Eugene P. Kiver
Jack Snavely[1]
and
Donna F. Snavely[1]
Department of Geology
Eastern Washington State College
Cheney, Washington 99004

Hydrogen Sulfide Fumes at the Summit of Mount Rainier Volcano, Washington

Abstract

Numerous small fumaroles occur on the rims and floors of the two summit craters of Mount Rainier volcano, but present H_2S emission is restricted to certain fumaroles along the west rim of the west crater and in a large west crater ice chamber called the Lake Grotto. A concentration of 57.3 ppm H_2S was measured in one Lake Grotto fumarole and 3.8 ppm in the Lake Grotto atmosphere. Increased H_2S concentrations can precede eruptions by a few months or years and could furnish an extremely useful method of monitoring volcanic activity.

Slow enlargement of the Lake Grotto and a similar chamber in the east crater since at least 1971 indicates that heat flow has recently increased. The remainder of the 2,200 m long geothermal ice cave system, as well as the surface of the overlying crater ice fill, have remained virtually constant in appearance. Thus, they are in dynamic equilibrium with geothermal heat release, the rate of melting of the cave walls and ceiling, the slow subsidence of the ice masses that fill the craters, and the annual accumulation and ablation of snow at the surface.

Introduction

A portable gas analysis device purchased with research funds from the Mazamas was used in August 1975 to measure hydrogen sulfide (H_2S) fumes at selected sites in the summit craters of Mount Rainier volcano. Sulfur odors were locally intense and "nauseating" when Stevens and Van Trump made the first authenticated climb of the 4,393 m high mountain (Stevens, 1876, p. 526). The west crater fumarole that they huddled around on the night of August 17, 1870, may have been one of several on the west rim of the west crater currently emitting detectable sulfur odors. However, the strongest sulfur odors originate from a fumarole cluster on the floor of the Lake Grotto (Fig. 1). Sulfur fumes are also occasionally noted at about 3,990 m elevation on the Ingraham Glacier where they emanate from crevasses.

Although the locations of sulfurous fumaroles were noted in 1971 when the Lake Grotto was first explored and mapped (Kiver and Steele, 1972), no attempt at quantitative analysis was made until the summer of 1975 when two of us (Snavely and Snavely) spent seven days at the summit. Subsequent measurements will determine if, and how much, H_2S composition varies during the present repose period. Significant increases in sulfur, H_2S, and other gases have occurred prior to volcanic eruptions (Sato and others, 1975; Tonani, 1972). If this increase also occurs at Mount Rainier, then a useful tool for predicting its eruptions could be established.

Methods and Materials

A detector tube system was used for the analysis because it is lightweight, compact, easy to use, and gives immediate quantitative results after simple elevation and gas tempera-

[1] Present address: 339 Stratford Court #305, Del Mar, California 92014

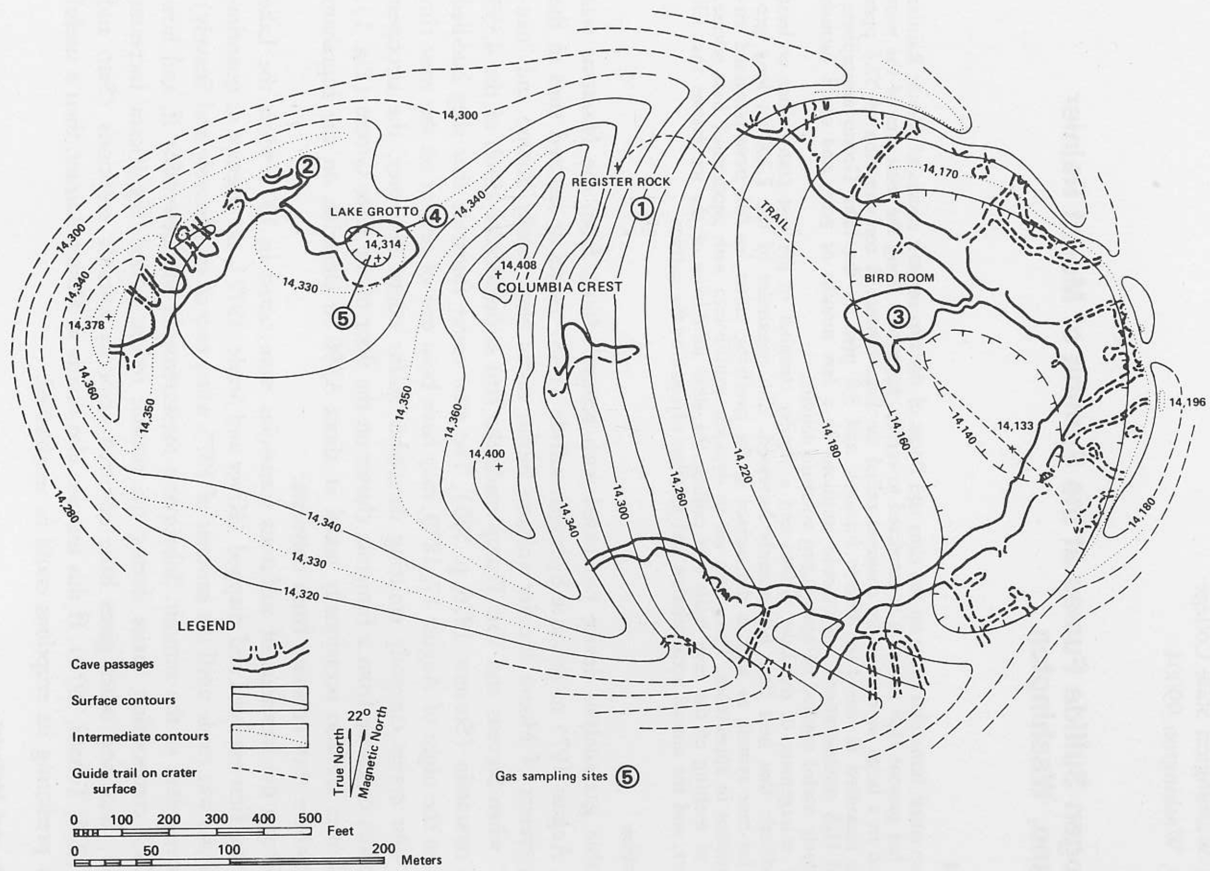

Figure 1. Map showing the topography and cave locations as they existed in 1971. Present conditions are virtually the same except that the Lake and Bird Grottoes have enlarged and the depression in the ice above the Lake Grotto has subsided 10 m to an elevation of approximately 4,388 m (14,304 ft). Art work by Fred Munich.

ture corrections are made. A detector tube is a sealed glass tube containing chemical reagents and is most often used in air pollution studies. The tube tips are broken off before an analysis and the tube is inserted into a pump that draws a known quantity of gas through the reagents. The length of the colormetric reaction of the reagents is then proportional to the concentration of a specific gas. For example, H_2S reacts with cupric sulfate ($CuSO_4$) to form blackish, brown-colored cupric sulfide (CuS).

The accuracy is within ± 25 percent of true value where interfering gases such as SO_2 are minor and the temperature of the detector tube is held between 0 and 40°C. Multiple analyses of a single fumarole usually give results reproducible to within 10 percent. Numerous detector tubes that measure other gases are manufactured, but were unavailable to us during the expedition. We believe that our H_2S and CO measurements at least give reasonable order-of-magnitude estimates.

Some error may have been introduced by measuring fumarole gases with temperatures as high as 80°C. The samples were taken relatively quickly, so that the tube and reagent temperatures were probably never in excess of the 40° C maximum recommended by the manufacturer. If SO_2 concentrations exceed 0.5 percent, then some error in the H_2S measurements will occur. Although SO_2 was not measured at Mount Rainier, measurements at Mount Baker (Kiver and Steele, unpublished) and Mount Hood (Phillips, 1935) suggest that SO_2 is absent or very minor in Cascade volcanoes. A laboratory analysis using a Naugton tube (Fuilayson, 1972) or other reliable sampler is needed so that the results of different analytical methods can be compared.

Results and Discussion

Gas sample sites at the crater surface (site 1) and in the caves (sites 2, 3, 4, and 5) are shown in Figure 1 and temperature and gas composition in Tables 1 and 2. Site 3 is the cave atmosphere in the large east crater Bird Room that measures 54 x 36 m in area

TABLE 1. Fumarole and/or Air Temperature (°C)

Site	Fumarole Temperature	Air Temperature
1	80	0
2	70	0
3	*NA	8
4	*NA	5
5	73	5

*Not applicable; cave air sample

TABLE 2. Fumarole or Air Composition by Volume (PPM)

Site	CO[a]	CO[b, c]	H_2S[a]	H_2S[b]
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	2.0	3.3
5	2	3.8[d]	20.0-30.0	38.2-57.3[c]

(a) Not corrected for elevation and temperature
(b) Corrected for elevation
(c) Corrected for temperature
(d) Value is probably in error, see text for explanation

and 21 m high, and site 4 is the cave atmosphere in the west crater Lake Grotto, an irregular ovoid measuring 52 m x 41 m and 10-14 m high. The floors of the Bird Grotto and the Lake Grotto are 98 m and 39m, respectively, beneath the surfaces of the overlying ice.

Gases from numerous fumaroles, as well as slowly circulating surface air, mix in these large cave rooms and allow average gas composition for the lower sections of the caves to be determined. The rooms are ideal sites for monitoring long-term changes in volcanic emanations because they are relatively easy to find, and their narrow connections with upslope cave passages prevent rapid mixing with outside air. Disadvantages are that increased volcanic emissions may allow gases in toxic concentrations to accumulate; and, secondly, increases in volcanic emissions are often accompanied by thermal increases that could cause considerable enlargement or collapse of the upslope connecting passage, or cause the ice ceilings to melt completely, thereby permitting rapid mixing with outside air.

Indeed, slow enlargements of the Bird and Lake grottoes since they were first entered in the early 1970's is probably due to small, recent heat increases. A depression in the ice surface above the slowly enlarging Lake Grotto has deepened from 5 m in 1971 to 15 m in 1975 and provides the first surface indication of cave enlargement. The remainder of the 2,200 m long geothermal ice cave system, as well as the surface of the ice that fills the summit craters, is unchanged.

The relatively constant level of ice fill from year to year since at least 1970 indicates that snowfall at the summit is more than adequate, even in extremely light snowfall winters like 1972-73, to fill the craters to normal snow level. Ablation has not been excessive during this period of time; thus, the observed changes in the caves and the deepening surface depression are not climatically caused.

The caves themselves furnish a means of monitoring volcanic heat release because a dynamic equilibrium normally exists between the amount of heat released, the rate of melting of the cave walls and ceiling, the slow subsidence of the ice masses that fill the craters, and the annual accumulation and ablation of snow at the surface (Kiver and Steele, 1975a). Changes in the morphology of the caves or the surface of the ice fill imply a change in one or more of these controlling factors.

CO at the summit is absent except possibly at site 5. However, the presence of H_2S at site 5 invalidates the CO test there because both H_2S and CO cause a similar stain in the potassium palladosulfite used as a reagent.

H_2S emission is presently low and restricted to the west crater. The 3.8 ppm in the west crater cave atmosphere is within the recommended 10 ppm limit for an average 8-hour exposure in industrial situations and requires no special breathing apparatus.

High concentrations of SO_2 or NO_2 gases could cause errors in H_2S measurements. Judging from our unpublished analyses and the preliminary analyses of Motoari Sato (pers. comm.) of the fumarole gases at Mount Baker, as well as analyses at Mount Hood (Ayres and Cresswell, 1951; Phillips, 1935), SO_2 and NO_2 are absent or relatively unimportant in Cascade volcanoes.

H_2S measurements of fumaroles at Mount Baker volcano, 208 km north of Mount Rainier, before and during the steam eruption that was first noted on 10 March 1975, showed a dramatic increase from .0074 percent during August 1974, to slightly greater than .15 percent on 31 March 1975, to 6.0-7.4 percent in September 1975 (Kiver and

Steele, 1975b). At this writing it remains to be seen whether the dramatic increase in H_2S concentration and steam activity at Mount Baker presages a more serious eruption.

With the exception of Lassen Peak, there has not been a Cascade eruption since the 19th century. The repose period of one or more of these volcanoes will probably terminate in the near future, making documentation of gas composition, temperature, micro-seismic activity, and other parameters an important goal. Gathering a maximum amount of scientific data soon, coupled with continuous or nearly continuous monitoring when possible premonitory signs develop, may determine important eruption prediction criteria.

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