VARIATION OF δ13C IN FUMAROLIC GASES FROM KILAUEA VOLCANO

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ABSTRACT

Values of δ13C in fumarolic gases from Sulphur Bank, the Puhimau thermal area, and a fumarole at Halema'uma'u have been determined for samples collected from June 1984 through December 1988. Samples from Sulphur Bank and Halema'uma'u have a δ13C of −3.5 ± 0.2 parts per thousand (permil) and show little change during this period. In contrast, the δ13C of samples from the Puhimau thermal area increased from −3.5 to values of −2.7 permil at the end of the collection period. Applying an equilibrium fractionation factor of 1.004 for the 13C distribution between carbon dissolved in the magma and the CO2 gas in equilibrium with the magma resulted in a calculated primary δ13C value of −7.5 permil for carbon dissolved in the Kilauea magma. The change of δ13C at Puhimau can be the result of cooling of a pod of magma beneath Puhimau caused by the closure of its feeder passage from the main magma body.

INTRODUCTION

The δ13C values of fumarolic gases are of interest for several reasons. The isotopic composition of mantle carbon is still a matter of conjecture, and the isotopic composition of mantle-derived gases is of importance in understanding the carbon cycle. Fumarolic gases are an important source of CO2 to the atmosphere, and a knowledge of the δ13C of such gases will help in understanding the atmospheric CO2 cycle.

The first analyses of fumarolic gases from Hawaii were made by Naughton and Terada (1954). Conversion of their published atomic ratios to modern δ notation gives the following values in parts per thousand, permil to a precision of about ±2 permil.

Sulphur Bank fumarolic gas
1949, Mauna Loa eruption 0 permil
1952, Kilauea in eruption 0 permil
1953, both volcanoes quiet 0 permil

Gas collected from Mauna Loa lava flow −24 permil
CO2 extracted from 1950 Mauna Loa olivine basalt −19 permil

Those authors commented on the constancy of the Sulphur Bank ratios and on the relative enrichment of Sulphur Bank samples in 13C as compared to the gas extracted from the chilled lava or from above the active lava flow. Thomas (1977) reported data on samples collected at Sulphur Bank as well as at 1971 and 1974 fissures at Halema'uma'u. His data are given in table 32.1.

EXPERIMENTAL PROCEDURE

In order to determine whether the variations found by Thomas were related to eruptive events, we initiated frequent sample col-
The $\delta^{13}C$ values of gases from both Halemaumau and Sulphur Bank appear to be fairly constant at $-3.5 \pm 0.3$ permil, in reasonable agreement with the results of Thomas. We plan to continue to research long enough to determine if this constancy of $\delta^{13}C$ will persist during periods of quiescence at Kilauea.

Gases emitted at the Puhimau thermal area show greater variation and indicate an increase in $\delta^{13}C$ from $-3.6$ permil in late June, 1984, to $-2.7$ permil in November, followed by a slow decrease to $-2.9$ permil in March 1985. The $\delta^{13}C$ at Puhimau remained constant until early November, when it increased to $-1.9$, and then decreased to $-3.2$ in late December. These changes may have been caused by a temperature decline in the gas source, related to either cooling of an isolated body of magma beneath the thermal area or to withdrawal of magma from under the site, followed in December by reintroduction.

### DISCUSSION

Pineau and others (1976) found the $\delta^{13}C$ of CO$_2$ released from vesicles in tholeiitic basalt from the mid-Atlantic ridge to be $-7.6 \pm 0.5$ permil and postulated that this value represents the $\delta^{13}C$ of primary deep-seated carbon in the ridge area. Mathey and others (1983) postulated that the $\delta^{13}C$ of volcanic carbon is $-4.2$ to $-7.5$ for basalt midocean ridges, $-2.8$ to $-6.7$ permil in glass from Hawaiian and Explorer Seamounts, and $-7.7$ to $-16.3$ permil for glass from basalts in backarc basins.

The $\delta^{13}C$ of dissolved carbon in 11 samples of glass from midocean basalt was determined by Des Marais and Moore (1984) to range from $-5.6$ to $-7.5$.

Javoy and others (1978) determined experimentally that CO$_2$ in equilibrium with carbon dissolved in tholeiitic magma at 1,120–1,280°C and 7.0–8.4 Kb, is enriched in $^{13}C$ by 4.0 to 4.6 permil relative to the magma. Therefore, if basaltic magma containing dissolved carbon with a $\delta^{13}C$ of $-7.5$ permil loses carbon dioxide to the atmosphere, we can expect that the initial fumarolic CO$_2$ will have a $\delta^{13}C$ of about $-3$ to $-3.5$ permil. Our results obtained at Halemaumau and Sulphur Bank agree with these expected values.

If the magma continues to lose CO$_2$ in an equilibrium distillation (a Rayleigh process), then the $\delta^{13}C$ of the CO$_2$ will continuously decrease as the amount of carbon in the magma decreases with time because of CO$_2$ loss.

The fairly constant $\delta^{13}C$ of the gases sampled at Halemaumau and Sulphur Bank indicate that only a small amount of CO$_2$ is lost from a large amount of magma, or that new magma enters the system in a continuous manner.

The increase of $\delta^{13}C$ with time observed at Puhimau thermal area can be explained by a decrease in the temperature of isotopic equilibration from about 1,250 to 1,100°C. This could occur by the cooling of a small pool of magma isolated by interruption of its feeder dike from a larger magma body, which has been the source of heat for the thermal area since its formation in 1936 or 1937. If this explanation is correct, the isolation must have occurred just before our initial sampling in late June 1984. The decrease in $\delta^{13}C$ observed in December 1985 may be due to reintroduction of fresh magma beneath the site.

Monitoring the $\delta^{13}C$ of fumarolic CO$_2$ at Kilauea can yield important insights into magma movement and the opening and closing of feeder dikes.

### REFERENCES


