Geophysical Research Abstracts
Vol. 12, EGU2010-11710, 2010
EGU General Assembly 2010

Emplacement of crystal-rich magmas: insights from the Snap Lake kimberlite intrusion (NW Territories, Canada)

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The Cambrian Snap Lake kimberlite intrusion (Northwest Territories, Canada) is a complex segmented diamond-bearing ore-body. Detailed geological investigations suggest that the intrusion is a multi-phase body with at least four different magmatic lithofacies. In particular, olivine-rich (phlogopite-poor) and olivine-poor (phlogopite-rich) varieties of hypabyssal kimberlite have been identified. Key observations are that olivine-rich lithofacies (ORK) has a strong tendency to be located where the intrusion is thickest and that there is a good correlation between intrusion thickness, olivine crystal size and crystal content. Accordingly the olivine-poor lithofacies (OPK) tends to be most abundant where the intrusion is thinnest. Complimentary studies demonstrate that the lithofacies are geochemically distinct, and are characterised by different diamond abundances and size distributions. Our data and observations suggest that the ORK and OPK represent different magma phases that have experienced different processes during transport and emplacement. Heterogeneities in the kimberlite lithofacies are attributed to variations in intrusion thickness and structural complexities. Auto-xenoliths of ORK within the OPK suggest that the magmas are closely related in time and have clearly exploited the same fracture system during intrusion, resulting in various degrees of intermingling. The geometry and distribution of lithofacies points to magmatic cointrusion, and flow differentiation driven by fundamental rheological differences between the ORK and OPK phases. The presence of such low viscosity, crystal-poor magmas may explain how extremely crystal-rich kimberlite magmas (> 60 vol.%) are able to reach the surface and erupt in kimberlite diatremes. We envisage that the low viscosity OPK magma acted as a lubricant for the highly viscous ORK magma; such rheological segregation is a common feature in other magmatic systems. The Snap Lake intrusion provides important insights into the architecture and dynamics of magmatic plumbing systems at high crustal levels, particularly in settings where sheet intrusions feed into point-source diatreme–vent systems. The study also has implications for predicting diamond distributions at other kimberlite intrusions where different magmatic lithofacies can be identified.