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Numerical modelling of hydrothermal convection within a permeable mineralized zone: application to orogenic gold mineralization in Ghana

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Fluid convection in faulted zones is recognized as an important mechanism for mineralization as it leads to fluid flow and mass transport. In order to investigate if 3D free convection in faults could be at the origin of a giant ore deposits such as the Palaeoproterozoic ore deposits of the Ashanti belt in Ghana, we have conducted several numerical simulations of heat and fluid flow applied to a realistic geological model. Such deposits are generally late orogenic and most of them are located at the vicinity of or within major structural accidents associated with particular fluid circulations and temperature distributions. In Ghana, deposits are concentrated along the western flank of the Ashanti greenstone belt where fault concentration is the highest and connection between them is maximal. In this region, several factors, identified in the field, are expected to affect hydrothermal fluid flows : (1) a 10 km-wide faulted zone is associated with a lateral permeability gradient ; (2) sedimentary and conglomeratic basins surround the faulted zone;(3) magmatic intrusions are located within the fault and at its vicinity. Our approach is defined by two steps: first, the numerical code solves equations related to heat transfer and fluid-flow in porous media with the above-cited appropriate boundary conditions; second, from the results of the modelling, we calculated the rock alteration index, RAI, which is proportional to the scalar product of the velocity by the temperature gradient. This index illustrates the geochemical alteration potential and depends on parameters such as gold solubility; it is used to identify regions where precipitation or dissolution can occur. Hydrothermal circulations are first investigated by the study of different synthetic cases corresponding to simplified models applicable to situations similar to the ones encountered in Ghana. In the case of a simple geometry, implying a fault zone surrounded by a sedimentary basin, transitions from 2D convective patterns in the adjacent basin to 3D circulations within the fault are observed for reasonable permeability gradients. For the most elaborate model, the RAI distribution shows that faulted zones where fluid flows are 3D lead to a spatial periodicity of ore deposits coherent with field data. Moreover in this case, a simple analytical application, demonstrates that the lifespan estimated for the Ashanti's hydrothermal system lies in the range of a few hundreds of thousands of years which agrees with the ones recognized for other mineralized systems.