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Noble Gas Signatures Under Transient Fluid Equilibrium: Correlation with N_2, CO_2, and CH_4 in Aquifers and Reservoirs

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Geochemical fluid tracing, through analysis of major fluid components distribution, offers insights into subsurface fluid source(s). However, complex thermodynamic behaviour of fluids complicates direct linkage with geological history. Noble gases are inert and scarce in geological fluids and exhibit predictable thermodynamic behaviour [1]. Additionally, their solubility coefficients control their distribution in multi-phase fluid systems, making them ideal tracers [2].

In this study, we analysed five fluid samples from different depths within a single underground reservoir. From the multiphasic column, we collected two samples from the gas, two from the oil, and one from the underlying aquifer. The study aims to understand fluid source(s) and timing of associated charge and migration processes.

The N_2 concentration in the water phase fits with expected equilibrium concentrations in open water bodies, indicating an atmospheric source [3]. The N_2 concentration pattern across the hydrocarbon column reveals a notable increase in concentration near the water contact, contrary to equilibrium expectations. CO_2 exhibits a similar vertical distribution to N_2 across all phases. However, since the main sources of CO_2 are metamorphic or magmatic, water is the carrier phase for CO_2 charge. Additionally, the CH_4 concentration in the water phase surpasses that within the oil phase, implying that the underlying aquifer serves as the carrier phase for the hydrocarbon charge. Lastly, the substantial presence of CO_2 and CH_4 in the aquifer suggests ongoing charging processes for both.

Noble gas signatures throughout the entire column reveals a vertical organization incompatible with a hydrocarbon column at steady state [4]. Given the reservoir's thickness, both the hydrocarbons and CO_2 charge must be younger than 1 Myr, affirming insights drawn from main phase components.

The inorganic origin of CO_2 implies a high-temperature process, either magmatic or metamorphic. This significant temperature may have facilitated source rock maturation, resulting in the generation and migration of hydrocarbons within a similar timeframe.

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