Isotopic Evidence for Tectonically Induced Mixing of Deep Shale Gases in Foothills Reservoirs of the Western Canada Sedimentary Basin

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In the Sukunka gas field, in the foothills at the very western edge of the WCSB, the best Permian and Triassic gas producing wells are in fault-propagation folds, and the gas is characterized by extremely unusual isotope reversals (Permian: δ13C methane -27 to -24 per mil, δ13C ethane -36 to -26 per mil; Triassic: δ13C methane -33 to -30 per mil, δ13C ethane -43 to -31 per mil). These isotope reversals are likely the result of mixing (1) conventional, over-mature, dry gas that was expelled from shale during late stages of burial with (2) another gas that has anomalously low δ13C ethane. The origin of this low δ13C ethane gas may be cracking of residual petroleum in deep shale source rocks. Intense folding and faulting during orogenesis liberated this secondary cracked gas from the shale and allowed migration and mixing in the structural trap. The folding and faulting at the edge of the foreland basin provided pathways and traps for accumulations of the deep gas.

Isotopically reversed gases are also found in the Triassic of Narraway and Minnow, Alberta to the southeast of Sukunka, B.C., in a similar position relative to the WCSB. In these fields, the best producing wells also have isotopically reversed gas, however the methane is less mature and its δ13C more variable (-42 to -34 per mil), whereas the δ13C ethane (-44 to -33 per mil) is similar to that of the Triassic in Sukunka. An additional complication is that normal thermogenic gases occur deeper in the section, in the Devonian Leduc Fm. Although one might have expected the same gas in all these foothills locations, the isotopic differences indicate a variation in the detail of the gas plumbing.

The lower δ13C methane in Narraway/Minnow can be attributed to an overall decrease in maturity of the gas to the southeast. The much greater variability in δ13C methane indicates a compartmentalization of the gas reservoirs not observed at Sukunka. The structural setting in Sukunka and Narraway/Minnow may be the same, except that at Narraway/Minnow there are more fault penetrated forelimbs that may create smaller pools and more compartmentalization. The isotope reversals indicate that Narraway and Minnow tap into the same deep shale gas source as Sukunka.

Our work suggests that these isotopically reversed, commercial foothills gases are sourced from deep shales and are analogous to unconventional shale gas. However, in the foothills, tectonic activity has created natural fractured reservoirs.