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He-Ne-Ar-O isotope geochemistry of Cenozoic basalts in the East Sea, Republic of Korea

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The East Sea (Sea of Japan) is a back-arc basin where Cenozoic intraplate volcanic activity provides insights into the tectono-magmatic evolution of East Asia. However, the origin of volcanism remains controversial, with various hypotheses proposed for the magma sources. Here, we report new helium, neon, argon, and oxygen isotope data in olivine and clinopyroxene phenocrysts from Cenozoic basalts collected from four volcanic edifices (Ulleungdo, Anyongbok, Dokdo, and Simheungtaek) in the East Sea. The analyzed olivine (Mg# = 72.5-89.0) and clinopyroxene (Mg# = 66.5-88.4) phenocrysts are generally in equilibrium with melt compositions, indicating the minerals are phenocrysts or antecrysts rather than xenocrysts. Helium isotope ratios ($^{3}He/^{4}He$; reported relative to the air ratio of 1 Ra = 1.4 x 10^{-6}) range from 4.5 to 6.0 Ra in the Dokdo and Ulleungdo samples, which overlap with the sub-continental lithospheric mantle range (SCLM, 6.1±2.1 Ra) [1] and notably lower than those of the asthenospheric mantle (8±1 Ra) or the plume source mantle (> 9 Ra) [2]. Most neon ($^{20}Ne/^{22}Ne$ = 9.72-10.16; $^{21}Ne/^{22}Ne$ = 0.0287-0.0299) and argon isotope ratios ($^{40}Ar/^{36}Ar$ = 312.9-709.7) closely align with the atmospheric values ($^{20}Ne/^{22}Ne$ = 9.8; $^{21}Ne/^{22}Ne$ = 0.0290; $^{40}Ar/^{36}Ar$ = 295.5), possibly reflecting atmospheric contribution mixed with mantle signature. Oxygen isotope compositions of olivine phenocrysts ($d^{18}O$ = 5.40±0.45‰ vs. V-SMOW) broadly fall within the range of typical mid-ocean ridge basalts (5.18±0.28‰), while most zircons from the cogenetic trachytes have been reported to show lower $d^{18}O$ values (3.82-5.82‰) than the typical mantle value (5.3±0.3‰) [3, 4]. It is likely that the low-$d^{18}O$ values of the trachytes resulted from assimilation with hydrothermally altered country rocks during magmatic differentiation. In conclusion, our results suggest that the East Sea magmas derived from partial melting of the upper mantle might have been influenced by SCLM. This has implications for the magmatic source enrichment in East Asian intraplate volcanisms during the Cenozoic.

[1] Day et al. (2015) GCA 153, 116-133. [2] Graham (2002) Reviews in Mineralogy and Geochemistry 47, 247-317. [3] Choi et al. (2024) Geoscience Frontiers 15, 1-14. [4] Cheong et al. (2024) Gondwana Research 129, 132-141.