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Quantifying radiogenic helium from mantle volatiles in the diapiric structures in the South China Sea

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Subductions have recycled extremely large crustal materials into the upper convecting mantle, deep mantle, and even to the core-mantle boundary. While radioactive elements in the crustal materials continue to decay and produce daughter elements (e.g., U/Th and ^{4}He pair), it remains unknown the fate of the radiogenic elements in the subducted materials and their interaction with mantle volatiles. The Hainan mantle plume (HMP), located in the South China Sea (SCS), provides a unique place to study the subducted crustal materials and their interaction with mantle volatiles. HMP is surrounded by a curved subduction system, which is encompassed by the India plate in the west, the Australia plate in the south, and the Philippine Sea-Pacific plate in the east. It is originated from the lower mantle and governed by subduction, mantle convection and mantle plumes.

We collected 19 CO_2-rich samples from industrial gas producing wells in the HMP region. They were all associated with diapiric structures under the SCS. Gas abundance, stable C/H and noble gas isotopic composition were analyzed. CO_2 and CH_4 are major gas components in the samples with trace amount of C_{2+}, N_2, H_2, and noble gases. CO_2 concentrations range between 3.3 to 93.5%, while $\delta^{13}C_{CO2}$ values range between 11.24 and 2.24‰. Majority of samples appear dry gas (avg. 36.5%CH_4) with dryness coefficients ($C_1/\Sigma C_{2-5}$) of 0.962~0.989, but some samples are wet gas (avg. 70.5%CH_4) with dryness coefficients of 0.784~0.888. Observed $^{4}He/^{20}Ne$ ratios suggest negligible atmospheric He contribution. Measured $^{3}He/^{4}He$ ratios (0.08R_a~2.17R_a, normalized to the atmospheric $^{3}He/^{4}He$ ratio R_a of 1.4×10^{6}) show mixing between mantle and crustal endmembers. $^{40}Ar/^{36}Ar$ ratios range between 550 and 1600, suggesting young age of the gas trapping structures in the SCS.

We have built models using combined noble gas and stable isotopes to trace the origin of gases (e.g., CO_2, CH_4) as well as processes and timing of the deeply recycled subducted material and its interaction with primordial mantle domains. Our findings reveal large-scale crust-mantle interactions under the SCS and significant volatile migration from deep mantle to shallow crust in the region.