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Noble gas geochemistry applied to CO_2 geological storage: Examples from French natural analogues

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We made analyses of noble gases and associated major compounds (in this case almost 100% CO_2) with the $\delta^{13}C(CO_2)$ from different places from the French carbo–gaseous province. We also made some petrological and sedimentological observations of the travertines present in all different sampled places, to determine wether some significant part of the leaking CO_2 could be trapped at the Earth surface. The purpose of the study is to determine, using natural analogues, which context is most favourable for future CO_2 storage.

We collected seven gas samples from natural bubbling sources and geyser near Sainte Marguerite, Allier, France. This area is known to present an important heat flow anomaly, and the probable existence of a mantle plume just below. The site exhibits many CO_2-rich sources, with also giant "bubbles" forming always at the same place in the Allier river.

Back in the laboratory, we analysed the gas which is composed of almost 100% CO_2 with a ^{13}C (CO_2) of around -5‰ compatible with a mantle-derived origin. We analysed noble gas concentrations and isotopic ratios.The preliminary results show helium concentrations in the range of 0.28 to 8.22 ppm, with 5 samples lower than the atmospheric helium concentration of 5.24 ppm.

However, within these samples, the $^4He/^{20}Ne$ ratios -even low- (from 2.12 to 198)- all are greater than air value of 0.288; thus air contamination can be discarded. The most intriguing result is that all our samples exhibit high and relatively homogeneous values of R/Ra, around 3.5 - 4, implying a large contribution of mantle-derived helium (R/Ra = 8 for the upper mantle, R/Ra around 6 for the SCLM) to the total budget of this gas.

The neon and argon isotopic ratios are not far from the atmospheric values, suggesting a small, if any, crustal contribution and an important Air Saturated Water (ASW) contribution, in agreement with this hydrothermalism. This is consistent with our very low total helium budget.

To our knowledge, this is the first time that so low helium concentrations combined with so high $^3He/^4He$ are measured in crustal fluids.

Our tentative interpretation is that gas comes from a degassing magma at depth, and then is transported to the surface as dissolved in water without accumulation. This is confirmed by the slight isotopic fractionation seen in the neon isotopes together with some elemental ratios, enriched in the lightest noble gas.

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