Applying noble gas isotopes to trace cross formational gas flow in the Williston basin

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The desire to understand cross formational flow of deep groundwater and hydrocarbon systems is driven by interest in natural resources and environmental issues, as well as carbon sequestration and radioactive waste disposal. Noble gases can provide a predictive understanding of fluid occurrence, residence time, transport and thus cross formational flow [1].

The Williston basin, in North America, is a Cambrian to Pleistocene sedimentary basin with multi-layered aquifers and aquitards. We have determined the noble gas and major chemistry of 48 samples from variably CH_4-N_2 dominated gas fields from the deepest (Deadwood) to the shallowest (Milk River) geological formation. ^{4}He concentration ranges from 2.84×10^{-5} (Midale) to 2.84×10^{-2} (Mannville) cc STP/cc. Measured ^{3}He/^{4}He, normalised to the atmospheric ratio Ra, varies between 0.08 Ra to 0.36 Ra, except for Bakken Weyburn which are consistent with crustal production. ^{20}Ne ranges from 4.63×10^{-9} (Midale) and 1.57×10^{-5} (Manville) cc STP/cc, indicating a large extent of interaction with the water phase for some of gas fields. Excess ^{40}Ar range from 4.86×10^{-6} (Midale) to 0.0051 (Bakken) cc STP/cc, indicating significant radiogenic argon production for some geological formations.

Neon isotopic ratios are consistent with a crystalline basement flux into the deepest Deadwood formation. Compared to reference values for closed systems, Paleozoic samples show different degrees of ^{4}He loss (from 30% to almost 100%), while the shallowest unit (Milk River) shows more than a 700% gain. The CH_4-N_2-^{36}Ar ratios can be used to identify gas migration in either a free gas phase or dissolved in solution [1]. The majority of the gas accumulations here can be explained by gas exsolution from a water phase. An advection-diffusion model is being developed to determine the relative importance of cross formational flow in a water dominated system.

[1]Ballentine, C. J. and et al., (2002). *Reviews in Mineralogy and Geochemistry,* 47**,** 539-614.