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Stable isotope fractionation in high-grade metamorphic and magmatic systems

HORST MARSCHALL

FIERCE (Frankfurt Isotope & Element Research Center), Goethe University Frankfurt

Presenting Author: marschall@em.uni-frankfurt.de

The variation of isotope ratios that are not influenced by radiogenic ingrowth – so called stable isotope ratios – is controlled by equilibrium and kinetic isotope fractionation in nature. Stable isotope ratios recorded in natural minerals, fossils and rocks have been employed to reconstruct geologic processes pretty much ever since the discovery of isotopes in the early twentieth century. The temperature dependence of stable isotope fractionation initially led to the paradigm that stable isotope fractionation would only operate at a significant scale at low temperatures, such as those at the Earth's surface. Processes operating at depth were thought to mix various isotopically different reservoirs, but would not cause fractionation. However, the ever increasing analytical capabilities of modern instruments has enabled us to unravel the much diminished effects of stable isotope fractionation at the elevated temperatures prevailing in the deeper crust and upper mantle, and it has provided access to a large number of metal isotope systems that were not available two decades ago. These metal isotope systems are now traditionally called 'non-traditional isotopes'.

This expansion of the isotope geochemist's toolbox has led to an investigation of equilibrium fractionation processes in the context of, for example, redox reactions, fluid-rock interaction, magma differentiation and metamorphism. Yet, kinetic fractionation also plays a major role in many high-temperature processes and causes much stronger isotopic excursions than the equilibrium processes and, therefore, has to be considered and illuminated before stable isotope ratios measured in a sample may be interpreted in the light of equilibrium fractionation. Kinetic processes may operate in magmatic (e.g., during degassing) or metamorphic systems (e.g., during diffusion). The talk will summarize recent non-traditional isotope studies and highlight some potential effects of kinetic fraction.