

Reactive Flow Models of Ore Formation in the Southeast Missouri District

MARTIN S. APPOLD[†], * AND GRANT GARVEN

Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, Maryland 21218

Abstract

Two-dimensional numerical reactive transport modeling was used to investigate the deposition of Pb-Zn-Cu ores in the Southeast Missouri district, central United States, by two potential mechanisms: cooling of a fluid carrying metals and reduced sulfur, and mixing of two fluids, one enriched in metals but poor in sulfur, and the other enriched in reduced sulfur but poor in metals. The mechanisms were studied within the context of the topography-driven ground-water flow regime established in the Ozark region by the Late Paleozoic Alleghanian orogeny. The models integrated geology, fluid flow, heat and solute transport, and chemical reaction, generating the most complete depiction yet of potential ore-forming processes in southeast Missouri.

Both mechanisms were found capable of generating important characteristics of the mineralization patterns observed in the field but fell short in other respects. In models of the cooling hypothesis, mineralization was indeed found to be concentrated within the southeast Missouri portion of the Ozark region. This was primarily because of the fact that mineralizing fluid underwent very little temperature change as it traversed the Ozark region until it arrived in southeast Missouri, where its temperature decreased significantly. The important association of mineralization with local basement highs within the Southeast Missouri district was also produced, caused by local increases of fluid velocity over the crests of the basement highs. Smaller scale models, however, revealed much of the mineralization to be concentrated within the basal Lamotte Sandstone rather than the overlying Bonneterre Dolomite, where it is actually concentrated in the field. This model result stemmed directly from the fact that permeability and, therefore, fluid velocities were higher in the Lamotte than in the Bonneterre. A further discrepancy with field observations was the high predicted concentrations of quartz, which exceeded those of galena by over two orders of magnitude.

Models of the mixing hypothesis also led to the regional concentration of mineralization in southeast Missouri, provided vertical dispersivities in the Lamotte Sandstone and Bonneterre Dolomite, the formations that transmitted the two different types of fluids, were low. When dispersivities were high, mineralization was produced more uniformly along the flow path. In further conformity with field observations, ore was concentrated in the Bonneterre Dolomite and particularly around the basement highs, demonstrating the importance of the Lamotte pinch-outs in causing the fluids to mix. The models reproduced well the observed vertical zonation in metals, which was controlled by the relative solubility differences among the primary sulfide ore minerals. However, though mixing was induced by the configuration of the local geology, its intensity was relatively low, leading to ore grades that were considerably less than would be expected from geochemical grounds alone. Because the flow regime is predominantly laminar, the two fluids tended to miscibly displace one another rather than vigorously mix with one another. While still potentially a viable ore-forming mechanism under conditions of high local dispersivity, high dissolved metal and sulfur concentrations, or high fluid velocity, the mixing hypothesis as typically formulated in southeast Missouri is nonetheless much less efficient than previously supposed. Greater efficiency could possibly be generated by reaction of aqueous species with solid phases in the matrix or gas (e.g., H₂S) being generated in the matrix.