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3D reactive transport simulations of coupled processes in fault planes: implications of chemically induced permeability evolution for the efficiency of ore formation.

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For a three-dimensional vertical fracture zone we use fully coupled reactive transport simulations to examine the effect of evolving fluid flow, temperature distribution and chemical alteration patterns on the distribution of ore deposits. It can be shown analytically and numerically that stable finger-like convection patterns may arise in a fault plane that is heated from below and sealed at the top. Under these ideal conditions the Rayleigh number which is a function of the thermal properties of the fluid and the rock, the vertical temperature gradient and the permeability of the fault can be used as an expression to describe the onset and pattern of convection. However, chemical interaction between the fluid and the rock leads to changes in the porosity and the permeability of the rock so that the convection pattern changes through time. In addition, fluid flow, temperature distribution and chemical alteration patterns respond to perturbations of a hydrothermal system at different rates, which leads to an overlap of alteration patterns in the rock. Local porosity/permeability changes are a result of time-integrated alteration processes.

Precipitation and dissolution reactions are most pronounced where large quantities of fluids are driven over compositional interfaces in the rock and/or over steep thermal gradients. These are also regions where the largest permeability changes due to chemical reactions can occur.

The formation of ore deposits requires efficient mass transport and an effective precipitation mechanism. If the alteration of the rock leads to a permeability increase along a section of a flowpath, fluid flow will be focused along this section. If the fluid carries dissolved metals and the reactions leading to the porosity/permeability increase are also an efficient process to precipitate the metal, a deposit may form. The generated porespace may further increase the volume and/or grade of the precipitating metal such that the efficiency of ore formation becomes self-enhancing. In order to predict the occurrence of mineral deposits, these zones of high flow-rates and effective metal precipitation need to be identified.

We use the goldfields in the Yilgarn Craton in Western Australia to loosely constrain the design and the chemical conditions of our model. For different initial Rayleigh numbers and permeability distributions we identify conditions and scenarios that are favorable for the formation of gold deposits.