Geophysical Research Abstracts
Vol. 17, EGU2015-1420, 2015
EGU General Assembly 2015

Pattern Formation in Mississippi Valley-Type Deposits

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Alternating, monomineralic dark and white bands are common features of ore hosting dolostones which are generally termed Zebra textures. These structures consist of coarse grained light and fine grained dark layers and accompany ore bodies of the Mississippi Valley-Type (MVT) worldwide. These deposits frequently develop in large hydrothermal systems, located in the flanks of foreland basins or in fold and thrust belts.
The microstructural- and microchemical analysis in this study were performed on samples which were collected in the San Vicente mine. This large MVT deposit is hosted in Triassic/Jurassic Platform Carbonates located in an east-vergent fold and thrust belt of the Peruvian Andes.
The thin sections were analyzed with petrographic- and scanning electron microscope. It is observed that one common striking feature is the high density of second-phase particles in the dark bands, whereas the coarser grained layers are virtually particle free. Furthermore, the particle distribution is found to be non-random. The highest particle densities in the samples occur on grain boundaries in the dark bands implying that grain boundaries can capture particles. Based on recent theories and the additional analytical findings, we developed a numerical simulation to study the pattern formation.
The modelling is performed in 2D at the scale of a thin section, using a boundary-model coupled with a lattice-particle-code. During the simulation two processes are active, first a reaction takes place that replaces calcite with dolomite driven by a fluid that infiltrates the model, followed by a grain growth processes with an average grain size increase as a function of surface energy reduction. Fluid infiltration in the rock is modelled assuming Darcy Flow and an advection-diffusion equation coupled with a reaction which is a function of concentration. The reaction increases permeability of the solid and thus enhances infiltration. The reaction front in the model shifts particles along until a critical threshold is reached and particles are released. Once grains are dolomitized the grain growth process starts where grain boundaries move as a function of differences in surface energy according to a kinetic rate law based on dissolution-precipitation processes. Grain growth is anisotropic based on differences in surface energy of grains as a function of their c-axis orientation. During progressive grain growth the particles that are situated on grain boundaries will exert a drag force according to the Zener theory for a volume distribution of particles, and particles whose diameters are below a critical size are shifted by the moving boundary.
The advancing dolomitization front produces layered particle distributions which then control grain growth such that growth is hindered in layers that have high particle densities, whereas grains can grow relatively freely in low density layers. This leads to a bifurcation in growth rates and can be the main process responsible for the genesis of the Zebra banding in MVT deposits.