GAS GEOCHEMISTRY OF MOBILE BAY: THERMAL CONTROLS ON GAS COMPOSITION AND IMPLICATIONS FOR RESERVOIR CONNECTIVITY

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The Mobile Bay gas field is located offshore Alabama in the northern Gulf of Mexico. Production is from eolian dunes of the Jurassic-Age Norphlet sandstone at depths exceeding 6,100 meters and temperatures greater than 200°C. Reservoir connectivity and compositional variation, including the distribution of non-hydrocarbon gases (H_2S and CO_2) are critical factors in production strategy. To help understand the controls on compositional variation and connectivity, detailed molecular and isotopic analyses were conducted for 29 wells.

Fluid inclusion volatiles analysis, which measures rough abundances and compositions of fluids trapped in mineral cements suggest that the field was originally filled with oil that was subsequently cracked to gas. A paleo-oil-water contact was detected above the current gas-water contact, and pyrobitumen occurs above this paleo-contact.

Both hydrocarbon and non-hydrocarbon gas contents vary significantly. Hydrocarbon-normalized wet-gas contents (C_{2+}) range from less than 0.1% to over 15%. Although carbon isotopic ratios of methane show only minor variation ($\delta^{13}C$ = -36‰ to -39‰), carbon isotopic values of wet-gas components vary dramatically, becoming progressively heavier as gas compositions become drier. Hydrogen sulfide contents range from trace amounts to 10%, with highest concentrations in the Aloe Bay (AB) and Mary Ann (MA) portions of the field (Figure 1). Higher levels of H_2S are generally associated with lower wet-gas contents, except where reservoir iron has scrubbed H_2S. Sulfur isotopic compositions for H_2S are similar to those for local evaporites ($\delta^{34}S$ = +15‰ to +16‰ CDT). These observations suggest that thermochemical-sulfate reduction (TSR) of hydrocarbons is responsible for the formation of H_2S and alteration of C_{2+} hydrocarbon compositions.

Additional evidence for TSR alteration comes from condensate analyses which show that 90%+ of the liquid yields are composed of diamondoids. The distribution of specific diamondoid hydrocarbons appears to be controlled by the extent of TSR. For example, "carbonate" signatures in the diamantanes (Schultz, et al., 2001) increase with increasing TSR, suggesting that exposure to reduced sulfur governs selective destruction of the 3,4 isomer.

In contrast to hydrocarbon and H_2S contents, CO_2 compositions are relatively constant throughout the field, averaging 3.5 mole percent. Carbon isotopic ratios for CO_2 parallel those for wet gas hydrocarbons but are heavier than expected for CO_2 originating from hydrocarbon oxidation via TSR. The narrow range of CO_2 contents and heavy isotope ratios suggest that CO_2 is also regulated by water-rock equilibration and calcite precipitation. Two distinct trends are evident for CO_2 isotopes; one trend may be affected by secondary fluid migration along Fault A (NWG1,2,3; Figure 1), while the second trend shows no fault-related migration effects (NCG2, MA, BSB). A transitional character for samples from NCG1 may reflect reduced levels of migration along Fault A as displacement decreases to the east.

Gas molecular and isotopic compositions help define reservoir compartments that are generally consistent with present-day gas-water-contact distributions. In some cases, gas compositional compartments may be baffled between dunes. Lack of communication between dune-sets may reflect inter-dune sealing lithologies. Similarly, the wide range of observed gas compositions and interpreted range in extent of TSR may reflect variations in within-dune or inter-dune (evaporite) lithologies.

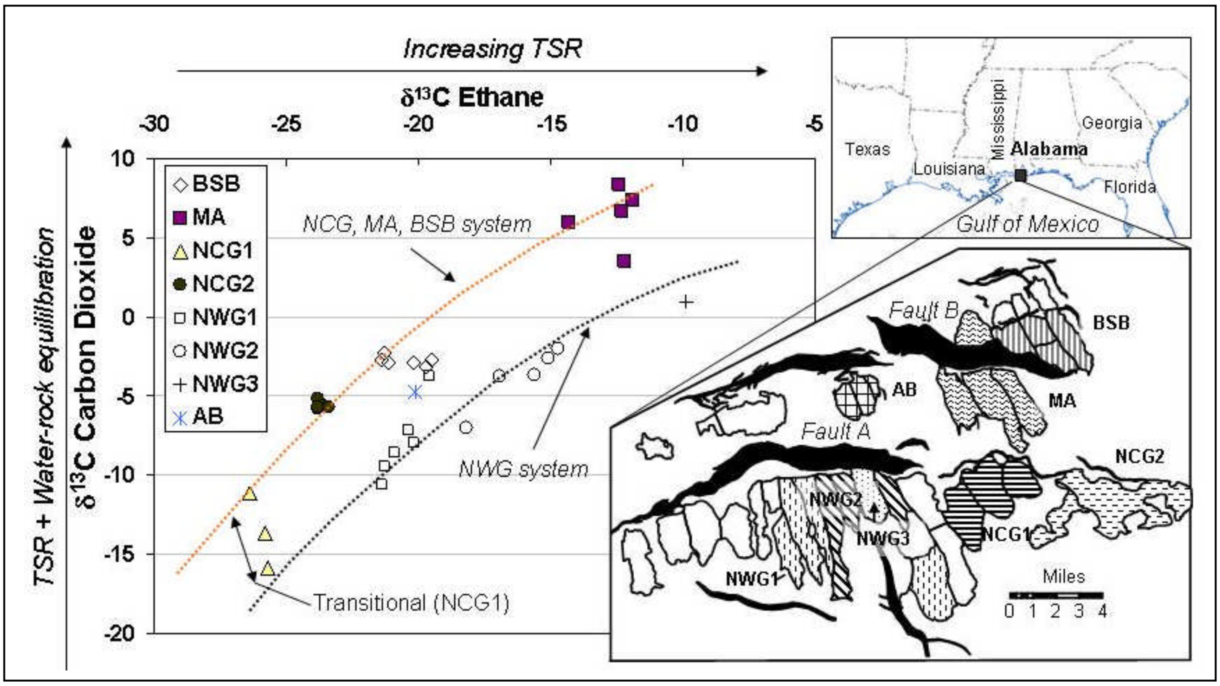

Figure 1. Plot of the carbon isotope ratios of ethane and CO_2 for sampled wells in the Mobile Bay field with adjacent map showing locations of gas families with similar compositions. Eight gas families are identified: three in the Northwest Gulf (NWG), two in the North-Central Gulf (NCG), and the Bon Secour Bay (BSB), Maryann (MA), and Aloe Bay (AB) families. Additionally, two possible CO_2 systems are interpreted from $\delta^{13}C$ of CO_2.

REFERENCES

Schulz, L.K., A.Wilhelms, E. Rein, and A.S. Steen. 2001. Application of diamondoids to distinguish source rock facies. *Organic Geochemistry* 32, 365-375.