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Application of Natural Gas Compositions to Migration and Filling Models in Large Tight Gas Sand Reservoirs of the Rocky Mountain, USA

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Gas compositions in Upper Cretaceous tight-gas-sand reservoirs of the Rocky Mountains vary significantly both in an areal and a stratigraphic sense. We have investigated gas geochemistry at three fields – Jonah Field, Green River Basin; the Mamm Creek-Rulison-Parachute-Grand Valley complex in the Piceance Basin; Greater Natural Buttes, Uinta Basin, using a combination of mud gas and production well data. These three fields display significant internal variability in bulk hydrocarbon gas, isotopic and noble gas composition. We interpret these data in the context of source rock, fluid inclusion data, maturation and migration models and hydrous pyrolysis experimental studies on possible source rocks in these basins. More specifically, we test three filling models for these reservoirs (Figure 1): (a) gas diffuses upward through a series of moderately permeable seals, (b) gas forces its way upward by fracturing intermediate seals, or (c) gas migrates up conduits such as faults or fracture systems and then diffuses laterally. Each model has implications for predicting the top of gas within fields and the distribution of fields within a sedimentary basin and for estimating the scale of the natural gas resource with sedimentary basins.

Jonah appears to be the simplest system. Gases in the Lance and Mesaverde reservoirs become systematically wetter with depth, from 0.10 to 0.27 C_{2+} fraction, and the carbon isotopic composition of each gas becomes more negative (Figure 2). The overall range of methane compositions is from -33 to -44‰. Gases from the transition between overpressured Lance reservoirs and adjacent normally pressured Lance appear to be wetter than gases at similar depth within the Jonah structure. Compositions are consistent with gas associated with condensate and gases derived from primary or secondary cracking of oil than gases derived from coally sources. Closely spaced (~2-3 kms) wells within the field commonly produce methane of isotopic composition that varies by very as much as 10-12‰, suggesting that these wells produce from different parts of the section. Noble gas data on a number of cross-plots are tightly clustered, indicating relative uniform gas sources and little fractionation.

In contrast, gases from Mesaverde reservoirs in the Piceance Basin show a wide variety of compositions and no obvious trend with depth. Wetness generally ranges from 0.00 to 15% C2+ fraction, and isotopic compositions for methane mostly fall in the range of -38 to -40‰. Cross-plots suggest that the fraction of gas derived from coally sources is relatively small and the fraction of gas derived from marine sources such as the Mancos is relatively large, somewhat surprising given the abundance of coal in the Mesaverde section. Noble gas compositions show a much wider range, suggesting mixing of different gas sources or fractionation during migration and indicating that the Piceance Basin petroleum system has a much more complex generation and migration history than does Jonah Field.

Basin and migration modeling will be applied to test gas fractionation during generation and migration.

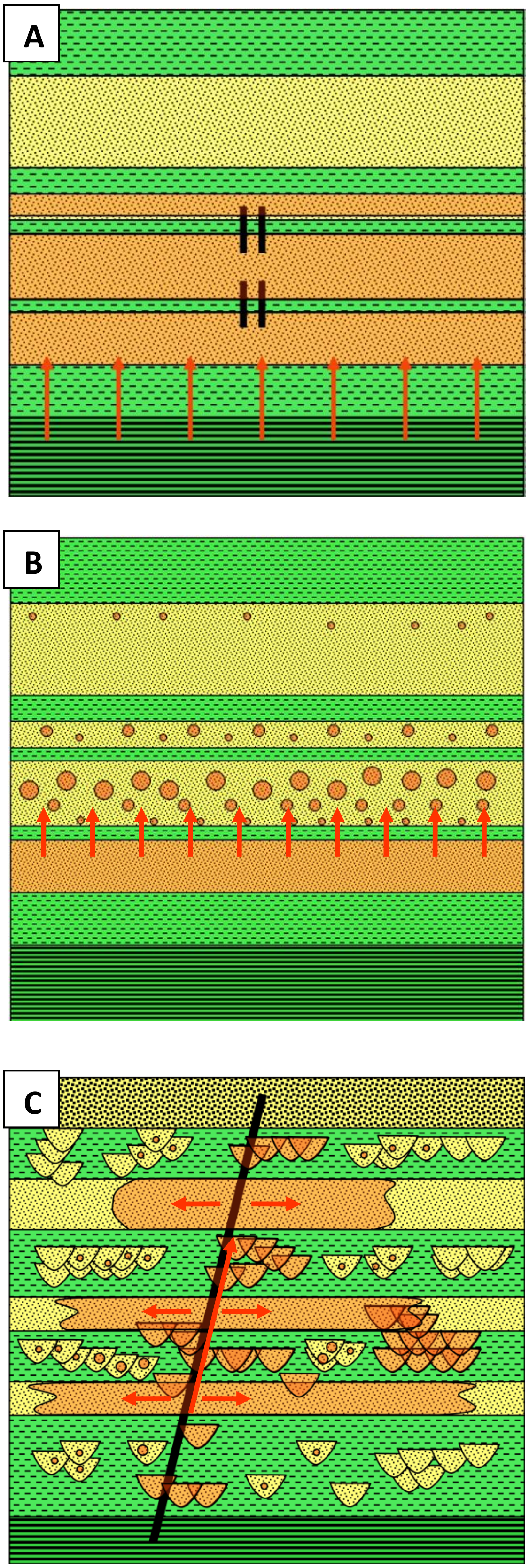

Figure 1. Reservoir filling models for large tight gas sand fields.

(A) Self-fracturing (after Cumella and Scheeval, 2008). The reservoir fills from bottom to top by the successive fill – seal rupture of successive reservoir compartments. Top-of-gas depends on: (1) differences in fracture strength of intermediate seals; (2) differences in geometry and distribution of lowermost reservoirs.

(B) Diffusion. Reservoir compartments fill by gas diffusion across intermediate seals (semi-permeable membrane). Diffusion is driven by pressure differences and concentration gradients. Top-of-gas controlled by: (1) unevenly distributed gas inputs into lowermost reservoir; (2) initial differences in gas distribution; (3) diffusion / permeability pathways.

(C) Migration fairways. Gas migrates vertically along fracture- / fault- controlled permeability pathways. Gas migrates laterally by flow along continuous reservoir pathways or by diffusion across side-seals.

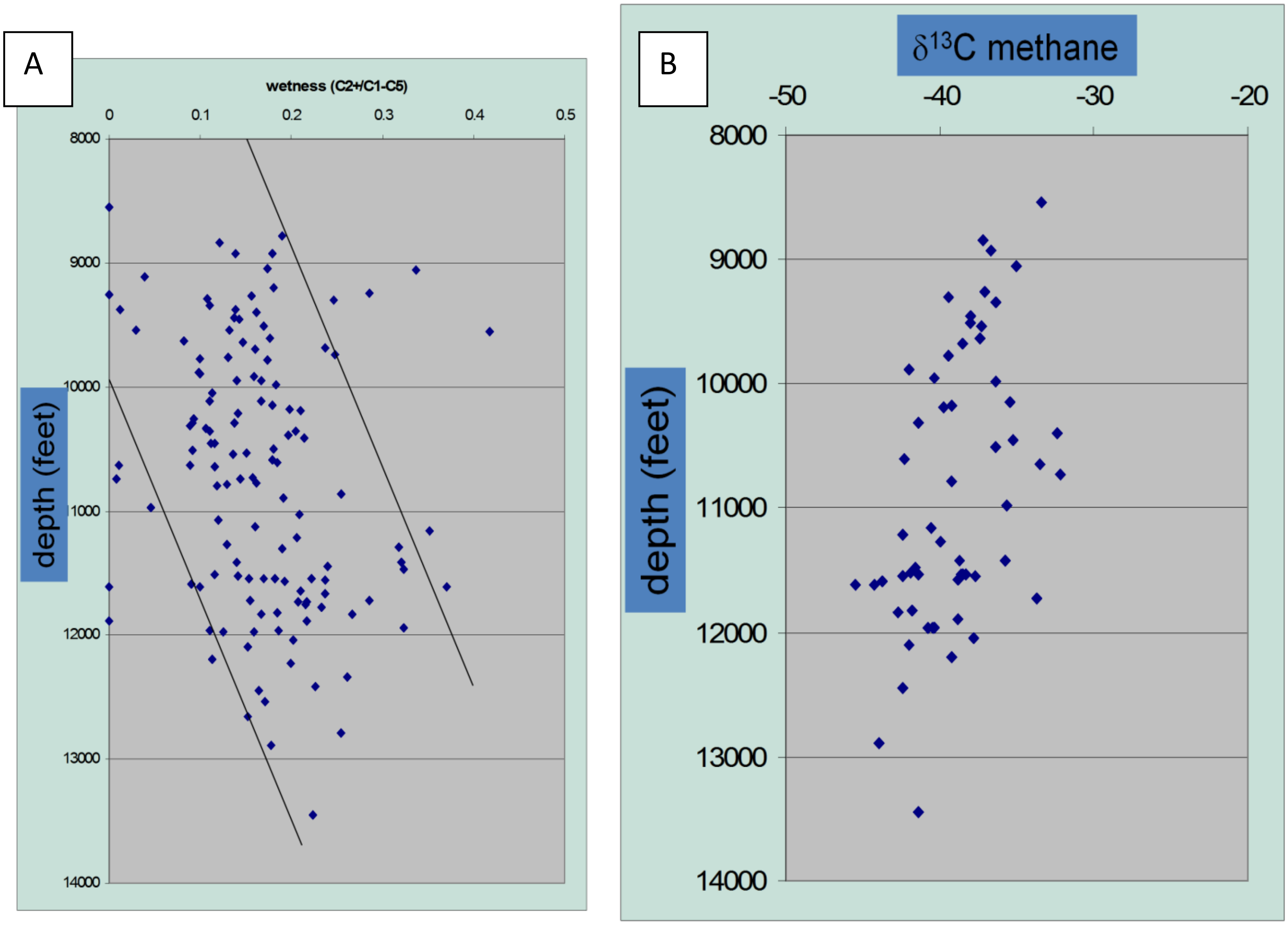

Figure 2. Gas compositions at Jonah Field. (A) Gases become increasingly wet with depth. (B) The carbon isotopic composition of methane compositions becomes increasingly more negative with depth.