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Resolving the sources of crustal noble gases in the Western Canada Sedimentary Basin to aid helium prospectivity

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Understanding how fluids move through the crust is critical for identifying accumulation of non-hydrocarbon gas reserves such as helium (He) and hydrogen (H_2). Due to their inertness, noble gases within natural gases can help to constrain gas origins and serve as useful tracers of the subsurface physical migration processes acting on them.

Here, we present a new compilation of noble gas data from the Western Canada Sedimentary Basin (WCSB) obtained from natural gas wells that sample the regional stratigraphy from Upper Cretaceous-Cambrian. We find that there is considerable variation in noble gas composition with age and depth across the basin.

We identify increases in ^{4}He, crust-derived radiogenic ^{21}Ne* and ^{40}Ar* in the deepest samples, while ratios of ^{21}Ne/^{22}Ne, ^{40}Ar*/^{36}Ar and ^{21}Ne*/^{36}Ar also increase with proximity to the Precambrian basement. This indicates a resolvable radiogenic flux is present throughout, which we assume to originate from the Precambrian basement. The youngest formations exhibit enrichments in light noble gases (^{4}He and ^{21}Ne) compared with the heavier (^{40}Ar). We suggest this due to solubility-controlled fractionation and the preferential release of lighter noble gases from minerals at shallower depths.

Calculation of expected initial ^{4}He in groundwaters within a closed system demonstrates that the deepest WCSB formations (Cambrian to Upper Devonian) exhibit some of the oldest ^{4}He ages compared to their formation ages, suggesting an external supply of radiogenic He is required, which also can be attributed to a basement source.

Higher in the stratigraphy, ^{4}He ages both older and younger than the respective lithologies are observed. This provides potential evidence of frequent formation and groundwater recharge potentially including glacial flushing events. This infers that some of the shallowest formations still require an external source of He, implying an open-system cross-formational flow of radiogenic noble gas within the WCSB.

We identify the most prospective formation for He accumulation in the WCSB to be the porous Devonian formations, as these are, in some regions, located directly above basement lithologies. The pervasive, low permeability Fammenian and Tournaisian bituminous shale (Exshaw and Bakken Fm.'s and equivalent) appears to be one of the most effective overlying seals in the succession.