The noble gas isotopic composition of the upper mantle in non-arc oceanic settings: Inferences from fluid inclusion studies

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1. Licence

2. Citation

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3. Data description

OIB localities (e.g., Tristan, Samoa) have been considered ideal natural laboratories for studying mantle heterogeneity. Indeed, Sr, Nd, and Pb isotopes of lavas collected from OIB systems have provided insights into the existence of distinct mantle reservoirs, the origins of which are closely related to local tectonic processes: DMM, HIMU, EM1, and EM2. In this context, we aim to investigate the isotopic composition of noble gases in fluid inclusions trapped in xenoliths and lavas from Samoa and Tristan islands, two well-known enriched mantle (EM) localities.

Our goal is to evaluate the role of noble gas cycling and active tectonic processes on the composition of the upper mantle. Our results show that CO2 is the most abundant volatile in all samples (lavas and xenoliths) from both localities. The 4He/20Ne ratio in most samples is lower than 150, suggesting the presence of atmospheric components in the fluid inclusions. This is further confirmed by the relatively low 40Ar/36Ar ratios, particularly in Tristan samples, which show values below 360. It is worth noting that the Samoa sample exhibits a 40Ar/36Ar ratio of 1000.4, the highest oft he dataset. The Rc/Ra values (3He/4He corrected for atmospheric contamination) observed in the Samoa samples align with the Ar ratios mentioned above, as the 3He/4He ratio is the highest reported (13.32Ra). This is above the MORB range, indicating a contribution from lower mantle fluids, likely derived from the Samoan hotspot. In contrast, Tristan samples exhibit low Rc/Ra values, with an average of 5.12Ra. These low helium ratios suggest the presence of a more radiogenic, 4He-rich mantle. The low helium ratios may be related to the EM nature of the mantle. Previous studies in the Canary Islands have shown a decrease in 3He/4He ratios in the eastern part of the archipelago, where EM components have been identified (Hoernle et al., 1991; Simonsen et al., 2000; Day and Hilton, 2011, 2021; Sandoval-Velasquez et al., 2021b). However, it is confirmed that an EM component can show a wide range of variation for the 3He/4He ratio, ranging from low values of 5-6Ra to values beyond the typical MORB range, which overlaps (and complicates the distinction) with other OIB contexts with HIMU signature.

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3.1. Sampling method

Samples were obtained from Tristan and Tau (Samoa) island. Samples include 5 lavas from Tristan and 1 dunite from Tau (Samoa). Samples were properly prepared at the University of Palermo: all samples were crushed and sieved with the aim of hand-picking crystals of olivine and pyroxene with diameters > 0.5mm. A minimum of 1gr of olivines was collected for each aliquot. After picking, samples were transferred to the noble gas isotopes Laboratory of the INGV-Palermo in order to be cleaned ultrasonically in HNO3, deionized water and high-purity acetone; subsequently, olivine aliquots were accurately weighed.

3.1. Analytical procedure

After cleaning samples were loaded into an ultra-high-vacuum (UHV) crusher for noble gas analyses that was pumped and backed for 48 h at 120 ◦C. As soon as the ultra-high-vacuum was reached, the gas trapped in fluid inclusions was released by single-step crushing at about 200 bar and room temperature (21 ◦C). The moles of CO2 were also quantified by measuring the total pressure of gas (generally CO2 + N2 + O2 + noble gases) released during crushing (by an IONIVAC Transmitters ITR90) in a known volume of the system, then subtracting the residual pressure of N2 + O2 + noble gases after removing CO2 in a “cold finger” immersed in liquid nitrogen. For noble gas analysis, the residual gas mixture was purified under Zr–Al getter pumps in a UHV stainless-steel preparation line. After then, Ar (and Kr and Xe) was removed in a “cold finger” with active charcoal immersed in liquid nitrogen. Finally, He and Ne were adsorbed in a cold head with active charcoal cooled at 10 K and then moved at 40 and 80 K in order to release first He and then Ne, respectively. He and Ne isotopes were analyzed using two different split-flight-tube mass spectrometers (Helix SFT-Thermo), while Ar isotopes were analyzed by a multi-collector mass spectrometer (Argus, GVI). Analytical uncertainties (1σ) for 3He/4He, 20Ne/22Ne, 21Ne/22Ne, 40Ar/36Ar, and 38Ar/36Ar ratios are <2.7%, <6.3%, <7.5%, <2.0%, and < 1.7%, respectively. The 20Ne/22Ne and 21Ne/22Ne ratios are corrected for isobaric interferences at m/z values of 20 (40Ar2+) and 22 (44CO2+2).

4. File description

4.1. File inventory

Data is reported in the file *2025-077_Sandoval-Velasquez-et-al_data_C1_015_CICNOS.xlsx*.

4.2. Description of the data table

4.2.1. 2025-077_Sandoval-Velasquez-et-al_data_C1_015_CICNOS.xlsx

Column header	Unit	Description
Sample	-	Sample name
Rock	-	Rock type
Locality	-	Sampling location
Date	YYYY-MM-DD	Sampling date
4He mol/g	mol/g	Helium-4 (moles per gram)
4He err	mol/g	4He measurement error
3He mol/g	mol/g	Helium-3 (moles per gram)
3He err	mol/g	3He measurement error
20Ne mol/g	mol/g	Neon-20 (moles per gram)
20Ne err	mol/g	20Ne measurement error
21Ne mol/g	mol/g	Neon-21 (moles per gram)
21Ne err	mol/g	21Ne measurement error
22Ne mol/g	mol/g	Neon-22 (moles per gram)
22Ne err	mol/g	22Ne measurement error
H2O+CO2	mol/g	Water vapour + carbon dioxide (moles per gram)
N2 tot	mol/g	Molecular Nitrogen (moles per gram)
Air mol/g	mol/g	Quantity of air found during the analysis (moles per gram)
40Ar mol/g	mol/g	Argon-40 (moles per gram)
40Ar err	mol/g	40Ar measurement error
38Ar mol/g	mol/g	Argon-38 (moles per gram)
38Ar err	mol/g	38Ar measurement error
36Ar mol/g	mol/g	Argon-36 (moles per gram)
36Ar err	mol/g	36Ar measurement error
40Ar* mol/g	mol/g	Argon-40 corrected for atmospheric contamination (moles per gram)
40Ar* err	mol/g	40Ar* measurement error
He/Ar	-	Helium-4/Argon-40 ratio
N2/Ar	-	Molecular Nitrogen/Argon-40 ratio
He/Ne	-	Helium-4/Neon-20 ratio
Err	-	Error associated with the isotopic ratio
He/Ar*	-	Helium-4/ Argon-40* (corrected for atmospheric contamination) ratio
Err	-	Error associated with the isotopic ratio
He/CO2	-	Helium-4/Carbon dioxide ratio
R/Ra	-	Helium-3/Helium-4 not corrected for atmospheric contamination
Rc/Ra	-	Helium-3/Helium-4 corrected for atmospheric contamination
Err tot +/-	-	Helium-3/Helium-4 corrected for atmospheric contamination (measurement error)
40Ar/36Ar	-	Argon-40/Argon-36 ratio
Err (%)	%	Argon-40/Argon-36 ratio (measurement error)

38Ar/36Ar	-	Argon-38/Argon-36 ratio
Err (%)	%	Argon-38/Argon-36 ratio (measurement error)
20Ne/22Ne	-	Neon-20/Neon-22 ratio
Err tot +/-	-	Neon-20/Neon-22 ratio (measurement error)
21Ne/22Ne	-	Neon-21/Neon-22 ratio
Err tot +/-	-	Neon-21/Neon-22 ratio (measurement error)
CO2/3He	-	Carbon dioxide/Helium-3 ratio
TOT mol/g	mol/g	Total gas content

Noble gas concentrations are reported in mol/g and uncertainties are 1σ. The measured 3He/4He ratios are expressed as R/Ra (where R is the ratio of the sample and Ra the He isotopic ratio of air = 1.39 × 10-6); this ratio was corrected for atmospheric contamination based on the measured 4He/20Ne ratio and the values are expressed as Rc/Ra:

*Rc/Ra = Rm/Ra * (He/Ne(m) - He/Ne(a))/(He/Ne(m) - He/Ne(a));*

where Rm/Ra and He/Ne(m) are the measured values, He/Ne(a) is the atmospheric value of 0,318 (Ozima and Podosek, 2001).

40Ar values were also corrected for atmospheric contamination:

40Ar = 40Ar(m) - (36Ar(m) * (40Ar/36Ar(a)));*

where 40Ar(m) and 36Ar(m) are the measured values and 40Ar/36Ar(a) is the atmospheric value = 295,5 (Ozima and Podosek, 2001).

5. References

Day, J.M.D., Hilton, D.R., 2021. Heterogeneous mantle-derived helium isotopes in the CanaryIslands and other ocean islands. Geology. https://doi.org/10.1130/G47676.1

Day, J.M.D., Hilton, D.R., 2011. Origin of 3He/4He ratios in HIMU-type basalts constrained from Canary Island lavas. Earth Planet. Sci. Lett. 305, 226–234. https://doi.org/10.1016/j.epsl.2011.03.006

Hoernle, K., Tilton, G., Schmincke, H.-U., 1991. SrNdPb isotopic evolution of Gran Canaria: Evidence for shallow enriched mantle beneath the Canary Islands. Earth Planet. Sci. Lett. 106, 44–63. https://doi.org/10.1016/0012-821X(91)90062-M

Ozima, M., Podosek, F.A., 2001. Noble Gas Geochemistry, 2nd ed. Cambridge University Press. https://doi.org/10.1017/CBO9780511545986

Sandoval-Velasquez, A., Rizzo, A.L., Aiuppa, A., Remigi, S., Padrón, E., Pérez, N.M., Frezzotti, M.L., 2021b. Recycled crustal carbon in the depleted mantle source of El Hierro volcano, Canary Islands. Lithos 400–401, 106414. https://doi.org/10.1016/j.lithos.2021.106414

Simonsen, S.L., Neumann, E.-R., Seim, K., 2000. Sr–Nd–Pb isotope and trace-element geochemistry evidence for a young HIMU source and assimilation at Tenerife (Canary Island). J. Volcanol. Geotherm. Res. 103, 299–312. https://doi.org/10.1016/S0377-0273(00)00228-6