©2004 by Economic Geology
Vol. 99, pp. 1435–1448

Sulfur and Oxygen Isotopes in Barite Deposits of the Western Brooks Range, Alaska, and Implications for the Origin of the Red Dog Massive Sulfide Deposits

Craig A. Johnson,†

U.S. Geological Survey, Box 25046, MS 963, Denver, Colorado 80225

Karen D. Kelley, and David L. Leach

U.S. Geological Survey, Box 25046, MS 973, Denver, Colorado 80225

Abstract

Sulfur and oxygen isotope analyses have been obtained for barite samples from the giant stratiform sulfide-barite deposits at Red Dog in the western Brooks Range of Alaska, from stratiform barite deposits elsewhere in the Red Dog district, and from stratiform and vein and breccia barite occurrences in the central Brooks Range. Twelve of the 15 deposits studied lie within middle to Upper Mississippian black shale and chert units. The data reveal two different patterns on $\delta^{34}S$ versus $\delta^{18}O$ plots. The first, which is best illustrated by the barite deposit at Anarraaq, shows linear trends with slopes that vary with barite texture. For most samples, $\delta^{34}S$ and $\delta^{18}O$ values are both higher than the values characteristic of Mississippian marine sulfate. The second pattern, which is evident at the Red Dog deposits, shows no correlation between $\delta^{34}S$ and $\delta^{18}O$. In most samples, $\delta^{18}O$ is below the value for Mississippian marine sulfate. Comparisons with sulfate in modern marine environments suggest a possible model for the mineralizing process. Anarraaq-type barite formed at sea-floor vents where ascending fluids carrying barium and methane encountered sulfate-bearing pore waters or bottom waters. Barite deposition was accompanied by the reduction of sulfate to H_2S by means of microbially mediated anaerobic methane oxidation. Red Dog-type barite was formed in a manner similar to Anarraaq-type barite but was overprinted by a massive sulfide-forming event. Red Dog sulfides precipitated where metal-bearing hydrothermal fluids encountered pore waters that had been charged with H_2S by anaerobic methane oxidation. Textural and isotopic evidence indicates that the sulfide bodies grew by consuming the available H_2S and then by reductively dissolving barite. Dissolution of barite caused barium to be released to higher stratigraphic levels where it was reprecipitated on encountering sulfate.

Isotopic evidence is presented for a link between methane venting and barite formation and raises the possibility that the coexistence of barite and sulfide at Red Dog, and the occurrence elsewhere in the district of barite-only and sulfide-only deposits, can be explained by a spectrum of vent types in the Mississippian basin analogous to the spectrum that is observed today along the modern continental margins. Authigenic barite formed at some but not all methane seeps, perhaps owing to differences in the barium content of vent fluids, differences in the relative proportion of aqueous fluid and gas emanating from vents, or differences in sulfate availability in local bottom waters. Some barite-forming seeps were later replaced by sulfides (Red Dog deposits) whereas others were not (e.g., Anarraaq barite horizon, Gull Creek, Moil). At sulfide occurrences where there is little evidence of preexisting barite (e.g., Anarraaq, Wulik, Suds), methane venting is indicated by fossils suggestive of chemosynthetic fauna. Mammiform sedimentary structures that are widespread in black chert at the top of the Kuna Formation may represent seeps that supported neither authigenic mineral formation nor chemosynthetic megafauna.

†Corresponding author: e-mail, cjohnso@usgs.gov

0361-0128/01/3465/1435-14 $6.00