

the intensities of all orders diminish, but those of higher order much more than those of lower. The effect was foreseen by the Dutch physicist Debye, and the amount of it was actually calculated by him on certain assumptions. I have found experimental results in general accord with this formula. In passing it may be mentioned that as the crystal expands with rise of tem-

perature the spacing between the planes increases and the angles of reflection diminish, an effect readily observed in practice.

This part of the work gives information respecting the movements of the atoms from their places, the preceding respecting their average positions. It is sure, like the other, to be of much assistance in the inquiry

as to atomic and molecular forces, and as to the degree to which thermal energy is locked up in the atomic motions.

This brief sketch of the progress of the new science in certain directions is all that is possible in the short time of a single lecture; but it may serve to give some idea of its fascination and possibilities.

The Geology of the Yellowstone National Park

A Striking Topographical Structure and a Complete Geological Problem

By Carl Hawes Butman

IN the year 1872 Congress set aside a tract of land in the the northwest corner of Wyoming for the benefit of mankind and the preservation of the natural wonders of the country. This became known as the Yellowstone National Park, and was the first tract thus set aside for this purpose. It includes some 3,340 square miles, but in relation to the whole of Wyoming it appears on the map as a misplaced postage stamp, which, like many stamps, overlaps the letter by extending a little way into both Montana and Idaho. Following the precedent thus established 40 years ago, Congress has since established eleven smaller parks in various places where the public might find recreation and where the wonders of nature therein might be preserved from desecration.

From the point of view of the geologist Yellowstone Park is in a way unique. Its central plateau, with the adjacent mountains, presents a sharply defined region contrasting with the remainder of the northern Rocky Mountains; a striking piece of topographical structure and a complete geological problem. The central portion consists of a broad, elevated irregular plateau of volcanic origin, some 40 miles square, extending between 7,000 and 8,500 feet above sea level, and surrounded on the north, northwest, south, east and northeast by mountain ranges, the peaks and highest points of which extend upward like a gigantic wall for 2,000 to 4,000 feet more.

Just south of the park the Tetons, the highest and grandest peaks in the northern Rocky Mountains, stand out prominently, but only the outlying spurs come within the limits of the park proper. These mountains are composed mostly of coarse crystalline gneisses and schists, probably of Archean age, abutted on the northern spurs by upturned Paleozoic strata.

On the eastern edge of the park the Absaroka Range stretches from the north to the south, where it connects with the northern end of the Wind River Range. For more than 80 miles this range presents a bold unbroken barrier along the eastern side of the park, its highest peaks towering 10,000 or 11,000 feet aloft.

At the northeastern corner of the park an irregular mass of mountains joins the Absarokas with the Snowy Range, which forms the northern boundary of the reservation, with its rough, snow-covered elevations. The rocks of the southern slopes of the Snowy Range, which extend into the park, are composed mainly of granite, gneiss and schist, while their sedimentary beds belong to the pre-Cambrian series.

Enclosing the park on the northwestern corner lies the Gallatin Range, separated from the Snowy Range on the east by the valley of the Yellowstone River. It is a beautiful mountain range, presenting diversified forms, as well as varied geological problems. Its crowning glory, Electric Peak, 11,100 feet in height, and incidentally the tallest peak in this region, gets its name from the magnetic disturbances discovered by the first explorers to carry surveying instruments up its slopes. An important part of the Gallatin Range is formed of Archean gneisses covered with a series of limestone, sandstone, and shale beds, both of the Paleozoic and Mesozoic eras, representing Cambrian, Silurian, Devonian, Carboniferous, Triassic, Jurassic and Cretaceous periods. Large masses of intrusive rocks, closely allied with the sedimentary beds, have taken an important part in creating the present structural features of this range. They are of the andesitic type and cover a broad range of mineral composition, including pyroxene, hornblende, and hornblende-mica.

The general region of the park was at one time subjected to severe dynamic action which affected all the ranges at about the same time, and probably occurred during the latter part of the Cretaceous period, although the work of mountain building seems to have continued into the Middle Tertiary period. During the latter period the site of the park was torn up by volcanic action, which continued to a lesser extent through the Pliocene and into the Quaternary periods. All such action has long since ceased, but the volcanic rocks remain, offering much interesting information. They comprise three groups which succeeded each other: andesites with basalts, rhyolites, and basalts. Probably the andesitic eruptions continued for the greatest period of time, since

there are evidences of plant life buried under 2,000 feet of volcanic material.

In Tertiary times there is supposed to have existed a large volcano, named the Sherman, and of which Mount Washburn is a more recent crater, the bursting forth of which caused the destruction of the original crater of the older volcano. Recent eruptions and erosions have so destroyed the early volcanic flows that it is difficult to identify the ancient andesitic lava which was afterwards submerged by immense quantities of rhyolite to a thickness of nearly 8,500 feet. In fact, nothing else remains to be seen but rhyolitic rock, except the mineral spring deposits, and the remains of the early crater rim on Mount Washburn. Another source of the rhyolite flows is supposed to have been Mount Sheridan in the southern part of the reservation, which towers to a height of 10,385 feet and offers a remarkable view of the volcanic region stretching across the park from east to west. The deep gorges of the Yellowstone, Gibbon and Madison Rivers have not worn through this tremendous thickness of rock, and only in the Grand Canyon of the Yellowstone are the ancient andesitic breccias exposed beneath the rhyolites, while nowhere are the sedimentary beds revealed. The central plateau includes the finest examples of structural forms, crystallization, and mode of origin of acidic lavas, varying from a nearly holocrystalline rock to pure volcanic glass, that can be found in the world.

Following the rhyolite eruption there came a period of faulting and displacement, succeeded by eruptions of basalt, which, however, deposited but a thin layer over the rhyolite and did practically nothing to change the physical aspect of the country. The glacial action which soon occurred, nevertheless, carved out the early drainage channels, cut gorges into the rhyolite lava, and shaped the two volcanoes into their present form. Traces of the ancient glaciers are to be found nearly everywhere, especially in the several mountain ranges, while in the Tetons there exist to-day glaciers characteristic of the ancient grand system which extended over the entire plateau. Erosion continued the work of the glaciers in remodeling the park surface, and this action has carved, since that time, the deep gorges of the Madison, Gibbon and Yellowstone rivers, veritable canyons, cut to a depth of nearly 1,500 feet and several miles in length.

Much evidence of the great glacial action is still at hand; the valley of the lower Yellowstone River is strewn with rocks brought by the glacier from both the east and west borders of the park. One example of the tremendous force of the ice floes of the early times is a great granite boulder (about 20 feet in diameter) brought down and deposited on the brink of the Grand Canyon. It is completely isolated from its fellows and quite 30 miles from where it must have been transported. The glacial action took place since the travertine deposits of the hot springs were formed. This is shown especially at Terrace Mountain near the Mammoth Hot Springs, where the travertine, covering the rhyolite plateau, is strewn with glacial boulders brought from the Gallatin Range some 15 miles away, indicating that the travertine is older than the glacier.

Probably the most interesting feature of the park today is the series of hot-water fountains, or geysers, which occur in three principle localities: Norris, Lower and Upper Basins, and include 16, 23, and 45 geysers respectively. The first group is located on the Gibbon Canyon Road about 20 miles south of the Mammoth Hot Springs. The second, about 20 miles farther to the south near the Fountain Hotel, is 7,240 feet in altitude, and largest of the three basins, but its individual geysers are scattered over a considerable area and not as available for inspection. The Upper Basin offers the most interesting and largest fountains. The Giant Geyser, which plays every seven or twelve days for about an hour, is the largest of the park geysers since the Excelsior of the Lower Basin ceased to play in 1888. It shoots a stream of hot-water and steam to a height of between 200 and 250 feet. Another famous geyser of this basin is Old Faithful, situated in the southernmost part at an altitude of 7,300 feet. This geyser has the reputation of maintaining a regular schedule as it plays every 60 or 75

minutes for a period of about 4 minutes, shooting its water column aloft for 125 or more feet, and has kept to its schedule since its discovery in 1870. One geologist has estimated its flow at 3,000 barrels per eruption.

Although the park's volcanoes are extinct the steam fountains which still exist are dependent upon the heated rocks and gases far below the surface, which raise the temperature of the percolating surface waters under great pressure and cause them to return to the surface with tremendous energy, often bursting out in fountains of hot-water and steam. Other theories as to the origin of geysers have been advanced—that they are caused by chemical action or burning coal—but of late scientists have shown that geysers and hot-water springs are only found in regions where volcanic rock abounds, and the general conclusion points out that the steam source is the still hot lava deep within the earth.

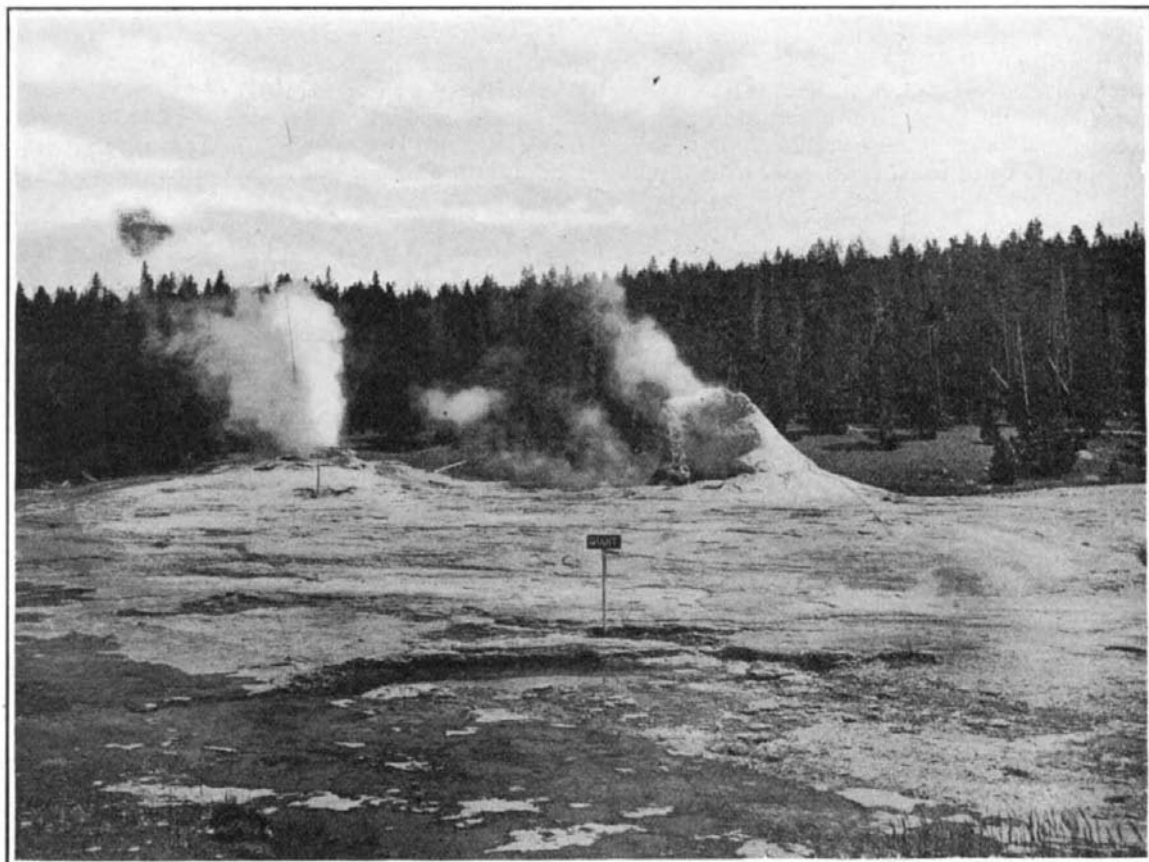
The ascending steam and hot-water have caused great geological changes in the surface rocks through which they have passed, as may be seen at many points in the park, especially in the Grand Canyon of the Yellowstone, where the walls are colored for three miles below the Lower Falls by this action. Fully 1,000 feet of the wall, from the brink to the water below, is decomposed rhyolite varying in hue through orange, red, purple and yellow. Here, too, the ancient steam vents may be described; while at the bottom of the canyon there are steam vents, hot springs and fumaroles which are still active.

Besides enabling the scientist to study the old vents and the discoloration of the walls, the Grand Canyon offers a fine example of erosion conducted on an immense scale within recent geological times, and its course was obviously determined by the easily eroded, decomposed rocks caused by the ascending steam and hot-water mentioned above. The two falls of the Yellowstone offer another feature of interest to the student, since they present a graphic example of the wearing effect of water upon the rocky walls and bed. The Lower Falls are the larger, being 308 feet in sheer drop.

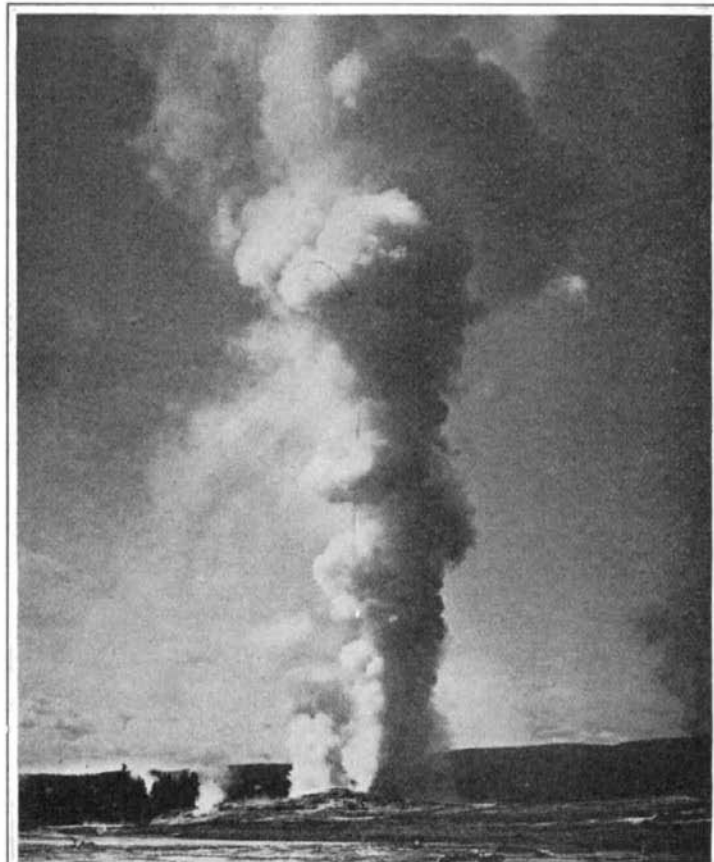
The Mammoth Hot Springs are located 4 miles south of the northern park entrance at Gardiner, and here also is situated the hotel of that name together with the army post. Southwest of the hotel is Terrace Mountain, an outlying ridge of the rhyolite plateau, which is covered with thick beds of travertine, deposited by the hot-water in the form of terraces from which the mountain derives its name. The deposits of the hot springs at this place are far different from those upon the plateau. Here they are nearly pure travertine, with traces of silica—analyses indicate about 97 per cent calcium carbonate, while on the plateau the greater part of the deposits are of siliceous sinter, called "geyserite." This variation is on account of the fact that the Mammoth Springs are formed by steam coming up from far below through the water of the Mesozoic strata, the Cretaceous limestones furnishing the lime held in solution and deposited on the surface as travertine; while the mineral constituents of the plateau waters are derived mainly from highly acidic lavas carrying only a small portion of lime.

The terraces of the Mammoth Hot Springs present the appearance of banks of ice and snow with irregular basins of water in their glimmering "stepped" terraces. Among the important ones are Minerva, Cleopatra, Hymen, Pulpit, Jupiter, and Mound Terraces, while the springs which flow into and over them are named Jupiter, Diana, Palette, Naiad and others. The coloring of the spring waters here is marvelous in its harmony and brilliant tints, and is due to Algae, which grow in hot-water up to a temperature of about 185 deg. Fahr. Many of the springs present the appearance of boiling caldrons of water, although this is not the case, the bubbles being formed by escaping carbonic-acid gas.

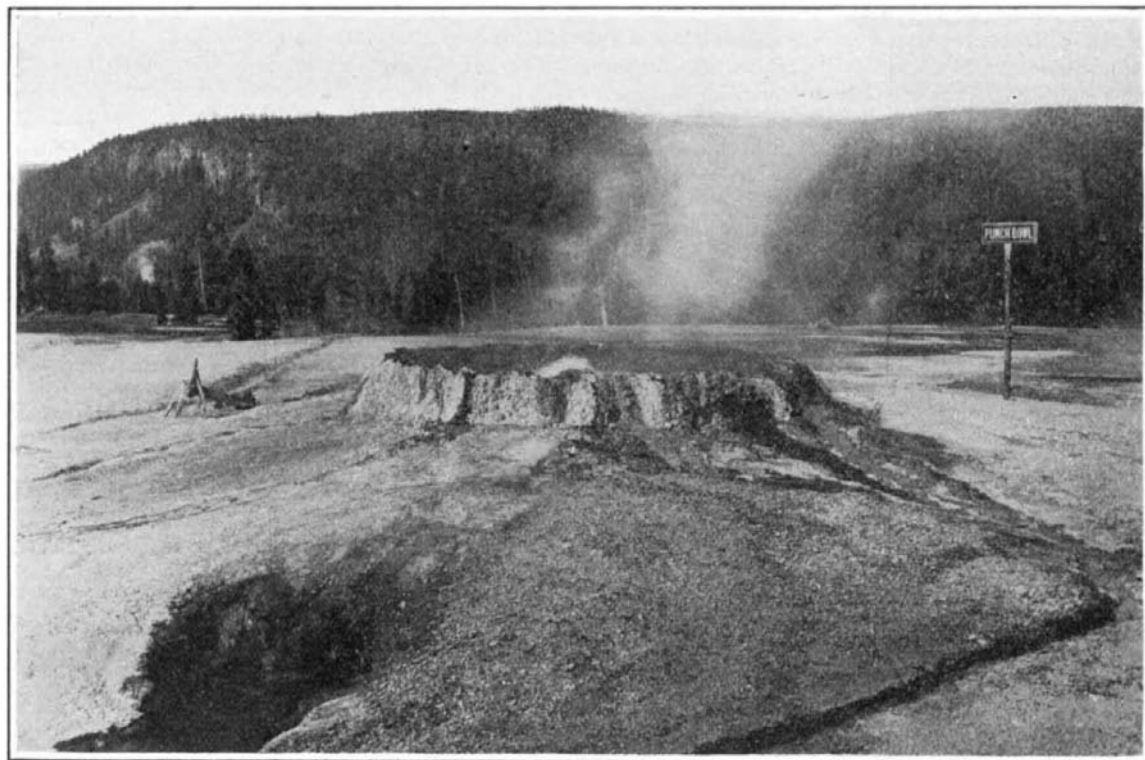
Yellowstone Park, with its many geological formations, its ancient volcanoes, lava flows, hot springs, and geysers, presents a wonderful natural laboratory for the geologist, as well as the chemist. Its formation dates back to that of the central table land of the continent, and yet changes are still going on within its limits, though not as actively as heretofore, which make it an ever interesting problem for the scientist.



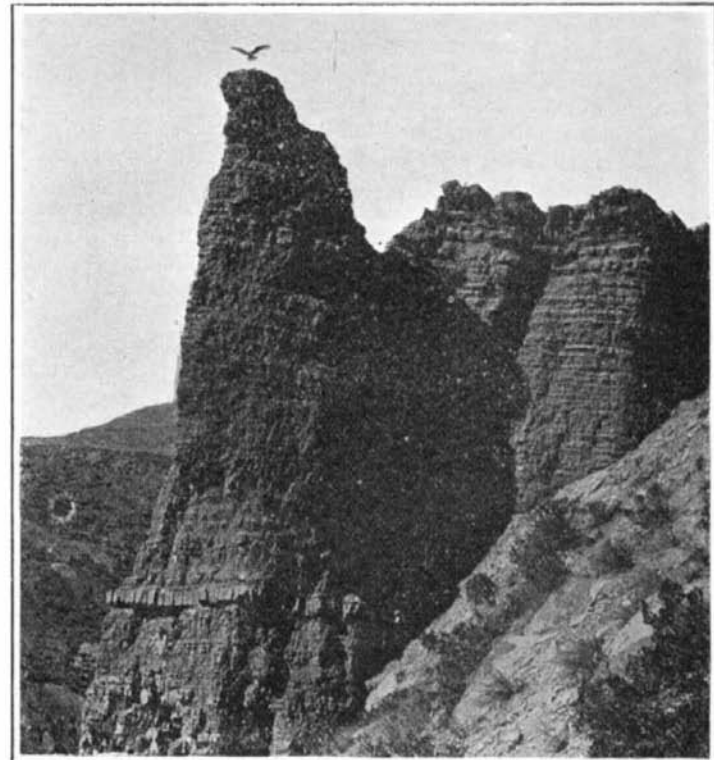
Cone of the Giant Geyser, as it appears when not playing.



The Giant Geyser, the largest geyser in the park.



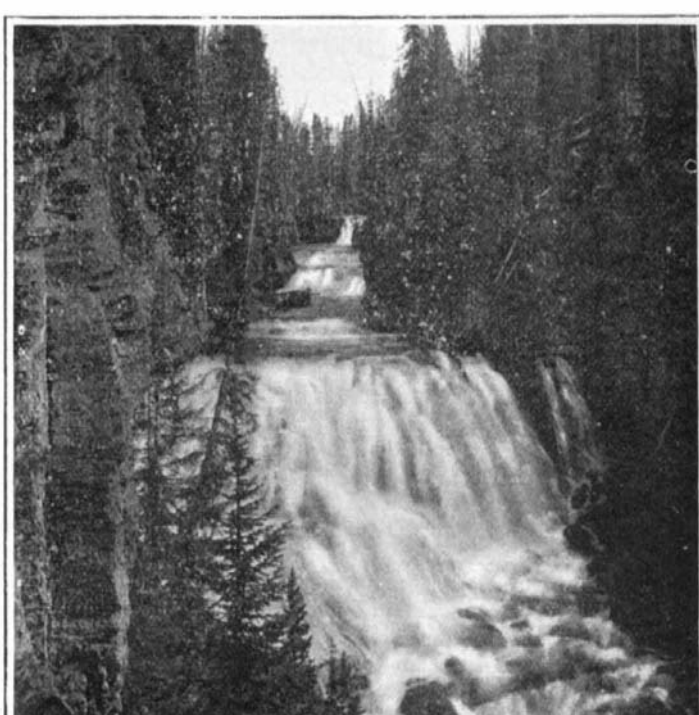
The Punch Bowl, located northwest of the Upper Geyser Basin.



Eagle Rest Rock, near Gardiner, the northern entrance.

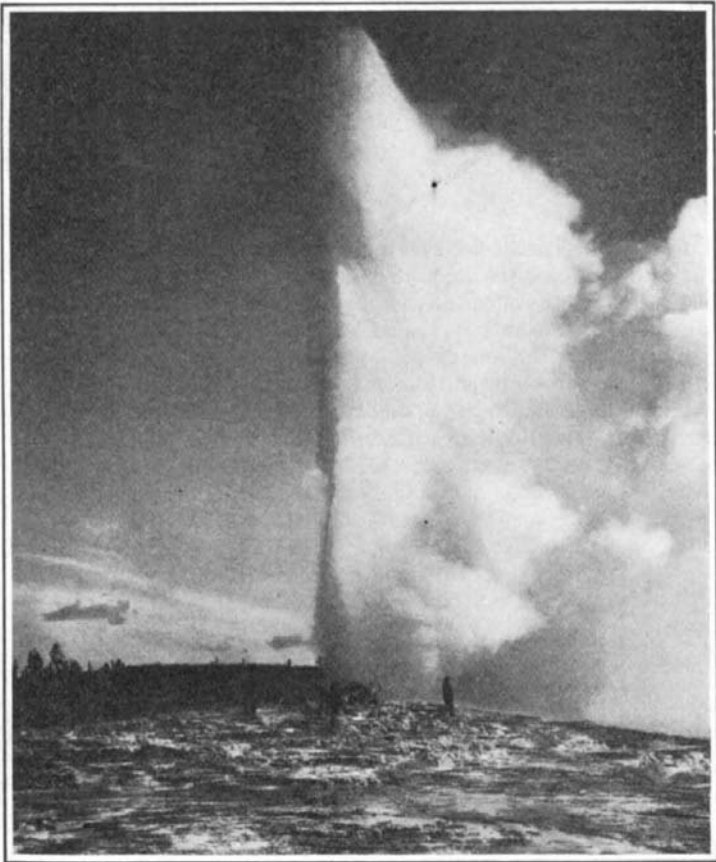


Washburn Hot Springs, on trail from the Grand Canyon to Tower Falls Station.



The Keppler Cascades, near Two Ocean Ponds.

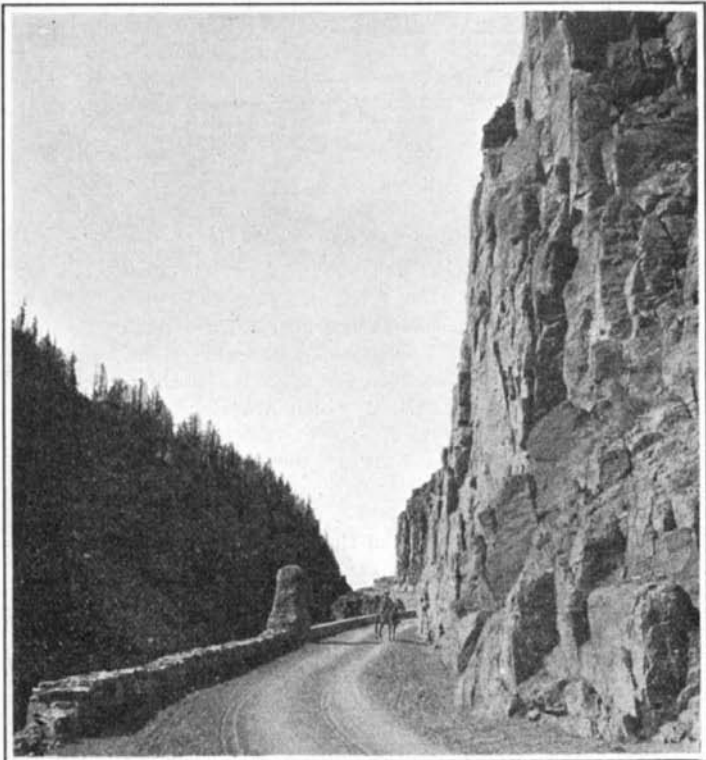
THE GEOLOGY OF THE YELL



The famous "Old Faithful" Geyser.



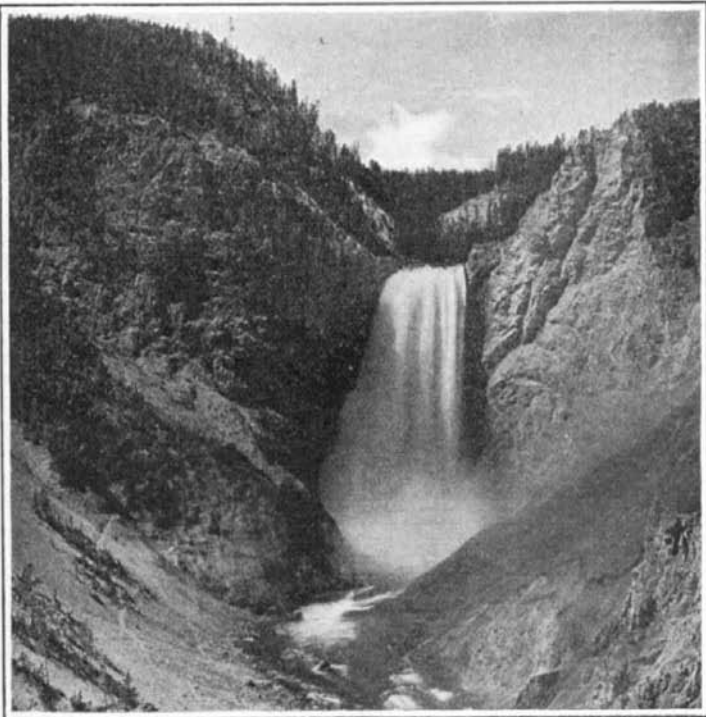
Looking up the Grand Canyon from Inspiration Point



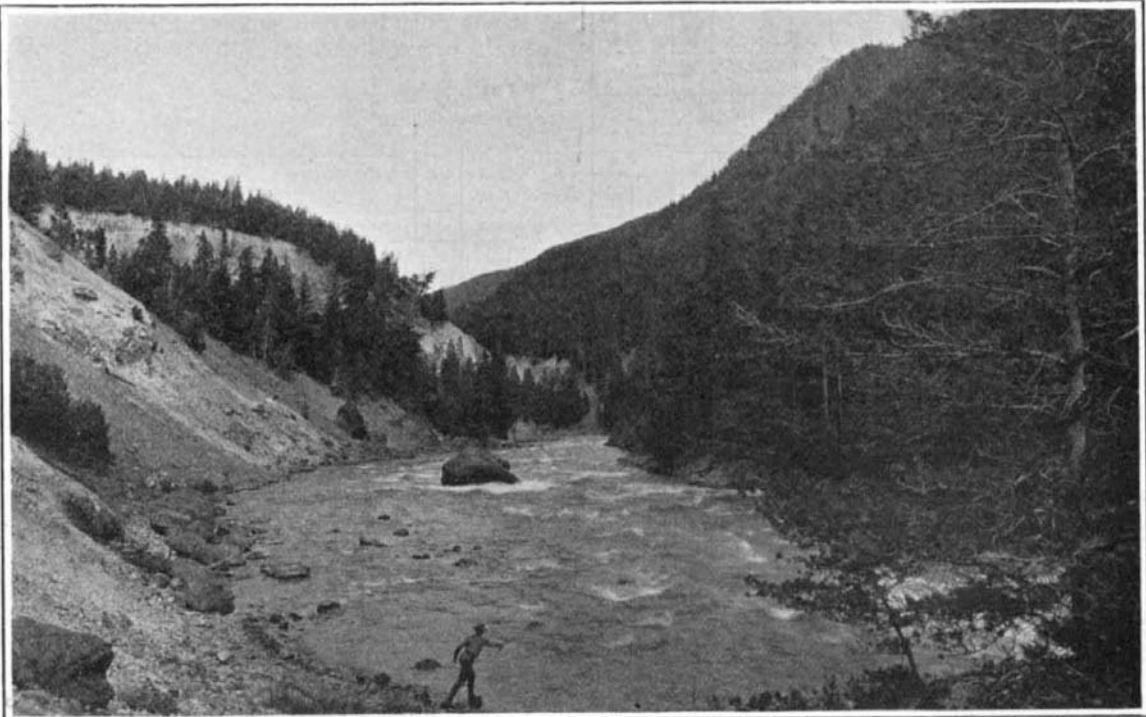
The Golden Gate, Swan Lake Basin.



The road along the Continental Divide.



The Great Falls of the Yellowstone.



A fishing hole on the Yellowstone River.

OWSTONE NATIONAL PARK