

Diffusive mass transfer and associated kinetic fractionation of stable isotopes in a metasomatic reaction zone: Model and nature

R. Dohmen (1), P. A. E. Pogge von Strandmann (2), H. R. Marschall (3), and T. Elliott (4)

(1) Institut für Geologie, Mineralogie und Geophysik, Ruhr-University Bochum, Germany (ralf.dohmen@rub.de), (2) Department of Earth Sciences, Oxford University, UK, (3) Department of Geology and Geophysics, Woods Hole Oceanographic Institute, USA, (4) Bristol Isotope Group, School of Earth Sciences, Bristol University, UK

Fluid-rock interaction plays a fundamental role in controlling the elemental and isotopic composition of rocks. In the classical picture the rock composition reflects thermodynamic equilibrium with the fluid and isotopic anomalies in the bulk rock are typically interpreted as a result from a simple mixing with an isotopically anomalous fluid or in case of low temperature systems as equilibrium fractionation. However, it now emerges that diffusion processes at length scales ranging from individual crystals to entire outcrops can lead to kinetic fractionation of isotopes, e.g., [1]. In addition, it should be considered that the detailed reaction mechanism of the fluid-rock interaction controls the effects of the fluid on the rock composition. The active reaction mechanism in turn controls the closure of the individual minerals for the exchange with the fluid. Two such possible mechanisms are diffusive intramimetal re-equilibration of the isotopes and mineral replacement by dissolution/precipitation processes of which the former is very inefficient for typical temperatures in the crust and within the subducting plate. The other case, mineral replacement, may only occur if the mineral is unstable in the presence of the fluid due to its specific composition and hence interaction with the fluid is limited to the time frame of the re-crystallization process. A reasonable scenario for a short and spatially localized mineral-fluid interaction is the diffusive transfer of elements through a fluid network and associated chemical reactions in melange zones. The diffusive transfer through the fluid also involves the possibility of diffusive fractionation of isotopes and hence the isotope composition of the fluid can be very heterogeneous and the reacted phase assemblage records only a part of it.

We have developed a new diffusion-reaction model for stable isotope fractionation of major elements in metasomatic systems taking into account the moving boundary in reaction zones, diffusive transport in the fluid network or the bulk rock, and the reactive transfer of isotopes from the fluid to the reactive products. With this model we are able to reproduce significant fractionation of Mg isotope ratios (down to -1.2 ‰ , at the scale of metres, observed in the metasomatic reaction zone of Syros, Greece [2]. An important outcome of our studies is that the final isotope composition in the rock is controlled by the combination of diffusive fractionation through the fluid network and the reactive transfer of elements to the newly formed mineral, where for the latter the detailed reaction stoichiometry is critical.

References

- [1] Teng, F. Z., McDonough, W. F., Rudnick, R. L. & Walker, R. J. (2006) *Earth Planet Sci Lett* 243, 701-710.
- [2] Miller, D. P., Marschall, H. R. & Schumacher, J. C. (2009) *Lithos* 107, 53-67.