$^{3}He/^{4}He$ isotopic ratios in volcanic-hydrothermal discharges from the Canary Islands, Spain: implications on the origin of the volcanic activity

N.M. Pérez *Dept. of Geology & Geophysics, Louisiana State University, Baton Rouge, LA 70803, USA*

H. Wakita
S. Nakai *Laboratory for Earthquake Chemistry, The University of Tokyo, Bunkyo-ku, Tokyo 113, Japan*

Y. Sano *Department of Earth and Planetary Sciences, Hiroshima University, Japan*

S.N. Williams *Department of Geology, Arizona State University, Tempe, AZ 85287, USA*

Introduction

Helium isotope ratios in natural systems are a potential tool for detecting mantelic degassing from different tectonics settings such as mid-ocean ridge basalts (MORB), oceanic volcanic islands, arc volcanism, and intraplate continental volcanism environments. Helium isotopic signature from mantle plume regions such as Hawaii, Iceland, and Yellowstone range from 9 to 30 Ra which indicates helium degassing from the lower mantle (Craig *et al.*, 1978; Kaneoka and Takaoka, 1980; Sano *et al.*, 1985).

Several hypothesis have been considered for the origin of the volcanic activity in the Canary Islands (Burke and Wilson, 1972; Schmincke, 1973; Anguita and Hernan, 1975; Schmincke, 1976; Ancochea *et al.*, 1990; Pérez *et al.*, 1992, Hoernle and Schmincke, 1993). Helium isotope systematics applied to the actual degassing will provide an additional insight to the discussion on whether the Canarian archipelago is indeed a hot spot.

Gas sampling and isotopic measurements

Gas samples have been collected from actual degassing sites at La Palma, Tenerife and Lanzarote islands since end-1990. The sampling distribution follows a well defined W-E trend of the Canarian archipelago. These samples were collected in 50 ml lead glass containers fitted with high-vacuum stopcocks. The $^{4}He/^{20}Ne$ ratios were measured by quadropole mass spectrometer (QMG112, Balzers) using atmospheric air as standard. Errors for $^{4}He/^{20}Ne$ ratio are estimated to be about 10%. Ion beams of ^{3}He and ^{4}He were detected with a high precision mass spectrometer (VG5400, VG Isotopes). Atmospheric helium was used as a running standard. Uncertainty for R/Ra ratios are about 1%. All helium isotope ratio measurements were carried out at the Laboratory for Earthquake Chemistry of the University of Tokyo. A detailed procedure of the helium isotopic ratio measurement has been described by Sano and Wakita (1988).

Results and discussion

The observed $^{3}He/^{4}He$ ratios vary significantly from 1.02 to 9.63 Ra, being Ra (atmospheric ratio) $= 1.40 \times 10^{-6}$ (Mamryin *et al.*, 1970). Most of the samples shows isotopic ratios higher than the typical atmospheric value indicating a contribution of mantle-derived helium. On the contrary, collected samples from Timanfaya (Lanzarote Is.) and Teneguía (La Palma Is.) volcanoes show $^{3}He/^{4}He$ and $^{4}He/^{20}Ne$ ratios which imply a strong atmospheric disturbance in these volcanic systems. Chemical characterization of these gas samples show also N_2/Ar molar ratios (84.2 and 84.5, respectively) which are very similar to the atmospheric value (84) (Pérez *et al.*, 1993). The highest observed helium isotopic ratio, 9.63 Ra, was detected inside Taburiente caldera (La Palma Is.). This $^{3}He/^{4}He$ ratio is higher than the typical MORB-type helium, 8 ± 1 Ra (Craig and Lupton, 1976; Kurz and Jenkins, 1981; Lupton, 1983) and agrees well with a plume-type helium. Other relatively high $^{3}He/^{4}He$ ratios up to 7.21 Ra have been measured from the summit fumarolic area of Teide volcano as well as from subsurface degassing sites located in the active rift-type structures of Tenerife island.

A simple mass balance calculation could estimate the percent of plume-type helium from the actual degassing sources in the Canary Islands. This method implies that the crustal-type He is negligible (Sano *et al.*, 1985) in this environment

due to the thickness of the oceanic crust. The results of the mass balance calculation show a 6.1% of plume-type helium from the mineral cold spring located inside Taburiente caldera. Such evidence supports that the volcanic-hydrothermal discharge in La Palma island is related to magma derived from a rising hot zone. Other recent geochemical and isotope geological studies have also indicated a hot spot origin for the Canary Islands (Hoernle and Schmincke, 1993) which are located on a very slowly moving plate and where the volcanic activity may be related to a weaker plume than those observed in other plume mantle regions such as Hawaii.

Conclusions

The geographical distribution of the $^3He/^4He$ Ra ratios shows the highest level of helium-3 emission on the westernmost zone of the Canarian archipelago. This $^3He/^4He$ ratio would imply the existence of a helium source degassing from the lower mantle. This result add an additional insight to the controversy on the origin of the volcanic activity of the Canary Islands which seems to be related to a hot spot model.

Acknowledgments

We are grateful to the Haciendas el Argual y Tazacorte, to the Cabildos Insulares de La Palma and Tenerife, to the ICONA, and to the Teleférico Pico Teide S.A. for their kind help during the field work. This study was supported by the CRR Foundation, a MEC/Fulbright Post-Doctoral fellowship from the Government of Spain, and a short-term scholarship from the Directorate General of Universities and Research of the Autonomic Government of the Canary Islands given to NMP.

References

Ancochea, E., Fúster, J.M., Ibarrola, E., Cendrero, A., Coello, J., Hernán, F., Cantagrel, J.M., and Jamond, C. (1990) *J. Volcanol. Geoth. Res.*, **44**, 231–49.

Anguita, F., and Hernán, F. (1975) *Earth Planet. Sci. Lett.*, **27**, 11–19.

Burke, K., and Wilson, J.T. (1972) *Nature*, **239**, 387–90.

Craig, H., and Lupton, J.E. (1976) *Earth Planet. Sci. Lett.*, **31**, 369–85.

Craig, H., Lupton, J.E., and Horibe, Y. (1978) In *Terrestrial Rare Gases* (ed. E.C. Alexander and M. Ozima), Japan Sci. Soc. Press., 3–16.

Hoernle, K. and Schmincke, H.-U. (1993) *J. Petrol.*, **34**, 599–626.

Kaneoka, I. and Takaoka, N. (1980) *Science*, **208**, 1366–8.

Kurz, M.D. and Jenkins, W.J. (1981) *Earth Planet. Sci. Lett.*, **53**, 41–54.

Lupton, J.E. (1983) *Ann. Rev. Earth Planet. Sci.*, **11**, 371–414.

Mamyrin, B.A., Anufriyev, G.S., Kamensky, I.L. and Tolstikhin, I.N. (1970) *Geokhimiya*, 721–30 (in Russian).

Pérez, N.M., Williams, S.N., Sano, Y., Carracedo, J.C., Coello, J. and Wakita, H. (1992) *Joint Meeting of the III Spanish Geol. Congess and VIII Latinamerican Geol. Congress*, **I**, 468–72.

Pérez, N.M., Sturchio, N.C., Williams, S.N., Sano, Y., Carracedo, J.C., Coello, J. and Wakita, H. (1993) *Ann. Geophysicae*, **C80**.

Sano, Y., Urabe, A., Wakita, H., Chiba, H. and Sakai, H. (1985) *Geochem. J.*, **19**, 135–48.

Sano, Y. and Wakita, H. (1988) *Bull. Chem. Soc. Jpn.*, **61**, 1153–7.

Schmincke, H.-U. (1973) *Geol. Soc. Amer. Bull.*, **84**, 634–48.

Schmincke, H.-U. (1976) In: *Biogeography and Ecology of the Canary Islands* (ed. Kunkel, G.), 76–184.