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Integrated Modeling of Cu-Rich Fluid Migration and Mineralization in the Katangan Basin, Central African Copperbelt: Insights from Numerical Experiments

Meissam Bahlali[1], Julia Woitischek[1], Carl Jacquemyn[1], Martin Purkiss[2], and Matthew Jackson[1]
[1]Imperial College London, Department of Earth Science and Engineering, London, United Kingdom of Great Britain – England, Scotland, Wales (m.bahlali@imperial.ac.uk)
[2]University of Oxford, Oxford, United Kingdom of Great Britain – England, Scotland, Wales

Sediment-hosted Cu deposits are a significant global source of copper. This study employs a mineral system approach, focusing on basin-scale groundwater flow as a key mechanism for Cu transport from source to trap. Numerical experiments using the open-source IC-FERST code investigate the controls on Cu transport in the Katangan Basin, Central African Copperbelt. The models developed for early and late stages of basin evolution incorporate fluid flow, heat and solute transport, and dynamic mesh optimization to enhance computational efficiency.

The early-stage model, corresponding to the salt deposition period, attributes the formation of saline brine to a dense residual phase resulting from evaporite formation. In the late-stage model, corresponding to Cu mobilization and mineralization, Cu dissolution and mineralization are simulated using a partition coefficient informed by experimental data.

Results reveal that density gradients induced by salinity and temperature variations play a crucial role in initiating convective groundwater flow. Highly saline, dense brines generated during salt deposition or dissolution form complex, downward-propagating plumes influenced by flow instabilities and geologic heterogeneity. Permeable faults and fractures in basement rocks enable groundwater to percolate, potentially mobilizing Cu from intra- or extra-basinal source rocks. Salinity and temperature gradients drive upwelling plumes, transporting Cu from deeper source rocks to shallower, organic-rich sedimentary rocks where mineralization occurs.