**REACTIVE TRANSPORT MODELING OF IN SITU LEACHING.** P. C. Lichtner, Los Alamos National Laboratory; Earth and Environmental Sciences Division; Hydrology, Geochemistry, and Geology (EES-6); MS F649, Los Alamos, NM 87501, USA, (lichtner@lanl.gov).

*In situ* leaching of ore offers a promising alternative to conventional mining techniques which require removal of large quantities of rock followed by crushing and milling operations. Solution mining typically involves introduction of an acidic leach solution, referred to as the lixiviant, into the ore zone through injection wells. The leach solution reacts with ore and gangue minerals and is extracted from one or more wells surrounding the injection well. The extracted solution is referred to as the pregnant leach solution. Solvent extraction methods are then used to recover the ore. Under the proper conditions the process results in an efficient, low cost method for ore production. Low grade ore bodies that are uneconomical by conventional means may become economically viable using *in situ* leach methods.

There are, however, several complicating factors that need to be considered during *in situ* leaching. One is the possible contamination of groundwater surrounding the ore deposit. The groundwater composition must be carefully monitored during the leaching process to ensure that none of the lixiviant escapes. After the leaching operation is complete it is usually necessary to restore the groundwater close to its original condition. Such environmental considerations can add to the cost of the solution mining operation, and in unfavorable circumstances even render the process uneconomic.

Reactive transport modeling of the *in situ* leach operation can provide insight into the processes taking place inside the leaching zone. Precipitation of secondary minerals as the lixiviant reacts with ore and gangue minerals can adversely affect the leach operation by consuming acid as well as clogging the pore spaces and halting flow through the ore body. In addition, secondary minerals may armor the surfaces of ore-bearing minerals thereby limiting the ability of the lixiviant to leach out the ore. Modeling may also be useful in reclamation of the site by, for example, providing an estimate of the number of pore volumes of ambient groundwater necessary to flush through the leach zone to restore the groundwater composition close to its original condition.

The computer code FLOTRAN, a multiphase, multicomponent, nonisothermal reactive transport model is used to simulate the leaching process of copper ore in a five-spot well pattern. The ore is assumed to be in the form of chrysocolla located primarily on fractures in a porphyry copper deposit. Gangue minerals are assumed to consist of quartz, kaolinite, muscovite and goethite representing a weathered zone in the ore deposit. A two-dimensional horizontal slice through the ore deposit is modeled.

The porosity of the oxide-ore zone is assumed to 0.1 with a permeability of $1.5 \times 10^{-15}$ m$^2$. An injection and extraction rate of 40 gpm (2.52 liter/s) distributed over a depth of 120 m corresponding to the ore zone is used in the simulation. Hydraulic conductivity is assumed to be homogeneous and isotropic. A spatial grid of $30 \times 30$ equally spaced nodes of 0.5 m over a symmetry element of the five-spot well pattern was used in the simulation. A steady-state flow field is computed first which is then used in the reactive transport calculation. The flow velocity varies spatially throughout the symmetry element. Calculations are carried out for a period of 5 years.

The initial fluid composition of the ore body was computed assuming a pH of 8 and equilibrium with minerals calcite, muscovite, kaolinite, goethite, chalcedony, and chrysocolla. The total concentration of sodium was fixed at $5 \times 10^{-3}$ M, sulfate at $5 \times 10^{-4}$ M, and the chloride concentration was determined by charge balance. A partial pressure of CO$_2$ of $10^{-3}$ bars was assumed. The composition of the raffinate was assumed to be constant during the course of the simulation. The raffinate was in equilibrium with minerals jarosite, gypsum, amorphous silica, and goethite at a pH of 1. Total sulfate was determined by charge balance.

The copper recovered at the extraction well referred to as the pregnant leach solution (PLS) and mineral alteration within the deposit are calculated as functions of time. Precipitation of amorphous silica and gypsum occur near the injection well. Precipitation of jarbanite results in a reduction in porosity across the flow field which could be detrimental to the leach operation if complete sealing of the pore spaces were to occur. It should be noted, however, that considerable uncertainty exists in thermodynamic properties and stable mineral phases at high aluminum concentrations in acidified groundwater.