Noble gas and CO_2 compositions of petit-spot magma

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Recent studies revealed that the upper mantle has some degrees of noble gas isotopic heterogeneity reflecting degassing history, recycling of atmospheric noble gases, and influence of deep plume source mantle [e.g., 1, 2]. To date, most studies of the upper mantle noble gas compositions have used quenched glasses of the Mid-Ocean Ridge basalts (MORB). Petit-spot volcanoes are formed near the flexure of subducting oceanic plates. The magma that forms petit-spot volcanoes contains very high concentrations of volatiles (CO_2: >5 wt% [3]) and is thought to originate from the asthenosphere. Thus, the petit-spot lava sample may allow us to study the noble gas composition of the source mantle that is far from the MORB mantle. A quenched basaltic glass of petit-spot volcanic lava containing many vesicles (6k#1466 R3-003) was collected from the seafloor near the Minamitorishima (Marcus) island on the westernmost part of the Pacific Plate. In this study, we performed a noble gas isotope analysis of this sample to investigate the noble gas and CO_2 compositions of the petit spot magma and its source mantle.

The gases contained in bubbles were released by stepwise crushing in sample containers connected to the noble gas mass spectrometer (VG-5400/MS-IV, The University of Tokyo) via a noble gas purification line. The total pressure of the released gases was monitored by a capacitance manometer. The gases were then purified by getter pumps in the purification line and introduced into the mass spectrometer to analyze the amounts and isotopic compositions of noble gases (He, Ne, Ar, Kr, Xe). The amount of CO_2 was estimated from the total pressure.

In the $^{20}Ne/^{22}Ne$-$^{21}Ne/^{22}Ne$ diagram, sample data plot along a straight line connecting to the atmospheric Ne ($^{20}Ne/^{22}Ne$ = 9.8). The maximum value of the $^{20}Ne/^{22}Ne$ (9.8–12.5) is comparable to the mantle value (~12.5 [4]). This indicates that the noble gases of petit-spot magma originate from the mantle. The $^{21}Ne/^{22}Ne$ of the petit-spot source mantle (0.054±0.001) is estimated from the regression line of $^{20}Ne/^{22}Ne$-$^{21}Ne/^{22}Ne$ compositions at the mantle $^{20}Ne/^{22}Ne$ of 12.5. Similarly, the mantle $^{40}Ar/^{36}Ar$ (25500^{+2800}_{-2200}) is estimated from the $^{20}Ne/^{22}Ne$-$^{40}Ar/^{36}Ar$ correlation. These are similar to the MORB mantle values of $^{21}Ne/^{22}Ne$ = 0.055–0.068 [1] and $^{40}Ar/^{36}Ar$ = 20000–50000 [2], but different from the plume-influenced OIB mantle values of $^{21}Ne/^{22}Ne$ = 0.034–0.048 and $^{40}Ar/^{36}Ar$ = 9400–17000 [e.g., 2, 5]. Consequently, our analysis revealed that the Ne and Ar isotopic compositions of the petit-spot source mantle are MORB-like.

The noble gas elemental ratios and $CO_2/^{22}Ne$ of petit-spot magma are estimated from the correlations between (^{36}Ar, ^{84}Kr, ^{130}Xe, CO_2)/^{22}Ne and $^{20}Ne/^{22}Ne$, assuming magmatic $^{20}Ne/^{22}Ne$ = 12.5. The elemental ratios are similar to those of the MORB magma [4] and the $CO_2/^{22}Ne$ is consistent with the MORB magma values. It has been suggested that some petit-spot magmas do not reach the surface and modify the compositions of subducting oceanic plates [6, 7]. Hence, the petit-spot magma may input MORB-like mantle volatiles into the subducting oceanic plates. The MORB-like $CO_2/^{22}Ne$ also suggests that the high CO_2 concentration of petit-spot magma is related to the low-degree partial melting of a mantle.

References

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