

American Forestry

MAY

1913

THE OHIO FLOODS: THEIR CAUSE
AND REMEDY

THE YELLOWSTONE NATIONAL PARK

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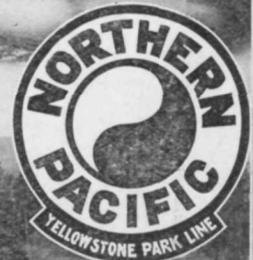
Panama-Pacific Expo. San Francisco, 1915

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It erupts every 65 or 70 minutes to the height of a fourteen story building.



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One of the five Superb Hotels
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YELLOWSTONE NATIONAL PARK

BY ARNOLD HAGUE, U. S. GEOLOGICAL SURVEY*

THE Yellowstone Park is situated in the extreme Northwestern portion of Wyoming. At the time of the enactment of the law establishing this national reservation the region had been little explored, and its relation to the physical features of the adjacent country was little understood. Since that time surveys have shown that only a narrow strip about two miles in width is situated in Montana and that a still narrower strip extends Westward into Idaho.

The area of the park as at present defined is somewhat more than 3,300 square miles.

The Central Plateau, with the adjacent mountains, presents a sharply defined region, in strong contrast with the rest of the Northern Rocky Mountains. It stands out boldly, is unique in topographical structure, and complete as a geological problem.

The central portion of the Yellowstone Park is essentially a broad, elevated, volcanic plateau, between 7,000 and 8,500 feet above sea level, and with an average elevation of about 8,000 feet. Surrounding it on the South, East, North, and Northwest are mountain ranges with culminating peaks and ridges rising from 2,000 to 4,000 feet above the general level of the inclosed table-land.

South of the park the Tetons stand out prominently above the surrounding country, the highest, grandest peaks in the Northern Rocky Mountains. The Eastern face of this mountain mass rises with unrivalled boldness for nearly 7,000 feet above Jackson Lake. Northward the ridges fall away abruptly beneath the lavas of the park, only the outlying spurs coming within the limits of the reservation. For the most part the mountains are made up of coarse crystalline gneisses and schists, probably of Archean age, flanked on the Northern

spurs by upturned Paleozoic strata. To the East of the Tetons, across the broad valley of the Upper Snake, generally known as Jackson Hole, lies the well-known Wind River Range, famous from the earliest days of the Rocky Mountain trappers. The Northern end of this range is largely composed of Mesozoic strata, single ridges of Cretaceous sandstone penetrating still farther Northward into the regions of the park and protruding above the great flows of lava.

Along the entire Eastern side of the park stretches the Absaroka Range—so called from the Indian name of the Crow Nation. The Absaroka Range is intimately connected with the Wind River Range, the two being so closely related that any line of separation must be drawn more or less arbitrarily, based more upon geological structures and forms of erosion than upon physical limitations.

The Absarokas offer for more than 80 miles a bold, unbroken barrier; a rough, rugged country, dominated by high peaks and crags from 10,000 to 11,000 feet in height. The early trappers found it a forbidding land; prospectors who followed them, a barren one.

At the Northeast corner of the park a confused mass of mountains connects the Absarokas with the Snowy Range. This Snowy Range shuts in the park on the North and is an equally rough region of country, with elevated mountain masses covered with snow the greater part of the year, as the name would indicate. Only the Southern slopes, which rim in the park region, come within the limit of our investigation. Here the rocks are mainly granites, gneisses, and schists, the sedimentary beds, for the most part, referable to the pre-Cambrian series.

The Gallatin Range incloses the park



OBSIDIAN CLIFF.

on the North and Northwest. It lies directly West of the Snowy, only separated by the broad valley of the Yellowstone River. It is a range of great beauty, of diversified forms, and varied geological problems. Electric Peak, in the Northwestern corner of the park, is the culminating point in the range, and affords one of the most extended views to be found in this part of the country.

The Absarokas rise as a formidable barrier on the Eastern side of the park, the Gallatins as a steep mural face on the West side, while the other ranges terminate abruptly, rimming in the park on the North and South, and leaving a depressed region not unlike the parks of Colorado, only covering a more extended area with a relatively deeper basin. The region has been one of profound dynamic action, and the center of mountain building on a grand scale.

The Central Plateau covers an area approximately 50 by 40 miles, with a mean altitude of 8,000 feet. It is accented by undulating basins of varied outline and scored by deep canyons and gorges. Strictly speaking, it is not a plateau; at least it is by no means a level area, but a rugged country, characterized by bold escarpments and abrupt edges of mesa-like ridges. But few

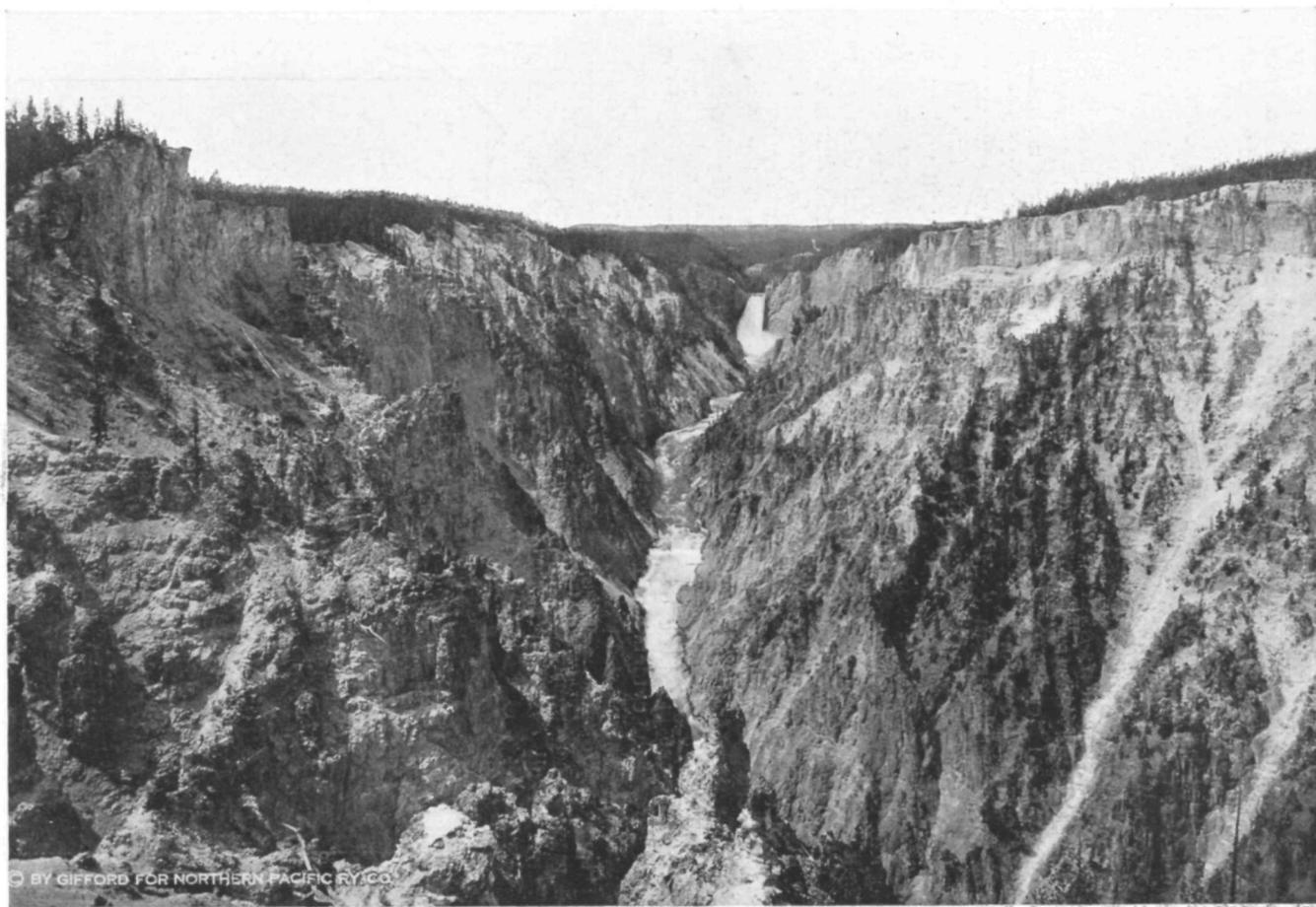
large vents or centers of volcanic activity for the rhyolite have been recognized, the two principal sources being the volcano to which reference has already been made and Mount Sheridan in the Southern end of the park. Mount Sheridan is the most commanding peak on the plateau, with an elevation 10,385 feet above sea level and 2,600 feet above Heart Lake. From the summit of the peak on a clear day one may overlook the entire plateau country and the mountains which shut it in, while almost at the base of the peak lie the magnificent lakes which add so much to the quiet beauty of the region, in contrast to the rugged scenery of the mountains. From no point is the magnitude and grandeur of the volcanic region so impressive. The lava flows—bounded on the East by the Absarokas—extend Westward not only across the park, but across the Madison Plateau, and out on to the great plains of Snake River, stretching far Westward almost without a break in the continuity of eruptive flows. Over the central portion of the park, where the rhyolites are thickest, erosion has failed to penetrate to the underlying rock. Even such deep gorges as the Yellowstone, Gibbon, and Madison Canyons have nowhere worn



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Courtesy of Northern Pacific Ry. Co.

MT. WASHBURN ROAD ALONG CASCADE CREEK,



GREAT FALLS AND GRAND CANYON FROM ARTISTS POINT,

Courtesy of Northern Pacific Ry. Co.

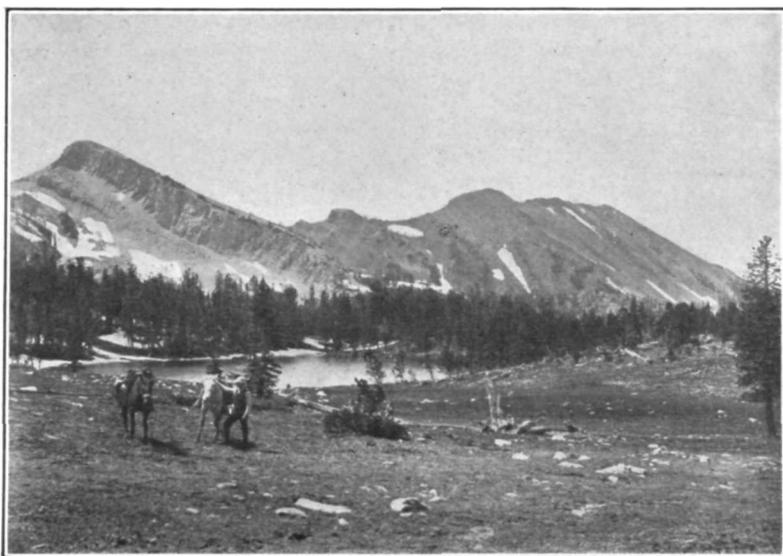
through these rhyolite flows. In the Grand Canyon of the Yellowstone the andesitic breccias are found beneath the rhyolites, but the deepest cuts fail to reveal the underlying sedimentary beds. Although the rocks of the plateau for the most part belong to one group of acidic lavas, they by no means present the great uniformity and monotony in field appearance that might be expected. These 2,000 square miles offer as grand a field for the study of structural forms, development of crystallization, and mode of occurrence of acidic lavas as can be found anywhere in the world. They vary from a nearly holocrystalline rock to one of pure volcanic glass.

Since the close of the ice period no geological events of any moment have brought about any changes in the physical history of the region other than those produced by the direct action of steam and thermal waters. A few insignificant eruptions have probably occurred, but they failed to modify the broad outlines of topographical structure and present but little of general interest beyond the evidence of the continuance of volcanic action into quaternary times. Volcanic activity in the park may be considered as long since extinct. At all events indications of

fresh lava flows within historical times are wholly wanting. This is not without interest, as evidence of underground heat may be observed everywhere throughout the park in the waters of the geysers and hot springs. All our observations point in one direction and lead to the theory that the cause of the high temperatures of these waters must be found in the heated rocks below, and that the origin of the heat is in some way associated with the source of volcanic energy. It by no means follows that the waters themselves are derived from any deep-seated source; on the contrary, investigation tends to show that the waters brought up by the geysers and hot springs are mainly surface waters which have percolated downward a sufficient distance to become heated by large volumes of steam ascending through fissures and vents from much greater depths. If this theory is correct it is but fair to demand that evidence of long-continued action of hot waters and superheated steam should be apparent upon the rocks through which they passed on their way to the surface. This is precisely what one sees in innumerable places on the Central Plateau. Indeed, the decomposition of the lavas of the



THE ABSAROKA RANGE ALONG THE EASTERN EDGE OF THE PARK.



THE GALLATIN RANGE IN THE NORTHEASTERN PORTION OF THE PARK.

rhyolite plateau has proceeded on a most gigantic scale, and could only have taken place after the lapse of an enormous period of time and the giving off of vast quantities of heat, if we are to judge at all by what we see going on around us today. The ascending currents of steam and hot water have been powerful geological agents, and have left an indelible impression upon the surface of the country. The most striking example of this action is found in the Grand Canyon of the Yellowstone. From the Lower Falls for three miles down the river abrupt walls upon both sides of the canyon, a thousand feet in depth, present a brilliancy and mingling of color beyond the power of description. From the brink of the canyon to the water's edge the walls are sheer bodies of decomposed rhyolite. Varied hues of orange, red, purple, and sulphur-yellow are irregularly blended in one confused mass. There is scarcely a piece of unaltered rock in place. Much of it is changed into kaolin; but from rhyolite, still easily recognized, occur transition products of every possible kind to good porcelain clay. This is the result of the long-continued action of steam and vapors upon the rhyolite lavas. Through this mass of decom-

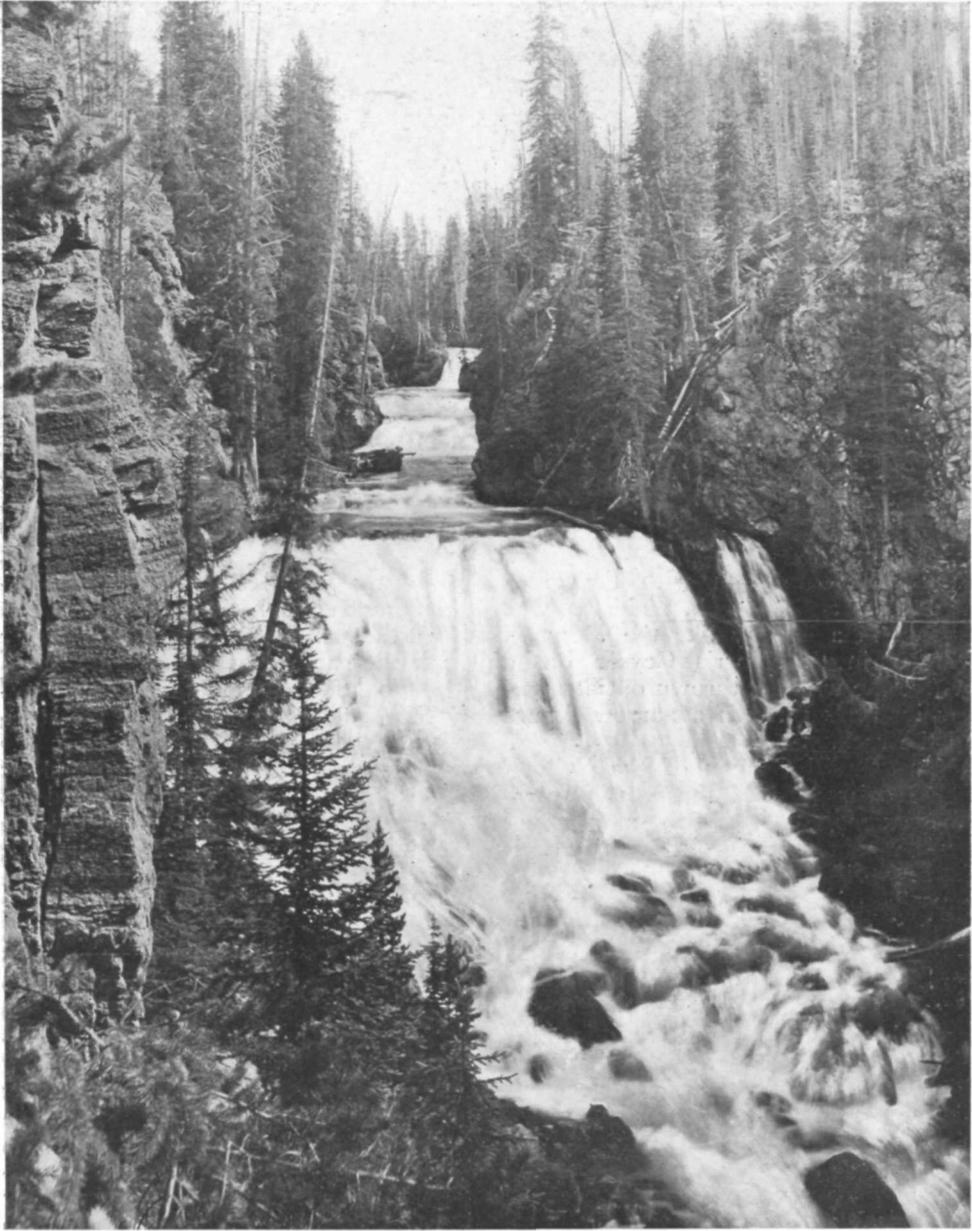
posed rhyolite the course of ancient steam vents in their upward passage may still be traced, while at the bottom of the canyon hot springs, fumaroles, and steam vents are still more or less active, but probably with diminished power.

Still other areas are quite as convincing, if not on so grand a scale, as the Yellowstone Canyon. Josephs Coat Basin, on the East side of the canyon, and Brimstone Hills, on the East side of the Yellowstone Lake, an extensive area on the slopes of the Absaroka Range, both present evidences of the same chemical processes brought about in the same manner. It is not too strong a statement to make to say that the plateau on the East side of the Grand Canyon, from Broad Creek to Pelican Creek, is completely undermined by the action of superheated steam and alkaline waters on the rhyolite lava. Similar processes may be seen going on today in all the geyser basins. A long period of time must have been necessary to accomplish these changes. The study of comparatively fresh vents shows almost no change from year to year, although careful scrutiny during a period of five years detects a certain amount of disintegration, but infinitely



UPPER FALLS FROM HOTEL WINDOW.

Courtesy of Northern Pacific Ry. Co.



Courtesy of Northern Pacific Ry. Co.

KEPLER CASCADE, JUST ABOVE UPPER BASIN, YELLOWSTONE PARK.



GLACIAL BOULDER NEAR GRAND CANYON.

small in comparison with the great bodies of altered rock. This is well shown in a locality like the Monarch Geyser in the Norris Geyser Basin, where the water is thrown out at regular intervals through a narrow fissure in the rock.

The Grand Canyon of the Yellowstone offers one of the most impressive examples of erosion on a grand scale within recent geological times. It is self-evident that the deep canyon must be of much later origin than the rock through which it has been worn, and it seems quite clear that the course and outlines of the canyon were in great part determined by the easily eroded decomposed material forming the canyon walls, and this in turn was brought about by the slow processes just described. The evidence of the antiquity of the hot spring deposits is, perhaps, shown in an equally striking manner and by a wholly different process of geological reasoning. Terrace Mountain is an outlying ridge of the rhyolite plateau just West of the Mammoth Hot Springs. It is covered on the summit with thick beds of travertine, among the oldest portions of the Mammoth Hot Springs deposits. It is the mode

of occurrence of these calcareous deposits from the hot waters which has given the name to the mountain. Lying upon the surface of this travertine on the top of the mountain are found glacial boulders brought from the summit of the Gallatin Range, 15 miles away, and transported on the ice sheet across Swan Valley and deposited on the top of the mountain, 700 feet above the intervening valley. It offers the strongest possible evidence that the travertine is older than the glacier which has strewn the country with transported material. How much travertine was eroded by the ice is, of course, impossible to say, but so friable a material would yield readily to glacial movement.

Deposition of sinter from the hot waters of the geyser basins depends in a great measure on the amount of silica held in solution, which varies considerably at the different localities and may have varied still more in past time. The silica, as determined by analyses, ranges from 0.22 to 0.60 grammes per kilogram of water, the former being the amount found in the water of the caldron of the Excelsior Geyser and the latter at the Coral Spring in the Nor-



MUD VOLCANO ON ROAD BETWEEN LAKE AND CANYON.

Courtesy of Northern Pacific Ry. Co.



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Courtesy of Northern Pacific Ry. Co.
TREE GNAWED BY BEAVERS, YELLOWSTONE PARK.



Courtesy of Northern Pacific Ry. Co.
YOUNG CUB BEAR IN TREE AT LAKE. NOTE MAN IN TREE BELOW THE BEAR FEEDING HIM SUGAR.

ris Basin. Analysis shows that from one-fifth to one-third of the mineral matter held in solution consists of silica, the remaining constituents being readily soluble salts carried off by surface drainage. A few springs highly charged with silica, like the Coral, deposit it on the cooling of the waters; but such springs are exceptional. At most springs and geysers it results after evaporation, and not from mere cooling of the water. It seems probable that the nature and amount of alkaline chlorides and carbonates present influence the separation of silica. Temperature also may in some degree influence the deposition. My friend, Mr. Elwood Hofer, has called my attention to an observation of his made in midwinter, while on one of his snowshoe trips through the park. He noticed that certain overflow pools of spring water, upon being frozen, deposited a considerable amount of mineral matter. He has sent me specimens of this material, which, upon examination, proved to be identical with the silica deposited from the Coral Spring upon the cooling of the water. Demi-johns of geyser water which have been standing for one or two years have failed to precipitate any silica. Quite recently, in experimenting upon these

waters in the laboratory, it was noticed that on reducing them nearly to the freezing point no change took place, but upon freezing the waters there was an abundant separation of free silica. The waters frozen in this way were collected from the Coral Spring, Norris Basin, and the Taurus Geyser, Shoshone Basin.

Again, there is no doubt that the algaous growths flourishing in the hot waters of the park favor the secretion of silica and calcic carbonate and exert a potent influence in building up both the sinter and travertine deposits far greater than one might at first be led to suppose. These processes of assimilation are steadily taking place without interruption, as all algæ act as geological agents. The silica and lime brought to the surface by hot springs is, upon the death of the algæ, transformed into sinter and travertine, becoming rock masses, which later show scarcely any sign of their origin from plant life. Tourists are seldom aware that the harmonious and brilliant tints are due to vegetable growths. Algæ develop equally well in the waters of all geyser basins and upon the terraces of Mammoth Hot Springs. Water boils in the Upper Geyser Basin at 198 degrees F., and



ALGAE BASINS.



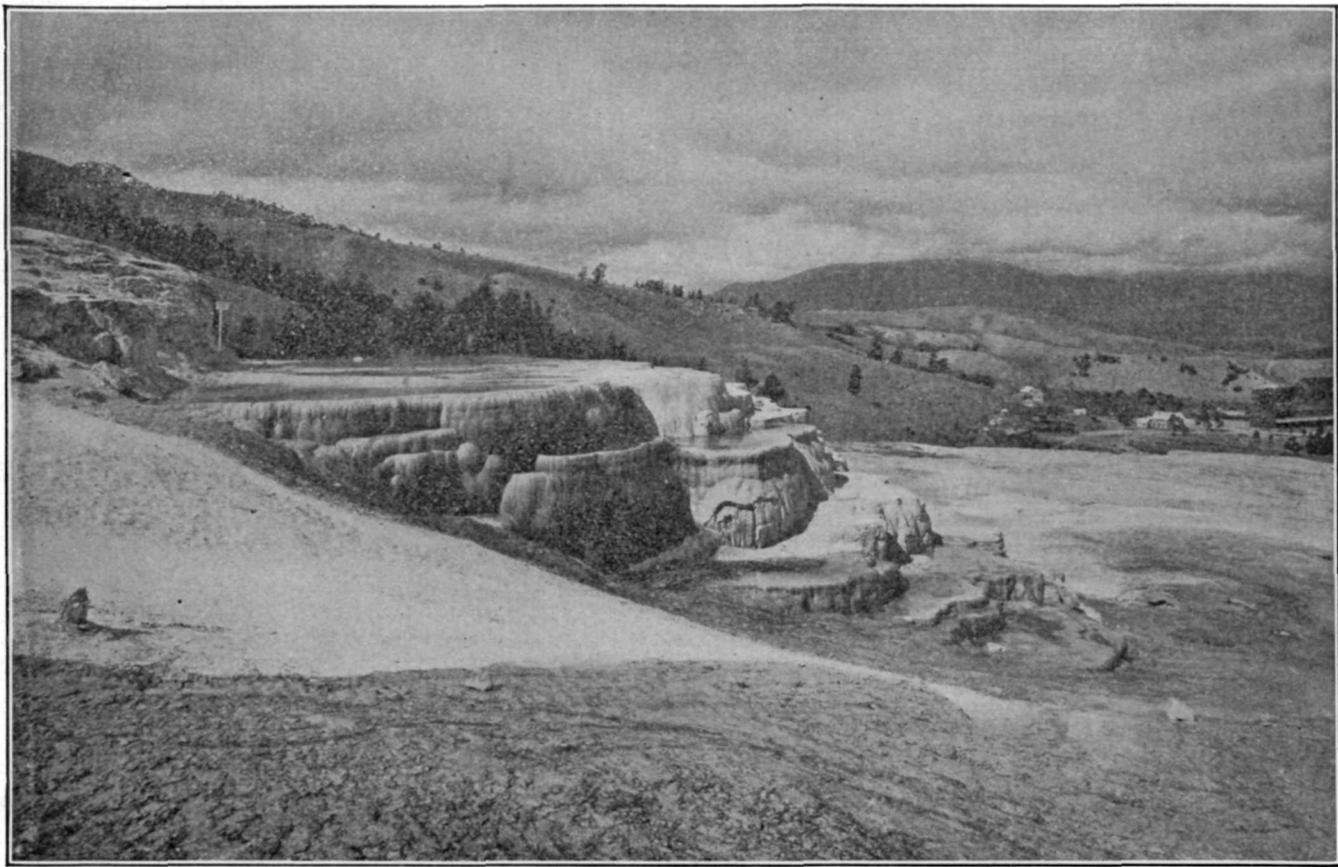
BOWL OF GREAT FOUNTAIN GEYSER, LOWER GEYSER BASIN.

rudimentary organisms appear at about 185 degrees F., although no definite line can be drawn beyond which all life ceases. These low vegetable organisms occur in nearly all pools, springs, and running water upon the plateau. Wherever boiling waters cool to the latter temperature algæ make their appearance, and with the lowering of temperature on exposure to air still more highly organized forms gradually come in. It is believed that at about 140 degrees F. conditions are favorable for a rapid development of numerous species. Many forms of algæ flourish within restricted ranges of temperature, and the different species possess characteristic colors and habits of growth dependent upon such changes of temperature. After a little experience it is quite possible, upon noting the nature of the plant life, to make a sure guess as to the temperature of the water in which the species grow. As water in the geyser pools and caldrons frequently stands at or near the boiling point, no life exists at the centers of discharge, but with a rapid lowering of temperature algæ appear, with corresponding changes of color, in the shallow pools and overflow channels. In the geyser basins the first evidence of vegetation in an overflow

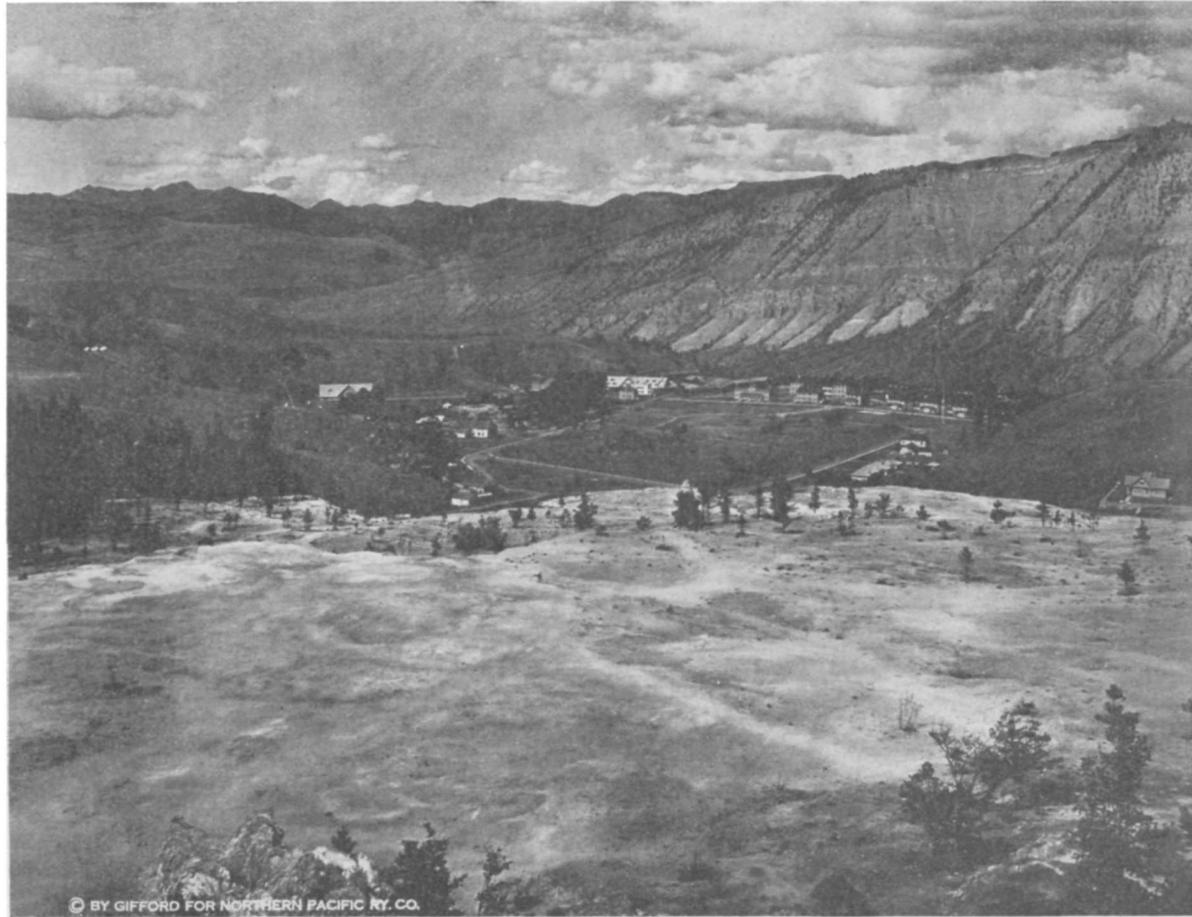
stream consists of creamy white filamentary threads, passing into light flesh tints, then to deep salmon. With distance from the source of heat the prevailing colors pass from bright orange to yellow, yellowish green, and emerald, and in the still cooler waters various shades of brown. This, of course, is a simple statement of phenomena which really display highly complex conditions. No two pools or overflow channels are quite alike in their occurrence either as regards flow of water or development of algæ.

Several methods have been devised for ascertaining the growth of deposition of the geyserite. One way is by allowing the water to trickle over twigs, dried grasses, or almost anything exposing considerable surface, and noting the amount of incrustation. This way gives the most rapid results, but is far from satisfactory and by no means reproduces the conditions existing in nature. Other methods employed are placing objects on the surface of the water or, still better, partially submerging them in the hot pools, or again by allowing the water to run down an inclined plane with frequent intervals for evaporation and concentration.

The vandals who delight to inscribe



TERRACES AT MAMMOTH HOT SPRINGS.

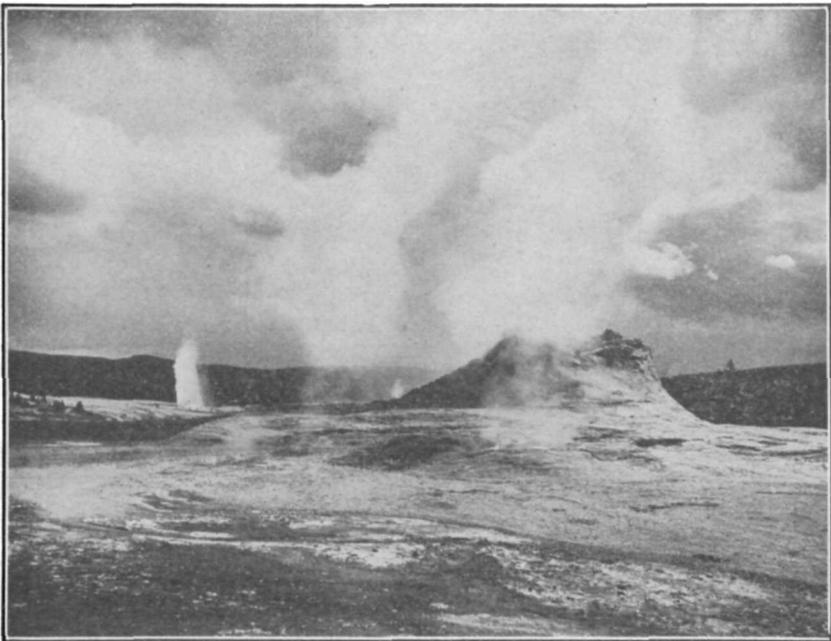


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VIEW OF MAMMOTH HOT SPRINGS FROM JUPITER TERRACE. *Courtesy, Northern Pacific Ry. Co.*

their names in public places have invaded the geyser basins in large numbers and left their addresses upon the geyserite in various places. It is interesting to note how quickly these inscriptions become indelible by the deposition of the merest film of silica upon the lead-pencil marks, and, at the same time, how slowly they build up. Names and dates known to be six to eight years old remain perfectly legible, and still retain the color and luster of the graphite. That there is some increase in the thickness of the incrustation is evident, although it grows with incredible slowness. Mr. Weed tells me that he has been able, in at least one instance, to chip off this siliceous film and reproduce the writing with all its original distinctness, showing conclusively that a slow deposition has taken place. Pencil inscriptions upon the siliceous sinter at Rotomahana Lake, in New Zealand, are said to be legible after the lapse of 20 or 30 years. It is easy to see that various ingenious devices might be planned to estimate the rate of deposition, but in my opinion none of them equal a close study of the conditions found in nature, especially where in-

vestigations of this kind can be watched from year to year. All observations show an exceedingly slow building up of the geyserite formation. This is well seen in the repair going on where the rims surrounding the hot pools have been broken down, and where it might be supposed that the building-up process was under the most favorable conditions; yet, in a number of instances, I can see no appreciable change in three or four years. Revisiting hot springs in out-of-the-way places after several years' absence, I am surprised to see that objects that I had noted carefully at the time remain unchanged. Taking the entire area of the Upper Geyser Basin covered by sinter, I believe that the development of the deposit does not exceed one-thirtieth of an inch a year, and this estimate I believe to be much nearer the maximum than the minimum rate of growth. Supposing the deposit around Castle Geyser to have been built up with the same slowness as observed today, and assuming it to grow at the rate given—one-thirtieth of an inch a year—it would require over 25,000 years to reach its present development. This gives us a great antiquity for the



CONE OF CASTLE GEYSER, UPPER GEYSER BASIN.

geyserite, but I believe that the deposition of the siliceous sinter in the park has been going on for a still longer period of time. It is certain that the decomposition of the rhyolite of the plateau dates still further back.

From a geological point of view, there is abundant evidence that thermal energy is gradually becoming extinct. Tourists revisiting the park after an absence of two or three years occasionally allude to the springs and geysers as being less active than formerly and as showing indications of rapidly dying out. It is true that slight changes are constantly taking place, that certain springs become extinct or discharge less water, but this action is fully counterbalanced by increased activity in other localities. Close examination of the source of the thermal waters fails to detect any diminution in the supply. Moreover, it stands to reason that if the flow of these waters dated—geologically speaking—far back into the past, the few years embraced within the historical records of the park would be unable to indicate any perceptible change based upon a gradual diminution of the heat.

The number of geysers, hot springs, mudpots, and paintpots scattered over the park exceeds 3,000, and if to these be added the fumaroles and solfataras, from which issue in the aggregate enormous volumes of steam and acid and sulphur vapors, the number of active vents would in all probability be doubled. Each one of these vents is a center of decomposition of the acid lavas.

Changes modifying the surface features of the park in recent times are mainly those resulting from the filling up with detrital material of the valleys and depressions worn out by glacial ice, and those produced by the prevailing climatic conditions. Between the park country and what is known as the arid regions of the West there is the greatest possible contrast. Across the Central

Plateau and the Absaroka Range the country presents a continuous mountain mass 75 miles in width, with an average elevation unsurpassed by any area of equal extent in the Northern Rocky Mountains. It is exceptionally situated to collect the moisture-laden clouds, which coming from the Southwest precipitate immense quantities of snow and rain upon the cooled tableland and neighboring mountains. The climate in many respects is quite unlike that found in the adjacent country, as is shown by the meteorological records, the amount of snow and rainfall being higher, and the mean annual temperature lower. Rainstorms occur frequently throughout the summer, while snow is quite likely to fall any time between September and May. Protected by the forests the deep snows of winter lie upon the plateau well into midsummer, while at still higher altitudes, in sheltered places, it remains throughout the year. By its topographical structure the park is designed by nature as a reservoir for receiving, storing, and distributing an exceptional water supply, not exceeded by any area near the headwaters of the great continental rivers. The Continental Divide, separating the waters of the Atlantic from those of the Pacific, crosses the park plateau from Southeast to Northwest. On both sides of this divide lie several large bodies of water, which form so marked a feature in the scenery of the plateau that the region has been designated the lake country of the park. Yellowstone Lake, the largest lake in North America at this altitude (7,740 feet) and one of the largest in the world at so high an elevation above sea level, presents a superficial area of 139 square miles, and a shore line of nearly 100 miles. From measurements made near the outlet of the lake in September, 1886, the driest period of the year, the discharge was found to be 1,525 cubic feet per second, or about 34,000,000 imperial gallons per hour.

*Extracts from a report by Mr. Hague.