Geophysical Research Abstracts
Vol. 18, EGU2016-17501-1, 2016
EGU General Assembly 2016

Noble gas as tracers for CO_2 deep input in petroleum reservoirs

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The sub-salt hydrocarbon reservoirs in the deep offshore part of the Atlantic Ocean passive margins are a new key target for frontier oil and gas exploration. Type I source rocks locally rich in TOC (Total Organic Carbon) combined with an important secondary connected porosity of carbonate reservoirs overlain by an impermeable salt layer gives rise to reservoirs with high petroleum potential. However, some target structures have been found to be mainly filled with CO_2 rich fluids. δ13C of the CO_2 is generally between -9 and -4 permil, compatible with a deep source (metamorphic or mantle). Understanding the origin of the CO_2 and the relative timing of its input into reservoir layers in regard to the geodynamic context appears to be a key issue for CO_2 risk evaluation.
The inertness and ubiquity of noble gases in crustal fluids make them powerful tools to trace the origin and migration of mixed fluids (Ballentine and Burnard 2002). The isotopic signature of He, Ne and Ar and the elemental pattern (He to Xe) of reservoir fluid from pressurized bottom hole samples provide an insight into fluid source influences at each reservoir depth. Three main end-members can be mixed into reservoir fluids (e.g. Gilfillan et al., 2008): atmospheric signature due to aquifer recharge, radiogenic component from organic fluid $\pm$ metamorphic influence, and mantle input. Their relative fractionation provides insights into the nature of fluid transport (Burnard et al., 2012)and its relative migration timing.
In the studied offshore passive margin reservoirs, from both sides of South Atlantic margin, a strong MORB-like magmatic CO_2 influence is clear. Hence, CO_2 charge must have occurred during or after lithospheric break-up. CO_2 charge(s) history appears to be complex, and in some cases requires several inputs to generate the observed noble gas pattern. Combining the knowledge obtained from noble gas (origin, relative timing, number of charges) with organic geochemical and thermodynamic understanding of the fluid, in regards with the geodynamical context, helps us to unravel the complex fluid history of these deep environments.

Ballentine C.J. and Burnard P.G. (2002). Rev. Mineral. Geochem., vol. 47, pp 481-538.

Burnard P et al. (2012) EPSL 341, pp 68-78.

Gilfillan, S.M.V. et al. (2008) GCA, vol. 72, pp 1174-1198.