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Numerical Techniques for Modelling Brine Lenses Formation due to Focussed Fluid-flow beneath Volcanoes

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Magma chamber degassing during cooling and crystallization leads to the release of hot water fluids rich in salts, metals, quarts, and other solutes into surrounding porous rocks. Under certain conditions these processes can lead to generation of porphyry ore deposits. Our conceptual model involves two-stage degassing [1]. At stage 1, the chamber is filled with silicic magma. Magma degassing results in flow of magmatic fluid rich in water, halite as well as copper in tracer amounts from depth to surface. At shallow depth the magmatic fluid condenses in a compact brine lens. The concentration of salt as well as copper that follows halite becomes very high in the brine lens. At stage 2 hot SO_2 reach gas interacts with the copper rich brine lens leading to precipitation of copper minerals.

We give an overview of the numerical techniques developed for modelling the brine lensing. We extended our parallel MUFITS simulator (www.mufits.imec.msu.ru) for NaCl–H_2O binary flows whereas other components (i.e. copper, quarts, and SO_2) are considered as tracers which have a backward influence on the fluid flow due to permeability reduction at precipitation. We developed a new equation of state for prediction of multiphase states of the NaCl–H_2O mixture under sub- and supercritical conditions. We apply a conventional system of balance equations and Darcy's law for numerical modelling of mass and heat transport. The system of equations accounts for multi-phase states of the mixture in a wide range of sub- and supercritical thermodynamic conditions, phase transitions, advective and conductive heat transport, relative flow of vapour and brine phases, and solid halite precipitation and associated clogging of the pore space. We assume instantaneous kinetics of the reactions at the stage 2, thus copper mineral concentration is determined only by presence of copper and sulphur in the aqueous phase. This method allows contouring copper deposits by post-processing of the porous flow simulations.

In order to investigate the influence of trace solutes precipitation on degassing dynamics at the stage 1, we conduct numerical simulation of supercritical brine flow with account for the transport and quartz precipitation. It is shown that the precipitation of quartz and the accompanying decrease in permeability reduces the dimensions of the concentrated brine lens formed above the chamber. The effect of hydraulic fracturing of rocks on the lens formation is studied. A non-stationary degassing regime is revealed, which is associated with a periodic increase and decrease in permeability due to fracturing and quarts precipitation. The simulation results are consistent with the geological data on the structure of copper deposits.

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[1] Blundy, J. et al., 2015. Nature Geosci. 8, 235–240. DOI: 10.1038/ngeo2351.