# Kimberlite magmas and eruptions: Origin and evolution

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**Introduction:**

Kimberlites are enigmatic and relatively rarely erupted magmas that provide an almost unique opportunity to study material directly sourced from the deep mantle. They are low-silica, volatile-rich, ultrabasic, low-degree partial mantle melts that carry a rich cargo of mantle and crustal xenoliths from depths of 200 km up to the surface (e.g. Sparks 2013). Kimberlite magmas primarily ascended through thick, old continental lithosphere, transporting diamonds from depth to the surface. Understanding the origins of kimberlite magmas and their transport mechanisms has economic importance. The climatic effects of kimberlite eruptions are also potentially significant, due to the release of unusually large amounts of CO2 (>5 wt%, Brooker et al. (2011)) in what is believed to be highly explosive eruptions (Wilson & Head 2007).

The youngest known eruption of kimberlite magma occurred in the Holocene (Brown et al. 2012), and consequently there are no eye-witness accounts which describe the processes that occur during such eruptions. Much of our understanding comes from studying ancient deposits, which are excavated during mining activity. However, the rocks we sample at the surface have often undergone substantial syn- and post- emplacement alteration (e.g. Stripp et al. 2006). Interestingly, detailed field mapping and petrographic analysis have demonstrated that erupted deposits exhibit a huge range of eruptive styles, from highly-explosive diatreme-maar forming activity to effusive flow. We can use comparable and better-understood magma compositions, such as basalt or carbonatite, to study kimberlites as these erupt more frequently but are likely to exhibit similar physical properties and dynamical behaviour.

It has been suggested that some, or potentially all, kimberlites originate as carbonatite melts, the composition of which is then modified during ascent through the preferential absorption of mantle silicate minerals, such as orthopyroxene or olivine, to produce a proto-kimberlite composition (e.g. Brooker et al. 2011). This assimilation results in effervescence of CO2 into a fluid phase, which may provide additional buoyancy to the melt and aid ascent to eruption (Russell et al. 2012). As kimberlite melts ascend they depressurise and cool by several hundred degrees (Kavanagh & Sparks 2009). Gas exsolution, crystal assimilation, crystallisation and the incorporation of xenolithic material all affect the composition and physical properties of the magma, and ultimately the likelihood and style of eruption.

**Project Summary:**

This project will combine petrographic textural analysis with numerical modelling and experiments to investigate the origin and evolution of kimberlite magmas and their eruption dynamics. Specific aims of the project will be to describe the petrographic characteristics of specific kimberlite and carbonatite rock samples, carry out simple temperature-time equilibrium experiments on hypothetical melt compositions, and use this information to develop and constrain a numerical model that accounts for the physio-chemical evolution of kimberlite melts from source to surface.

Kimberlite samples from South Africa will be analysed using a combination of optical microscopy and scanning electron microscopy (SEM), with energy dispersive spectroscopy (EDS), electron backscattered diffraction (EBSD) and X-ray diffraction (XRD) to characterise and quantify rock and mineral chemistry, textures and fabrics at high resolution (e.g. Prior et al. 2009). This will be complemented by field studies and analysis of samples to be collected from Calatrava, Spain, which was the site of substantial carbonatite-silicate volcanism from 8-0 Ma (Humphreys et al. 2010; Bailey & Kearns 2012).

Thermodynamical modelling will constrain temperature changes during kimberlite magma ascent, considering a range of starting compositions from carbonatite to basalt. Adiabatic depressurisation, exsolution of volatiles, the assimilation of xenocrysts and crystallisation of phenocrystic minerals will be included in the model. The evolution of kimberlite magma will be studied in the laboratory by heating synthetic melt compositions in a controlled atmosphere using a horizontal tube furnace and a Simultaneous Thermal Analyser (STA), which couples differential scanning calorimetry (DSC) to a thermo-gravimetric analyser (TGA). These time-increment experiments will consider both constant and transient temperature conditions, from 300 – 1700 ºC with a resolution better than +/- 1 ºC. During the experiment, the mass of the sample charges will be measured continuously at extremely high accuracy (+/- 25 ng) and the enthalpy and heat capacity of the reaction will be monitored. Together, this combined petrographic, petrological and numerical data will provide strong integrated constraints to advance our models and understanding of kimberlite origins and evolution from their source to the surface.

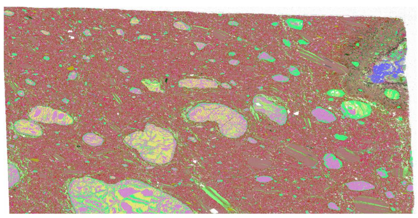

**Image 1–** High-resolution QEMscan image of group 2 kimberlite from Helam Mine, South Africa.

**Image 2** Panoramic view of Venetia diamond mine, South Africa.

**References**


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