Alteration origins of different interclast mineral assemblages of kimberlite and implications for original textural character of kimberlites (Jericho and Muskox pipes, Canada)

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The extent to which the preserved textures of kimberlite reflect primary processes is a matter of debate (Cas et al. 2008; Field and Scott Smith, 1999; Sparks et al. 2006; Stripp et al. 2005). Most studies on kimberlite geology document at least some alteration, mostly in the form of serpentinisation of olivine crystals (e.g., Field and Scott Smith, 1999; Hetman et al., 2004; Nowicki et al., 2004; Webb et al., 2004), about which there is no real debate that at least some minerals are secondary. The origin of matrix/groundmass minerals, however, is less clear. Some studies propose that the matrix in fragmental kimberlite represents primary crystallisation phases from the kimberlite melt, volatiles, or condensates (Clement, 1982; Field and Scott Smith, 1999; Mitchell, 1986), while others consider many of these phases to be of secondary origin (Cas et al., 2008; Stripp et al., 2005). Using compositional studies (XRF, XRD and EPMA) together with field and petrographic studies, we attempt to better understand the origin of interclast minerals and provide insight into the interpretion of the original textural character in terms of physical volcanological processes.

The Jericho and Muskox kimberlites (Northern Slave Province, Nunavut, Canada) were both emplaced in the Jurassic into granodiorite basement overlain by limestone beds. Both contain VK, which ranges from clast-supported to matrix supported, from very poorly sorted to moderately sorted, and contain varying proportions of olivine crystals, country rock debris and fine kimberlite matrix interpreted to have originally consisted of ash. Volcaniclastic kimberlites are polylithologic and contain an uneven distribution of components. Coherent kimberlite occurs in both pipes and contains small amounts of country rock and ranges from extremely olivine rich to olivine-poor varieties. Coherent kimberlite has a uniform distribution of crystals and clasts.

We recognise four common interclast mineral assemblages for volcaniclastic kimberlite (VK) and two different mineral assemblages for coherent kimberlite (CK). The variety of interclast mineral assemblages observed in kimberlite from the Jericho and Muskox pipes are ascribed a secondary origin, forming in response to mixing varying proportions of clay to silt-sized olivine crystals and crystal fragments, country rock debris, and kimberlite ash/groundmass. Most interclast phases (serpentine, biotite, chlorite, saponite, monticellite, spinel and possibly calcite) lack either igneous or clastic textures and are better explained by alteration. For example, small (<25 μm) Fe-Ti spinels are common interclast minerals in coherent and some fragmental kimberlites and have highly irregular cores that include serpentine. In addition, monticellite grains are irregularly shaped and tend to form in clusters. Further support for an origin through alteration is provided by diopside microlites, which occur in clusters within the matrix and on the rims of crystals and lithic clasts. These diopside microlites often transect crystal margins and therefore must be products of alteration. The presence or absence of some interclast phases likely attests to differences in P-T-X conditions as opposed to differences in physical sorting processes. For example, the composition of interclast serpentine that occurs in the mineral assemblage with Fe-Ti spinels has $Mg^{2+}/(Mg^{2+}+Fe^{2+})$ values >0.90, whereas other recognised interclast mineral assemblages that include serpentine but contain little or no spinels have $Mg^{2+}/(Mg^{2+}+Fe^{2+})$ values that are generally <0.90. In these cases, the absence of Fe-Ti spinels is not an indication that the matrix is fines-depleted through elutriation.

Interclast minerals grow under low pressure and variable temperature conditions, likely driven by hydrothermal alteration reactions as the deposit cools. The contribution of meteoric waters to driving alteration reactions is poorly constrained but likely significant in some instances (Sheppard and Dawson 1975). Although void filling is likely to occur, the majority of interclast minerals overprint the original matrix/groundmass. Alteration is particularly intense in kimberlite containing abundant lithic clasts of country rock (and clay- to silt-sized material derived from the lithic clasts, as determined by XRF), such as granodiorite, that are out of equilibrium with ultramafic kimberlite ash/groundmass. The system as a whole is considered essentially closed, restricting element redistribution within the pipe, as indicated by the freshness of granodiorite >~2 m from the pipe infill. Components that may be added to the system include H_2O and CO_2.

After back-stripping the effects of alteration, we interpret the different VK facies in terms of physical volcanolgical processes. Volcaniclastic kimberlites studied are mostly matrix-supported with wackstone-like textural configurations. This textural configuration is consistent with deposits that form by en mass deposition from poorly expanded high particle concentrates, such as ignimbrites. We interpret VK with wackestone-like textural configurations as having formed by the collapse of an eruption column into the volcanic conduit. One VK facies is clast-supported with a fine-grained matrix and has a packstone-like textural configuration. This deposit is analogous to a crystal-rich ignimbrite and is interpreted as having formed by en mass deposition into the conduit from a collapsing eruption column. Crystal enrichment likely occurred in the eruption column.

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