can be made available to the farmer. Chief among these are the following:

Henry's Fork runs along the northern slope of the Uintah Mountains, and empties into Green River before the last-mentioned stream enters the range. There is a narrow alluvial valley along its course for nearly fifty miles, in a few places two or three miles in width, and covered here and there with a growth of cotton-wood trees, but, being more than 6,000 feet above the level of the sea, it is rather cold; but the pasture-lands and grass-lands to the south, on the slopes of the Uintah Mountains, would be of great value to settlers.

Brown's Park is a valley twenty miles long and from six to ten miles wide; it is an expansion or widening of the cañon of the Green where it has a westerly course. Eight or ten small but beautiful streams come down from the mountains on either side, and can be easily controlled and used for purposes of irrigation.

Forests of cotton-wood are found along the flood-plain of the river; the hills further back are covered with cedars, and the mountains on either side carry great forests, and a few miles to the north are extensive coal deposits. This valley is a few hundred feet lower than the last mentioned, and hence much warmer.

On the south side of the Uintah Mountains we find a broad, rich valley. A large body of land can be cultivated here by the use of the waters of the Green, but will require a large outlay of capital. It has many natural meadows, and a warmer climate than either of the last-mentioned valleys, being but little more than 5,000 feet above the level of the sea.

The valley of the Uintah and its branches is one of the finest known to me in all the southwestern portion of the United States. The Uintah has more than a score of important tributaries, all running near the surface, easily controlled, and capable of furnishing sufficient water to irrigate more than 150,000 acres of the adjacent lands, which are well situated for that purpose. On either side there are grass-lands of value, and in the mountains to the northwest, and the Ta-vá-puts plateau to the south, there are pine-forests practically inexhaustible. Along the lower valley of White River there are extensive bodies of lands which can be redeemed by taking out the waters of that river, but it will be attended with much expense.

South of Gunnison Plateau, along Green River, is Gunnison Valley; here a narrow belt of land can be cultivated by taking out the waters of Green River, but this can only be done by the expenditure of large capital. Below this point all of the tributaries of the Colorado River within the country under consideration, run in their lower courses through cañons affording practically no area for cultivation, but along the middle courses of these streams there are many valleys and parks of limited area which will eventually be settled. Already pioneers have penetrated into some of them, as the Rio Virgen, Kanab, Paria, and Escalante.

HYDROGRAPHY.

The hydrography of the country is intimately associated with the study of the valleys, for under favorable hydrographic conditions only can they be cultivated. The amount of water carried by the Colorado and its tributaries has been carefully estimated. The springs also have been located, and mention will hereafter be made of them in the geological section of this report.

FORESTS.

The extent of the forests in the region of country embraced in the survey has been carefully noted, in order that they may be represented on the maps; they are of pine, fir, and other coniferous trees. The forests on the Uintah Mountains are of great value, and extend to the west beyond the limits of our survey. The Ta-vá-puts Plateau is covered with a pine forest interspersed with meadows and pasture-lands. Gunnison Plateau is covered with a scant growth of dwarf-cedars. The Wasatch Plateau is only partially forest-clad. Extensive and valuable forests are found on the Aquarius, Pauns-a-gunt, and Mar-ká-gunt plateaus. Kai-par-o-wits, Colob and Paria plateaus are covered with a scant growth of dwarf-cedars and piñon pines. The Kiabab Plateau is a forest of giant pines and firs.

There are forests on the three great mountain masses of the U-in-kar-et Plateau. Scattered pines and cedars are found on the Shí-vwits Plateau. The great Colorado Plateau is covered with one of the most extensive forests of the Southwest. In a few places the low mesas and valleys are scantily clothed with piñon pines and low cedars, but the greater part of all the lower region is naked. I have thus briefly indicated the operations in geodesy, hypsometry, and topography, and the general observations made for the purpose of properly representing the character and extent of the work which has been performed.

GEOLOGY.

SECTIONS.

We turn now to the geological work. A running section has been made from a point twelve miles above Green River Station, following Green River and the Colorado to the mouth of the Rio Virgen, a distance of more than a thousand miles. This section is unbroken for the entire distance; the rocks are exposed in escarpments varying from one hundred to more than six thousand feet in altitude. Perhaps no other section has ever been made, the elements of which are of such magnitude. In this region of country, as fast as atmospheric agencies disintegrate the rocks, the loose sands are washed away so that the escarpments are clear of soil and vegetation, and under these circumstances it was found possible to collect a great amount of details.

Again, the geological structure of the country is very complex. Great and minor folds, great and minor faults, and great and minor non-conformities are found, so that the sections are also exceedingly complex and elaborate.

The Uintah Mountains having an easterly and westerly directions, stand across the course of Green River. Here we have a great fold, the anticlinal axis of which has an easterly and westerly direction, and a total displacement of about 27,000 feet, so that in going down the

river from Green River City to the heart of this range, we find a succession of beds 27,000 feet in thickness including rocks from the Miocene Tertiary to the Silurian. On the north flank of the range we have an extensive development of crystalline schists. I considered them to belong to the same horizon as the non-conformable beds immediately below the carboniferous rocks elsewhere exposed in the cañons, and further that I could trace the metamorphism laterally into these rocks through a series somewhat like this—gneiss, plicated schists with veins of quartz, quartzites, and regularly bedded sandstones. In that portion of the cañon where no metamorphism is seen, I obtained 11,000 feet of these beds. In this district our work overlaps that done by parties directed by Clarence King.

The grand fold of the Uintah Mountains is greatly complicated by a series of transverse and oblique minor folds, some of which are anticlinal, others monoclinal. Our general section on the river, with a number of minor sections in various directions, together with the colored geological maps of the mountains, will explain this complex system of corrugations; and, what I have considered of equal importance, the progress and extent of erosion which is here exhibited on a vast scale since the region was left by the retiring sea.

Going on south we pass a synclinal trough marked, topographically, by the valley of the Uintah River, coming down from the Wasatch Mountains on the west, and by the valley of White River, coming down from the Rocky Mountains on the east.

Still continuing to the south, we find rocks dipping to the north, and in our progress down the river we pass a succession of underlying beds until we find about 8,000 feet of Tertiaries at the foot of the Cañon of Desolation, then, 2,500 feet of Cretaceous rocks at the foot of Gray Cañon, nearly 2,000 feet of Jurassic, and an equal amount of Triassic at the foot of Labyrinth Cañon, when we once more enter beds of Carboniferous age.

In descending through Still-Water Cañon, and the upper half of Cataract Cañon, we run into a great fold the axis of which is probably marked by the Sierra La Sal. Then we turn through the lower end of Cataract Cañon and Narrow Cañon until we pass out of the fold on the same flank by which we entered it, and once more find beds of Triassic age.

From this point to the southern extremity of the great system of southern plateaus, marked by a line of eruptive mountains, of which San Francisco Mountain is the culminating peak, the general dip of the formation is to the north, extending from a line some distance to the east of the Colorado, and westward to the foot of the Pine Valley Mountains; but this general slope is greatly modified by another, and doubtless later systems of displacements which have northerly and southerly axes. These displacements are either faults or monoclinal folds. I shall recur to them again.

Descending the Colorado through Glen Cañon, we find this chasm to be cut through rocks of Triassic age developed to a thickness of about 1,800 feet. On the way we cross an abrupt monoclinal fold, the drops of which is to the east, and the total displacement about 1,400 feet. At the foot of this cañon we cross another of these folds, the drop of which is to the east. Here we enter Marble Cañon, a chasm cut through rocks of Carboniferous age.

The course of the river is nearly south, and the dip as above stated, is to the north, so that at the foot we have passed through about 4,500 feet of carboniferous rocks. In passing through Grand Cañon we are going in the general direction of the strike of the beds, but there are great displacements due to faults, which, back from the river, are in many places monoclinal folds. The summit of the Grand Cañon is every-

where the summit of the carboniferous, which is from 4,000 to 4,500 feet in thickness; but the gorge is sometimes more than 6,000 feet deep, and at these points we obtain a succession of sections of non-conformable shales, sandstones, and limestones, the greatest of which gives us a little more than 10,000 feet of beds. These are traversed by dykes of trap, or green-stone, and irregular beds of the same eruptive material are found in places between these non-conformable rocks, and the overlying beds of Carboniferous age. Provisionally, I call these sedimentary rocks Devonian and Silurian.

Still underlying these we find an extensive series of metaphoric crystalline schists, in some places yet showing faint traces of the original stratification, but usually these are so degraded that the total thickness of the beds cannot be determined, or at least we were unable to do so. In places they constitute about a thousand feet of the altitude of the walls. These beds are traversed by dikes of granite, and beds of granite are found. I believe these beds to be intrusive, hence of igneous origin. In some places the evidence is complete. An extensive period of erosion separates these schists and granite from the overlaying Silurian and Devonian rocks.

In the Grand Cañon we also have the records of an extensive period of deposition in the schists, followed by plication, erosion, fissuring, and eruption. Again we have an invasion of the sea, which remains until 10,000 feet of shales, sandstones, and limestones are deposited; and this is followed by a dry-land period, marked in some places by at least 10,000 feet of erosion, and accompanied by plication, fissuring, and eruption.

Then follows another period, when the sea had dominion until the rocks of Carboniferous age and the Triass and Jura and the Cretaceous beds were deposited, and perhaps some Tertiaries; of this we cannot now be certain; but at least 10,000 feet of beds were formed. All this is succeeded by a long period of erosion, in some places stripping off the whole 10,000 feet of later beds, and in the gorges, where the streams have made greater progress than the rains, channels are cut through the underlying rocks of Devonian and Silurian age, and still deeper into the schists and granite.

Such are some of the facts brought to light in the great section made from Green River Station to the mouth of the Rio Virgen.

It has already been seen, in the account given of the geographic work, that a much greater length of time was expended in the studies made on land than in those made on the river.

A geological section has been made from the Grand Wash to the Vermillion Cliff, west of Marble Cañon, near the parallel of 36° 30′; another from the Colorado River west to the Pine Valley Mountains, near the parallel of 37° 30′; another from the Sevier River east across the Wasatch Plateau, and still on to Green River. One has been made along the course of the Paria from its source in the Pauns-á-gunt Plateau to its mouth, including rocks from the Tertiary age to the summit of the Carboniferous. Another has been made from the Pauns-á-gunt Plateau south along the course of the Kanab to its mouth, representing rocks of ages extending from the Tertiary to the base of the Carboniferous. Still another has been made from the summit of the Mar-ka-gunt Plateau, down the Rio Virgen to its mouth, embracing a series of rocks from the Tertiaries through the Carboniferous, Devonian, and Silurian, into the schists.

In addition to these general or running sections, numbers of vertical sections have been made for the purpose of giving the details of stratification.

PLAN OF SECTIONS.

The plan for these sections is as follows: The base-line at the bottom of the section represents the level of the sea; the line immediately above this, and parallel to it, represents the altitude above the sea of the lowest point observed in the section; the upper line represents the highest point. The meandering line between these points represents the line of lowest observation in the escarpments seen along the course of the chasms through which the sections are made, and a reference to the scale gives the altitude of any point along this line above the level of the sea.

Between this meandering line and the upper line the section is so constructed with colored bands as to represent the general facts of geological structure, *i. e.*, the succession of geological formations and many important facts of stratification, and the faults, folds, and nonconformities; and these colored bands are so arranged as to represent the magnitude of the escarpment which has been studied, and the altitude of the upper line of the section above the level of the sea, so that the highest as well as the lowest line above the sea can be determined by reference to the scale.

Thus the sections not only represent the structural geology, but also constitute a double profile; the lower profile or lower line of observation being the profile of the bottom of the cañon, the upper line the profile of the summit of the wall, and the two combined the proper longitudinal profile of the cañon itself.

FAULTS AND FOLDS.

An extensive system of faults of great magnitude has been discovered, usually having a northerly and southerly direction. In many places these faults change either abruptly or gradually into monoclinal folds, and these displacements are often scores or hundreds of miles in length, and the throw varies from two or three hundred feet to two or three thousand feet.

Some of the most wonderful and important topographic features of the country are due to these displacements. The materials have been collected for the preparation of a series of diagrams to represent the ever-changing throw of these faults and folds, to be accompanied by transverse sections exhibiting the varying characteristics which are revealed in tracing these long lines of displacements.

ERUPTIVE ROCKS.

After the sea had left this region the last time, and during the progress of folding, eruptive matter has been poured out, trachytes and rhyolites at first, then basalts. In some regions this eruptive matter constitutes an important part of the mass of the groups of mountains which stand on the plateaus; this is especially the case in the group of mountains standing on the Mar-ka-gunt and Aquarius Plateaus. The Henry Mountains are composed of beds of eruptive matter overlying sedimentary beds.

The U-in-kar-et group is composed of three principal mountain-masses, Mount Trumbull, Mount Logan, and Mount Emma, and 118 volcanic cones, which are distributed in part over the mountains themselves and scattered about the adjacent country for a distance of fifteen or twenty miles. The general surface of the U-in-kar-et Plateau, on which these

mountains and cones stand, is composed of the upper strata of the Carboniferous age, so that all the elevation above the general level of the plateau is due to the occurrence of other rocks. An examination of the three great mountains reveals the fact that the first floods of basalt were poured out here, before the beds of Triassic age had been swept away. These mountains are composed very largely of variegated shales and sandstones of Triassic age, and the summits are great sheets of basalt. Then we find a succession of lava-floods coming on with the progress of erosion, always breaking out at later times and at lower altitudes, so that the flanks of the mountains are covered with beds of basalt of later age.

It is thus seen that the eruptive matter has protected certain districts of sedimentary rocks from erosion, while the extension of these same beds over the adjacent country has been degraded by atmospheric causes, and these mountains remain as evidences of a wider geographic distribution of great formations that can now only be studied within limited areas. There would have been no mountains had there been no floods of lava; yet the mountains themselves are not principally composed of lava, so that they can be called eruptive mountains only in the sense that had there been no eruption there would have been no mountains, but the plateau would have been degraded to a comparatively uniform plain.

The general statement may be made that all the eruptive mountains in the region which we have surveyed exhibit like facts.

Besides the mountain-masses due to eruptive agencies, and composed in part of eruptive matter, there are many later floods of basalt found throughout the country, spread as great protecting sheets over sedimentary beds, or elsewhere refilling valleys or cañons; and, with few exceptions, all of the floods of basalt are crowned with cinder-cones. The faulting and folding, of which mention has heretofore been made, independently of the eruptive matter which is found so widely distributed, reveals the fact that the sedimentary beds of this country have been fractured on an extensive scale, and we are able to trace great lines of fracture in tracing the faults and folds. The relation of the eruptive beds and volcanic cones in geographic position to the great fractures that have been discovered in the faults has been a subject of much study, and interesting results have been obtained. The oldest beds of the series of eruptive rocks above mentioned overlie Eocene-Tertiary formations, and the succession of later beds, which have been poured out *pari passu* with degradation, are found to overlie sedimentary beds of earlier geological formation. So, in general terms, it may be stated that the later beds of igneous origin are associated with the earlier beds of aqueous origin. Thus, floods of basalt have run down into valleys deeply eroded in Carboniferous strata at a period so late that sufficient time has not elapsed since their cooling for atmospheric agencies to have any appreciable effect upon them. Nor are they even lichened. It is more than probable that some of these have been poured out within the last two or three centuries.

Besides this great period of eruption, thus briefly mentioned, there are two other eras of eruption revealed to the geologist in this region. It has already been stated that the Carboniferous beds are deposited unconformably upon the underlying Silurian and Devonian beds, and the period of erosion intervening between the disposition of these two unconformable series was also a period of eruption, for again we find faults, dikes, and beds of trap in the rocks of greater age, which do not penetrate the beds of Carboniferous age.

The metamorphic crystalline schists revealed in the section along the Grand Cañon are seen to underlie Devonian and Silurian rocks unconformably; and here again, between the junction of the two, we find another period of eruption, for the schists are traversed by dikes and beds of granite, but which do not penetrate the overlying Devonian and Silurian rocks.

In the sections along the Grand Cañon, we are able to study three great periods of oceanic sedimentation, three great periods of atmospheric erosion, and three great periods of eruptive activity.

LITHOLOGY.

The lithology of the country has also been studied, and collections have been made of hand-specimens of the metamorphic crystalline schists and of the intrusive granites. Others have been made of the traps found in the dikes and intrusive beds of Silurian and Devonian age.

Extensive suites of the eruptive rocks of later age, trachites, rhyolites, and basalts have been collected. The geological limits and relations of these beds have been studied carefully, and when the hand-specimens are carefully studied it is believed that important facts will be revealed from all the data that are collected.

EROSION.

Erosion has been a subject of much study. The region of country drained by the Colorado River and its tributaries is more than eight hundred miles in length, and from two hundred and fifty to five hundred miles in breadth. There are two distinct portions embraced in this great drainage basin. The lower third of the valley of the Colorado lies but little above the level of the sea, except that here and there ranges composed of older rocks and eruptive matter stand across the country, whose peaks reach an altitude of from three thousand to six thousand feet above the sea.

The upper two-thirds lies from 4,000 to 8,000 feet above the level of the sea. The line between these two regions is often well defined; sometimes it is a bold escarpment, in other places it is complicated by folds and groups of eruptive mountains. All of the region embraced in the survey is in this upper portion of the valley.

On the east, west, and north the rim of the basin is set with snow-clad mountains, reaching an altitude of from 10,000 to 14,000 feet above the level of the sea. The plains, benches, mesas, plateaus, and groups of low mountains within the basin receive but a scant supply of water from the annual discharge of the clouds, but all winter long snow falls on the mountain-crested rim, filling the gorges, half burying the forests, and covering the crags and peaks with a mantle of snow. When the summer sun comes this snow melts and tumbles down the mountain sides in innumerable cascades. Millions of these brooks, interrupted by cascades, unite to form thousands of creeks that run in torrents, and these unite to form a hundred rivers beset with cataracts, and these all unite to form the Colorado that rolls a mad stream into the Gulf of California.

Let us look at the action of one of these rivers, its source in the mountains, its way through the arid plateaus and plains. If at the river's flood storms were raging along its course the adjacent country would be washed down simultaneously with the deepening of the channel, but the conditions for the precipitation of moisture are such that the river cuts

its gorge much faster than the adjacent country is degraded; there is more through erosion than lateral wear, and the cañons mark the difference between the progress of the general erosion by rains, and the progress of the erosion by rivers. In this way the Colorado has cut along its course, for a thousand miles, a series of narrow, winding gorges. The Rio Virgen Kanab, Paria, San Rafael, and many others on the west, Diamond, Coanine, Flax River, San Juan, and many others on the south and east, have cut for themselves narrow, winding gorges in the solid rock.

Every creek entering a river runs in a cañon; every brook tributary to a creek has cut a cañon; every rill, born of a shower and born again of a shower, and living only during these showers, has cut a narrow, winding gorge through the solid rock, so that the whole of this region is traversed by a labyrinth of cañons.

While the amount of this river erosion is so great as to almost stagger belief, it represents but a small part of the total amount of erosion exhibited. There are places where by general atmospheric agencies not less than 27,000 feet of beds have been stripped from the country, and all this since the sea last retired. We cannot suppose that there is any part of the country where there has been no erosion, but there are districts where there has been 27,000 feet less than the maximum. Why more in some places and less in others? This has been a very interesting problem, and for its solution we have accumulated many facts.

A glance at the map reveals the fact that the contours of this region are angular; cañons whose walls are everywhere abrupt, long lines of cliffs, bold escarpments forming difficult, and in some places impassable barriers to travel, benches, mesas, and plateaus that terminate in escarpments. Rounded hills and gentle valleys are rarely seen. The conditions under which corrugation, erosion, and eruption have produced these wonderful and gigantic topographic features have been the subject of much study.

I cannot here give the results of these studies, although the theme is greatly attractive, but I will briefly state one conclusion at which we have arrived. The displacements marked by the folding and faulting, the erosion and the eruptions, were simultaneous; they began at about the same time, and have all continued until a very recent period, and probably are still in progress.

GEOGRAPHIC DISTRIBUTION.

In a region of country in many places of naked rock and everywhere exhibiting escarpments of great magnitude it is possible to trace with accuracy the geographic distribution of the beds, and this has been done with such care that we shall be able to indicate with minuteness the surface exposure of all the great formations extending throughout the country which has been surveyed. It is hoped that this can be done on a map, the topographic features of which are indicated by contour lines. The material for such a map has been prepared.

PALEONTOLOGY.

While much time has been devoted to the structural geology of the country, we have not neglected the paleontology, and we have had such success in collecting fossils as to be able to refer all these rocks to the grand groups which have been established on a paleontological basis in the general geology of North America. At the initial point of our work,

Green River Station, we have collected a good suite of Tertiary fossils, consisting of the remains of vertebrates, insects, mollusks, and plants. In the cañons along the northern flank of the Uintah Mountains we have again collected fossils of Tertiary age, and also of the Cretaceous, Jurassic, and Carboniferous ages.

On the southern slope of the Uintah Mountains a like series was collected but in reverse order; in the Jura, especially, we find a great variety of forms. Again, in the Cañon of Desolation we collected Tertiary fossils; in Gray Cañon, Cretaceous fossils, and on the river below fossils of the Jura. In Cataract Cañon we succeeded in making a large collection of the remains of Carboniferous age, consisting of fish, teeth, shells, and corals. In the Grand Cañon of the Colorado, carboniferous forms were found in abundance. In like manner all of our geological sections can be studied with the aid of the fossil remains which have been collected.

ECONOMIC GEOLOGY.

In much of the area embraced in the survey there are extensive beds of coal. We first met with them in descending Green River, about eight miles below the railroad crossing, and I note the interesting fact that we discovered vertebrate and invertebrate fossils immediately overlying the heaviest bed of coal. We again found extensive beds outcropping in the upturned edges of the Tertiary rocks on the northern flank of the Uintah Mountains; still other beds are found on the southern slope of these mountains and in the valley of the White and the valley of the Uintah. Again a series of beds was discovered in Gray Cañon. On the headwaters of the Price and San Rafael Rivers, or in Castle Valley, beds of great geographic extent and great thickness were discovered and we traced them on to the south by the headwaters of the Dirty Devil, the Escalante, the Paria, the Kanab, and the Rio Virgen, and then to the north on the western escarpment of the Pauns-á-gunt Plateau. All of these coal-beds have been carefully studied, so as to determine as far as possible their geographic extent, their thickness and their geological relations; and this survey has revealed the important fact that a great district of country which is already becoming the seat of many mining enterprises, for gold, silver, copper and other minerals, has also an abundant supply of coal.

The deposits of salt on the Rio Virgen in Nevada, Salina Creek and Salt Creek in Utah, and others on the northern slope of the Paria Plateau and the eastern escarpment of the same, have been examined.

There are also extensive deposits of salt in the Devonian and Silurian rocks of the Grand Cañon. All of these salt-beds have been the subject of much study.

I have thus briefly outlined the extent of the geological work which has been performed. I have mentioned the fields of geological study which have been entered, and have given a few of the general results for the purpose of indicating the character of the work which has been performed. With what degree of fidelity and skill we have pursued these studies can only be revealed by the complete publication of all the maps, sections, illustrations, and discussions.

ETHNOGRAPHY.

During the continuance of the survey much time has been devoted to the ethnography of the country; and these studies have been ex-

tended to tribes beyond the limits of the country embraced in the survey. I will briefly indicate the character of the material collected.

LANGUAGE.

The following is a list of the languages or dialects studied, and the number of words collected in each:

Pai-Utes	1,500	Shī'-ni-mo	500
Ute	1,500	Nav'-a-jo	300
Nu-a'-gun-tits	1,200	Chem-a-hui'-vis	250
Go-si-Utes	800	Pa'-vants	150
Pa-vi-o'-tsoes	800	Sho-sho-nee	100
To'-so-wēts	500	Mo-ja'-ve	50

We have also paid some attention to the structure of the languages, and have collected a large amount of grammatical material, especially in the Ute, Pai-Ute, and Go-si-Ute. The words denoting personal relationship among all the tribes have been carefully studied, so that their systems of recognized consanguinity have been determined.

We have found another interesting field of work in obtaining geographic, astronomic, and meteorologic names and terms, and this has revealed to us some very interesting facts concerning the Indian's conception of nature.

Their numeral systems have been carefully studied, and in some tribes two systems of numbers have been discovered.

Their mythological terms and names have been collected, as far as possible, and this has resulted in a study of their mythology, of which I shall make mention hereafter.

The pronoun has also been carefully studied, and many interesting facts have been discovered; for example, it is found that the general concept of possession as denoted in the simple form of the English is, among the Indians, divided into three forms: one class of possessive pronouns denoting entire possession, another is used to designate the person or thing possessed from others of the same kind, and a third to designate the possessor.

But the grammatical structure has been chiefly studied in the verb. Nouns become verbs to predicate existence and other ideas, by suffixing grammatical inflections to denote number, tense, and mode. In like manner adjectives become verbs, and so also do prepositions; but this subject is so intricate as to preclude its discussion here.

POLITICAL ORGANIZATION.

All that great region of country between the Rocky Mountains and the Sierra Nevadas, stretching from Northern Oregon to the Gulf of California, is, by the Indians, divided into territories, sometimes well defined by natural boundaries, such as mountain-chains, streams, cañons, &c., and to each district there belongs a tribe of Indians. These Indians have no term which signifies tribe or nation—that is, a collection of people under one government, but each tribe takes the name of the land to which it is attached, and if you desire to ask an Indian to which tribe he belongs, you must say, "how are you land-named?" or "what is the name of your land?"

For illustration: with a certain tribe in Northern Arizona, *kaivw* is the word signifying mountain; *a-vwi'* means reclining or lying down; *Kai'-vav-wi*, a mountain lying down, is the name for a plateau. A great plateau north of the Grand Cañon of the Colorado is called by them

Kaí'-vav-wi, and the small tribe of Indians inhabiting it are *Kaí'-vav-wits.*

The Indian is thus attached to his land and his name is his title-deed to his home. These *land-names* are those by which the Indians know themselves, and by which the tribes who are on friendly and intimate relations know each other.

But another class of names is found by which tribes farther separated, either in geographic distribution, language, or hereditary enmities, know each other. These names denote some peculiarity in the people, their habits or customs.

Certain tribes of Central Nevada are known by the surrounding tribes as To'-so-wēts or White Knives; the Utes call the Sioux Sa-rī'-ti-kai, or Dog Eaters; they call the Navajos, Pa'-gu-wēts or Reed Knives; and so any one tribe may be known to the surrounding tribes by several names.

I have found in no instance do the white men know the Indians by their true names, but usually some name by which a little tribe has been known to another has been adopted, and corrupted, more or less, and applied indefinitely to a number of other tribes. Thus, all the tribes of this country have at least three names, one by which they know themselves, one or more by which they are known to the surrounding tribes, and a third by which they are known to white men. Their general government by chiefs and councils has also been a very interesting subject of study.

HABITS AND CUSTOMS.

Their habits and customs, such as their preparation of shelters from inclement weather, the rules which govern them in the selection of camp-sites, their method of preparing food, their rules of hospitality, the division of the spoils of the chase, their marriage customs and burial rites, their sports and games, and many other items have also been noted.

MEANS OF OBTAINING SUBSISTENCE.

Special attention has been paid to their means of obtaining subsistence, their methods of fishing, hunting, and snaring. All these Indians subsist chiefly by the products of the soil. They live on the seeds, fruits, leaves, bark, fleshy stalks, roots, and bulbs of many plants.

Each little tribe, or governmental organization, is strictly confined to the territory giving its name to the tribe, and they move about only within these limits, seeking seeds and roots in their several seasons, and usually, year by year, perform the same round of journeys. Their methods of collecting and preparing these foods have been carefully observed, and, as far as possible, the seeds of these plants have been collected, sometimes in rather large quantities, so that very many bushels have been brought on and distributed to botanists, ethnologists, and scientific institutions, both in America and in Europe, through the Smithsonian Institution. The collections of the last year are yet to be distributed.

INDUSTRIAL ARTS.

The condition of industrial art among these people, as illustrated by their manufacture of lodges and other shelters, clothing, basket ware, agricultural implements, domestic utensils, hunting and fishing tools, ornaments, &c., has been noted. Their method of manufacturing these articles has been studied; for instance, it has been found that stone im-

plements are made as follows: The obsidian or other stone of which the implement is to be made is first selected by breaking up larger masses of the rock and choosing those which exhibit the fracture desired and which are free of flaws; then these pieces are baked or steamed, perhaps I might say annealed, by placing them in damp earth covered with a brisk fire for twenty-four hours, then with sharp blows they are still further broken into flakes approximating the shape and size desired. For the more complete fashioning of the implement a tool of horn, usually of the mountain sheep, but sometimes of the deer or antelope, is used. The flake of stone is held in one hand, placed on a little cushion made of untanned skin of some animal, to protect the hand from the flakes which are to be chipped off, and with a sudden pressure of the bone-tool the proper shape is given. They acquire great skill in this, and the art seems to be confined to but few persons, who manufacture them and exchange them for other articles. To illustrate this branch of this subject we have made extensive collections, the catalogue of which embraces many thousand of articles.

MYTHOLOGY.

We have found among these Indians a large body of mythology, given in a vast number of stories or accounts, which purport to be the history and doings of their mythological personages or gods. These people have no conception of an all-wise, all-powerful, or all-great being. They believe in a multitude of gods, some better than others, some wiser than others, some shrewder than others, some more powerful than others, but no one of superlative attributes.

The earth, at one time, was peopled by a race of beings with wonderful powers; they could transform themselves or each other; they could make themselves invisible, though in immediate presence; they could restore each other to life, and even had the power of bringing themselves to life after certain periods of death. Many very wonderful attributes had these people. At last they quarrelled and fought, and for their sins and through their evil deeds they degenerated into the present species of animals which inhabit the earth. Each species of animal—mammal, bird, reptile, fish, and even all the invertebrates—had its progenitor or prototype in those wonderful ancient beings.

All the prototypes of existing species of animals are called by the same name as these animals themselves, but sometimes slightly modified. Shin-av is the wolf, Shin-au′-av the progenitor of wolves. Kwī′-ant is the bear, Kwī′-ats the progenitor of the bear. Kwai′-nants is the eagle, and Kwai′-nants that mythological eagle.

Among these ancient personages those who take the greatest part in their mythological history are perhaps, Ta-vwots, the prototype of the little rabbit, (*Lepus artemisia*;) Shin-au′-av, the prototype of the wolf; Kwī′-ats, the prototype of the grizzly-bear; si-kōr′, of the crane; To-go′-av, of the rattle-snake; Ong, of the Canada jay; Mu′-tu-chats, of the humming-bird, and Po-a′-gunt, of the duck.

Then there is Tum-pwi-nai′-ro-gwi-nump, signifying one who has a stone shirt, who is the prototype of an animal said to be covered with an armor, probably the armadillo. The Indians aver that it lives to the south. Won′-sits, the ancient antelope, is said by some tribes to have been all eyes; by others to have two eyes in the head, an eye in each shoulder, an eye in each hip, and an eye in the end of his tail, so that he could see in every direction. Tum-pwi-nai′-ro-gwi-nump, the god with the stone shirt, and Won′-sits, the god with many eyes, were

often engaged as watchmen and defenders of other gods, especially of Ta-vwots, Shin-au′-av, and Si-kōr′.

There are many other of these personages who take a greater or less part in the stories, but these are perhaps the most important. Of the original form and appearance of these people there seems to be a strange uncertainty and indefiniteness in the mind of the Indian. Sometimes they are represented as having the forms of men; at others as having the forms of animals, and of assuming temporarily many other shapes; yet they all spoke the Indian language, though somewhat modified in tone, for the grizzly-bear growled his words, the wolf howled his language, to-go′-av, the rattlesnake, hissed his speech, and a′-rum-pats, the grasshopper, had a buzzing tongue. Such are the gods of the Numas.

The Indian was a hunter; he depended in part, at least, on the animals by which he was surrounded for his food and clothing. Not supplied with fire-arms as now, but using rude and imperfect hunting-tools, the wild animals were much more abundant than they are at present. These hunting implements were also noiseless, and it is probable that the game was less shy than at present. His food, clothing, and most valuable ornaments came from these animals, and his greatest skill was employed in their capture. He studied carefully their habits, and watched closely all their movements, and doubtless became more familiar with them than with any other objects or phenomena of nature. He witnessed their wonderful instinctive skill, and saw that for which his simple philosophy gave no account.

The powers, too, of these animals was a source of wonderment. The badger lived in mysterious underground compartments; the squirrel made his home in the trees, and could pass from branch to branch, and from tree to tree, with a celerity which he could not understand; the lizard made its way over the face of the rocks and cliffs with an ease and swiftness that he could not comprehend; then he saw the serpent swift without legs; the rapid darting of the trout in the waters; the soaring of the eagle in the heavens; the art of the spider to make his snare, and all the wonderful feats of the hosts of animals with which he could never vie, and which he could not explain, and from admiration he grew into adoration, and these animals became his gods.

Then another principle or sentiment, which seems to exist almost universally in the minds of men, appears to exert a modifying influence on his mythological beliefs. The men of to-day are never esteemed as the men of yesterday; we can see their weaknesses, their foibles, their faults, and their sins. Only the men of yesterday or yesterday's yesterday are great men; the perspective haze of time covers all that was unlovely. If this sentiment prevails with civilized nations, it is entertained to a much greater extent by savage people.

Everywhere they bitterly mourn the degeneracy of the present time, and speak with pride of their fathers and grandfathers. And this same mental characteristic is observed in their deification of animals. The wolf of to-day is a howling pest, but the wolf of yesterday is a god.

In addition to the animal gods, the sun and moon are recognized as deities, and they have gone but a step or two beyond this in creating for themselves purely imaginary gods.

Some of the tribes have a god of thunder; still it is an animal god. It is a monstrous bird perched on the clouds, and its cries are the rolling thunder, its wings are the cloudlets, and it soars to earth at times and carries away entire tribes on its back.

Then there is still another god or goddess, of which mention should be made: Si-chom′-pa Ma′-so-its, the old woman of the sea. She it was who

brought up the tribes of Utes from the depths of the ocean, and placed them on the land, and allotted to each its portion of the earth, and she taught them their arts.

This mythology is their account of the origin of things and the explanation of the phenomena of nature. They accept as an original or primary concept that there is a land and a sea, an abyss below and a night above. They have no term for, and seem to have no conception of, earth as composed of land and sea. The land is a vast surface bounded by lines of cliffs and by the sea; the cliffs are precipitous, and he who is so fool-hardy as to stand on the brink will lose all control of himself and be compelled to cast himself therefrom into the abyss below. The sea is also bounded by lines of cliffs in the same manner.

Above is night, and between the land and sea below and the night above there is a great dome-shaped space. The firmament is the side, face, or surface of the night. To'-gwum is night—both the night of space and the night of time. (And just here let me remark that it would be very interesting indeed, to show how the Indian often confuses time and space.) Pai'-av means face, side, or vertical surface. So we have mu-kwá-ni-kunt pai'-av, the face of the cliff or wall, and we also have to'-gwum pai'-av, the face of the night, meaning the sky or apparent firmament. The edge of the sky rests upon the sea or brink of the cliffs; but these are so irregular that there are many places where the people may fall through into the abyss below. This boundary of the land and sea—the lower edge of the sides of the night, the horizon—is called kung-war-ru. They give no account for the origin or making of the sun, but they have a host of mythological stories giving the reason why the sun, a god, and a great god, who should have a will of his own, is yet compelled to travel by a definite trail along the face of the night. Others give the origin of the moon.

I was greatly puzzled for a time as to the true character of their belief concerning the stars, and it is not usually very well defined, but in general terms I will say that the stars are translated personages, either gods or men, transferred from earth to the face of the night, where they are compelled to travel in appointed ways. They distinguish between individual stars themselves and groups of stars or constellations.

Concerning the constellations they have many interesting stories, and while the individual stars are personages, the groups of stars are various personages in attitudes performing various acts, or are spoken of as things without life; and these stories of the constellations are considered by them as mere fabrications. A meteorite is said to be star-dung, and curiously enough a snail is called by the same name, and supposed to be the excrement of some stellar personage; that is, snails are fallen meteors. They explain the origin of cañons and valleys, of fire and water, of snow, hail, and rain, of the rainbow, and many other things.

The means by which this mythology is preserved from one generation to the other is very elaborate and very efficient.

DEMONOLOGY.

In addition to the mythological personages they believe in a great number of beings which may be called demons. Kai'-nu-shuvs are beings who live in the high mountains; they usually remain in deep chambers, caves, and underground apartments in the mountains by day, but when the storms gather over the mountains they come out under cover of the clouds, mount their fleet chargers, the mountain sheep, and ride at

bréak-neck speed over the peaks and crags. They are supposed to have special control over the mountain sheep, elk, and deer; and an Indian, when he kills one of these animals, leaves some portion of the carcass near by where the animal has fallen, to propitiate the good-will of Kai-ni-shuv. They tell many wonderful stories of these beings. Pong-a-wits is the sprite of the spring. Po-wha is the Demon of the Lake. The U-nu-wits is the genie who performs many strange deeds, and has the power of transforming himself in magical ways. The Tu-mu-ur-ru-gwait-si-gaip, or rock-rover, lives among the naked rocks and cliffs. His special delight is to catch unwary people and take them to the brink of frightful precipices, and there exact from them promises, a failure to fulfill which causes the wicked violator of his vows to lose his own ghost, and another takes possession of him, and causes him to behave in unseemly ways. This is their explaination of insanity.

The Yan-tups are the beings who produce the various diseases; thus an Indian does not understand a sickness to be an improper working of the physical system, but to be an entity—an evil being—a devil—a Yan-tup who takes possession of the man, and all their medical treatment is sorcery.

They have a great variety of ceremonies, observances, and cruel torturings by which these evil beings are driven from the sick. I have myself witnessed a great number of them, and made record of what I have seen.

POETRY.

Of poetry they have a great store, consisting of songs, usually of few stanzas, rarely more than half a dozen, chiefly celebrating the beauties of nature and the doings of the gods. Of these I have collected more than a hundred. I will give an illustration:

THE EARTHQUAKE.

Tu-wip′ pu-a tu-wip′ pu-a
A-vwim′-pai-ar-ru-wip pu-a
Tu-rá-gu-ok tu-rá-gu-ok
Kai-vwa mu-tú-rai-ka-nok.

In that land, in that land,
In that glittering land;
Far away, far away,
The mountain was shaken with pain.

SUNSET CLOUDS.

Un-ká-pa-ris whu-ká-ri-nu-mí-va
Pí-vu-rant kaivw-ok′-u-mai.

The red clouds of sunset are drifting
Like down on the peaks of the mountain.

EAGLE'S TEARS.

Tá-vi kwai-nant′-si yá-ga-wats
Si-chōm′-pa kung-war′-ru
Tu-yung-wi-ra-vats.

At morn the eagle will cry,
On the farther shore of the sea,
And a rainbow will be in the sky.

THE RED ANT.

Tá-si-av ku-maí-a
  Ma-ná-pa win'-ka
So-ku-nas so'-ma
  Wi-a wi-gá-va.

The little red ant
  Descended the hill
With one arrow only.

A PARADOX.

Wi-gĭv'-a ka-rí-ri
  Yú-gu-kai-maí-u-uk
Yú-gu-kai-maí-u-uk
  Ma-mŭm'-pa-ri-tum-pa.

The crest of the mountain
  Forever remains,
  Forever remains,
Though rocks continually fall.

ANTIQUITIES.

California, Nevada, Utah, Arizona, and New Mexico were at one time populated by races who built for themselves houses of stone or adobe often three or more stories high. They also cultivated the soil, raised cotton, and had some ceramic art. They had also devised a system of picture-writing, the characters of which were made by painting or carving on wood, and by etching on stones.

The ruins of many of these houses have been discovered in the valley of the Colorado, and in them broken pottery, stone implements, and baskets have been found. In many places, also, their etchings on the rocks have been preserved, and these have been copied to a definite scale, giving us an interesting set of their picture-writings.

The same system of picture-writing still exists with the remnant of this great race that inhabits the pueblos of New Mexico and Arizona, and we are able, in part, in the studies made among these later people, to discover some of the meanings of these writings, but their full interpretation has not yet been made. It is hoped that future studies will throw much light on this subject.

I have thus briefly indicated the extent of the ethnological work which has been done, giving only such illustrations as were necessary to indicate the character and direction of the studies.

NATURAL HISTORY.

In the earlier part of the work, collections of mammals and birds were made; no new species were found, but facts concerning the geographical distribution were obtained. During the same time collections of reptiles, fishes, and insects were made. These were deposited in the building of the Chicago Academy of Sciences, for the purpose of identification by specialists; but, in the great fire at Chicago, all these collections were lost. Both in the earlier and later part of the work extensive collections of plants have been made, and eighteen species have been added to the known flora of North America.

PHOTOGRAPHY.

Since the spring of 1871, a photographer has accompanied the expedition for the purpose of making views of geological and topographical interest. Many of these are of prime importance to the geologist, presenting to the eye the structural geology of the country, and to the topographer also, in presenting to the eye the outlines of cliffs and mountains which are to be reproduced on the maps. Such ruins as present walls or other features that could be caught by the camera, were also photographed.

A great many Indian pictures also were made, representing the Indians engaged in their daily labors, or in attitudes which illustrate their habits and customs. Altogether more than seven hundred and fifty negatives have been made.

PROGRESS OF THE OFFICE-WORK.

The computations for astronomic, geodetic, and hypsometic works have only been partially made. A computer is now engaged on that work.

Preliminary maps of the country surveyed have been constructed as working-plans for the final maps, and for geological discussions.

The text of the report on structural geology is partly prepared, but much of it yet remains in the form of field-notes.

The first draught of the ethnological report of the work has been made; this needs re-arrangement and careful revision and correction before it can be submitted to the printer.

FORMER APPROPRIATIONS.

The appropriations which have been made for the work above described are as follows:

For the fiscal year ending June 30, 1871	$12,000
For the fiscal year ending June 30, 1872	12,000
For the fiscal year ending June 30, 1873	20,000
For the fiscal year ending June 30, 1874	10,000
Total amount of appropriations	54,000

Under authority of a joint resolution of Congress, approved June 11, 1868, the Commissary-General of Subsistence has issued rations to the parties under my charge during all the time field operations have been in progress. With this expenditure forty-five thousand square miles of territory have been explored and surveyed, including more than a thousand miles of a river running in a deep gorge varying from a few hundred to more than six thousand feet in depth, descending in that distance more than 5,000 feet, and beset with rocks and interrupted by rapids and cataracts, making the navigation both difficult and dangerous. The territory as a whole presents more obstacles to the explorer than any other portion of the territory of the United States, as it is traversed by deep gorges and set with long lines of cliffs, in many places forming impassable barriers to travel. Much of the country is also arid and destitute of vegetation.

WHAT IS NECESSARY FOR THE COMPLETION OF THE WORK.

For the proper representation of the minute topographic features which have been noted, it will be necessary to construct maps on a

scale of four miles to the inch—1-253,440. This will require seven atlas sheets. For general discussion it will be necessary to have a map embracing the entire area surveyed on a scale of twenty miles to the inch —1-1,267,200. For the purpose of representing the distribution of agricultural lands, waters available for irrigation, pasture-lands, and timber tracts, a second map on the same scale as the last will be necessary. This can be reproduced from the same working-plan, and, being an outline map, will be inexpensive.

For geological purposes, seven maps on the same scale as those first mentioned will be necessary, but the topography should be represented by contour lines.

A special map on a scale of one inch to the mile will be needed for the region of the U-in-ka-ret Mountains, and another on the same scale for the great bend of the Grand Cañon of the Colorado, south of the Kia-bab Plateau.

The two latter will also be comparatively inexpensive. It will thus be seen that an atlas of eighteen maps will be required to properly represent the work which has already been accomplished.

ESTIMATE FOR APPROPRIATIONS.

For the preparation and publication of the work the following sums will be necessary:

To complete the computation and to prepare the topographic, geological, general, and special maps ready for the printer by the process of photo-lithography	$12,000
For the special study of fossils, minerals, and natural history collections	1,800
For the preparation of geological sections and other illustrations ready for the printer	4,000
For the preparation of the text of the geological report ready for the printer.	3,000
For the preparation of the illustrations of the ethnological report ready for the printer	2,000
For the preparation of the text of the ethnological report ready for the printer	3,000
Total	25,800

Should Congress decide that it is best to have the maps engraved on stone, it will be necessary to increase the above estimate of $12,000 to $25,000.

There is a district of country lying to the north of the region embraced in the above-mentioned triangulation, and to the west of the belt of country explored along Green River and the upper course of the Colorado, and south of the country surveyed by Clarence King, of which little is known to geographic science. Government expeditions made prior to the inauguration of this survey have crossed it on two lines, and one of Lieutenant Wheeler's parties has since penetrated the country for a short distance. Our own parties have crossed it by several other lines in an easterly and westerly direction, and traversed it for its entire length in a northerly and southerly direction. This was done, not for the purpose of making a survey of the country, but in order that we might reach the river. Yet topographic and geological facts were collected. It is greatly to be desired that a survey be made of this area. As there is but one base-line in the territory which has already been surveyed by our parties, the only proof of the accuracy of the work rests upon the astronomic checks and the connection made between two separate lines of triangulation around the Kai-bab Plateau.

If this district could be surveyed from a new base-line, and the geo-

detic points be connected with those of the last survey, and also with those made by Clarence King to the north, and those by Dr. Hayden on the east, all of the work could be properly proved and correlated with the other surveys.

The great structural lines of geology and topography in the region already surveyed extend to the north through the country under consideration; in fact, it is a part of the same region of cañons and cliffs, a region entirely unique in geographic science.

To complete the survey of the country under consideration by the methods which were adopted during the latter part of our work, an appropriation of $16,000 will be necessary.

We have already gained some knowledge of the country, its topography and geology; we have men instructed and skilled in the work; we have a train, instruments, and camp-equipage sufficient, with a very little addition, to serve for this purpose, and doubtless the work could be performed now at a much less expense than it could were it necessary to organize an original party for the same.

In case it should be decided to prosecute this field-work the coming season, the appropriation for the office-work should be cut down from $25,800, as above estimated, to $15,000, thus making a total appropriation of $31,000.

I beg leave to call your attention to the fact that heretofore all the work has been accomplished for which estimates have been made, and to state that the estimates above have been carefully considered, and that they will be sufficient to accomplish all that has been represented, but that the work cannot be done for a smaller sum.

Invoking your attention to the statements made concerning the methods and the extent of the work which has been accomplished, and to the estimates which I have submitted for the continuance of the survey,

I am, with great respect, your obedient servant,

J. W. POWELL.

Prof. JOSEPH HENRY,
Secretary Smithsonian Institution, Washington, D. C.