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Zircon as a tracer of mantle processes and kimberlite magmatism

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Zircon ($ZrSiO_4$) is the oldest mineral on Earth, commonly found in felsic rocks and used to date rocks. Zircon provides invaluable information about continental crust formation due to its superb stability and high content of trace elements and isotopes. Zircon megacrysts of unclear origin also occur in kimberlites, the deepest mantle-derived magmas. Recent studies found zircon in other mafic and ultramafic rocks providing evidence for zircon stability in the Earth's mantle. However, its origin remains enigmatic.

To use zircon as a geochemical tracer in mantle rocks, it is essential to establish zircon saturation and determine the effect of pressure on zircon stability in the mafic mantle melts. This project aims to understand the origin and survival of mantle-derived zircon and use the composition of mantle zircons to examine processes at the lithosphere-asthenosphere boundary and their relation to kimberlite magmatism. The experimental data on zircon solubility in mafic systems are limited, especially at P-T conditions of the mantle.

We investigated zircon stability and Zr diffusivity in melts using synthetic kimberlites with variable carbonatitic and silicic components and natural mid-ocean ridge basalt (MORB) glass. We used natural zircon crystals (Mud Tank, Australia). The experiments at pressures from 0.5 to 3 GPa were conducted in a piston-cylinder apparatus (Dalhousie University, Canada), and experiments at 7–15 GPa employed multi-anvil apparatus (Clermont-Auvergne University, France). Compositional profiles (Fig. 1) of the samples at the melt-zircon interface were obtained using EPMA (Castaing Centre, France). This allowed us to determine zircon saturation: C_{sat}(MORB) = 2.0 wt% (2GPa, 1400ºC) – 5.4 wt% (0.5GPa, 1400ºC) and C_{sat}(kimberlite) = 3.3 wt% (2GPa, 1400ºC) – 6.1 wt% (1GPa, 1300ºC); and to calculate the Zr diffusion coefficient: D_{Zr}(MORB) = $4.69\cdot10^{-9}$cm^2/s (1GPa, 1350ºC) – $8.3\cdot10^{-8}$cm^2/s (0.5GPa, 1400ºC) and D_{Zr}(kimberlite) = $6.56\cdot10^{-8}$cm^2/s (2GPa, 1400ºC) – $6.3\cdot10^{-7}$cm^2/s (2GPa, 1350ºC). Our results show that zircon stability increases with pressure. Zircon is more stable in basalt than kimberlite but less stable in silica-rich kimberlite with a lower carbonatitic component. The obtained Zr diffusion coefficients align with the previous estimates for basaltic melts, whereas Zr diffusivity and solubility in kimberlites are significantly lower than predicted by the existing models.

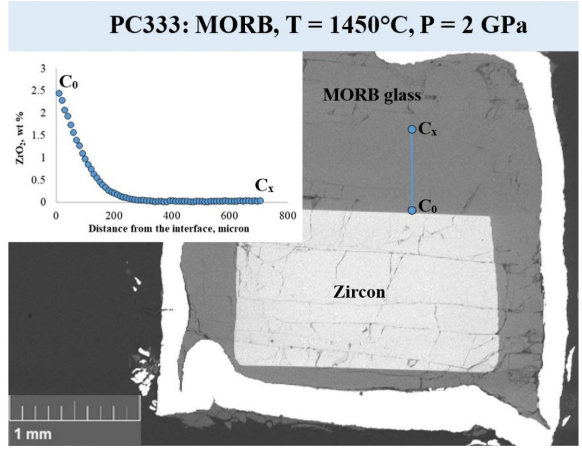

Figure 1. BSE image of experimental sample PC333 showing congruent zircon dissolution in MORB melt. The corresponding plot presents measured Zr concentrations in the glass as a function of distance (in micrometers) from the zircon crystal in the same sample.