Numerical Modelling of Basin-Scale Fluid Flow and Cu Transport in the Katangan Basin, Central African Copperbelt

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Sediment-hosted copper deposits host 23% of the world's copper. The mineral systems approach has been applied to characterise the formation of these deposits, sequentially considering source, transport, trap, and deposition. Here we focus on basin-scale groundwater flow as a mechanism to transport copper from source to trap. Numerical experiments are conducted to investigate controls on copper transport in the Katangan Basin, Central African Copperbelt, using the open-source IC-FERST code, coupling fluid flow, heat and solute transport and employing dynamic mesh optimisation (DMO) to reduce computational cost. DMO allows the mesh to refine or coarsen as necessary during a simulation to capture key aspects of flow. The lower computational cost compared to conventional numerical methods allows for efficient assessment of groundwater flow and metal transport scenarios associated with the mineral systems approach, with application here to 3D models of the basin at various stages of basin evolution.

Results show that density gradients induced by gradients in salinity and temperature play a major role in the initiation of convective groundwater flow. Highly saline, dense brines are created during deposition of salt or by dissolution of salt deposits and form downwards-propagating plumes with complex geometry controlled by the interaction of flow instabilities and geologic heterogeneity. Permeable faults and fractures in basement rocks allow groundwater to percolate through the basement and potentially mobilise copper from extra-basinal source rocks. Otherwise, flow is restricted to the permeable basin-fill deposits, and potential sources are restricted to intra-basinal sedimentary deposits and/or intrusive igneous rocks. The combination of salinity and temperature gradients drives upwelling plumes of groundwater, which can transport copper upwards from deeper, intra- or extra-basinal source rocks, into shallower, organic-rich sedimentary rocks where mineralisation occurs. Development of 3D convection cells may explain why mineralisation is often localised, with deposits potentially corresponding to metal-enriched upwelling plumes.