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Noble gases in Jackson Dome gas deposits: identifying and quantifying natural CO_2 sequestration processes

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Jackson Dome natural CO_2 gas deposit, one of the deepest commercial CO_2 gas fields in the world, is located in central Mississippi, USA. It provides an important analogue for studying natural CO_2 sequestration process. We show in this presentation how noble gases can be used, together with other gases, to identify and quantify the origin, migration and sequestration processes of CO_2 gas in the Jackson Dome reservoir. We collected 10 gas samples from producing wells from Jackson Dome reservoirs. The Jackson Dome gas is dominated by CO_2, which ranges from 98.75% to 99.38%. The trace amounts of CH_4 and N_2 are correlated, and both correlate negatively to CO_2, suggesting that they have a common source. The greatest admix of N_2 and CH_4 is found on the crest of the trapping structure, however, the purest CO_2 is found at the field margins. $^3He/^4He$ ratios range between $4.27R_a$ and $5.01R_a$ (where R_a is the atmospheric value of 1.4×10^6), indicating a strong mantle signature. $CO_2/^3He$ ratios vary between 1.07×10^9 and 4.62×10^9, they all fall in the range of the values found in pure magmatic samples ($1\text{-}7\times10^9$). ^{20}Ne concentrations correlate with resolved crustal radiogenic ^4He concentrations, suggesting radiogenic noble gases also dissolved into groundwater before partitioning into the gas phase. The negative correlation between air-derived ^{20}Ne and $CO_2/^3He$ ratios shows that water plays a role in CO_2 sequestration, it can be responsible for more than 70% of CO_2 loss. The difference in mixing characteristics between the various gas reservoirs suggests that either the magmatic or crustal fluid end member varies from one system to another over relatively short distances. $^{40}Ar/^{36}Ar$ ratios are between 4071 and 6420, the resolved radiogenic $^{40}Ar^*$ contributes more than 90% of the total ^{40}Ar. The relationship among major gases (CO_2, N_2), ^{40}Ar, ^4He and Ne isotopes shows that the gases in Jackson Dome reservoir are a mixture of a fractionated air component, a magmatic end member and a radiogenic/crustal component. Elemental fractionation of $^{20}Ne/^{36}Ar$ in the gas phase increased the ratio from 0.156 to between 0.798 and 1.35. $CO_2/^3He$ ratios correlate with both $^{20}Ne/^{36}Ar$ and $\delta^{13}C$ (CO_2) values. We explored a variety of models to explain this data including: oil-groundwater partitioning; gas-groundwater partitioning; excess air dissolution and noble gas re-dissolution. A solubility controlled Rayleigh fractionation of groundwater modified by oil interaction can account for the correlations. In this case all the gases are dissolved in the groundwater on reaching the trapping structure. The concentrations of air-derived noble gases and other gas species (e.g. CO_2, CH_4 and N_2) also tell us the migration history of CO_2 gas in the reservoir. Relatively high concentrations of ^{20}Ne, ^4He, CH_4, N_2 and low concentrations of CO_2 in gas samples from the centre of reservoir are consistent with the solubility partition of gases between gas and groundwater phases at the first degassing stage. At the later stages of the partition, gases with relatively high CO_2 concentrations and low ^{20}Ne, ^4He, CH_4 and N_2 concentration fill the margin of the trapping structure. We are exploring other models to identify whether or not this concept provides a unique solution.

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