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TYPICAL AQUEOUS RARE EARTH ELEMENT BEHAVIOR IN CO-PRODUCED BRINES, WYOMING

NYE, Charles[1], QUILLINAN, Scott[1], MCLING, Travis L.[2], NEUPANE, Ghanashyam[2] and GANSHIN, Yuri[1],
(1)Carbon Management Institute, University of Wyoming, Dept. 4902, 1000 E. University Ave., Laramie, WY 82071, (2)Idaho Falls, ID 83415, cnye3@uwyo.edu

Normalization of Rare Earth Elements (REEs) is important to remove the distracting effects of the Oddo–Harkins rule and provide a meaningful baseline. Normalizations for rocks are well developed and include chondritic meteorites, UCC, PM, PAAS, and NASC. However normalizations for aqueous REEs are limited to oceanic regions such as the North Pacific Deep Water or North Atlantic Surface Water. This leaves water in contact with continental lithologies without a suitable normalization.

We present a preliminary continental aqueous REE normalization derived from 38 deep basin hydrocarbon brines in Wyoming. The REEs in these waters are seven orders of magnitude more dilute than NASC but with significant europium enrichment. Gromet 1984 reports NASC Eu/Eu* is 0.2179, whereas in the normalization offered here, Eu/Eu* is 3.868. These waters also are free from the distracting reduction-oxidation cerium behavior found in ocean normalizations. Because these samples exhibit both the uniform behavior of NASC and the absolute concentration of seawater, a normalization based upon them offers a unique combination of the advantages of both. We used single-peak gaussian analysis to quantify the mean values for each REE and estimate the distribution variability.

Additional sample collection during the last year revealed that the Powder River Basin (PRB) is atypical relative to the other sampled basins of Wyoming. Those other basins are the Wind River Basin (WRB) Green River Basin (GRB) and Wamsutter Area (WA). A pre-normalization gadolinium anomaly (Gd/Gd*) of between 4 and 23 with a mean of 11.5, defines the PRB samples. Other basins in this study range from 1 to 7 with a mean of 2.8.

Finally, we present a preliminary model for ligand-based behavior of REEs in these samples. This model identifies bicarbonate, bromide, and chloride as forming significant complexes with REEs contributing to REE solubility. The ligand model explains observed REEs in the sampled Cretaceous and Paleocene clastic reservoirs. However, the presence of more REEs than predicted in six samples suggests that there is an additional, unconsidered ligand contributing to REE dissolution. Further work will identify this ligand, which appears to be confined to calcium-cemented and dolostone systems.