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Numerical investigation of fluid flow and Cu transport in the Katangan Basin, Central African Copperbelt

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Sediment-hosted copper deposits represent a major global source of copper. The mineral system 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 resolution of the mesh to vary over time and space to satisfy a user-defined solution precision for selected fields, refining where the solution fields are complex and coarsening elsewhere. The lower computational cost compared to conventional numerical methods allows for efficient assessment of groundwater flow and metal transport scenarios associated with the mineral system approach, with application here to 3-D models of the basin at various stages of the 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.