Geochemical inversion of regional alteration assemblages for fluid compositions

Evgeniy Bastrakov[1], Coralie Siegel[2], Juerg Hauser[2], David Champion[1], David Huston[1] and Karol Czarnota[1]
[1]*Geoscience Australia*
[2]*CSIRO*
Email: Evgeniy.Bastrakov@ga.gov.au

Understanding the distribution of alteration patterns is critical to assess the potential of a sedimentary basin to host base-metal deposits. Regular sequences of alteration zones can be used as vectors towards mineralisation and can constrain the compositions and sources of fluids. We offer a workflow for the inversion of empirical geochemical data to establish the compositions of hydrothermal fluids.

First, we run multiple 1D fluid infiltration models to predict results of water-rock interaction for a particular rock protolith (a "step flow through reactor model" by Shvarov et al., 2000). Model runs are completed for the same T-P conditions and vary only in composition of the initial fluid. Isothermal-isobaric conditions ensure formation of discrete alteration zones of constant mineralogical compositions. The output from the forward modelling is recalculated into the bulk chemical composition of the modelled rock.

Second, we identify clusters in empirical multi-dimensional geochemical data that might represent distinct alteration zones. We employ HDBSCAN (Campello et al., 2013), a clustering algorithm with a capability to identify arbitrarily shaped clusters and data outliers.

Third, we quantify how well the forward modelling predictions match the empirical clusters. For each cluster, we use kernel density estimation to create a probability function that allows us to quantify the likelihood of a predicted alteration zone to belong to the cluster. For each predicted alteration zone, we choose the most probable cluster. Given the individual likelihoods for each of the predicted alteration zones we compute a conditional likelihood to express the overall fit of the model to the data.

For a test case of the greater McArthur, characterised by extensive alteration of mafic rocks, the best performing models implicate potassium-rich fluids that might have resulted from either an evaporitic origin of brines or their interaction with felsic rocks prior to mobilisation of Zn and Cu from basalts.

References

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Campello, R. J. G. B., Moulavi, D., and Sander, J., 2013, Density-based clustering based on hierarchical density estimates: Lecture Notes in Computer Science, 7819, 160–172.