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HOW OLD IS OLD FAITHFUL GEYSER?

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ABSTRACT. Since its discovery in 1870, students of Old Faithful geyser have postulated its age without taking into consideration numerous aspects of its mound, by which alone the geyser's age can reasonably be determined. Detailed study of the mound shows that much the greater portion of its bulk was built by hot springs in at least two stages, with a period of dormancy between long enough for the mound to be partially covered with pine forest. Old Faithful itself has played but a minor and recent role in mound's development; it has probably been playing for only a few centuries. Radiocarbon dating of silicified wood found embedded in the mound supports this deduction.

INTRODUCTION

It is doubtful if there is any other natural feature in the world comparable to Old Faithful Geyser in fame and general interest about which so many misconceptions are entertained by the average person. Many of the erroneous ideas have resulted from a partial to complete distortion of facts by popular writers in newspapers and periodicals. There would seem to have been an undue effort to sensationalize, and this although a true delineation of the story of Old Faithful contains every element of the melodramatic.

By no means all the past and current misconceptions about Old Faithful have resulted from a distortion of assembled data; some have arisen from a lack of objective and scientific study of the problem. The amount of water discharged from Old Faithful is but one example. Early in the history of Old Faithful it was speculated that 100,000 gallons or more of water were discharged at each eruption. Some observers stated that "the discharge may be as great as 750,000 gallons an hour" (Cleland, 1916, p. 67). For nearly half a century these and similar high figures were given to park visitors with no basis in actual measurement. At the time (1925 to 1932) that Dr. E. T. Allen and Dr. Arthur L. Day, under the sponsorship of the Carnegie Institution, were making a scientific study of Yellowstone's hot springs, they questioned the accuracy of the high discharge figures they heard given by park personnel. In commenting, they state: "The discharge of Old Faithful has probably been more frequently estimated (never separately measured) than any other geyser in the Park. The figures commonly current in the past seem to the writers absurdly excessive" (1935, p. 183). To arrive at a reasonably correct answer, they requested M. C. Boyer, an experienced gauger of the U. S. Geological Survey, to undertake measurements. Mr. Boyer's measurements, made in August 1929, put the discharge at "from ten to twelve thousand gallons," a figure much reduced from the 100,000 gallons tourists were asked to swallow.

As to Old Faithful's age, the figures given were no less out of line with the facts. "In the endless variety of conditions in nature one need not wonder at the varying results. He should rather wonder that in a single instance nature has produced a combination of such perfection as is found in Old Faithful, which for thousands of years has performed its duty with the regularity of clock work" (Chittenden, 1924, p. 184). The reason for attributing great age to Old Faithful is more readily understood than the excessive figures for volume discharge. The age of a geyser, it had been assumed, was the time it would have taken that geyser at its present rate of deposition to build the mass of geyserite about its orifice.

It is well known that siliceous sinter is deposited very slowly. Allen and Day state: "Attempts to measure the rate at which siliceous sinter is deposited have all led to the conclusion that it must be very slow" (1935, p. 151). Over a nine months' period they tested "more than 50 springs." In the Upper Basin they found the rate of deposition to "vary greatly, from 0.1 to 2.7 mm" (1935, p. 153).

At this slow rate some of the large mounds, such as Old Faithful's, might have taken several thousand years to build. It has generally been assumed that the current hot spring has been in existence for the entire lifetime of the associated mound. Old Faithful's mound rises nearly 12 feet above its base and its perimeter is 615 feet; hence, at the rate given above, its age must be "thousands of years." The age of a mound, however, is not always a measure of the age of the hot spring now situated on the mound. This is particularly true of Old Faithful Geyser, as the following data show.

DESCRIPTION OF THE MOUND

A brief description of the mound is in order to give the reader a fuller appreciation of the change that has been and is taking place in the mound and the bearing this has on the age of the geyser. The mound has a circular appearance though both the basal and top sections are oblong; the top appears flattened. As measured by the Hayden Survey in 1878, at the base it was "145 x 215 feet, 20 x 54 feet at the top. It rises 11 feet and 11 inches above its base" (1878, pt. 2, p. 220). The long axis at the top lies generally east-west and is nearly at a right angle to that at the base.

The mound is decidedly terraced. On the north and northwest sides the terraces are very prominent. The east side shows much past and present erosion; here the sinter is scoured and broken. Deep erosion channels are working back into the cone on this side, one of them right at the base, and here stumps and tree sections are protruding through the eroded geyserite. The west side is covered with a beautiful fretwork of sinter deposited from Old Faithful's water. It is on this side only, in the direction of the prevailing winds, that Old Faithful is now adding mineral matter to its cone. The orifice is not centrally located on the cone; it is on the extreme western end of the flattened top. The mound, shaped like a huge shield, rests upon glacial gravels.

SOME OF THE WRITER'S OBSERVATIONS OF OLD FAITHFUL

I have observed Old Faithful, as a naturalist in Yellowstone Park, during the years 1931, 1937-1941, and 1946 to the close of the 1955 season. During the latter part of the 1938 season Dr. C. Max Bauer, Chief Park Naturalist, set up apparatus for making automatic recordings of Old Faithful's eruptions. A barograph was also set up to determine possible correlations between eruption intervals and barometric pressure. I was assigned to look after the apparatus and change the graphs in the recorders.

During frequent visits to the top of Old Faithful's mound, I had an excellent opportunity to observe it as well as the vent in considerable detail, and I found that the contours of the mound are being actively altered from some earlier pattern. On certain sections of the mound geyserite is being deposited; on other sections it is being eroded. On the east side where erosion is evident, stumps and tree sections stand out in relief. The existence of these trees and stumps had been noted by many observers over the years, but apparently little significance had been attached to them, and none had suggested that they might provide evidence as to the age of Old Faithful. Several years prior to my observations, some of this wood had been sent to Professor E. A. Longyear of Colorado State College for classification, and he reported that it was lodgepole pine (*Pinus contorta*), the common pine now growing in the geyser basins.

In addition to the stumps and partially exposed logs, large protuberances of geyserite are present near the apex of the mound, close to the vent on the down-basin side. They rise 4 feet above their base and 30 inches above the mound's flattened top (Marler, 1953, p. 23). They had been attributed to the surging of Old Faithful preliminary to its eruptions, providing more frequent wetting and accelerated deposition on those particular spots. Careful investigation of these knobs revealed that, instead of being massive geyserite, they are large tree stumps heavily encrusted with siliceous sinter; the stumps served as nuclei over which the silica was deposited. The rapid rate of deposition on the protuberances is the result of the increased surface exposure on the stumps. The initial irregularities of the stumps are preserved in the present structure.

HISTORY OF OLD FAITHFUL'S MOUND

The shape and nature of the geyserite deposited about the orifice of a hot spring provide evidence concerning the history of activity of that spring. "The cone is not only a measure of a geyser's age and activity, but it tells in a way the nature of the eruption" (Weed, 1929, p. 27). The general pattern and broad outlines of the deposition vary with the temperature and nature of the discharge, though in many instances the resulting pattern has been modified by rocks, gravel, wood, and other such irregularities. There is an almost infinite variety of hydrothermal deposition, from broad flattened sinter sheets to vertical pillar-like cones, just as there is an equally wide variety of activity.

Critical examination shows positive correlation between deposition and activity. Old Faithful's activity completely rules it out as the active agent in the deposition of the bulk of its mound's geyserite. The terraced pattern, a marked feature of the cone, is presently found forming only about hot springs with radically different activity, the Great Fountain Geyser being an example. The symmetrical terraces, which are now in an active state of growth about the Great Fountain, result from a pulsing type of activity. During an active phase, lasting about one hour, repeated heavy surges send the water rolling from the vent in all directions.

Furthermore, had Old Faithful been the active agent in building the mound through which it functions, a near balance between weathering and deposition should have been established long ago. On the contrary, present activity is not enlarging the mound's general symmetry and contours, but is rapidly changing its configuration. Erosion is dominant over deposition, and each season more sinter is washed away than is added to the mound. That the erosion is pronounced is indicated by the amount of shortening of the long axis at the top of the cone since 1878. Careful measurements made in the winter of 1952 showed that in 74 years this axis had shortened from 54 to 41.8 feet. All this shortening is on the eastern end of the axis, the side away from the protuberances and vent.

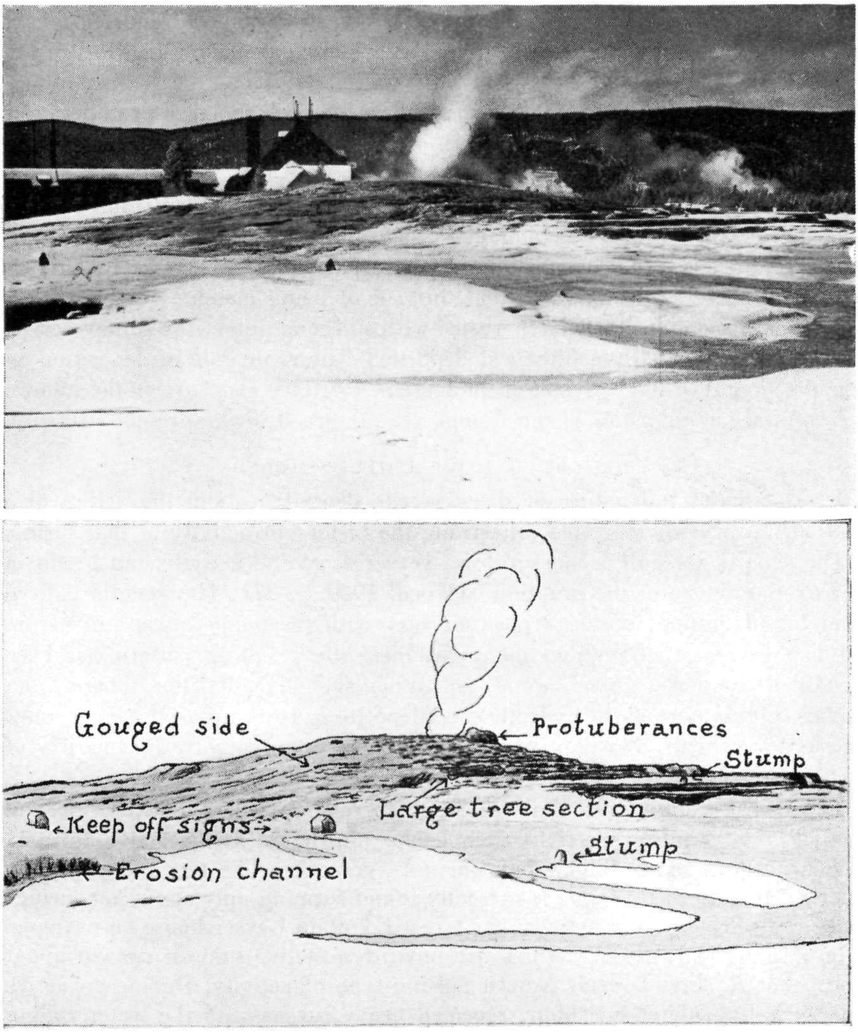

Fig. 1. Old Faithful's cone, looking west, January 1952—below zero weather. The terraces on the north side (covered with ice), built by the intermediate spring, and the gouged eastern side show well. An erosion channel which is working back into the base of the mound can be seen at the left. Tree stumps show at points designated in the drawing, also a silicified tree section.

Because of freezing (fig. 1), erosion is much more rapid in winter than in summer. In winter the water rushing down the drainage channels following an eruption is frequently gray with the load of weathered geyserite, and small deltas of fragmental sinter extend out into the Firehole River where the drainage channels enter the stream. During the 1951-1952 winter, two large blocks of sinter spalled from the east end of the top of the mound. As closely as could be determined this single incident shortened the axis between 4 and 6 inches.

The terraces, which were at one time nearly symmetrical about the entire cone, have been completely obliterated on the eastern side, and the cone deeply gouged by the hydraulic action of Old Faithful's falling water. On the westerly side the terraces have been partially filled and effaced by mineral deposition since Old Faithful came into being. This recent deposition rests on an older geyserite, and represents a very small fraction of the entire cone. It is scarcely more than a veneer, ranging from a mere shell to a maximum of nearly 6 inches in the most favorable locations.[1]

The pronounced erosion taking place on the east end of Old Faithful's mound, and the cutting of the drainage channels into an older sinter, are thus certain evidence of a marked change of present activity from that of an earlier period. Moreover, the silicified wood shows incontrovertibly that the mound has passed through a period of complete dormancy. "Manifestly, it would have been impossible for trees to have been growing over this mound while any hot-spring activity was taking place. The partially exhumed logs and stumps are certain evidence of a long period of dormancy. That trees will grow on a mound of geyserite can be seen by observing the large mound 300 feet east of Old Faithful. Trees are now growing over its north and east sides. Old Faithful's mound would have presented a similar appearance at one time.

"The tree stumps and tree sections which are now being exposed by Old Faithful's erosive water were interred by a hot spring antedating the present geyser. The fact that the trees are imbedded in a geyserite that is now being eroded is indicative of at least two separate periods of activity with an intervening dormant period before Old Faithful came into being. First there was the activity which built the cone to near its present dimensions. This was followed by a long period of dormancy during which trees grew over the mound. Then the mound was rejuvenated and an activity very different from Old Faithful's took place for a relatively long period. It was this activity that buried the logs and stumps," and "built the terraces. Whether a period of dormancy occurred following the closing of this chapter in the mound's history and the coming into being of Old Faithful is uncertain" (Marler, 1953, p. 28).

It is highly probable that the spring which built the bulk of the sinter in Old Faithful's mound became extinct because the internal deposition of silica, at least in the upper reaches of its plumbing, sealed off all egress of water. We have only suggestive evidence to indicate what brought this dormant stage to an end and opened a second hot spring (referred to below as the intermediate spring), with none of the functional characteristics of the

[1] Measurements in 1952 and 1953 suggest that the rate of deposition of silica on the west side of Old Faithful's mound is between 0.6 and 0.8 mm per year.

earlier one. The mound shows surface evidence of a break through its center. From the eroded side the break is very apparent. It extends in a fairly straight line from the vent along the axis of the top of the mound and down the east side to the bottom. At the surface on the west side, mineral deposition obscures it. That it extends westward can be determined by looking into the vent; it is through a section of this fracture that Old Faithful's water now issues. That the fracture is deep-seated was noted by Allen and Day: "Immediately below the geyser orifice is a long, narrow chamber some 8 feet deep, the bounding side walls of which recede into the darkness so that its dimensions can only be surmised. This chamber remains empty for a considerable time after an eruption, revealing a long straight, narrow crack in the bottom nowhere more than 3 inches wide and also extending (N.W.-S.E.) back into the shadows at both ends. It is visible in favorable light for perhaps 20 feet" (1935, p. 198).

There is abundant evidence that most of the alkaline springs in the geyser basins had their origins in acid ground. This was no doubt true for the hot spring which first developed at the site of Old Faithful's mound. A large fumarole on the flank of the dormant mound nearest Old Faithful's is now in acid ground, though the water of the spring which built this mound was alkaline. The intermediate spring, however, began as an alkaline spring, and Old Faithful developed from this spring with no apparent change in the character of the water, for there is no evidence of acid decomposition in the mound between the oldest spring stage and the present. In my opinion the intermediate spring, which built the terraces and interred the stumps and prostrate tree sections, began to flow when some mechanical adjustment broke the geyserite shield, thereby tapping arteries that had been sealed off in their upper reaches; it did not follow the normal slow process of chemical development as did the fumarole just mentioned. This view is strengthened by the presence of innumerable pine needles and staminate and pistillate cones embedded in the geyserite that was deposited by the intermediate spring. A rather sudden extrusion of water from the cone, while the trees were still alive, seems required for the nearly perfect preservation of these specimens, particularly the staminate cones.

Probably the intermediate spring had very different activity from Old Faithful, both because a large section of the crack served as an orifice, and because one or more of the large neighboring cones were then active. Like other groups of closely spaced springs in Yellowstone, Old Faithful and its neighboring mounds would all seem to be connected subterraneously (Marler, 1951). Even if the mound passed through a dormant stage following the intermediate spring, this stage must have been very short. Probably the intermediate spring was a direct precursor to Old Faithful, which took on its present pattern of play at about the time one or more of the other connected springs, including a section of the crack, became choked with mineral accretion, diverting all the thermal energy to Old Faithful. The shape of the terraces provides additional evidence that Old Faithful is now erupting from a section of the intermediate spring's vent; thus the long axis of the top of the cone is at a right angle to the basal axis, probably because the water at the intermediate stage issued along the greater length of the crack at the top of the mound. A section of the crack, 4 feet east of the present orifice, is still a steam vent.

HOW OLD IS OLD FAITHFUL?

On those sections of Old Faithful's mound where there is current addition of silica, only a short time would have been required to deposit the rind-like encrustation of geyserite. This, in connection with the marked amount of erosion on other sections, led to the conclusion: "As a geyser, Old Faithful is undoubtedly a newcomer in the geyser basins since embraced by Yellowstone Park. When the mass of geyserite in and about its cone is measured against the minute fraction it has added, it becomes evident that Old Faithful is a very recent addition to the imposing list of geysers now found in the Upper Geyser Basin. At best it cannot be more than *a few hundred years old*" (Marler, 1953, p. 30).

In September, 1954 Dr. Harmon Craig of the Institute for Nuclear Studies, University of Chicago, was in Yellowstone Park studying the origin of the hot waters and steam by natural isotopic tracer techniques. He became much intrigued with the silicified wood found embedded in the geyserite about a number of the hot springs, and sent a specimen of the wood from Old Faithful's mound to Dr. Meyer Rubin at the U. S. Geological Survey Radiocarbon Laboratory for carbon 14 analysis. In reporting the results of the test, Dr. Rubin stated: "Our number for the sample is W-311 and the age determined, 730 $\pm$ 200 years" (personal comunication, dated November 7, 1955).

The data presented in this paper make it reasonably certain that the origin of the intermediate spring goes back to the period dated by carbon 14. The origin of this spring and the age of the wood are essentially the same. In determining the age of Old Faithful the problem is to find how long the intermediate spring functioned before Old Faithful began playing. The amount of geyserite deposited by the intermediate spring no doubt holds the key to the answer; as yet no exact determinations of the amount have been made, but it seems to be about three times as much as the amount deposited by Old Faithful. If the intermediate spring deposited silica at about the same rate as it is currently being added to the mound, then it would necessarily have been in existence about three times as long as Old Faithful. The logical inference is that Old Faithful Geyser began to erupt only about two centuries ago.

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