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Metasomatic textural changes in hypabyssal transitional kimberlites: Inferences for the texture and mineralogy of KPK

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Diatremes form by explosive emplacement of many types of magma. While steep-sided diatremes filled with Kimberley-type pyroclastic kimberlite (KPK, Scott Smith et al. 2018) share similar features with other diatremes, they also contain textures without analogues in any other volcanic rocks. One of their most distinctive features is the occurrence of elliptical serpentinized melt-bearing pyroclasts (also known as pelletal lapilli) with thin magmatic mantles and clinopyroxene (cpx) rims fully embedded in a serpentine (srp)-dominated carbonate-poor matrix (Scott-Smith et al., 2018). Given the economic significance of KPKs for diamond mining, multiple models have been advanced to account for the formation of the matrix-supported textures and to explain the mineralogy of these rocks deviating from the mineralogy of the crystallized kimberlite melt. We show that elliptical serpentinized melt-bearing pyroclasts with cpx rims in hypabyssal transitional kimberlites (HKt) may form in subsolidus metasomatic reactions between the kimberlite and entrained crustal silicate xenoliths. The latter include igneous and metamorphic basement and overlying magmatic and carbonate-poor sedimentary crystalline rocks.

Petrographic and drill core observations were carried out on kimberlites ranging from hypabyssal (HK) to hypabyssal transitional (HKt) to Kimberley-type pyroclastic (KPKt and KPK) from Renard 65 in the Renard cluster (Quebec) and Pipe 5034 in the Gahcho Kué cluster (Northwest Territories, Canada). Observations on 700 m of drill cores from several pipes from both kimberlite clusters show the kimberlite textures change with modes of silicate xenoliths (Fig. 1). We studied granitoid and gneiss xenoliths altered by reactions with the host kimberlites to assemblages of pectolite–cpx–phlogopite–srp-hydrous calcic silicates. The completely reacted xenoliths are composed of only Al-rich, low-Ni serpentine (Kopylova et al., 2024). It extends from the original xenolith volume as offshoots, protrusions and veinlets and disrupts, replaces and “inflates” the HK groundmass (Fig. 2). Serpentinized olivine microphenocrysts with thin rims of the groundmass become fully enveloped by the serpentine. We call these oval domains “pseudoclasts”. Radial outward-oriented microlites of fibrous cpx form reactive coronas on the xenoliths and grow in the same manner on serpentinized olivine. The resulting texture of the rocks with serpentine segregations around reacted xenoliths resembles pyroclastic textures in KPK and HKt (Fig. 2). Petrographic evidence for post-emplacement, metasomatic development of pseudoclastic texture matches the Perple_X phase equilibria calculations that model the formation of the reactive mineralogy in the subsolidus, at T<600ºC, in skarn-like reactions triggered by gradients in the chemical potentials of Si, Al, Ca, and Mg across the xenolith–kimberlite contacts. The mass transfer is demonstrated by bulk compositions, thermodynamic modelling, and conserved element ratio analysis (Fig. 3). The serpentine-producing reactions constrained by the observed mineralogy expand the HK volume by 3-44%. The low-temperature mineralogy of the fluid-limited thermodynamic calculations, where H_2O and CO_2 are imposed by the kimberlite, reproduces the observed mineralogy better than a fluid-saturated model with a meteoric fluid composition. Our findings imply that external fluids are not necessary for the serpentinization; the increased Si activity rather than H_2O controls serpentine production (Frost and Beard, 2007).

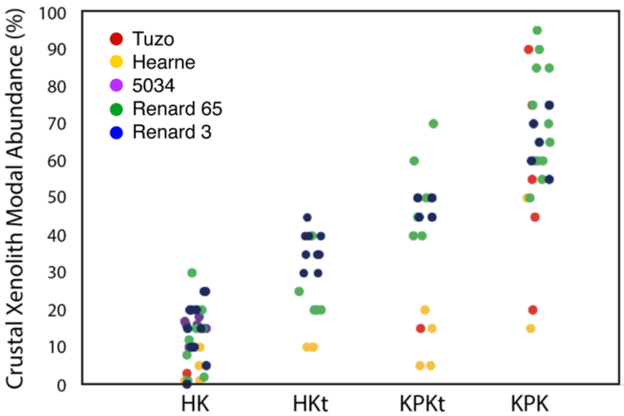

Figure 1. Correlations between crustal xenolith modal abundances and kimberlite rock textures for kimberlites in multiple pipes from Gahcho Kué (Tuzo, Hearne, 5034) and Renard (Renard 3, 65) clusters. Original data for Renard 65 are supplemented by data for Gahcho Kué pipes (Hetman et al., 2004) and Renard 3 (Muntener and Scott Smith, 2013).

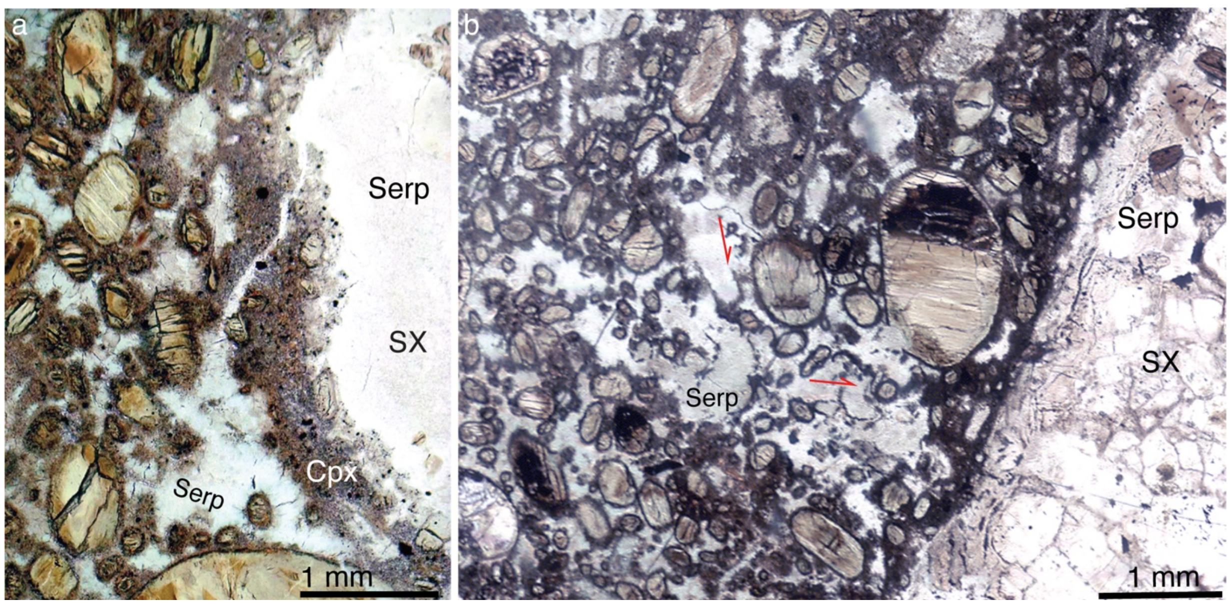

Figure 2. Photomicrographs (plane-polarized light) of 5034 HKt surrounding reacted silicate xenoliths (SX). Serpentine expands beyond the original volume of the xenolith and a cpx-rich corona in a vein (a) and makes segregations by replacement of the groundmass (b). The kimberlite in the proximity of the xenoliths has pseudoclastic texture, whereby oval clasts consist of serpentinized microphenocrysts with thin rims of the former CK groundmass overgrown by cpx. Red arrows point on pseudoclasts where the groundmass rims are replaced by colourless serpentine.

Our observations show that fluidal, round shapes of pyroclasts are not uniquely explained by the fragmentation of melt, but may also be due to a preferential replacement of the fine groundmass between elliptical olivine microphenocrysts and macrocrysts (Fig. 2). The pseudoclastic texture forms when silicate xenoliths are abundant, adding enough Si to ensure voluminous srp and cpx production and decomposition of primary kimberlitic calcite. Metasomatic "fragmentation" observed in HKt needs to be taken into account when we revise volcanological models of KPK formation. Our understanding that some of HKt melt-bearing pyroclasts are actually pseudoclasts may be relevant to KPKs as i) there is a gradual transition from HK to KPK textures correlated with the silicate xenolith modes (Fig. 1), and ii) KPK textures are exclusively associated with the geological settings where country rocks are competent crystalline silicate rocks. KPK textures may primarily reflect the volcanic or subvolcanic explosive fragmentation of silicate country rock, while magma fragmentation may have played a subordinate role.

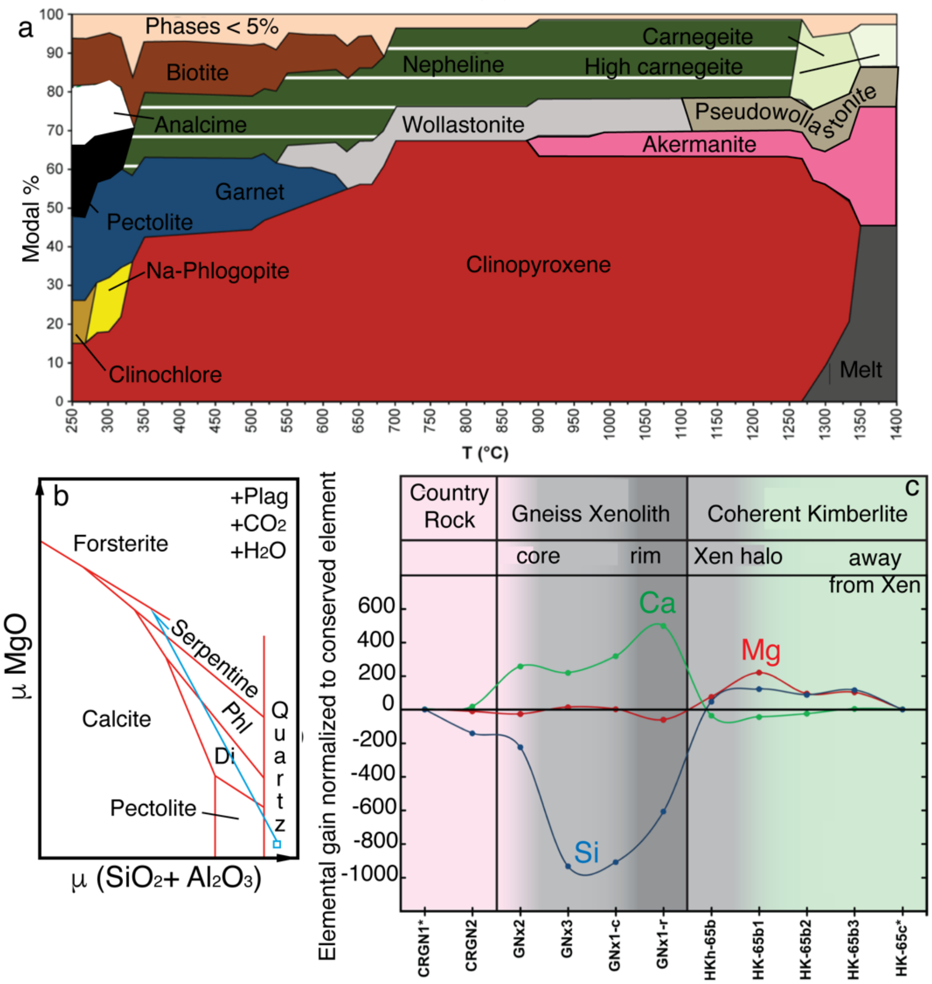

Figure 3. a) Perple_X phase equilibria model for temperatures and abundances for minerals replacing a gneiss xenolith as a result of reaction with CK at *P* = 300 bar. Field of Clinochlore approximates thermal stability of srp. b) Chemical potential diagram in the μ(SiO_2 +Al_2O_3) − μMgO space for the MgO–SiO_2–Al_2O_3–CaO–Na_2O–K_2O–H_2O–CO_2 system explaining formation of mineralogical zonal patterns observed in and around the completely reacted xenoliths. Blue arrow marks evolution from quartz-bearing xenoliths to reacted serpentinized xenoliths. c) Elemental mass transfer in a traverse from gneiss to CK. Left to right represents the transition from fresh country rock gneiss to reacted gneiss xenolith to the host CK with increasing distance from the xenolith contact. Elemental abundances of Si, Mg, and Ca are calculated as moles per 100 g of element normalized to conserved element Mn. Negative values below the zero-base line correspond to a loss of an element; positive values refer to an elemental gain. Modified after Niyazova et al. (2021), where the methods and sample details are provided.

References

Frost Br, Beard JS (2007) On silica activity and serpentinization. J. Petrology, 48: 1351–1368

Hetman C, Scott Smith B, Paul J, Winter F (2004) Geology of the Gahcho Kué kimberlite pipes, NWT, Canada: root to diatreme magmatic transition zones. Lithos, 76: 51–74

Kopylova, M., Sismondo, C., Vanderzee, S. (2024) Serpentine mineral association, texture and composition as keys to serpentine origin in kimberlites, Petrology, 32, 2: 258–282

Muntener C, Scott Smith B (2013) Economic geology of Renard 3, Québec, Canada: A diamondiferous, multi-phase pipe, infilled with hypabyssal and tuffisitic kimberlite, in Proceedings, 10th IKC, Special Issue of the J. Geological Society of India, 2, 241–256

Niyazova S, Kopylova, M, Dyck B, Benisek A, Dachs E, De Stefano A (2021) The assimilation of felsic xenoliths in kimberlites: insights into temperature and volatiles during kimberlite emplacement. Contrib Miner Petrol, 176: 84

Scott Smith BH, Nowicki TE, Russell JK, Webb KJ, Mitchell RH, Hetman CM, Skinner EMW, Robey JV (2018) A Glossary of Kimberlite and Related Terms. Published by Scott-Smith Petrology Inc., North Vancouver, Canada. 3 Parts, 259 pp. www.scottsmithpetrology.com