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A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

THE GEYSERS OF CALIFORNIA*
(1873)

View from Witches' Caldron.

Yosemite, the Big Trees and the Geysers are thought by California tourists to be the great wonders of the Golden State, next to her matchless climate and the modesty of her people. Much has been written about the marvelous gorge in the Sierra, where rivers are flung over granite precipices, and the diameter and altitude of the giant Sequoia are familiar enough to the ordinary reader; but less has been said about the Geysers, although they possess features of remarkable interest. Geysers they are not, in the sense in which the word is usually understood; and the traveler who expects to see, on reaching their

*Condensed from an article in SCRIBNER'S MONTHLY, Vol. VI, No. 6, October, 1873. Contributed by Herman Lund, Maxwell, California.

locality, high fountains of boiling water like those in Iceland and the Yellowstone region, will be disappointed. Yet are they richly worth the journey, as the journey itself is its own sufficient reward without any other motive than the scenery along the route. Besides the broad Sacramento Valley, two narrow Coast Range valleys open from the bay on the north—the Sonoma and Napa—each some forty miles long by an average width not exceeding three miles, nearly level, and bounded by high ridges of metamorphic rock of cretaceous age, which sometimes break down into low-rolling hills that invade the plain, giving its surface a picturesque variety. Napa Valley—named from a nearly extinct tribe of aborigines—is the inner one of the two. Like its companion, it is traversed for a part of its length by a creek, navigable as far as the tide extends, which empties into the bay through a wide expanse of salt marsh. Through either valley the mountain—road that leads to the Geysers may be reached. The usual route, however, is through Napa Valley.

Early in the morning a stage leaves Calistoga, which is at the head of Napa Valley, for the Geysers, distant twenty-eight miles. This "stage" is simply a very strong and comfortable open spring-wagon, seating nine to twelve persons. Last year it was not uncommon for half a dozen such wagons to make the trip daily. The road soon quits the valley, ascends a range of wooded hills to the northward, crosses it at a height of three of four hundred feet above the valley and seven hundred and fifty above the sea, and descends to the north-west into Knight's Valley, which is drained into Russian River. There are numerous creeks in this region, leading to many picturesque side valleys heading in the hills. Broad natural meadows are dotted with groves of oak, and in the spring months the green levels and slopes are spangled thick with flowers, including the blue lupin, larkspur, purple primrose, yellow poppy, and a profusion of buttercups and daisies.

As the Geyser mountains are neared the valleys narrow to ribbons, run into hills, and end in a dense forest-glade where lighter wagons are taken for the ascent. From this point teams are not allowed to travel in opposite directions; the road is too narrow and dangerous for two to pass. Hence the teams going out and in meet in this glade composed of lofty firs in great part, and having the hushed air and soft carpet of a true forest. The summit of the first range of hills is about 1,700 feet above the station at its foot, or nearly 2,300 feet above the sea, and the ascent is made in a distance of about four miles. These hills form the lower slope of Geyser Peak, which is 3,471 feet high, and forms one of the triangulating stations of the United States Coast Survey, being plainly visible from the Ocean and from San Francisco.

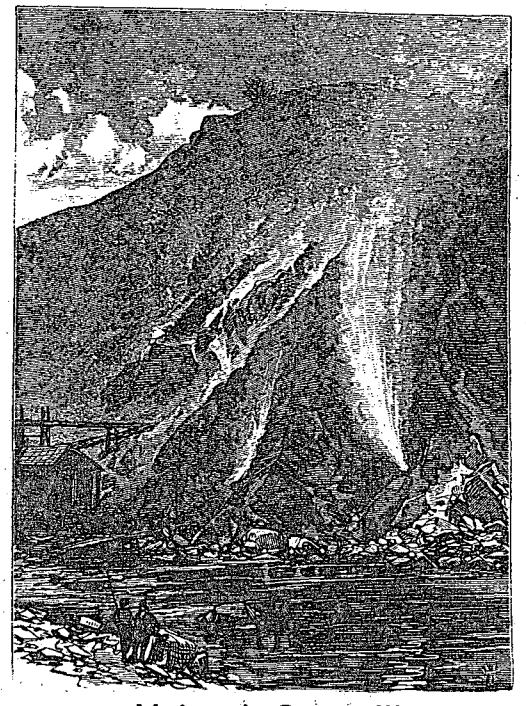
Resting the sweating horses for a few minutes on one of the wild harvest-spaces, and looking about, the stage-load of passengers have a view never to be forgotten. Across a gulf to the east rises the commanding bulk of Mount St. Helena. To the west and south descend the hills we have been climbing, and others beyond them, leading the eye to Russian River Valley, where the stream makes a sharp turn and can be traced on its gleaming course for many miles. The receding hills, with their shaggy coating of forest and chemisal, are softened with a violet haze. The valley shimmers in its heat, and through a cleft in the far blue wall of the outer Coast Range the sunny Pacific is seen melting into heaven. As the road winds higher toward Geyser Peak, it leaves the forest, and passes through a dense thicket of chemisal shrubbery, oak, laurels, small bays and ceanothus. The last, called California lilac, is covered till late in the spring with powdery blossoms that give forth honeyed odors. Masses of stained and blackened rocks, serpentine, sandstone and trap, rise here and there, giving the nearing summit a desolate look, which is increased by the few contorted pines that suck a feeble life from the crevices where they grow. A narrow ridge called the Hog's Back—just wide enough for the wagon—connects two spurs of the range at this point, separating Sulphur and Pluton Creeks. It is the parapet of a wall whose sides slope at sharp angles a thousand feet, and riding over it at high speed one looks into a chasm on either hand, catches breath, and hopes the

harness and wheels may be strong. The Hog's Back, however, forms part of the old road which is not traveled now, except by daring tourists who insist upon going back by that route especially to enjoy a sensation. The new road keeps more to the flank of the ridge, and curves about precipices instead of crossing them. Both roads approach within two or three hundred feet of the summit of Geyser Peak, and then plunge suddenly down its farther and steeper flank to the cañon of Pluton River, on whose right bank are the Geysers. The greatest elevation either road attains is about 3,200 feet. As the Geyser Hotel is 1,692 above the sea, the descent is about 1,500 feet. This is made on the old road in a distance of two miles. Foss, the proprietor of the road and stage line, and one of the celebrated "whips" of California, used to call this steep descent "the drop," and as he began it would tell his passengers to look at their watches and hold on to their seats and hats. He would then crack his whip, and the horses—sometimes six to a wagon—would start at a keen run and make the distance in nine and a half minutes. There are thirty-five sharp turns in "the drop," and the road, just wide enough for the team, frequently hugs the edge of steep rocky precipices, whose sides and bottoms make a green concavity of bristling fir-tops, hiding the stream whose murmur comes faintly up. The new road makes the descent to the cañon of Pluton Creek, or River, by a longer route, with more curves, in a lighter grade; but is equally narrow, and follows closely for long distances the steep precipices that line the creek. Over this, too, the teams are driven at a rate of speed frightful to timid persons unaccustomed to mountain stage-travel in California. But, dangerous as these roads seem, not a single accident has occurred on them, for the wagons are kept very strong, the horses are of the best roadster stock, and the drivers masters of their trade. The great speed maintained, instead of increasing the danger, lessens it. Yet there are persons in almost every wagonful of passengers who pale and shrink as the vehicle dashes widly down, and as they see below them, under the very wheels, as it were, the yawning chasms that threaten death. Women sometimes sink into the bottom of the wagon, and hide from their eyes the spectacle so dreadful to them that is so sublime to cooler heads and calmer nerves. When the wagon reaches the hotel, however, all its tenants have a half-wild-look, as if they had just come down in a balloon and were thankful it had "lit."

The Geyser Hotel is a lightly-constructed frame house, L-shaped, with double piazzas on all sides. It stands amid a grove of tall firs and massive evergreen-oaks, on a narrow bench about one hundred feet above the bed of Pluton Creek, the mountains rising straight behind it. This creek is a tributary of Russian River. It heads up toward Mount St. Helena, and until it comes within the influence of the Geysers is a charming trout-stream. Its banks and bed are extremely rocky. Huge bowlders of granite and sandstone choke its course, and black volcanic masses rise in frowning cliffs by its side, sometimes softened with a drapery of vines, and bearing trees on their creviced tops. Great blocks of conglomerate, apparently formed almost *in situ* by the mineral constituents of the waters percolating through the diluvium, are also seen obstructing the creek. Occasionally it has cut through a bed of this conglomerate, which forms its banks. For all this ruggedness the creek is very picturesque, and has many spots of gentle beauty where the sun beams athwart quiet pools, and maples and pepper-trees mix their gentle grace with the somber foliage of fir and bay and evergreen-oak. Pleasant paths wind along its banks under archways of green, where ferns and flowers thrive and coax the hand to pluck. Between the rocks round plats of tuft-grass make soft stepping-places. The quail is heard calling his mate in the thicket, and the robin chants his song at morn and eve in the tree-tops.

The best time to visit the Geysers is early morning, before the sun has risen above the mountain-tops and drank up the vapors. From the red riven side of the ridge facing the hotel columns and clouds of steam may then be seen rising to a height of two hundred feet or more, obscuring the landscape like a fog just rolling in from the sea. The same phenomenon is visible, but in a less degree, toward night. It is pleasanter to take a good

rest at night, to enjoy the concert of the birds in the grove about the house, listen to the soughing of the firs, the soft roar of the creek, and the distant puffings and gurgitations of of the Geysers; and then, from your bedroom opening upon a piazza, gaze out, as you lie with open door and window, in that balmy climate, at the keen stars beaming with their eternal quiet over that strange scene. Up before the sun, don an old suit, swallow a cup of coffee, and join the laughing party of tourists gathered about the guide on the fenced space before the house. Every one takes a "Geyser pony,"—that is, a stout stick to help him or her over the rocks and springs,—and then all start down the trail, Indian file, to Pluton Creek. Before reaching it, the guide, who perhaps is the jolly landlord himself, points out a chalybeate spring of the fine tonic properties, whose waters his guests imbibe, mixed with soda-water. The banks are charged with iron salts for a great distance up and down, and their solutions have given the earth its red tinge, and hardened the gravel-beds into a semi-metallic mass. In curious contrast, at the crossing to Geyser Cañon, is the whey-like tint of the water in the creek, which for a quarter of a mile or more is affected by the sulphur discharges, some of which bubble up through the very bed of the creek itself. Thermal springs of various sorts are numerous along the creek, especially on its right bank, for several miles; but the most remarkable are those facing the hotel. The prevailing rocks are metamorphic sandstone, silicious slates, and serpentine. Their stratification is boldly exposed, and dips at a sharp angle to the line of the creek. Through the lines of fracture or cleavage, from the water's edge to a height of fifty or a hundred feet up the slope opposite, where the creek is crossed by a rustic bridge, numerous springs and steam-jets escape, coloring the face of the slacking rocks vividly with the yellow, red and white salts of sulphur, iron, lime and magnesia that they deposit. The springs are of various temperatures, some of them exceeding 200°. One forms quite a large stream, and is led by troughs into a row of small shanties, where its steam is used for bathing, the bather jumping immediately after into a rocky basin of the creek two or three feet off, the waters of which are almost shockingly cool.



Vulcan's Steam-Works,
From Pluton Creek.

Where no heated waters flow from the rock the steam issues under a high pressure, intensely hot, and shrieking or hissing. From one hole a foot or two wide, at the base of the bank, it escapes with a noise like that of a high-pressure steamboat "blowing off," and this vent is appropriately called the Steamboard Geyser. For a hundred yards here the rocks are hot under the feet, and as they are also slippery with moist mineral salts and puffing from numerous small vents, the spectacle they present is in sharp contrast to the sylvan beauty of the creek. Yet grasses grow in these heated rocks, out of the very salts, and one or two thermal plants dare to blossom at the edge and in the very breath of the hottest springs, whose waters are sometimes greened with low forms of microscopic plant-life, which also slime the rock where they overflow.

Following down the right bank of the Pluton for a short distance, the trail turns to the right and enters a gorge densely embowered by shrubs at its mouth, but soon opening into the desolate regions of the Devil's Cañon. The nomenclature, like the scenery, from this point, is all infernal, suggestive of Dante

and his awful journey, except that the tourist hither seems to have reversed the course that Dante took, approaching Pluto's sphere from the regions of elysian beauty, instead of passing through that to these. Much of the nomenclature fastened to various points in the cañon is arbitrary and impertinent enough, and one wishes it were possible to see the place dissociated from all names that suggest superstition and cruelty. Climbing up a ledge that crosses the cañon, we suddenly gain a view of the principal Geysers. The gorge for half a mile up the side of the mountain lies before us, a steep ascent, filled with steam and noise, its bare sides painted many colors, its bed obstructed with bowlders, around and under which turbid waters gurgle and smoke; at the very head of all the apparent combustion and explosion an abrupt and tall cliff of red rock, bearing a flag-staff. The ascent of this gorge is toilsome but exciting.

Before the crusts of salt and sulphur and decomposed rock had been disturbed, and a trail marked out where the footing was known to be solid, the ascent may have been dangerous. It is certainly not so now, although to many persons very unpleasant. The hot ground under the feet; the subterranean rumblings; the throbs and thuds near some of the largest and most energetic steam-vents; the warmly moist atmosphere, filled with acidulous and sulphurous vapors, sometimes charged with strong odors of sulphuretted hydrogen; the screaming, roaring, hissing, gurgling, and bubbling of the various springs; all contribute to make the scene as repellent to some natures as it is grand and exciting to others. Where the vapors are thickest, and the noises loudest, the guide says, "This is the Devil's Laboratory;" and so his Satanic Majesty gets the credit all the way for some of the most curious and instructive of the inner workings of that kindly power whose most terrible forces are instruments of good—manifestations of laws that operate through all time and space with impartial grandeur, without vindictiveness or hate.

There are no spouting fountains in the cañon, but numerous bubbling springs, that sink and rise with spasmodic action. These number a hundred or two, and are of varying temperature and constituents. A few are quite cold, closely adjoining hot springs; while others have a temperature of 100 to 207 degrees. Some appear to be composed of alum and iron, others of sulphur and magnesia, while a few are strongly acidulous. Here the water is pale yellow, like that of ordinary white-sulphur springs; there it is black as ink. The mingling of these different currents, with the aid of frequent steam injections, intensifies the chemical action, the sputter and fuming, that are incessantly going on. These phenomena are not confined to the narrow bed of the gorge, but extend for a hundred or two feet in places up its sides, which slope at a pretty steep angle. These slopes are soft masses of rock decomposed or slacked by chemical action, and colored brillantly with crystallized sulphur, and sulphates of iron, alum, lime and magnesia, deposited from the springs and jets of steam, which are highly charged with them. As the rocks decompose and leach under the chemical action to which they are subjected, the soft silicious mass remaining, of a putty-like consistence, mixes with these salts. Some of the heaps thus formed assume conical shapes. They have an apparently firm crust, but are really treacherous stepping-places. One of the most remarkable steam-vents in the cañon is in the top of such a pile, fifty feet up the steep slope. It blows like the escape-pipe of a large engine. The beautiful masses of crystallized sulphur which form about it, as about the innumerable small fumeroles that occur along both banks, tempt one to dare to climb, and face the hot steam. The mass shakes beneath the tread, and is probably soft to a great depth. Wherever in these soft heaps a stick is thrust in, the escaping warm air soon deposits various salts. Of course a walk over such material is ruinous to boot and shoe leather, while the splash of acid waters often injures the clothing. Everybody stops to gather specimens of the various salts and rocks. The guide presents to be tasted pure Epsom-salts (sulphate of magnesia), and salts of iron and alum, of sida and ammonia. Few care to taste the waters, however, which rival in their chemical and sanitary qualities all the springs of all the German spas together. Perhaps the most remarkable of the Geyser springs

The Devil's Cañon. View Looking Up.

is that called, happily enough, the Witches' Caldron. This is a black cavernous opening in the solid rock, about seven feet across, and of unknown depth, filled with a thick inky liquid, boiling hot, that tumbles and roars under the pressure of escaping steam, emitting a smell like that of bilge-water, and seems to proceed from some Plutonic reservoir. One irresistibly thinks of the hellbroth in *Macbeth*, so "thick and slab," and repeats the words of the weird sisters:

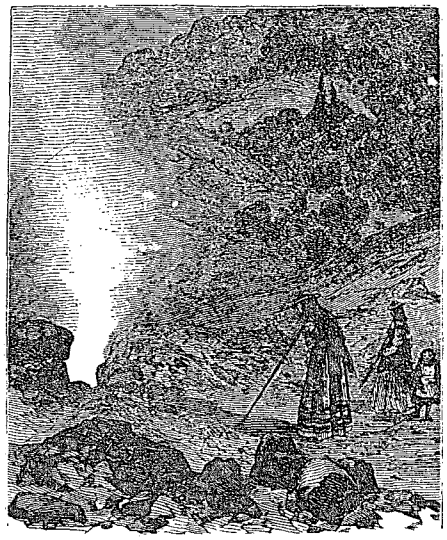
"Double, double, toil and trouble,
Fire burn and caldron bubble."

A clever photographer, Mr. Muybridge, conceived the idea of grouping three lady visitors about this caldron, with hands linked, and alpenstocks held like magic wands, in which position he photographed them amid the vaporous scene with telling effect. Another notable spot is the Devil's Gristmill, where a large column of steam escapes from a hole in the rock with so much force that stones and sticks laid at the aperture are blown away like bits of paper. The internal noises at this vent truly resemble the working of a gristmill. Milton's hero is sponsor for another spring called the Devil's Inkstand, notable for its black waters, specimens of which are taken off in small vials, and used at the hotel to inscribe the names of guests on the register. Dr. James Blake, who has read before the California Academy of Sciences several papers giving the results of his observations on the Geysers, says that the water of the Devil's Inkstand contains nine per cent. of solid matter in the form of soluble salts and sediment, the former being in the proportion of 2.7 per cent., the remaining ingredients being in the form of a dark black sediment. The matter has a thoroughly acid reaction, which it owes to the presence of free sulphuric acid. It would seem that a large portion of the soluble matter is composed of ammoniacal salts, probably the sulphate of ammonia. This salt, which rarely occurs in the natural state, has been found by Mr. Durand, another academician, precipitated in large quantities from the vaporous exhalations at the Geysers. Dr. Blake's analysis of the water of the Devil's Inkstand shows that about fifty per cent. of the saline ingredients consists of volatile salts, the remainder being salts of magnesia, lime, alumina and iron. The presence of so large a quantity of ammoniacal salts in the water of a mineral spring is quite exceptional. These salts have long been recognized as occurring in the fumeroles, in the neighborhood of volcanoes, and their origin, particularly in such large quantities as at these Geysers, opens up some very interesting questions as to the nature of the strata from which so much nitrogenous matter can be derived. The sediment in the above water, in the proportion of more than an ounce to a quart, is probably some compound of iron and sulphur. Prof. Whitney, of the Geological Survey, accounts for the black color and villainous smell of the water in the Witches' Caldron, as follows: the iron held in solution comes in contact with water

holding sulphuretted hydrogen, when an ink-black precipitate of sulphuret of iron takes place.

Wherever one treads, going up the Devil's Cañon, the step slips or crunches on some of the chemical products of these springs. It is a relief, after a while, to emerge from the heated vapors and sulphurous smells, and, standing on the flag-staff cliff (called the Devil's Pulpit, of course), look down the cañon and across to the hotel. Phenomena of the same sort, on a smaller scale, however, are visible in the higher slopes, and in the lesser gulches, up and down the creek. One place, called the crater, a circular cavity of considerable depth, with a level, hollow-sounding floor, is evidently the site of exhausted thermal action, where the mineral constituents in the rock had all been slacked out and the ground had sunk in; though about the lips of this "crater" one or two vigorous steam-vents are still in operation, and sulphur continues to be deposited in fine needle-crystals. Half a mile below Geyser Cañon are a large sulphur heap, incrustations, and other evidences of former activity, some heat still remaining in places. A ravine near by contains a clear hot spring, which was formerly built over with stones and sticks by the Indians, and the steam used as a sanitary agent. It is still known as the Indian Spring. Just without the rude wall enclosing it, runs a cold spring of excellent drinking water. Four miles up the Pluton Creek occur what are called the "Little Geysers," similar in character to the larger ones, except that they issue from a gently sloping hill-side, instead of a deep gorge. The rocks and the chemical action are the same.

As to the origin of the phenomena we have been describing, it may be said that there are two theories—volcanic and chemical. Prof. Whitney says (in his *Report of Progress*, vol. i., page 95) that there will be no difficulty in understanding them when we consider that they are displayed along a line of former volcanic activity, and where even now the igneous forces are not entirely dormant. "The dependence of the Geysers for their activity, in



Devil's Tea-Kettle.

part, on the recurrence of the rainy season indicates clearly that the water, percolating down through the fissures in the rocks, meets with a mass of subterranean lava not yet entirely cooled off, and becoming intensely heated, under pressure, finds its way to the surface along a line of fissure connecting with the bottom of Geyser Cañon; in this heated condition it has a powerful action on the rocks and the metallic sulphurets which they contain, especially in the sulphuret of iron everywhere so abundantly diffused through the formation, and so dissolves them and brings them up to the surface, to be again partly redeposited as the solution is cooled down by contact with the air." Prof. Whitney adds that phenomena of the same kind as those observed at the Geysers, and sometimes even on a larger scale, are exhibited all throughout the now almost extinct volcanic regions of California and Nevada. Even on Mount Shasta the last expiring efforts of this once mighty volcano may be traced in the solfatara action still going near the summit, and which is undoubtedly due to the melting snow finding its way down to the heated lava, or other volcanic materials below, in the interior of what was once the crater, from and around which a mass of erupted matter has been poured forth and piled up to the height of several thousand feet. We know, on other authority, that earthquakes

have frequently been experienced at the Geysers, accompanied by loud noise. Two smart shocks on the night of Febrary 20th, 1863, were followed by the bursting forth of new openings of steam and boiling waters. Such an outburst, on one occasion, caused a gush of steam up the left side of the cañon so hot as to kill all the trees and shrubs in its course.

The chemical theory asserts that all the phenomena are ascribable to the action of water percolating through mineral deposits, and creating heat, expansion, and explosion by simple chemical decomposition; without the aid of a heated volcanic mass. The two theories may be harmonized, for the mineral matter is probably of volcanic origin, and whether it is heated before the water acts upon it is not very material.

In spite of the hot water, the steam, and the saline deposits, vegetation flourishes far down the slopes of Geyser Cañon, about the margins, and in some of the very waters. The evergreen-oak thrives almost within reach of the exhalations, and maples and alders are found on the banks of the creek close to some of the steam-vents. A grass called *Panicum thermale* grows near the hot springs. Animal life dares to invade the scene, for dragon-flies of great beauty may often be observed, while birds build their nests and sing in the adjacent trees. Dr. Blake found two forms of plant-life in a spring having as high a temperature as 198 degrees. These were delicate microscopic confervae. In a spring having a temperature of 174 degrees, many oscillariae were found, which, by the interlacement of their delicate fibers, formed a semi-gelatinous mass. In a spring of the temperature of 134 degrees, layers of filamentous green and red algae were freely formed as the water flowed over the rocks. Unusual masses of oscillariae flourish in the waters of Pluton Creek. Their presence in the highly mineralized waters of a spring with a temperature of 174 degrees, shows how great is the range of the conditions in which these forms of plant-life can be developed.

One returns to the hotel after a morning tramp through Geyser Cañon and along Pluton Creek with an enormous appetite, and is glad to rest for a few hours. Afterward, there are delightful strolls up and down the creek, and good trout-fishing for those who will go far enough. Deer and grizzly bear are to be had for the hunting in the mountains—the grizzly sometimes without hunting. But the sportsman had better be accompanied with some one familiar with the country, unless he is a good forester and can find his way without a path. A San Francisco lawyer was lost for several days on a hunting-trip, and nearly starved to death before he was found. It was a roving hunter, of the true Leatherstocking sort, named Elliot, who first, of white man, found the Geysers, in 1847. Coming suddenly to the edge of the cañon, he was amazed at what he beheld, and on returning to his companions told them, in his rough way, he had found the mouth of the infernal regions. Elliot fell in a fight with a tribe of Nevada Indians, not many years ago—a true border-hero to the last. The mountain over which he probably approached the Geysers, called Cobb's Peak, commands one of the greatest views obtainable in California. Northward, only fifteen miles off, lies Clear Lake, divided in two parts by the purple bulk of Uncle Sam Mountain, and surrounded by the rugged spurs of the Coast Range. On a clear day, one can see in that direction two hundred miles in an air-line, where the snowy crown of Mt. Shasta, 14,440 feet above the sea, floats in the sky like a fixed cloud.

Mount St. Helena and Napa Valley lie nearer at hand, and to the westward the eye takes in the Pacific Ocean for a hundred miles along the coast. Mount Cobb can be ascended on horseback. The timber is not thick on the way, and many charming outlooks are obtained. Another scenical treat may be had by returning from the Geysers to San Francisco Bay, by way of the old road across the Hog's Back, to Ray's Station, and thence into Russian River and Sonoma Valley. These valleys, though more extensive than Napa, have similar characteristics. They are very fertile, contain a number of pleasant and thriving towns, are traversed by a railroad, and are very picturesque. Reaching San Francisco by this route, the tourist will have gained a very good idea of the northern coast-valleys of

California, and the noble bay into which they partly drain. No trip equaling it for variety and beauty of scenery can be made in the same time, at so little cost, and with so much comfort. It can be done in three days, but the lover of nature will want to give more time to the trip, and the invalid, who seeks the Geysers for the medicinal use of their waters, must stay longer to test their certain efficacy.

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DIRECT UTILIZATION PUBLICATIONS

Two handbooks on the direct use of geothermal energy have just been released. They are the result of a workshop held at Diamond Lake, Oregon in 1979, and are a joint project by the Geo-Heat Utilization Center and the Geothermal Resources Council and funded by DOE. Specific chapters deal with: 1. Nature and Distribution; 2. Exploration, Confirmation, and Evaluation; 3. Reservoir Development and Management; 4. Utilization; 5. Economics; 6. Financing; and 7. Legal Institutional, and Environmental.

The two publications are:

Direct Utilization of Geothermal Energy: A Technical Handbook, Special Report No. 7—$10.00

Direct Utilization of Geothermal Energy: A Layman's Guide, Special Report No. 8—$8.00

Both are available from the Geothermal Resources Council, Post Office Box 98, Davis, CA 95616, for the indicated price.