

## 2.5.14

### Reactive transport simulation of processes in hydrothermal systems and their implications for the formation of ore deposits

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Reactive transport modelling is used to examine the formation of ore deposits and the spatial distribution of ore minerals and associated alteration patterns in hydrothermal systems. Processes during the evolution of a hydrothermal system are interwoven and dependent on each other: fluids transport heat and solutes, chemical reactions occur through temperature changes, fluid mixing and fluid/rock interaction, chemical reactions modify the porosity and permeability of the rock which in turn affects the flow pattern and flow velocities. Reactive transport models are required to keep track of the spatial and temporal variations of flow rates, thermal conditions and chemical reactions and to understand the mineral patterns and assemblages that are left behind in the rock.

This study illustrates the use of reactive transport models to explore issues related to ore deposition and alteration processes through the formation of a redox-front at an unconformity. The simulations show the spatial distribution of ore and alteration minerals as a function of the mixing ratio between an oxidized and reduced fluid.

We present results from a reactive transport simulation of the evolution of three-dimensional convection and mineral alteration patterns in a fault plane. We examine how mineral patterns affect the porosity / permeability distribution in the fault and demonstrate how the flow pattern controls the distribution of gold along a lithological interface that is intersected by the fault.

## 2.5.15

### Oxygen and iron isotope tracing of metallic-element migration in the continental sub-surface

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We use a combination of petrography,  $E_H$ -pH calculations and the stable isotopes of oxygen and iron to explore the geochemical processes that lead to iron-ore deposition in fault zones of the Negev Shear Zone, southern Israel, and ferroan (Fe-) dolomitization of the adjacent Cretaceous limestone. The sources of the elements and the transport of the metalliferous fluids are thought to have been in the Nubian sandstone aquifer underlying the carbonate sequences, with rise of the hydrologically-overpressured fluids up the fault zone. The iron ores are localized in the fault zones as goethite-hematite lenses with minor syngenetic quartz. The Fe-dolomitization spreads laterally from the fault zone into the limestone host rock as stratabound (clay-capped) horizons. Petrographically, the dolomitized rocks reveal a complex cyclic history defined by periods of Fe-dolomite growth followed by iron-oxide exsolution from the mineral lattice.  $E_H$ -pH calculations suggest that this cyclicity is largely related to fluctuations in the fluid redox state (reduced conditions favoring Fe-dolomite; increased  $E_H$  favoring iron-oxide deposition/exsolution). The oxygen isotope fractionation between syngenetic quartz and iron-oxides gives a temperature of 50°C for the mineralization

$\delta^{18}\text{O}$ - $\delta^{13}\text{C}$  variations of dolomites point to the aqueous fluid being derived from the mixing of at least two end-member components: one with a high  $\delta^{18}\text{O}$  value ( $\geq 0\text{‰}$ ) and the other with a lower value ( $\leq -6\text{‰}$ ). These end-member fluids could include higher  $\delta^{18}\text{O}$  formation brines and evaporite-sourced brines and low  $\delta^{18}\text{O}$  meteoric waters. Iron isotope compositions ( $\delta^{57}\text{Fe}$  IRMM) of iron oxides and Fe-dolomites range from  $-1.3$  to  $-0.5\text{‰}$ . Thus, these minerals are isotopically-depleted with respect to lithogenic source iron minerals and provide a strong indication that the Fe(II) in the continental subsurface groundwaters underwent a redox-related fractionation.

The overall picture that emerges is that overpressured, reduced, Fe(II)-bearing groundwaters drive Mg-enriched brines into the fault zone, but that fluctuations in redox conditions at the geochemical interface with the carbonate rocks control the complex sequences of reactive transport phenomena observable at a macroscopic in the field and at the microscopic scale.