Light hydrocarbon and noble gas migration as an analogue for potential CO_2 leakage: numerical simulations and field data from three hydrocarbon systems

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Abstract

Sites where anthropogenic CO_2 captured from industrial sources is stored in deep geological formations for climate change mitigation are required to show secure retention of the injected CO_2. Monitoring, reporting, and verification (MRV) plans are needed to indicate that no CO_2 release has occurred. We explored the degree to which direct comparison between a surface anomaly and reservoir geochemistry using various geochemical parameters can be used for attribution. We used data collected on light hydrocarbons and noble gases throughout the sedimentary column at three CO_2 enhanced oil recovery (EOR) sites to understand the processes that may cause fluid evolution. Light hydrocarbon and noble gases were sampled from reservoirs, gas-bearing intervals above reservoirs, and groundwater. Vertical profiles indicated that lighter components are relatively enriched during migration (i.e. chromatographic separation). Static and numerical models were designed to simulate episodic gas migration and geochemical alteration of these geochemical parameters from solubility and sorption. The effects of hydrocarbon solubility were minimal (Bernard ratio changes within 5.2%) although field data were within the range of expected alterations from sorption. Forward models of CO_2 migration and noble gas interactions showed that CO_2 stripping causes an enrichment of crustal noble gases. In areas where natural fluxes of CO_2 from depth are non-existent, the occurrence of crustal noble gas signature may distinguish fugitive CO_2 from the reservoir from natural near-surface sources, and could be considered to explain apparent fluid anomalies.