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The Migration and Influence of Thermogenic Hydrocarbons in Shallow Aquifers across the Karoo Basin, South Africa

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While horizontal drilling and hydraulic fracturing have enhanced global production of unconventional hydrocarbons, these developments have raised environmental concerns regarding water usage and contamination near unconventional energy extraction. We conducted a comprehensive pre-industrial evaluation of the baseline water quality and geochemistry of groundwater in the water-restricted Karoo Basin of South Africa. Our analyses utilized a multi-tracer geochemical approach to evaluate gas and salt chemistry within this sensitive region. Stray gas contamination of groundwater remains a risk for a subset of groundwater wells near shale gas development. Thus, we focus our current efforts on characterization of gas geochemistry of natural hydrocarbon-gas-rich springs and groundwater wells across the Karoo Basin. Twenty-two samples were analyzed for water parameters, dissolved ion chemistry, water isotopes, major gas geochemistry, compound-specific stable isotopes of hydrocarbons, dissolved inorganic carbon and CO_2, noble gas elemental and isotope geochemistry, and tritium. We find that methane-rich springs targeted for elevated gas contents are associated with Na-Cl-type waters and contain elevated levels of ethane, ^{4}He and noble gases produced by radioactive decay, and less negative δ^{13}C-CH_4 compared to background samples. Gas- and salt-rich samples display evidence of mixing between a low- to mid-thermal maturity thermogenic natural gas that experienced fractionation during migration into shallow aquifers that later mixed with variable amounts of hydrogenotrophic biogenic methane. Gas- and salt-poor samples instead contain more negative δ^{13}C-$CH_4$and a subset which represents mixing between hydrogenotrophic and acetoclastic methanogenesis. Our approach allows us to identify sources and migration histories for naturally-occurring hydrocarbons in the Karoo Basin.