HOT SPRINGS OF THE VALLEY OF TEN THOUSAND SMOKES

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The Katmai region of the Alaskan peninsula presents considerable interest on account of the great eruption of Mount Katmai in 1912 and the associated fumarolic activity of the Valley of Ten Thousand Smokes discovered by Professor R. F. Griggs in 1916. This region has been investigated by the members of several expeditions sent out by the National Geographic Society, one of which was accompanied by a party from the Geophysical Laboratory. The reader is referred to the published accounts for the detailed description of the general geological and chemical features of this region.[1]

[1] R. F. Griggs, "The Valley of Ten Thousand Smokes," *Nat. Geog. Mag.*, Vol. XXXI (1917), pp. 12–68; Vol. XXXIII (1918), pp. 115–69; "Are the Ten Thousand Smokes Real Volcanoes?" *Ohio Jour. Sci.*, Vol. XIX (1918), pp. 97–116; "The Great Hot Mudflow of the Valley of Ten Thousand Smokes," *ibid.*, pp. 117–42; "The

The fumaroles of the Valley of Ten Thousand Smokes were investigated in 1919 by Allen and Zies.[1] They found that the temperatures of the gases escaping from the fumaroles ranged from 97° to 645° C. and that the chief constituent of these gases was steam, which was present to the extent of about 99.9 per cent. They also found that even though the activity was vigorous, as indicated by the velocity and high temperature of the escaping steam, considerable evidence was at hand to show that the activity of the lower or northern part of the Valley had appreciably waned in the course of one year.[2] This was shown by the lower temperatures found in 1919 as compared with the temperatures obtained in 1918 by Sayre and Hagelbarger[3] in the same vents. In the upper or southern end of the Valley a number of fumaroles were discovered in which the temperature of the escaping steam proved to be higher than any so far recorded. Sayre and Hagelbarger unfortunately did not have the opportunity to study these fumaroles in 1918, but several areas were identified in this part of the Valley which they had studied, and even here lower temperatures were found. In 1917 Shipley[4] located a fumarole near the base of Mount Cerberus, in which the temperature of the steam was high enough to cause mercury to boil. In 1919 this same area was carefully examined but no such temperature was found. All of the evidence indicates that in the upper Valley the thermal activity in several areas was lower in 1919 than in 1918 or 1917.

Character of the Eruption as Indicated by Its Effects on Vegetation," *ibid.*, Vol. XIX (1919), pp. 173–209; *The Valley of Ten Thousand Smokes* (Washington: National Geographic Society, 1922), 340 pp., 16 pls., 9 maps. J. D. Sayre and P. R. Hagelbarger, "A Study of Temperatures in the Valley of Ten Thousand Smokes," *Ohio Jour. Sci.*, Vol. XIX (1919), pp. 249–78. J. W. Shipley, "Some Chemical Observations on the Volcanic Emanations and Incrustations in the Valley of Ten Thousand Smokes, Katmai, Alaska," *Amer. Jour. Sci.*, Vol. L (1920), pp. 141–53. C. N. Fenner, "The Katmai Region, Alaska, and the Great Eruption of 1912," *Journal of Geology*, Vol. XXVIII (1920), pp. 569–606; "The Origin and Mode of Emplacement of the Great Tuff Deposit in the Valley of Ten Thousand Smokes," National Geographic Society, *Contributed Technical Papers*, Katmai Series, No. 1, 1923. E. T. Allen and E. G. Zies, "A Chemical Study of the Fumaroles of the Katmai Region," *ibid.*, No. 2, 1923.

[1] *Op. cit.*

[2] Allen and Zies, *op. cit.*, p. 106.

[3] *Op. cit.*

[4] Private communication.

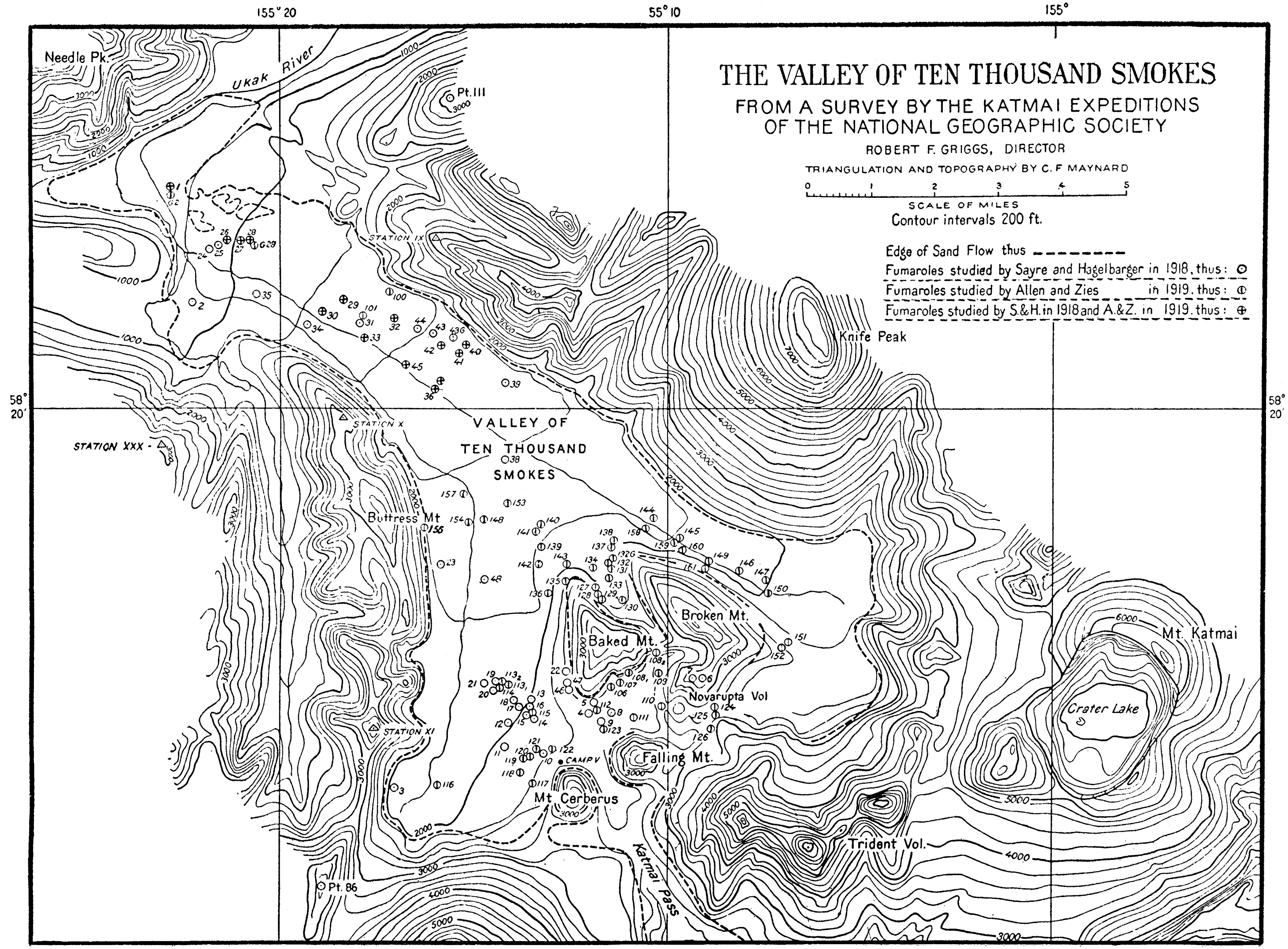
THE VALLEY OF TEN THOUSAND SMOKES
FROM A SURVEY BY THE KATMAI EXPEDITIONS
OF THE NATIONAL GEOGRAPHIC SOCIETY
ROBERT F. GRIGGS, DIRECTOR
TRIANGULATION AND TOPOGRAPHY BY C. F MAYNARD
0 1 2 3 4 5
SCALE OF MILES
Contour intervals 200 ft.
Edge of Sand Flow thus
Fumaroles studied by Sayre and Hagelbarger in 1918, thus:
Fumaroles studied by Allen and Zies in 1919. thus:
Fumaroles studied by S.&H. in 1918 and A.&Z. in 1919. thus:
155° 20
55° 10
155°
58° 20′
Needle Pk.
Ukak River
Pt. III
STATION IX
STATION X
STATION XXX
STATION XI
VALLEY OF
TEN THOUSAND
SMOKES
Knife Peak
Buttress Mt
Broken Mt.
Baked Mt.
Novarupta Vol
Falling Mt.
CAMP V
Mt Cerberus
Katmai Pass
Trident Vol.
Mt. Katmai
Crater Lake
Pt. 86

Fig. 1

The incrustations found at the fumaroles also furnish a clue which frequently helps the observer to ascertain the present and former temperature. When the temperature of the steam was 300° or more, the vents of the fumaroles were usually lined with a hard white baked crust made up of cemented pumice grains. In other cases the presence of pumice cemented with hematite was an indication of elevated temperatures. The presence of large amounts of magnetite was a sure sign of a similar thermal condition. Allen and Zies[1] have shown that relatively large amounts of HCl and HF escape with the steam. It is evident that under these conditions magnetite can not persist for more than a short period when once the temperature of the steam has fallen low enough to permit copious condensation in the throat of the vent. Such fumaroles in which temperatures below 150° were found often retained vestiges of the products mentioned above together with the products characteristic of lower temperatures, namely, sulfur and the chlorides and fluorides of iron and other bases.

In 1919, along with the many active events, there were several hundred fumaroles in the Valley in some of which visible activity had ceased, while in others no thermal activity whatsoever could be ascertained. Usually, remnants of the incrustations characteristic of more elevated temperatures were found.

Finally, in 1919, a few hot springs were found in the lower part of the Valley. This was the first time that such activity had been observed since this region had been under investigation. Hot springs represent the closing stage of thermal activity in a volcanic region.

Evidence was obtained in 1919 by Allen and Zies which points clearly to the most active agency that is responsible for the thermal retrogression just outlined. Before examining this evidence, it will be desirable to present briefly some of the salient features of the pumiceous deposit in which nearly all of the fumaroles are located. Fenner[2] has come to the conclusion that an acid magma was injected as a sill under the old valley floor and in part ejected as a rhyolitic pumice through the fractured floor, completely covering

[1] *Op. cit.*, p. 138.

[2] *Op. cit.*

it to an unknown depth. Griggs,[1] Fenner,[2] and Allen and Zies[3] are in agreement as to the belief that the fumaroles are deep seated in their origin. Lacroix[4] has shown that at Mont Pelée such fumaroles as had their origin in the pumiceous deposit remained active only a few days. In the Valley vigorous activity persisted in 1919, seven years after the great eruption.

The length of time over which the solfatara condition may persist will depend on the rate at which the lava body beneath the old valley floor gives up its heat to the pumice and the steam and other gases escaping from the fumaroles. This rate will be greatly accelerated if drainage water can percolate through the highly porous pumiceous deposit. The solfatara region of Krisuvig, Iceland, is of considerable interest in this connection. Schneider[5] was able to demonstrate the intimate connection existing here between the intensity of the thermal activity and the drainage water. When the solfataras were artificially stopped up, the boiling springs and mud volcanoes rapidly increased in activity. When the surface waters in the vicinity were artificially dammed up, the boiling springs gave off steam instead of water. Allen and Zies[6] have shown that the streams draining the Valley possess several unusual characteristics. In 1919, all of the streams had a much greater volume in the upper part of their course than in the lower part. Knife Creek was fed by a mountain torrent whose volume could be readily estimated. It was found to be 7 feet deep, 5 feet wide, and flowing at the rate of 12 miles per hour. This stream at its confluence with the Lethe, 12 miles down the Valley, had dwindled into an insignificant trickle. The tributaries to the two principal streams behave in a similar manner. The great decrease in volume of Knife Creek and its branches is not due to evaporation, since

[1] R. F. Griggs, *Ohio Jour. Sci.*, Vol. XIX (1918), p. 97.

[2] C. N. Fenner, "The Origin and Mode of Emplacement of the Great Tuff Deposit in the Valley of Ten Thousand Smokes," *National Geographic Society, Contributed Technical Papers*, Katmai Series, No. 1, 1923.

[3] *Op. cit.*, p. 95.

[4] A. Lacroix, *La Montagne Pelée et ses Eruptions*. Paris, 1904.

[5] K. Schneider, "Beiträge zur physikalischen Geographie von Island," *Petermanns geogr. Mitt.*, 1907, pp. 177–88.

[6] *Op. cit.*, p. 117.

the temperature of the water is practically the same in the upper and lower parts of its course. The Lethe is fed by waters derived from the melting of Mageik glacier. About one mile below its source its volume was estimated from the following data: depth, 2 feet; width, 50 feet; rate of flow, 6 miles per hour; and volume about 3,200,000 cubic feet per hour. At its confluence with Knife Creek it had dwindled, in 1919, to a stream 1.5 feet deep, 5 feet wide, and flowing at the rate of 5 miles per hour; volume about 200,000 cubic feet per hour. The Lethe at this point was hot, about 80° C, hence the loss in volume can in part be accounted for by evaporation. This can, however, be only one of the minor contributing causes, since it is only in the lower third of its course that the water becomes appreciably warmer than in the upper part of its course. On the basis of this evidence, and in view of the highly porous character of the pumiceous deposit, Allen and Zies have come to the conclusion that the drainage of the mountain slopes bordering on the Valley is for the most part absorbed by the pumice, vaporized, and drawn into the more or less pervious walls of the fumarole vents by the jet action of the steam and gases escaping from the lava below.

With such an agency at work it is evident that it will take but a few years to bring about an even greater decline in fumarolic activity and an appreciable increase in hot-spring activity. That such a change is likely to take place becomes even more apparent when we bear in mind the relatively rapid lowering of the temperatures of the fumaroles in the lower Valley.

Some idea of the magnitude of this hot-spring activity could be obtained if the amount of water given off as steam by the fumaroles were known. Unfortunately, the available data are insufficient to enable one to obtain with reasonable accuracy the amount of this water. Such meager data as are available will now be used in determining the upper and lower limits of the volume of this water.

In order to obtain samples of the "insoluble" gases, Allen and Zies[1] aspirated the fumarolic exhalations through a copper tube with a cross-section of 50 sq. mm. and condensed the steam in an appropriate chamber. Usually only enough difference in pressure

[1] Allen and Zies, *op. cit.*, p. 113.

was required to overcome the friction offered by the 6-meter tube. The average amount of water condensed at 25° was 350 cc. per 45 minutes, or 470 cc. per hour, per 50 sq. mm. cross-section.[1] This average, in all probability, is much too low since there were a fairly large number of huge fumaroles in which the velocity of the steam and the general thermal activity was so great that no gas samples could be taken. A rough calculation of the cross-section of the steaming vents of the fumarolic areas studied yields the total of 600 square meters. This amount must be much too low since the steaming mud-field areas and many fumaroles on Mount Trident are not included. These data yield the result that about 5,700 cubic meters of water per hour are exhaled by the fumaroles as steam. This volume is equivalent to the volume of a stream 1 foot deep, 10 feet wide, and flowing at the rate of 4 miles per hour.

The value for the upper limit of the volume of water given off as steam is obtained by comparing this volcanic area with that of the well-known area of Larderello in Tuscany. At Larderello the steam is used to generate power, and the amount of water equivalent to the steam exhaled is well known.[2] One of the steam wells, about 20 cm. in diameter, yields 5,500 cubic meters of steam, equivalent to 8 kilograms of water, per second. The characteristics of these steam wells, as deduced from the accurate descriptions given in the papers previously cited, leave the writer with the very definite impression that there are many vents in the Valley in which the volume of steam given off will, when condensed, equal or more than equal this volume of water. The area designated on the map as 32 gave off a column of steam in 1919 that was about 100 feet in diameter. On calm days this column rose to an estimated height of 2,000 feet. Area 101 is located on three parallel fissures about 800 feet long. The average width of the steam cracks was 2 inches, and the steam rose to a height of 30 feet. Either one of these areas must have yielded a very much greater volume than the Larderello steam well. I feel certain that there were in 1919 about

[1] Allen and Zies, *op. cit.*, p. 114.

[2] R. Nasini, *I Suffioni Boraciferi e la Industrie dell' Acido Borico in Toscana.* Rome, 1906. pp. 109. V. Funaioli, "The Larderello Natural Steam Power Plant," *Engineering* (London), 1918.

200 areas in the Valley in each of which the volume of steam was about ten times that of the Larderello well. Using the figure 80 kilograms of water per area, we find that the combined areas would yield 16,000 kilograms of water per second or 58,000,000 kilograms per hour, approximately 58,000 cubic meters per hour. This is equivalent to the volume of a stream 1 foot deep and 130 feet wide, flowing at the rate of 3 miles per hour. This upper limit is in all probability much nearer the truth than the lower limit previously given.

That such a thermal retrogression as outlined in this paper is very likely to take place in the Valley of Ten Thousand Smokes receives considerable confirmation from another source. One of the largest thermal regions in the world is located on the North Island of New Zealand. In 1886 Mount Tarawera, which up to that time was looked upon as an extinct volcano, suddenly became violently active. The explosion blew out enough material to leave a rift in the mountain ¼ mile wide and 12 miles long. Many fumaroles were located in this rift. Intense solfataric activity continued for several years and thereupon resolved itself into a series of hot springs and a few steam jets.

It is evident that at some time in the near future the present thermal activity of the Valley of Ten Thousand Smokes will resolve itself into that of a hot-spring area. Considerable interest is thus attached to the changes that will take place in the progression from an intensely hot fumarolic area to that condition in which hot springs are the dominant thermal activity. Equally as interesting, on account of the many economic minerals found in the incrustations, are the mineralogical changes which must of necessity take place as the temperature of the region grows less. For this reason alone the Valley is worthy of additional study.