Heavy noble gases help distinguish mantle and lithospheric contributions in southwestern US hot springs

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Although $^{3}He/^{4}He$ can provide unambiguous indications of mantle-derived gases in continental settings, it remains difficult to accurately discern lithospheric vs. mantle contributions in many continental environments or to determine the timing and mechanisms by which mantle/lithospheric fluids migrated to the surface. For example, mixing with either a crustal- or lithospheric-sourced fluid could drive a fluid with an asthenospheric helium isotopic signature ($^{3}He/^{4}He$ = 8R_A) lower (crustal $^{3}He/^{4}He$ = 0.02R_A; $^{3}He/^{4}He$ = 4-6R_A). Further, source apportionment is sensitive to the residence time in the crust due to ^{4}He production from radioactive uranium and thorium isotopes. For these reasons it can be challenging to determine lithospheric vs. mantle contributions in hot springs with non-crustal $^{3}He/^{4}He$ (i.e., > 0.02R_A). Our preliminary data suggest that heavy noble gas (Ar, Kr, Xe) data, particularly xenon isotopes, provide a potential tracer that can help resolve asthenospheric vs. lithospheric contributions in hot springs and provide some constraints on the relative residence time of CO_2 degassing in continental settings. The simultaneous enrichment of both resolvable primordial (^{129}Xe, which is predominantly produced from the radioactive decay of extinct ^{129}I) and radiogenic (e.g., $^{131,134,136}Xe$, which are produced from the fission decay of ^{238}U) xenon isotopes suggest the presence of a lithospheric endmember in fluids measured in hot springs at some locations in the Four Corners area of the western US.

To test these hypotheses, we analyzed a suite of noble gas isotopic compositions in hot springs in the Colorado Plateau and Rocky Mountains, US. Many samples, specifically those with high gas/water ratios, display resolvable excesses in ^{3}He and ^{129}Xe relative to air-saturated water with variable excesses in $^{40}Ar^*$, and radiogenic xenon isotopes. Excess ^{3}He and ^{129}Xe are consistent with mantle contributions, while variable radiogenic gases reflect the relative mixtures of air-saturated water, mantle, lithosphere, and the crust providing insight on their history during crustal emplacement.