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Mg Isotopes Reveal Thermal Gradients within the "Hot Spot" of Piston Cylinder Assemblies

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The piston cylinder apparatus is widely used in experimental petrology due to its ability to replicate the pressures and temperatures of planetary interiors. However, piston cylinder assemblies possess inherent thermal gradients, particularly in the longitudinal direction. The thermal distribution of piston cylinder assemblies has previously been mapped using numerical simulations[1,2] as well as the temperature-sensitive thickness of the spinel layer that forms from the reaction between Al_2O_3 and MgO[3]. To minimize the impact of thermal gradients, experimentalists typically adopt a small sample size within the "hot spot" of an assembly, which is usually centered in the cylindrical graphite heater with temperature variations ~10°C[3]. While this magnitude of temperature variation has negligible effects on phase equilibria, element partitioning, and diffusivity, the effect on measured isotope compositions can be significant[4].

Here, we used stepped heaters to melt basalt at >1375°C and 0.75 GPa for >45 hours within the traditionally defined hot spot of a ½" piston cylinder assembly. While we found minimal element variations along the length of the experimental run-products, significant Mg isotope variation (>0.5 ‰ in $\delta^{26/24}$Mg) was measured using LA-MC-ICPMS. The most plausible origin for this isotopic variation is thermodiffusion. Hence, the assumption of within-phase isotopic homogeneity in piston cylinder runs could lead to spurious and irreproducible results for isotope equilibration experiments. We propose that isotope equilibration experiments should utilize a more stringent definition of the hotspot, and that this "isotope hot spot" should be located by performing isotope analyses longitudinally along the experimental charge. Although undoubtably useful, experimentalists aiming to measure equilibrium isotope fractionations should avoid relying upon spinel thickness and elemental ratios to demonstrate the absence of thermal gradients.

[1]Schilling & Wunder (2004). *Eur J Mineral*, *16:* 7–14.

[2] Hernlund et al (2006). *Am Mineral, 91*: 295-305.

[3] Watson et al (2002). *Contrib Mineral Petrol, 142: 640-652*

[4] Richter et al (2009). *Geochim Cosmochim Ac*, *73*: 4250–4263.