Quantifying natural gas and groundwater interaction with noble gases in the Sichuan Basin, China

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Groundwater plays an important role in the formation of natural gas reservoirs. It can preserve, transport and release gases under favourable geological conditions. However, quantifying the contribution of gases derived from groundwater in a natural gas reservoir remains a challenging question. This study uses a full range of noble gas isotopes combined with gas abundance and stable isotope data to quantify the natural gas and groundwater interaction in the Anyue gas field, Sichuan basin, China.

The Anyue gas field is a supergiant field discovered recently. The gas in the Anyue field is dry with methane content between 98.73-99.32%. As for heavy hydrocarbon gases, only trace ethane is detected between 0.03-0.16%. There are also trace amount of CO_2, N_2 and noble gases in the gas samples. The carbon isotope of methane in gas samples ranges between -34.2‰ and -32.5‰. The carbon isotope of methane in groundwater samples collected at gas-water separator is much less negative than that of gas samples, indicating apparent distillation effect of formation water on carbon isotope in methane. The carbon isotope in reservoir bitumen shows much more negative values than that of the gas samples. All gas abundance and stable isotope data suggest that significant amount of gases in the Anyue field are derived from groundwater.

$^3He/^4He$ ratios are between 0.01-0.02R_a (R_a=$^3He/^4He$ in atmosphere) showing clear crustal signature. $^{40}Ar/^{36}Ar$ ratios range between 897 and 115000, demonstrating a large radiogenic component of ^{40}Ar. $CH_4/^{36}Ar$ ratios are higher than a complete degassing model would predict, suggesting gases in the Anyue field are a mixture of gases derived from groundwater and other sources. Abundances and elemental fractionation of water derived noble gases, e.g. ^{20}Ne and ^{36}Ar are used to model the gas and groundwater interaction. Based on these models, volume of groundwater associated with the gas reservoir is quantified. In addition, radiogenic noble gas isotopes, e.g. ^4He and ^{40}Ar, are used to date ages of the groundwater system to better understand the accumulation mechanisms of the Anyue gas field.