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High-resolution rock-core porewater hydrocarbon characterization for determining baseline groundwater quality in the Liard Basin, NWT

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Fresh groundwater resources overlying oil and gas plays may be vulnerable to the migration of stray gas (e.g., methane) from deep and intermediate depths into the shallow subsurface along natural and anthropogenic pathways. Field-based hydrogeological investigations to characterize baseline conditions and monitor potential long-term impacts is needed.

In this study, rock core porewater hydrocarbon (C_1-C_4) concentrations were measured on numerous depth-discrete samples using a high-resolution and field-based discrete fracture network methodology for sedimentary rock systems in the Liard Basin, Canada's second largest oil and gas basin proximal to Fort Liard, Northwest Territories. Continuous rock core down to ~149 m bgs was recovered from three locations along a ~25 km transverse spanning multiple fine-grained lithologic units and regional fault structures that serve as possible boundaries in the basin, influencing the groundwater flow system. The depth-discrete porewater geochemistry results, including hydrocarbon composition and associated stable carbon isotope ratios for methane, along with complementary datasets (e.g., borehole geophysical and hydro-physical logs) were used to interpret natural gas origins and migration pathways from within or from below the shallow fresh groundwater zone.

The observed distribution of methane and associated hydrocarbons (C_2-C_4) within the fresh groundwater zone, sampled on average every 1.5 m with depth, shows considerable variability with depth with discernable trends associated with hydrochemistry and lithostratigraphy along the transect. The high-resolution sampling strategy permitted alignment of methane concentration profiles and its carbon isotope signatures to the stratigraphic column, creating a continuous rock matrix concentration profile over a 269 m stratigraphic section of the subsurface. Rock core porewater samples from the Dunvegan Formation contained hydrocarbons with a mixed origin between microbial (80-95%) and thermogenic (5-20%) sources while samples from the underlying Sully Formation were likely thermogenic in origin. The rock core sample frequency also revealed specific depth-discrete biogeochemical reactions occurring within the shallow fresh groundwater zone involving the production and consumption of methane, ethane, and sulphate through microbial reactions associated with coal seams. These results will support the sedimentary rock depositional history, burial, and local methane alteration over geologic timescales, providing a strong basis for baseline conditions that inform future monitoring regarding mobility.