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Carbon Stable Isotope Geochemistry of Gases from a Unique Natural Unconventional "Semi-closed" System: the Duvernay Fm. of the Western Canada Sedimentary Basin

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Over the last 30 years, Muehlenbachs' laboratory has archived thousands of natural gas isotope analyses. Unique among them are gases from the Upper Devonian Duvernay Formation of the Western Canada Sedimentary Basin, which is a prolific unconventional petroleum system. The isotopic response of gases sourced from the Duvernay Fm. distinguishes itself by its consistent pattern on the "natural gas plot", in contrast to other gas reservoirs. I applied the "natural gas plot" after Chung et al. (1988), a geochemical tool that illustrates the relationship between the $\delta^{13}C$ values of each component of thermogenic gas and $1/n$, where "*n*" represents the carbon atom count in the hydrocarbon. This method assumes predictable mass-dependent kinetic isotopic fractionation between kerogen and gas. Seldom observed in the field, ideal gas isotopic behavior can be detected in the Duvernay sourced gases. These gases align nearly perfectly on this plot, indicating near closed system behavior with minimal mixing or alteration within the reservoir.

This study is based on the $\delta^{13}C$ of 113 production gas samples from the Duvernay. Traditional gas isotope geochemistry showed responses of hydrocarbon gases derived from a kerogen Type II in "oil-window". Their "natural gas" hydrocarbon systematics were statistically inspected, correlation and fit of each gas isotopic fingerprint were evaluated. This allowed a system re-classification, as: unaltered, mixed and altered systems. Samples with relatively high wetness (%), exceeding 20% overall, exhibit a statistical fit exceeding 99.99%. Conversely, samples with low wetness, particularly those in higher-pressure zones, show weaker correlations (fit <99.95%). Thus, gases showing unaltered $\delta^{13}C$ systematics were used as a proxy for wetness and fluid type prediction. Filtering the data for the best fit also enables extrapolated predictions of $\delta^{13}C$ kerogen values that correlate with basin morphology and source rock distribution. Notably, predicted kerogen values derived from gases with the most reliable statistics remain unaffected by maturity, affirming the independence of Duvernay gas generation from heating rate. Our comprehensive analysis enables the prediction of geochemical processes within this "semi-closed" system, corroborating previous findings from pyrolysis experiments conducted on Duvernay source rocks.

Chung et al. (1988). *Chemical Geology*, *71*(1–3), 97–104.