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HELIUM IN FUMAROLE AND WELL GASES AS AN INDEX OF LONG-TERM GEOTHERMAL POTENTIAL

John J. Naughton and Donald Thomas

Chemistry Department and Hawaii Institute of Geophysics,
University of Hawaii,
Honolulu, Hawaii 96822

ABSTRACT

We have used fumaroles and degassing vents around Kilauea volcano as models of producing geothermal areas. Excess helium has been found in gases from fumaroles characterized by long-term activity, and is absent in gases from short-lived hot spots, from dry vents or fissures formed by recent activity, and from old degassed lava lakes. From this it is inferred that the absence of helium in gases from geothermal areas would indicate that they receive heat from a limited magma body, and would be expected to yield extractable heat for only a comparatively short period. The geothermal well at Puna, Hawaii, has given positive helium indications.

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One factor that must be of concern in the economic development of geothermal areas is the expected longevity of the sources as viable heat producers. Fumaroles and hot springs frequently are found as surface manifestations of such regions. Also fumaroles are generally associated with volcanoes. Kilauea volcano on the island of Hawaii has several of these in various stages of activity. Some have been continuously active throughout historic times and others appear and disappear sporadically depending on conditions from prior or impending eruptions. Isolated, crusted-over lava lakes and hot spots also exist. We have used these areas as models for various types of geothermal activity, and have investigated the changes of the composition of emitted gases with time. Here we will attempt to show the potential of helium as a gaseous indicator of geothermal potential.

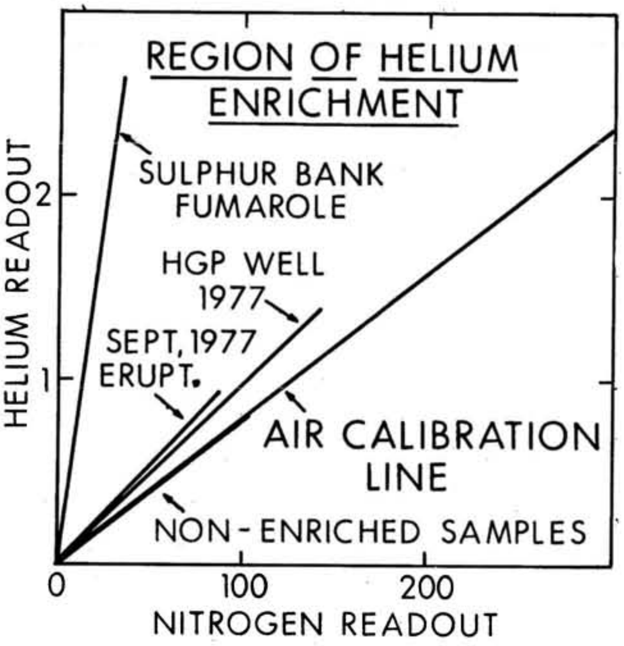

Fig. 1. Helium-nitrogen plot for standard air and for geothermal gases. Instrumental integrator readouts for each gas are in arbitrary units.

Helium is present in the gases issuing from many fumaroles [1] and hot springs [2], and the isotopic composition ($^3He/^4He$ ratio) indicates that such gases tap sources deep within the crust of the earth, or even within the mantle [3][4]. The ready emission of this gas might be expected since its easy diffusion through hot silicates has long been known and studied. The concentration found in geothermal gases is low and requires special equipment for detection, but in some cases it can exceed the concentration in air by about two orders of magnitude.

We have sampled fumarolic and volcanic gases using various evacuated and pump-through devices, but generally we have favored collection into evacuated tubes which contain activated silica gel. This adsorbs certain of the gases and quenches the high temperature composition [5]. Also it prevents reaction between

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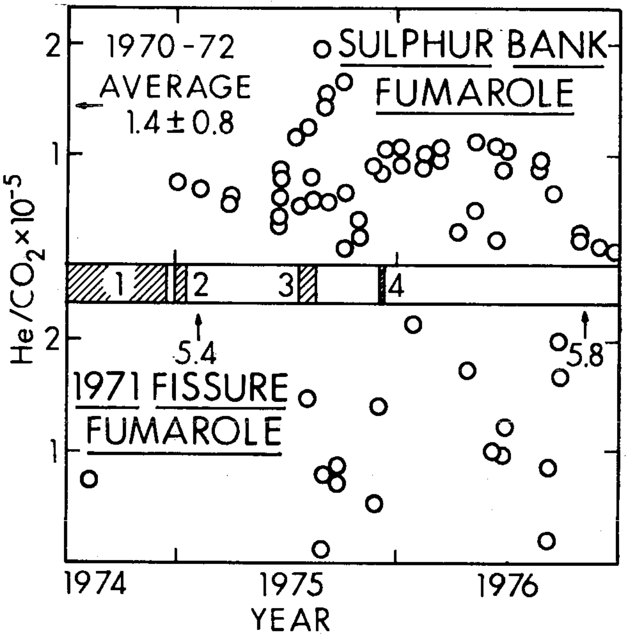

Fig. 2. Change of He/CO_2 ratios as a function of time for Sulphur Bank and 1971 Fissure fumaroles. Activity of neighboring volcanic complexes noted by numbered region in center. 1. Activity at Mauna Ulu (decreasing). 2. Kau eruption. 3. Mauna Loa eruption. 4. Earthquake. Small Kilauea eruption.

components which may occur during long-time holding at room temperature. Analyses of the collected gases has been carried out using gas chromatography with conventional thermal conductivity detectors [5]. For the analysis of helium in recent work we have used a small, very sensitive helium mass spectrometer (a "leak detector"). Each analysis is compared with that of an air standard in which the helium content is known and constant (5.24 ppm). A complete quantitative analysis of a geothermal gas also can be made with this equipment.

An indication of the presence of helium in excess of the content in air is sufficient for the purpose of this work. This can be made graphically by a plot of the instrumental readouts for helium and nitrogen (Fig. 1). A series of determinations are made on each sample to give a meaningful average. These plot as points on a straight line as the sample pressure is lowered by consumption in the analyses. The reference air sample is run, and is followed by the geothermal gas sample. An excess of helium is revealed by the position of the He vs. N_2 plot lines with reference to a similar plot obtained for the air standard (Fig. 1). Some data plots of recent collections are shown on this figure by way of illustration.

To study time related trends at a single fumarole we also have determined the complete gaseous composition, in some cases over a period of several years. From these data helium-to-carbon dioxide ratios can be calculated (Fig. 2). These are believed to be of greater geochemical significance than the analytical content of He in the total gas mixture since there is evidence that CO_2, like He, has its source deep in the magma column [6]. In addition it is a major component of almost all geothermal gases, and, in our experience, varies by only about 1% over a long period from a long-lived fumarole. Also it is little influenced by air infilteration or other meteoric imput as would be the case for the other major geothermal gaseous components (H_2O, O_2 and N_2). Thus it makes a good internal reference standard with which to compare other components such as helium. We have sought to relate this He/CO_2 ratio to the activity of the associated volcanic complex, but thus far have found no very certain correlation (Fig. 2). This type of study must, however, be systematically continued over long periods for such interrelations to be unambiguously detected.

From the He-N_2 plots, helium enrichment has been noted in the gases from the following sources: (1) Sulphur Bank, a solfotaric fumarole situated on an older Kilauea caldera rift to the northeast of the present caldera, which has been active continuously throughout historic times. This fumarole yields a varying flow of helium with an average concentration about two orders of magnitude greater than that found in air. Also it has a $^3He/^4He$ isotopic ratio greater than any other thus far found from a terrestrial source [4]. (2) The fissure produced by the August 1971 eruption on the floor of Kilauea caldera contains fumaroles that continue to yield helium in relatively high concentration. Fluctuations in the He/CO_2 ratio with time (Fig. 2) are evident for these first two high helium fumarolic areas, and these may be connected with eruption events at Kilauea, but many more closely spaced sample analyses are needed over a long period to definitely pin down on such correlation. (3) The fissure produced by the July 1974 eruption across the floor of Kilauea caldera at first showed a slight enrichment in helium, but this dropped off within a few months despite the continuous emission of hot gases.

It has become analogous to a typical "hot spot" in its behavior, and the excess of helium seems to have disappeared.

On the other hand we have found no evident enrichment of helium in the gases collected under the following conditions which might be expected to produce geothermally associated material: (1) Soil gases extracted from the thin soil cover near an erupting volcanic vent (Mauna Ulu); (2) gases from old lava tubes in a hot steaming area (a "hot spot" near prehistoric Kalalua crater); (3) gases from a very hot (~700°C) fissure near the vent at Mauna Ulu (which died out after a few weeks); (4) gases collected from deep within dry fissures into which lava from recent eruptions had withdrawn (May 1973 rift); (5) gases from a non-producing exploratory well drilled near the summit of Kilauea (Keller's well); (6) gases from fumaroles at the edge of Halemaumau crater; (7) and gases from a hole recently drilled by the U. S. Geological Survey through the thick crust of the old Kilauea Iki lava lake (formed 1959-60). We note then that helium seems to be absent in gases emitted from short lived "hot spots" or "rootless" regions, and these would be expected to yield extractable heat for only a relatively short period.

Finally we may conclude from the results obtained thus far that helium seems to be found only in gases from fissures and fumaroles which have a history of long-term, vigorous and continuous activity. Consequently, we may deduce that the continuous presence of excess helium in the gases being emitted from vents or wells in a possible geothermal area is a good indicator of the long-term potential of such a region as a viable geothermal source. Such excess helium has been detected in the gas from the Hawaiian Geothermal Project (HGP) well at Puna, Hawaii.

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