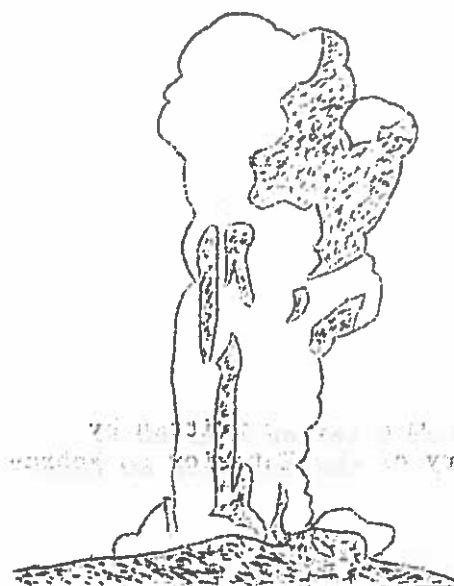




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The purpose of this publication is to provide scientific and historical data for the use of Park personnel engaged in interpretive activities.

Issues will appear at random; depending upon availability of suitable material, and employees are urged to contribute articles.

The Park historian will serve as editor. Contributions or inquiries concerning published material should be addressed to him.

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The following is an excerpt from a letter written by Ferdinand V. Hayden to the Secretary of the Interior on February 21, 1878:

"I beg permission to state here, that, so far as I know I originated the idea of the park [Yellowstone], prepared the maps designating the boundaries, and in connection with Hon. W. H. Clagett, then Delegate from Montana Territory, wrote the law as it now stands. During the pending of the bill, every effort was made by myself and other members of the survey to remove all objection to the bill, and the labor was constant and great. It is now acknowledged all over the civilized world that the existence of the National Park, by law, is due solely to my exertions during the sessions of 1871 and 1872. The growing opposition to the withdrawal of any portion of the public domain for any purpose, however laudable, would undoubtedly have prevented the success of this bill at any subsequent session."

[45th Congress, 2nd Session: House. Executive Document No. 75] .

A BIOGRAPHICAL SKETCH

Ferdinand Vandiveer Hayden was born at Westfield, in southwestern Massachusetts, on September 7, 1829. His father died when he was ten years old, and the remainder of his boyhood was spent with an uncle in Ohio. He began teaching in country schools at the age of sixteen, and entered Berlin College two years later. After graduation, in 1850, he undertook the study of medicine -- gaining a sound education in geology and paleontology while earning his degree of M. D.

Upon leaving the Albany Medical School in 1853, he was induced to spend a summer collecting tertiary and cretaceous fossils in the White River Bad Lands near Fort Pierre, Dakota Territory. That adventuring turned Hayden's interest irrevocably toward geology. With financing supplied by individuals, organizations and the federal government, he continued the field work which was his apprenticeship as a scientific explorer.

Hayden passed the Civil War years as a surgeon in the Union Army, ending his service in 1865 with the rank of brevet lieutenant-colonel. During the years immediately following that conflict, he was elected a professor of mineralogy and geology in the medical department of the University of Pennsylvania, but that wedding of his two fields of interest did not last.

Hayden was able to obtain \$5,000 of unexpended federal funds in 1867, conducting a geological survey of the new State of Nebraska on that modest budget. The Hayden Survey thus launched was financed thereafter by a combination of appropriated funds and contributions from private sources. When the fledgling organization passed under the control of the Secretary of the Interior in 1869, it also received a formal title, becoming "The United States Geological Survey of the Territories".

The Washburn-Langford-Doane Expedition of 1870 created a public interest in the Yellowstone region, and Hayden was able to capitalize upon that interest by persuading Congress to grant \$40,000 for a scientific exploration of its wonders. The work of the Hayden Survey during the summer of 1871 was probably of crucial importance in obtaining the passage of the Act creating

Yellowstone National Park on March 1, 1872.

The Hayden Survey accomplished important work in Yellowstone Park and the surrounding area in 1872 and 1878 before the organization was merged with the surveys of King and Powell to form the United States Geological Survey (1879). It was been claimed that Hayden "worked so rapidly and published so quickly that shoddiness became the hallmark of his reports"; yet, overall, he was essentially correct in his geological interpretation of a staggering amount of the unknown West.

Hayden continued as a geologist with the United States Geological Survey until 1886, when failing health caused his retirement. He died the following year -- a man described by Chittenden as "intensely nervous, frequently impulsive, but ever generous . . . his honesty and integrity undoubted".

Dr. Hayden, who held a degree of LL.D. from the University of Rochester and the University of Pennsylvania, was a member of 17 scientific societies in this country and a corresponding member of 70 foreign societies. His published titles exceed 158. Truly, he was a man whose work for his government, and for science, was a labor of love.

ALH

One of the members of the Hayden Survey party of 1872 was Albert C. Peale, a twenty-three year old medical doctor who was serving as a geologist. He was a grandson of the famous artist, Charles Willson Peale, and his cultured background appears to have increased his perception of the fine points of English usage, a la frontier. On a back leaf of his 1872 diary is this terse and understanding comment:

"An ascending scale

You bet

You bet your life

You bet your sweet life

You bet your d.....d life."

THE 1959 HEBGEN LAKE EARTHQUAKE ALTERS YELLOWSTONE'S HOT SPRINGS

George D. Marler*

INTRODUCTION

When the last embers of August 17, 1959, had faded, to all appearances darkness had settled on just another day of bustle and ado in Yellowstone's busy tourist season. Except for nocturnal pleasure seekers most park visitors had ensconced themselves for the night. Little did any one imagine that the day would be brought to a close by such earth-jarring experiences as struck at 11:37 p.m. Stresses, which had been building up possibly for hundreds of years, reached a critical point in buckling rock formations. Then, suddenly, and without warning, the rocks snapped, sending out vibrations that were felt over an area of 550,000 square miles. Once more tremors in the earth's crustal rocks had reached a magnitude large enough to be classed as a major earthquake. Readings taken at Pasadena showed an intensity of 7.1.

The epicenter for this earthquake was just west of Yellowstone National Park. It was in this area that the greatest concussions and destruction took place. Cliff faces were suddenly sheared, sending slides and cascading boulders into canyons. Avalanching occurred, not only near the Hebgen Lake area, but in directions extending outward over great radii. Great rifts in and displacements of surface structures suddenly appeared. Fortunately for Yellowstone visitors, the tons of rock that hurtled onto and over Park roads took place at nearly midnight and not 11:37 a.m., when bumper-to-bumper travel is common.

EARLY CHECK OF THERMAL SPRINGS

What would seem to be the most important effects of the earthquake in Yellowstone Park were the changes in hot-spring behavior. The springs along the Firehole River drainage were particularly affected, and, to a lesser extent, those on the Gibbon River drainage. The hot springs in eastern sections of the Park had very little change in function.

After experiencing the severe jarrings on the night of the 17th, I was apprehensive of what I considered might be undesirable effects upon the geysers. Had complicated mechanisms and

* The information appearing here is a revision of an article published in Billings Geological Society (Proceedings of the 11th Annual Field Conference), September 7-10, 1960, pp. 61-66.

delicate balances that Nature had laboriously perfected over the centuries been adversely altered? As soon as daylight of the 18th made reconnaissance possible, I began a hurried survey of all basins along the Firehole. Before the day ended, cursory ramblings evolved into critical inspections of all springs, a procedure which continued for several days.

My fears of lessened geyser activity were not borne out by the events either of the 18th or of succeeding days. Instead of adversely disrupted geyser behavior, there was a noticeable increase in thermal energy. While a few geysers did not seem to be particularly affected, many of the larger and better known ones were playing for shorter intervals. Geysers, which had been dormant during all of the relatively long period I had been in the basins, were erupting. Many cyclic geysers, which were in dormant cycles at the time of the quake, had been stimulated into active phases. Of the big geysers that had shown a degree of regularity in pattern of play prior to the earthquake, only one, Grand, seemed to be affected adversely.

In addition to a general increase in activity of geysers with predictable patterns of play, other unexpected results of the big shock were: (1) the general murkiness of most springs; (2) their ebbd condition; and (3) the compelling evidence that scores of springs, with no record of previous geyser functioning, had erupted immediately following the initial jarring. There is little doubt but that the earthquake acted as a trigger to start eruption of hundreds of thermal springs, creating a scene without precedent in Yellowstone Park. Hydrologic conditions all at once became either so favorable or unfavorable, depending upon the point of view, that underground water, like stirred ants, shot into the air through every possible escape avenue. It was as if a giant hand had suddenly applied pressure to underground hot-spring structures, literally forcing water from their conduits in a manner comparable to the squeezing of a sponge.

For a proper perspective of the scope and degree of earthquake effects upon the thermal springs, some of the findings of the initial surveys will be presented. When it became evident that the status quo had been almost completely disrupted, I visited most of the springs along the Firehole River, the region of Yellowstone's most famous geysers and hot springs. My object was to determine the state of the water in springs and particular observation was directed toward evidence of eruptive activity.

The results of the findings are as follows:

(1) There were pertinent data to the effect that before daylight of the 18th, 298 springs and geysers had erupted.

(2) Of this number 160 eruptions were of springs with no records extant of ever having played. Some of these previously obscure springs had erupted very powerfully. Large pieces of fragmental sinter were strewn for a distance about their craters. That night 160 new geysers were

added to the Firehole Geyser Basins' repertoire of erupting fountains.

(3) The beautifully colored limpid water of hundreds of springs had changed as if by magic to hues ranging from light gray to muddy. I counted 590 murky springs. After the first few days, most began to clear. Months later a few were still turbid. Some of the geysers ejected muddy water.

(4) The water table was considerably lowered, this no doubt being due to the tremendous discharge following the quake. On the morning of the 18th the water had ebbed from a few inches to several feet in 363 springs. There was a noticeable increase in activity in 333 others. Only 57 seemed to be normal, but most of these underwent alteration in function during the weeks following the August 17 incident.

By the end of the year I could point to but nine springs that had showed no changed attributable to the earthquake. It can safely be said that a greater amount of change took place in the Firehole Geyser Basins during the night of August 17, 1959, than during all of the 89 years since their discovery.

CAUSE OF MURKINESS

The causes of earthquake-induced turbidity in the hot springs are perhaps manifold and complex. Without doubt one factor producing murkiness was the stirring up of unconsolidated sediments by the sudden uplift and surging of water in scores of hitherto quiescent springs. The hydrous silicate, deposited as geyserite about the orifices of the hot springs and wherever the water courses, is also precipitated as discrete particles in the water of the crater. These comminuted particles settle on the sides of the crater, sometimes in great thicknesses, as in Cyclops and Turquoise Pools, and also wherever descending currents might carry them. Sudden surging or eruption of such a quiescent spring would act like an eggbeater, and leave its water in a muddy state. That this was probably the most important cause of murkiness in numerous springs is indicated by the rate at which they cleared following cessation of turbulence. The much slower clearing in others resulted from continuing agitation. Slowness in clearing might also be due to the presence of disturbed unconsolidated sediments at great depth. A longer time would be required for currents and convection to establish pre-eruption equilibrium in these sediments.

CAUSE OF EARTHQUAKE-STIMULATED ACTIVITY

Had the earthquake not occurred at night, a better idea might

have been gained as to why so many normally quiescent springs erupted, apparently contemporaneously with, or immediately following the initial tremors. It was not at all certain that the ejected water in many instances was at or above the boiling point. It was obvious that the waters in the craters of a number of springs that had erupted during the night was considerably below the boiling point the morning of the 18th. In the Firehole Lake area the slumping could have produced sufficient pressure to have caused the discharge of most of the springs that had erupted during the night.

The fact that springs of quiescence and relatively low temperature before the earthquake showed greatly increased temperature and continued eruptive activity is positive evidence of a sudden increase in thermal energy arising from some source. This could have been brought about in a number of ways. Gases and fluids, issuing from fissures or a fault connected to the source of magmatic energy, might be given a sudden impetus of movement by fresh fracturing, thus making more ready ascension possible. It would also be probably that steam, resident in surficial structure, but normally impeded in egress by overlying rocks and clay, was suddenly made available. That such a heat potential exists is based on borings which have been made in many tracts of hot ground, particularly those in California and Italy. Should this be the principal source of present post-quake increase in thermal energy, it would not be inconceivable that the overall temperature in the geyser basins might, as a result of this heat dissipation, decline below pre-quake conditions.

MARKED CHANGES

The most important changes in hot-spring behavior during the first few days following the earthquake were in the Lower Geyser Basin. In this area a greater proportion of the springs had ebbed and had become murky. In the Fountain Group major geysers Morning, Fountain and Clepsydra, were playing in concert. Such activity was without precedent. These three geysers are connected underground. Their previous activity in recent years had been an interesting chain action. Morning, one of the most spectacular geysers in the Park, would erupt for about an hour. Following its activity, Clepsydra would play for a duration of 3 to 6 hours, to be followed by Fountain which would erupt for nearly an hour. It was a tremendous surprise to see them all playing simultaneously. Clepsydra, which erupts from four vents, has played continuously since the quake, until the spring of 1963. At this time 1 vent stopped playing and the remaining three cease playing occasionally for 2 or 3 minute intervals.

It was determined by direct observation that the above geysers were triggered into activity by the first big shock. Familiarity with the progressive changes during and following most geyser functioning confirmed the speculation that the great majority of the geysers, as

they did the Fountain Group, began erupting nearly simultaneously, and as a result of the initial jarrings. What a spectacle would have been presented had it happened during daylight hours! From hundreds of craters water would have been seen rocketing in the air. Yellowstone's geysers dying out? You should have been in the Park the night of August 17, 1959, and during all succeeding days.

To the west of the Fountain Group several new geysers have been erupting periodically since the quake. One, near Geyser Pool, was very impressive for several weeks, playing over 100 feet high. It was named Earthquake Geyser. A steam explosion near Earthquake, and along the same rift from which it played, brought about cessation of major eruptive activity.

On the Firehole Lake loop road great changes took place. Crisscrossing cracks and breaks traversed the whole area around Firehole and Black Warrior Lakes. Measurements made later indicated that were these breaks in a straight line, it would be 9,072 feet long. Nearby Pink Cone Geyser had been playing 2 to 3 times each week. Following the earthquake it erupted several times each day. It is still more active than before the quake. The most important geyser on the loop road, the Great Fountain had been playing about every 12 hours. Since August 17 it has almost doubled in frequency. An interval under 4 hours has been checked. Its pre-eruption symptoms were greatly altered. It is now erupting about every 8 hours.

Following the earthquake the great majority of the geysers in the Upper Basin began playing at shorter intervals. Castle, Grotto, Oblong and Daisy have been erupting almost twice as frequently. In early 1960 Daisy's intervals were lengthened, not due to waning energy, but because of a partial shift of the thermal energy to a spring with which Daisy is connected subterraneously. The activity of this spring, Bonita, eventually brought about the dormancy of Daisy.

Most of the springs on Geyser Hill erupted the night of the quake. The Giantess played continuously for over 100 hours. The longest previously recorded duration was 36 hours. Cascade and Economic Geysers, which had been dormant for over 40 years, were rejuvenated by the earthquake. A number of cyclic geysers, which were dormant previous to the quake, were stimulated into cyclic, eruptive activity.

The most spectacular change in geyser activity occurred in Biscuit Basin. Sapphire Pool, a true geyser, had been erupting from 3 to 6 feet high about every 15 to 20

minutes. Following the quake, it boiled steadily and violently 6 to 8 feet high until September 5. On this date it blossomed into one of the most spectacular geysers in Yellowstone. Its eruptions recurred about every 2 hours. The bursts of water were from 100 to 150 feet high and fully 200 feet broad. After a short lapse back into steady surging, it again became eruptive on September 29. There was no further dormancy until January. During the first 6 months of 1960, Sapphire has had occasional dormant periods, but periods of activity have far exceeded quiet ones. The intervals, as well as the magnitude of the eruptions vary considerably in length.

It was determined by careful estimates that some of the bursts from Sapphire discharged fully 50 tons of water. The tremendous discharge that has been going on since it became a major geyser has resulted in great destruction to existing formations. The geyserite about Sapphire's crater and in the drainage channels looks as if a bulldozer had been at work. Hundreds of tons of sinter have been washed into the Firehole River. Some of the eruptions tear out sections of internal structure. If this internal destruction does not destroy essential mechanism, Sapphire may eventually stabilize into one of Yellowstone's most interesting geysers.

During the first 10 days following the earthquake Old Faithful showed little evidence of any change. From August 17 until September 1 its average interval lengthened from 61.8 to 62.1 minutes. From then until January there was a slow but gradual lengthening, the average reaching 66.67 minutes. Since January there has been a slow decrease in average time. The longer average in January 1960 was not due to the cold of winter (Marler, 1954, p. 38-54).

Practically all of the major quiescent springs underwent profound change. The immediate effect of the earthquake was the appearance of murky water with progressive ebbing. Some, such as Celestine, Silex, and Leather, after a few days of ebbing, became violently active, ejecting muddy water. After several weeks, a few of these lovely quiescent springs returned to pre-earthquake conditions, but in the case of the majority quake alterations persist.

Of the big geysers that were showing a degree of frequency and regularity before the earthquake, the Grand showed the most adverse effect. Before the quake it was active about every 8 to 10 hours. Following a quake-induced eruption, it became dormant until February 19. Following this rejuvenation Grand has been showing increasing evidence of recovery to its pre-quake state.

EARTHQUAKES IN THE FUTURE

The 1959 Hebgen Lake earthquake is not an isolated incident. Since Yellowstone became a National Park in 1872 a number of earthquakes have been recorded. Many of these quakes, all small, have had their epicenters in the rhyolite mass forming the central plateau. Seismic records indicate that on an average of about once in every 10 years a strong earthquake is registered in the states adjoining Yellowstone (Fischer, 1960, p. 24). The last major earthquake along the Hebgen Lake fault system previous to August 17, 1959, was November 23, 1947. Neither the 1947 earthquake, nor any previous historic one, have been of sufficient intensity to produce attributable hydrothermal changes.

While man has no record of earthquakes in Yellowstone Park that are at all comparable to the one of 1959, not so with Nature. She keeps her own records, sometimes obscure and hypothetical, but, in general, physical evidence is of such a character that a story of past events is indelibly etched. Now that gigantic boulders are seen to have been broken from stony escarpments and cascaded into canyons, weathered rocks of similar size and shape are noted lying beside them, and at even greater distances from the cliffs. Through these lichen-covered boulders Nature would seem to say of the recent incident: "See, I did it again."

Not only have big earthquake-caused rockslides occurred in Yellowstone Park during earlier periods, but the hot springs have also been subjected to major alterations. Earthquakes have played an important role in the genesis of some geysers. Many of the old fractures in the geyserite, through which some of the hot springs issue, were in all probability caused by an earthquake. When discussing the characteristics of Old Faithful to thousands of Park visitors, the writer has frequently pointed out that Old Faithful "might have come into being as the result of an earthquake." The large crack which crosses the mound, and from which Old Faithful issues, gives substantial evidence to this surmise. In referring to an "intermediate spring", a direct precursor to Old Faithful, the writer has stated (Marler, 1954, p. 620): "In my opinion the intermediate spring, which built the terraces and interred the stumps, began to flow when some mechanical adjustment broke the geyserite shield, thereby tapping arteries that had been sealed off in their upper reaches." Radio-carbon dating of entombed tree sections on Old Faithful's mound indicate that the earthquake that split open the mound occurred from 500 to 700 years ago.

The record of the past would seem to offer indubitable evidence that major earthquakes will occur again in Yellowstone. Such occurrences are but the natural shiverings that accompany mountain-building and an ever-changing world. However, the forces that produced the tourist scare of August 1959 should be at rest for a relatively long period. Yellowstone should be one of the safest vacation areas on the continent. This fact, plus newly energized geysers and refreshed hot springs, make it an attraction without peer.

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"People can and do enjoy, and are attracted and inspired by, nature in her finer expressions. . . Creating such higher tastes is half the battle for preservation of the things of nature from which substantial satisfactions derive."

H. Raymond Gregg

[Excerpt from a paper presented at the Meeting of the International Union for the Protection of Nature, at Caracas, Venezuela, September 3-9, 1952].

THE GRASSHOPPER GLACIER

by

John M. Good

Grasshopper Glacier, near Cooke City, Montana, is a shrinking ice mass which probably has lost more than half its volume in the past 40 years. Scattered through it are the remains of many grasshoppers which were blown up into the mountains by strong west winds. The grasshoppers come from Nevada, Oregon, and possibly northern California. It is probably inaccurate to say that the grasshoppers fly over the glaciers; rather they are carried in air masses that sweep over the mountains. As velocity decreases along the mountain ridges, the grasshoppers fall to earth where they die. Those that fall on ice are preserved. The occurrence in Grasshopper Glacier is not unique as grasshopper remains are found in many glaciers of the Beartooth country.

This glacier and others of the Beartooth Mountains are quite small and are still shrinking. All are found on north and northeast facing slopes which offer maximum protection from the sun and at sites where snows, blowing off exposed slopes, are dumped in drifts of abnormal thickness by southwest winds. These glaciers are not remnants of Pinedale valley glaciers which originated in the Beartooth Range 10,000 years ago. That Pleistocene ice melted in prehistoric time during the altithermal period which cleared all Rocky Mountain cirques of ice. A "Little Ice Age" followed the altithermal, and existing Beartooth glaciers date from that time.

The major scientific interest in Beartooth glaciers is their importance as climatic indicators. Poised on the east front of the Rocky Mountains and far from other glacier bearing ranges, they are sensitive indicators of climatic changes in this part of our country. Grasshopper Glacier is particularly interesting because we can trace its history back to the 1890's through photographs.

Grasshopper Glacier is not in Yellowstone National Park, but rather in a wilderness section of the Custer National Forest, administered by the Forest Service.

The best way to reach the glacier is to drive through Cooke City, turning north on a dirt road before reaching the Cooke Ranger Station. About two miles up the road, park your car at an abandoned mine and hike up the jeep road to Goose Lake. The whole route is obvious on the Cooke City, Montana-Wyoming U.S.G.S. quadrangle.

STEAMBOAT GEYSER

by

George D. Marler

Like many of the geysers in the Park, Steamboat is characterized by having more than one type of an eruption. In its history it has shown extreme variations in thermal intensity. The typical, or most frequent type of activity occurs at intervals ranging from 2 to 3 minutes, jetting water from 15 to 25 feet. At times, however, there are more forceful eruptions when the intervals vary from 4 to 5 minutes and the height from 40 to 50 feet. This interesting geyser has still another type of an eruption - an eruption that rates it as the most powerful geyser in Yellowstone Park.

In the early morning hours of September 2, 1961, the rangers at Norris Geyser Basin were startled by earth-roaring noises resulting from the issuance of steam from Steamboat Geyser. The steam was rising fully 1000 feet. Investigation of this eruption disclosed that during the early stages water had been projected at an angle for a distance of several hundred feet. The trees were encrusted with grayish mud for a distance of over a thousand feet from the crater.

Records are indicative that on 4 previous occasions, 1878, 1882, 1902 and 1911, Steamboat had performed in a manner similar to the September 2, 1961 eruption. Following the 1961 eruption, Steamboat resumed its minor type of activity until August 27, 1962, when it again erupted violently. Following the August 27 eruption, it was known to erupt about once each month until early spring. Since March of 1963, it has been putting on a power display about three times each month. If these eruptions continue, Steamboat will become one of the most eagerly sought geysers in the Park by those who are interested in Yellowstone's hydrothermal wonders.

During a major eruption of Steamboat, the water is projected at an angle of about 45 degrees in a northeasterly direction. The apex of the arch is in excess of 300 feet. One eruption was measured to a height of 383 feet. The water phase of the eruption lasts for nearly half an hour and then gradually changes to steam. The steam phase lasts for several hours. During the early stages the roar of the escaping steam sounds somewhat like a jet engine.

As yet the amount of water discharged during an eruption has not been determined. However, for a geyser, it is tremendous, as a river of water pours down the hillside during an eruption. The water of the eruption in cascading down the hillside is effecting a great erosion. In the early stages of the eruption, the issuing water is clear, but it soon becomes muddy by the dirt and rocks that are washed into the crater. The eroded rocks that pour back into the crater are hurled high into the air by the force of the exploding water, necessitating that the spectator stay some distance from the scene.