THE PETROLOGY AND GEOCHEMISTRY OF THE SWARTRUGGENS AND STAR KIMBERLITE DYKE SWARMS, SOUTH AFRICA

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INTRODUCTION

The Swartruggens and Star kimberlites are two Group II, diamondiferous, hypabyssal kimberlite dyke swarms, situated in the Northern Province and the Free State respectively, South Africa. Representative samples from all dykes from each locality have been analysed for their major and trace element contents.

Primary kimberlite magma chemistry is subjected to considerable modification due to the incorporation of both mantle and crustal material during ascent to the surface, crystal fractionation, and post-emplacement alteration by deuteric fluids. This study aims to constrain the effects of these processes, and thus to identify least-modified, close-to-primary, parental magma compositions, with the view to understanding the source region characteristics of, and the petrogenetic processes giving rise to, these kimberlites.

ANALYTICAL

The samples were crushed to approximately 1cm in size using a jaw crusher. Fragments were then picked by hand in order to avoid, as far as possible, all xenolithic material, veins, and weathered surfaces, before being powdered in a carbon-steel Sieb swing mill. Major and some trace element analyses were carried out by X-ray fluorescence (XRF) using a low dilution fusion technique and a Philips X'Unique wavelength spectrometer. Errors and detection limits are similar to those reported by le Roex et al. (1981). The majority of trace element analyses were determined by solution ICP-MS, using a Perkin Elmer ELAN 6000 ICP-MS with the method, accuracy and detection limits described in le Roex et al. (2001). CO_2 analyses were carried out using a karbonat-bombe with the method of Birch (1981), with approximately 5% relative precision.

PETROGRAPHY

Petrographically the kimberlites at both localities are similar to other South African micaceous kimberlites, containing rounded, anhedral, macrocrystic olivine (variably altered to serpentine and calcite) and kink-banded macrocrystic phlogopite in a fine-grained groundmass of phlogopite, olivine, and carbonate with or without diopside, melilite, and minor apatite, perovskite and Fe-Ti oxides. Occasional rounded eclogitic garnets are present in some samples. The Muil (barren) dyke of the Swartruggens kimberlite is petrographically different from the others in that it consists of olivine macrocrysts in a groundmass of phlogopite, diopside and sanidine. Sanidine is not normally present in a kimberlite and the Muil dyke has previously been described as lamprophyric (Skinner and Scott, 1979).

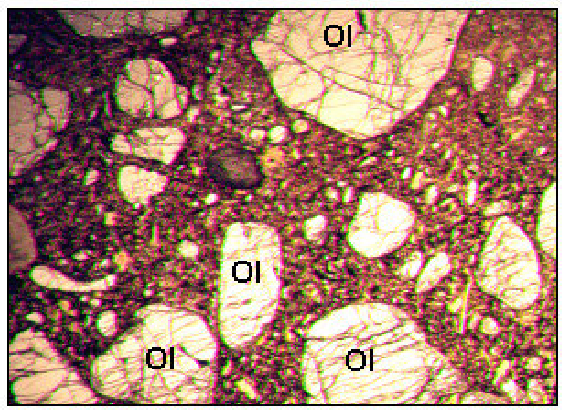

Figure 1: Photomicrograph showing typical appearance of rounded olivine macrocrysts in a macrocrystic section of the East Star Dyke, Star. Ol = olivine macrocryst. FOV = 5mm

GEOCHEMISTRY

Major and trace element variations are considerable at each locality. The Swartruggens kimberlite has MgO = 10 – 25 wt%, SiO_2 = 25 – 47 wt% and K_2O = 1.6 – 6.6 wt%. In contrast, Star has MgO = 9 – 33 wt%, SiO2 = 23 – 46 wt% and K_2O = 1.8 – 5.6 wt%. For a given MgO content, the Swartruggens kimberlite is slightly richer in SiO_2 and TiO_2 (Fig. 2). Trace element abundances are equally variable with the Swartruggens kimberlite having La = 57-300 ppm, Zr = 142-668 ppm and Nb = 54 - 227 ppm, whereas the Star kimberlite dykes show slightly less incompatible element variation, e.g. 119 – 285 ppm La, 31-410 ppm Zr and 68 - 200 ppm Nb. Compatible element abundances are also variable with Swartruggens kimberlite having

Ni=61 – 1471ppm, Cr = 620 – 2088ppm, and Star Ni = 684 - 1710ppm and Cr = 1800 – 2600ppm. In contrast incompatible trace element ratios are more restricted and are similar between the two dykes swarms (Swartruggens: Zr/Hf = 47 ± 4, La/Th = 8 ± 1, Ce/Pb = 12 ± 5, K/Rb = 166 ± 55; Star Zr/Hf = 41 ± 5, La/Th = 7 ± 1, Ce/Pb = 16 ± 1, K/Rb = 195 ± 15; e.g. Fig. 3).

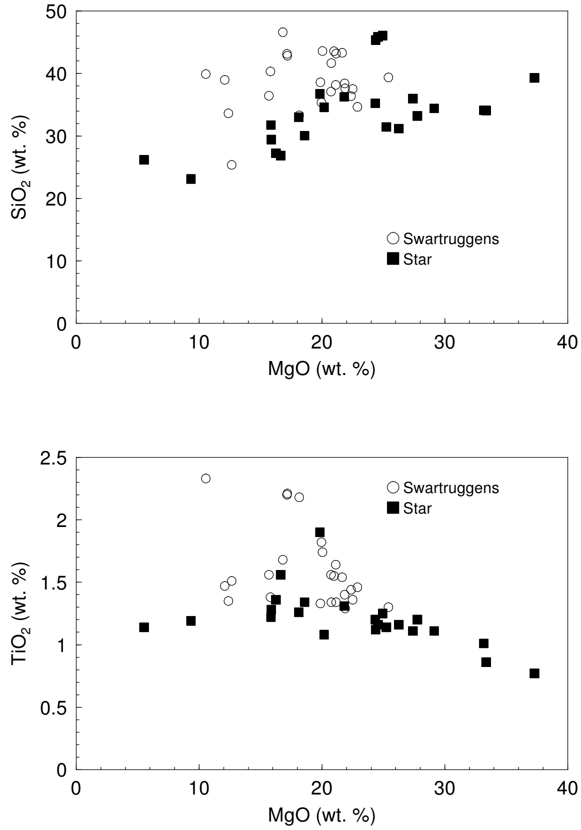

Figure 2: Selected major element variations within the Swartruggens and Star kimberlite dykes.

Chondrite normalised rare earth element patterns define steep, sub-parallel arrays, which are strongly enriched in the light rare earth elements (LREE) relative to heavy rare earth elements (HREE), with average La/Yb_n of 97 for the Swartruggens kimberlite and 205 for the Star kimberlite dykes. Normalised heavy REE abundances are 3 – 15 times chondrite for the Swartruggens kimberlite and 2 - 6 times chondrite for the Star kimberlite.

Primitive mantle normalised incompatible trace element patterns show strong negative Ti and Sr abundance anomalies, subdued negative K, Rb, Nb and Ta and positive Pb anomalies for both localities (Fig. 4). In addition, the Star kimberlite has slight negative Zr and Hf anomalies. The Muil dyke at Swartruggens is

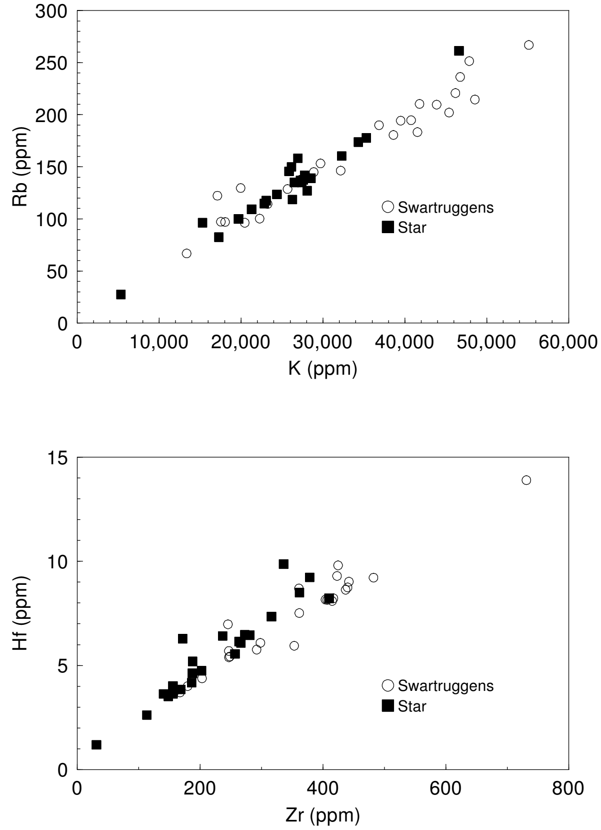

Figure 3: Incompatible trace element variations within the Swartruggens and Star kimberlite dykes; Rb versus K and Hf versus Zr.

considerably less enriched than any of the other dykes and shows no Ti anomaly (Fig. 4).

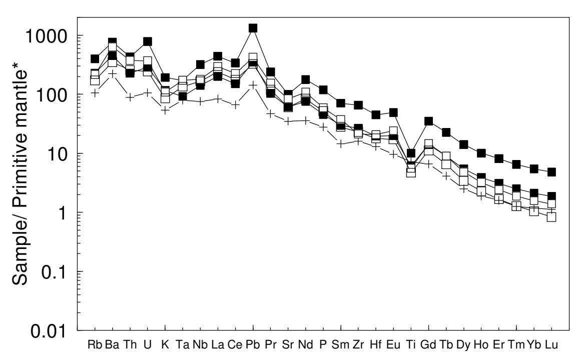

Figure 4: Primitive mantle normalized incompatible trace element diagram showing selected representative samples from Swartruggens and Star. Solid squares = Swartruggens, open squares = Star , crosses = Muil dyke. Primitive mantle normalizing values taken from Sun and McDonough (1989).

Ni variations indicate that there is no simple genetic relationship between the individual dykes at either locality, although intra-dyke variability is broadly consistent with olivine plus phlogopite control, inferred to occur through flow differentiation processes. This relationship is best developed in the Muil Dyke (Swartruggens).

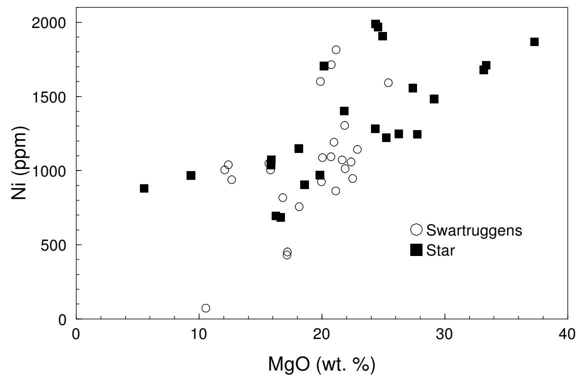

Figure 5: Ni versus MgO for the Swartruggens and Star kimberlites

Integration of major and trace element data together with petrography allow the nature of the likely source region of the primary kimberlite magmas to be inferred. Assuming low degrees of partial melting (e.g. Dalton and Presnall, 1998) the source regions to both these two Group II kimberlites were strongly enriched in incompatible trace elements, and, importantly, depleted in HREE relative to chondritic or primitive mantle values. This latter observation suggests that the respective source region of the Star and Swartruggens kimberlites were located within the lithospheric mantle, rather than within a convecting asthenospheric or plume mantle, and both sources had experienced a melt depletion event prior to strong metasomatic enrichment preceding kimberlite genesis (e.g. Tainton and McKenzie 1994).

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