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On alkalis and the alkalinity of asthenospheric melts – from kimberlites to OIB

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Isotopically, kimberlites to ocean island basalts derive from the convecting asthenosphere; geochemically they model well as low degree melts of enriched mantle with a contribution of recycled oceanic crust. Yet, kimberlite rocks are almost Na-free and extremely Al-poor (1-3 wt%), while the most Si-undersaturated primitive ocean island basanites/melilitites reach total alkalis of 5-6 wt% (at 9-12 wt% Al_2O_3). To understand the origins of these melt types, we conducted several series of multi-anvil experiments (3-7 GPa) focusing on adiabatic temperatures. These also allow to model $D_{Na}^{cpx/melt}$ as a function of pressure and SiO_2^{melt} (for carbonatites to kimberlites to basanites, 40-5 wt% CO_2). Experiments on asthenospheric melting yield kimberlitic melts at 7 GPa, which evolve to melilitites or basanites when rising in an asthenospheric melting column to 3 GPa. As $D_{Na}^{cpx/melt}$ decreases from 0.4 to 0.25, while $Al_2O_3^{melt}$ increases from ~2 to ~9 wt% (from 7 to 3 GPa), the proto-kimberlitic melts are the most alkaline, i.e. have the highest alkali/Al_2O_3 ratio, yet kimberlites lost their sodium likely through devolatilization. 3 GPa melts are more alkali-rich, but also much more Al-rich due to a decreasing garnet-stability. In terms of majors these melts hence belong to a continuous series, but are withdrawn from asthenospheric equilibration at different depth (i.e. their LAB) and do not require substantial lithospheric contributions. Na_2O/K_2O ratios for asthenospheric melts are generally > 2, and no known asthenospheric process decreases this ratio substantially, rendering a potassic character the most powerful indicator of lithospheric interaction (in tectonic environments without ongoing subduction).

Lithospheric melting alone falls instead short. Experiments consent that carbonatite melts with little alkalis (3-5 wt%) form at the solidus of carbonated average mantle, exhausting all carbonate. Their thermal expansivity causes carbonatite melts to picker along their solidus during rise, leading to imminent death at the carbonated peridotite solidus ledge. The ultra-low viscosity and best wetting behavior of all known geological melts would lead to immediate extraction of all carbonate, carbonated silicate melts can thus not form through direct melting of average composition lithosphere. Yet, a phlogopite bearing lithospheric mantle may yield ultrapotassic carbonatites that may reach the surface.