

Length scales of chemical transport in the lower mantle: Mn, Fe, Co, and Ni diffusion in periclase

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Periclase is the second most abundant mineral in Earth's lower mantle and is key to understanding chemical exchange mechanisms and diffusive length scales in the lower mantle. There have been several previous studies on transition metal diffusion in periclase but this study is the first to examine multiple transition metals simultaneously in a single crystal with a fixed concentration of cation vacancies. Experiments were performed to determine diffusion rates of Mn, Fe, Co, and Ni in periclase at temperatures between 1473K and 2073K in a piston cylinder apparatus. Both graphite and nickel capsules were used to control the fO_2 . The cation vacancy concentration was controlled by doping the periclase crystal with approximately 5000 ppm Al^{3+} . This approach eliminates the influence of additional vacancies being introduced during the experiment due to oxidation of the diffusing transition metal cations. This may have been an issue in early experiments [1] that examined Fe, Co, and Ni in separate experiments with variable atmospheres.

Wuensch and Vasilos [1] found that diffusivity in periclase increases in the order $Ni < Co < Fe$, contrary to expectations when considering their ionic radii. The same trend is found here, but with significantly smaller differences among the elements. The activation energies are not correlated with ionic radius but are correlated with crystal field stabilization energy, similar to results reported for Cr^{3+} and Ga^{3+} [2]. If Fe, Co and Mn undergo spin transitions within Earth's lower mantle, their crystal field stabilization energies in periclase would increase. This might cause these elements to diffuse more slowly in the deep mantle, with a reversal in their relative diffusivities.

[1] Wuensch & Vasilos (1962) *J. Chem. Phys.* **36**, 2917–2922.

[2] Crispin & Van Orman (2010) *Phys. Earth Planet. Interiors* (in press).

Mantle-crust interactions and implications for the lithosphere of the Southern Rio Grande Rift (New Mexico) from Pb isotope data

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The Pb isotope composition of volcanic rocks in the Rio Grande Rift (RGR) can be used to investigate the interaction of mantle melts with continental lithosphere, and has important implications for the composition of the lithosphere. Although previous studies have established preliminary correlations between amount of extension, and volcanic compositions and their mantle sources [1], we suggest some compositional signatures may pre-date current tectonic processes. Existing data from several volcanic fields in New Mexico show a converging pattern on a very limited Pb isotope range, corresponding to lower crustal xenolith compositions from Kilbourne Hole [2]. The different volcanic fields show Pb isotope trends diverging from this lower crustal composition, likely depicting mixing with different upper crustal reservoirs. These observations suggest initial mixing of mantle melt with very constant lower crustal compositions that overwhelmed the mantle isotopic signature, subsequently contaminated by variable upper crust. The geographically wide-spread lower crustal, low radiogenic Pb compositions are best explained with time-integrated low U/Pb ratios that may be related to metasomatism above an ancient subduction zone.

In this study, we focus on the Pb isotope compositions of the Potrillo, Elephant Butte, Palomas, and the Hillsboro volcanic fields in the southern RGR in New Mexico to test our hypothesis. These fields represent a range in erupted volumes and are spread out over a significant area, therefore likely representing a range in crustal interaction. We also present results for the analysis of a set of USGS rock standards and show that our measured compositions are in good agreement with high precision double-spike Pb analyses from the current literature [3, 4].

[1] Baldrige (2004) *N. M. Geol. Soc. Spec. Pub.* **11**, 312–330.

[2] Reid *et al.* (1989) *N. M. Bur. Mines Mineral. Res. Bull.* **131**, 222. [3] Weis *et al.* (2006) *Geochem. Geophys. Geosyst.* **7**, 10.1029/2006GC001283. [4] Baker *et al.* (2004) *Chem. Geol.* **211**, 275–303.