Coherent kimberlite at EKATI, Northwest Territories, Canada: textural and geochemical variations and implications for emplacement

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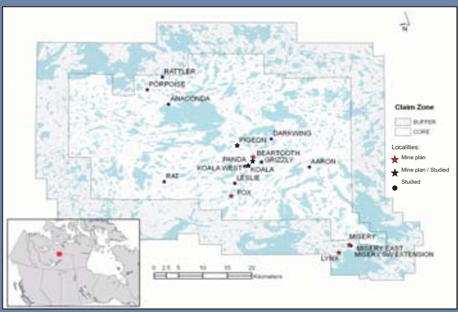
INTRODUCTION

- 'Coherent': non-genetic term for kimberlite with crystalline groundmass and lacking readily discernable evidence of fragmentation.
- Coherent kimberlite (CK) at EKATI occurs as two end-member types:
  - minor sheet intrusions: classified as hypabyssal kimberlite (**HK**)
  - volumetrically significant high-level pipe fills: termed pipe-fill CK (**pfCK**)
- This study confirms and builds on investigation by Nowicki et al.(2004, 2008) of geochemical trends in a variety of EKATI volcaniclastic (VK) and coherent kimberlites.
- Petrographic and geochemical characteristics of a larger set of CK samples from fourteen localities representing six contrasting geological settings are examined and compared to Panda and Koala pyroclastic kimberlite (PK).
- Settings are interpreted from drill core, in some cases supported by geophysics and/or mining excavations.

Location of EKATI kimberlites studied



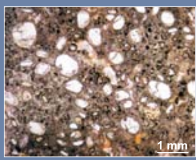
Kimberlites investigated in this study categorized by CK type and geological setting

CK type	Apparent Geological Setting	Kimberlite
HK	A) minor intrusion in host rock, isolated from pipes	Anaconda Porpoise
	B) minor intrusion in host rock, peripheral to pipe	Koala W Misery SW
	C) minor phase within VK pipe fill - probable sheet intrusions	Rat Rattler Pigeon SC
pfCK	A) large volume pipe fill CK, no associated VK	Leslie Grizzly
	B) large volume pipe fill CK, associated with VK	Darkwing Pigeon
	C) smaller bodies of CK within or associated with VK-filled pipes	Aaron Panda Misery E

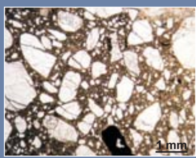
PETROGRAPHY

OLIVINE
distribution and broken crystal content

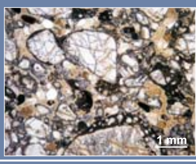
(a) Porpoise HK: olivine is uniformly distributed in the crystalline groundmass and broken olivine is absent.



(b) Grizzly pfCK: olivine is locally heterogeneously distributed in the crystalline groundmass and broken olivine is common.



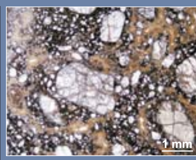
(c) Koala PK: note the contrast in olivine abundance, distribution and degree of breakage compared to samples of CK, and the presence of magmaclasts.



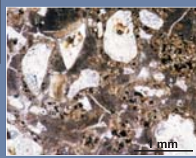
Type	Kimberlite	Drill Hole	Samples	OLV % total	OLV distrib	OLVm % brk	Magma clasts	VK autoliths
HK-A	Anaconda	96-17	1(9)	50	uniform	< 2	absent	absent
	Porpoise	94-11	2(6)	45-50	uniform	0	absent	absent
HK-B	Koala W	KWDC-01	2(4)	40-45	uniform + alignment	< 2	absent	present
	Misery SW	MDC-01	1(5)	50	uniform + alignment	3-5	absent	absent
HK-C	Rat	94-08	4(7)	45-50	uniform	2	pseudo	common
	Rattler	96-13	3(6)	45-50	uniform	1-3	absent to pseudo	absent to present
	Pigeon SC	97-54	0(2)	n/a	n/a	n/a	n/a	n/a
pfCK-A	Leslie	LDC-03	6(8)	45-55	heterog	5-10	absent to pseudo	absent
	Grizzly	92-02	2(6)	50-60	heterog	7-10	absent to pseudo	absent
pfCK-B	Darkwing	07-06	5(4)	45-50	uniform to heterog	1-5	absent to pseudo to possible true	absent to common
	Pigeon	97-54; -55	2(4)	35-40	uniform to heterog	15	possible to probable true	present
pfCK-C	Aaron	97-57	2(4)	50-60	uniform to heterog	5	absent to pseudo	absent
	Panda	PUC3-1 / UG	6(5)	40-65	uniform to heterog	1-5	pseudo to possible & probable true	absent to common
	Misery E	93-13	2(7)	50	uniform	2	pseudo	absent

- **OLV % total:** no systematic difference
- **OLV distrib:** commonly heterogeneous in pfCK
- **OLVm % broken:** subtle but notable difference
- **Pseudomagmaclastic textures:** occur only in HK within VK-filled pipes and in pfCK
- **True magmaclasts:** only in pfCK-B and -C settings
- **VK autoliths:** occur in both HK and pfCK bodies where associated with VK
- **Primary mineralogy:** no systematic difference

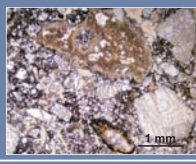
TEXTURE AND COMPONENTS
alteration, magmaclasts, autoliths



(a) Rat HK: displays a pseudo-magmaclastic texture resulting from the inhomogeneous replacement of primary groundmass by serpentine and clay.



(b) Pigeon pfCK: possible true magmaclasts and broken free olivine occur in a carbonate-clay matrix.



(c) Rat HK: altered volcaniclastic autolith incorporated during intrusion through the VK pipe fill.

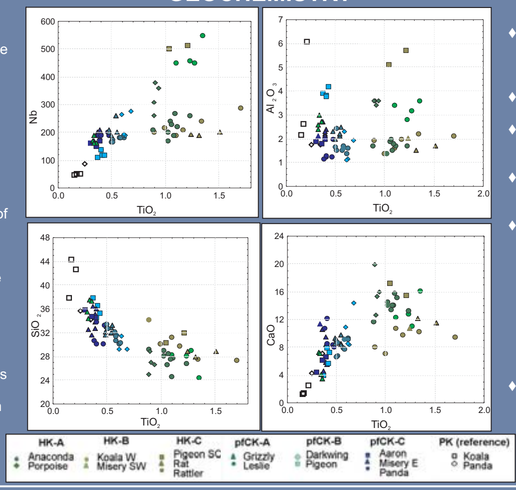
GEOCHEMISTRY

pfCK vs HK

- pfCK samples characterised by lower concentrations of TiO_2 relative to HK.
- Other incompatibles (e.g. La, Nb) also relatively depleted in pfCK.
- pfCK generally has lower V and CaO than HK.
- SiO_2, MgO and Ni concentration mostly higher in pfCK than in HK.

- No consistent difference in Al_2O_3 rules out contamination as cause of compositional differences.
- Trends intermediate between HK and pyroclastic kimberlite (PK).
- Differences consistent with relative depletion of pfCK in melt component of kimberlite magma and enrichment in olivine crystals.
- May reflect eruption processes.

- Composition of Misery SW samples suggests they are also pfCK and have been misinterpreted as HK in drill core.



Trends within CK

- HK samples define broadly cohesive overlapping to discrete compositional fields for each locality.
- Reflects compositional differences between source magmas.
- No consistent trends between or within HK compositional fields.

- pfCK samples define broad linear arrays with respect to several elements.
- Some correlation with geology/petrography:
  - Samples from large volume pipe-fill CK bodies (pfCK-A) plot close to the HK end of the pfCK compositional range.
  - Samples from Pigeon (with clearest petrographic evidence for fragmentation) plot close to PK end of compositional spectrum.
- Trends suggest degree of fragmentation and fines loss may be key factors controlling the composition of pfCK.

KEY QUESTIONS AND RESULTS

- Do HK intrusions within host rock and HK intrusions within VK pipe fills differ?
  - Subtle geochemical differences are evident.
  - HK intruding VK: petrographic evidence for interaction with VK (autoliths) and alteration overprints (pseudo textures) possibly related to volcanic degassing.
- What textural and component characteristics are diagnostic of specific emplacement settings?
  - Broken olivine abundance: higher in pfCK than HK and olivine distribution is commonly heterogeneous = suggest magma fragmentation.
  - pfCK: highest olivine breakage in large volume settings.
  - pfCK: of the large volume settings, only Pigeon has true magmaclasts.
  - pfCK: alteration overprints (pseudo textures) common to all settings.
- Do variations in geochemical composition correspond with the observed spectrum of petrographic characteristics?
  - pfCK: samples define broad linear arrays with respect to several elements
  - Some correlation with geology/petrography of large volume settings:
    - Leslie & Grizzly (high olivine breakage) plot close to HK end of pfCK compositional range;
    - Pigeon (high olivine breakage and magmaclasts) plots close to PK end.
- Are these data indicative of processes involved in formation of pipe-fill CK, and how do these relate to volcaniclastic emplacement processes?
  - pfCK: broken olivine; heterogeneous textures; geochemical evidence for fines loss; various localities together form part of overall broadly linear HK-pfCK-PK array.
  - ⇛ volcanic eruption accompanied by varying degrees of magma fragmentation and fines loss is responsible for much of the compositional and textural variations in EKATI pfCK.

APPLICATION

- Results demonstrate potential for effective application in exploration, evaluation and (to lesser extent) mining.
- Combine assessment of geological context, petrographic characteristics and geochemical composition in order to:
  - Confirm CK type and geological setting;
  - Predict and delineate extent, morphology, internal geology of body;
  - Constrain emplacement processes;
  - Interpret potential controls on diamond distribution.
- Apply to single drill core intersections or limited sample suites.
- Further research planned:
  - Do textural and geochemical relationships established for CK at EKATI apply to other kimberlite fields?
  - Can this approach help to constrain processes involved in formation of CK in root zone intrusions?

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REFERENCES

Nowicki, T., Crawford, B., Dyke, D., Carlson, J. McElroy, R., Oshust, P. and Helmsteadt, H., 2004. The geology of kimberlite pipes of the Ekati property, Northwest Territories, Canada. Lithos, 76(1-4):1-27.

Nowicki, T. Porritt, L., Crawford, B. and Kjarsgaard, B., 2008. Geochemical trends in kimberlites of the Ekati property, Northwest Territories, Canada: insights on volcanic and resedimentation processes. In press.

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