Numerical simulation of anhydrite, pyrite and chalcopyrite formation in hydrothermal system: a single pass model study

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High-temperature focused venting, which are often accompanied by nearby low-temperature diffuse flow, are discovered at oceanic spreading centers comprising a full range of spreading rates. The high-temperature upflow inevitability mixed with cooler seawater, especially for detachment fault controlled systems at ultraslow spreading ridges, hydrothermal circulation could be deep to ~13 km below seafloor(Tao et al. 2011). The mechanism that sustain high-temperature and high heat output venting in a long time scale is poorly known. One possible mechanism is that minerals (e.g. anhydrite) precipitation changing permeability structure around the flow path in oceanic crust(Lowell et al., 2003). However, the details of minerals precipitation and its significance are still not well understood. We develop a reactive-transport model and construct a two-branch single-pass model to investigate the role of anhydrite, pyrite and chalcopyrite precipitation in mixing between high-temperature , sulfate-free, calcium-rich hydrothermal upflow fluid and cooler, sulfate-rich seawater.

Heat and chemical compositions transportation (diffusion and advection) are based on finite element method(Hasenclever et al., 2014). And the chemical reactions are determined by solubility product(Kawada and Yoshida, 2010) of each minerals (anhydrite: $CaSO_4$, pyrite: FeS_2 and chalcopyrite: $CuFeS_2$). The dissolved ions are transported with hydrothermal fluid, while the precipitated minerals stay on the nodes and change the saturation, therefore change saturation of the fluid. We adopt an empirical formula between saturation and permeability to update the permeability structure. Anhydrite precipitation forms a chimney-like low-permeable barrier between focused and diffusive flow. Pyrite precipitation occurs in front of focus flow as a low-permeability cap. Chalcopyrite precipitate around “pyrite cap” but the amount is less than pyrite which depends on solubility of chalcopyrite and boundary condition of concentration of Cu. Anhydrite, pyrite and chalcopyrite formation significantly affect permeability structure, behavior of fluid flow and vent temperature.

Hasenclever, J., Theissen-Krah, S., Rüpke, L.H., Morgan, J.P., Iyer, K., Petersen, S., Devey, C.W., 2014. Hybrid shallow on-axis and deep off-axis hydrothermal circulation at fast-spreading ridges. Nature 508, 508–512.

Kawada, Y., Yoshida, S., 2010. Formation of a hydrothermal reservoir due to anhydrite precipitation in an arc volcano hydrothermal system. J. Geophys. Res. 115, 1531.

Lowell, R.P., Yao, Y., Germanovich, L.N., 2003. Anhydrite precipitation and the relationship between focused and diffuse flow in seafloor hydrothermal systems. Journal of Geophysical Research: Solid Earth 108, 838.

Tao, C., Lin, J., Guo, S., Chen, Y.J., Wu, G., Han, X., German, C.R., Yoerger, D.R., Zhou, N., Li, H., Su, X., Zhu, J. 2011. First active hydrothermal vents on an ultraslow-spreading center: Southwest Indian Ridge. Geology 40, 47–50.