TEMPORAL AND GEOMAGNETIC RELATIONSHIP OF EKATI ECONOMIC KIMBERLITES

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INTRODUCTION

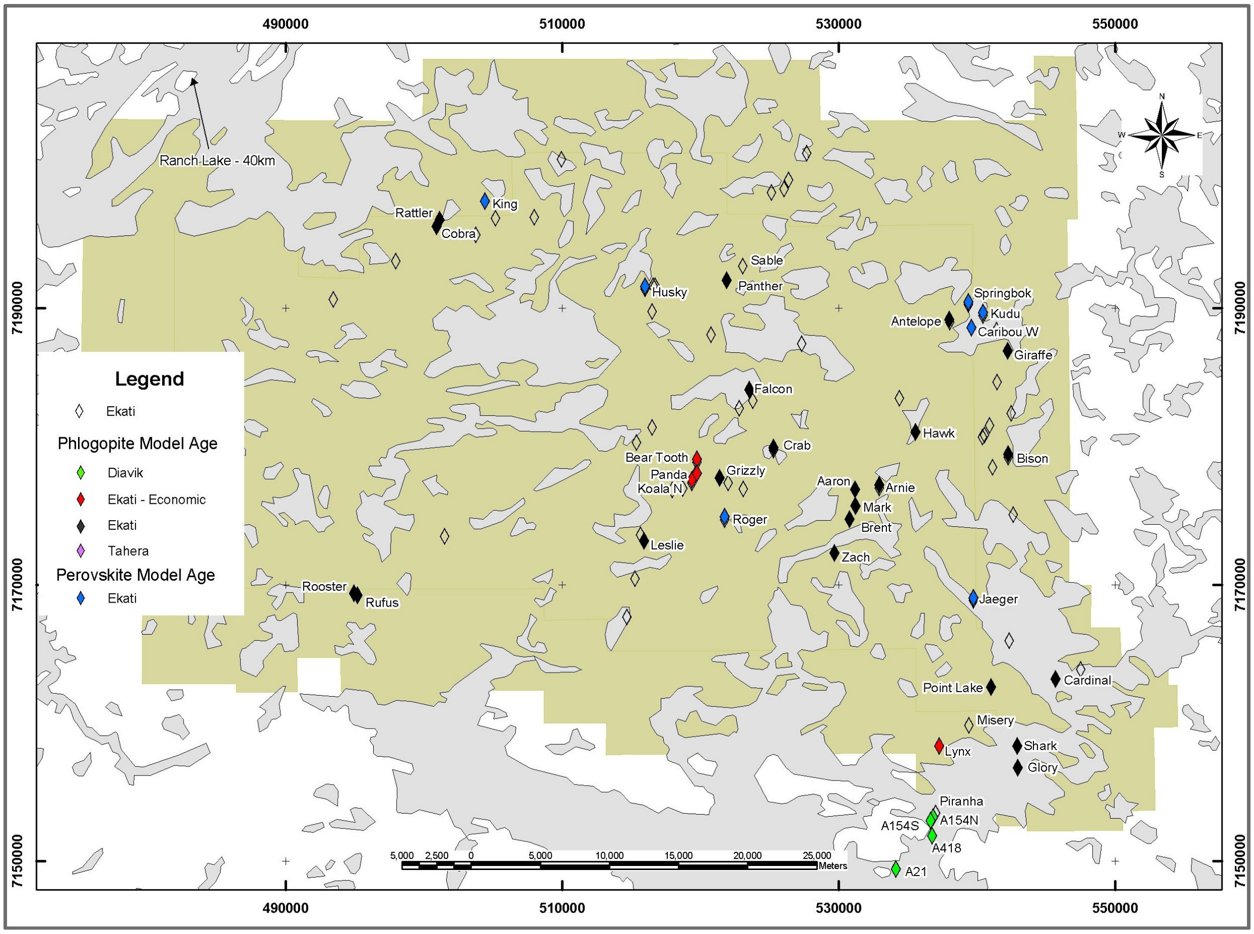
The natural remanent magnetisation of twenty Lac de Gras kimberlites has been correlated with their age as determined by isotopic dating techniques, and placed in a refined temporal context by comparison to a well-determined geomagnetic polarity time scale. The data show clustering of economic kimberlite magmatism at 55.4 ± 0.5 Ma and 53.1 ± 0.3 Ma, but do not preclude other potentially economic intrusive episodes within the age range of 75 to 45 Ma. The known economic intrusive episodes show distinct remanent magnetic characteristics that are evident at the scale of detailed aeromagnetic data sets.

The kimberlite magmatism appears to have occurred in a number of intrusive episodes. Each episode lasts for about 0.5-1.0 Myr and is separated by a 1-3 Myr hiatus. All episodes are roughly equally distributed throughout the Ekati property. Perovskite-bearing kimberlites represent the oldest kimberlites (67.4 ± 6.4 Ma) in the field and they appear to be barren or weakly diamondiferous. Phlogopite-bearing kimberlites are younger (61-47 Ma) and they tend to be moderately to highly diamondiferous.

ISOTOPIC AGE DATING

The Ekati isotopic model age database consists mostly of Rb-Sr mica model ages for kimberlitic phlogopite. Model ages have been obtained from phlogopite-poor

Figure 1: Location map of dated Lac de Gras kimberlites.



kimberlites using U-Pb dating of kimberlitic perovskite.

RB-SR MODEL AGES

The Ekati kimberlite age database contains 29 single-point Rb-Sr isotopic model ages for 23 separate kimberlites and 7 multi-point model ages for 4 kimberlites. The model ages range from 61 to 45 Ma with, on average, a ±1.0 Ma error (2σ).

U-PB MODEL AGES

Phlogopite-poor kimberlites have been dated by U-Pb analyses of kimberlitic perovskite. The perovskite component of the age database consists of 8 single-point model ages for 7 different kimberlites. The model ages range from 71 to 64 Ma with large errors (2σ) of 3.0 to 9.0 Ma. The extremely long decay constants of the U-Pb system are thought to account for inaccuracy of dating the geologically young Ekati kimberlites. The arithmetic mean of the U-Pb model ages, of 67.4 ± 6.4, is older than the oldest phlogopite-bearing kimberlite and they appear to be completely unrelated (Grutter, 2002).

GEOMAGNETIC FIELD REVERSALS

The Earth's geomagnetic field flips polarity at irregular intervals. The timing of the polarity changes is well constrained for the Upper Cretaceous and Tertiary times, which span the emplacement ages of Ekati area kimberlite (Cande & Kent, 1995). The geomagnetic polarity at the time of eruption is recorded by Natural Remanent Magnetisation (NRM) of the kimberlites. Polarity referencing allows for the refinement of the isotopic model ages.

INFERRED POLARITY FROM AEROMAGNETICS

A kimberlite's magnetic signal consists of an inductive magnetisation (M_{ind}) component and a NRM component. It is the NRM containing the geomagnetic polarity information at emplacement that is of interest. In cases where the NRM dominates M_{ind}, i.e. the Konigsberger Ratio (Qr) is much greater than 1, then the remanent polarity may be determined from aeromagnetic survey data. The remanent polarities for many of the kimberlites are easily inferred from aeromagnetic data, in particular from kimberlites expressed as magnetic "lows".

MEASURED POLARITY

Laboratory paleomagnetic measurements on oriented core samples are required to determine the remanence polarity when Qr ≤ 2. When Qr is near unity and the remanent polarity is reversed, a kimberlite will be magnetically invisible in aeromagnetic data. This appears to be the case for most of the economic kimberlite occurrences in the Misery-Diavik area.

Paleomagnetic studies of Ekati hypabyssal and primary volcaniclastic kimberlite samples indicate that the primary remanent magnetisation of kimberlite can be attributed to thermal cooling of titanomagnetite through its Néel (Curie) point (Enkin, 2003). The Néel temperature for magnetite is about 580°C, well within expected eruption temperatures of magmatic kimberlite, and it decreases with increasing titanium substitution to -150°C for ulvospinel (Merrill et al., 1996). Some of the Ekati samples show nice "square-shoulder" demagnetisation plots indicative of single domain carriers. The unblocking temperatures around 500°C suggest possible TM10 to TM20 compositions rather than pure magnetite (Enkin, 2003).

NRM REFINED MODEL AGES

The emplacement chronology of twenty Ekati are kimberlites, previously dated by phlogopite Rb-Sr model age techniques, was refined by referring the kimberlites' remanent polarity to a geomagnetic polarity timescale. The refinements relate to periods of normal or reverse NRM polarity and are outlined in Table 1. Large errors in the perovskite ages span numerous reversals and thereby prevent age refinement (Table 1). Longer periods of normal polarity in the late 60's Ma and early to late 70's Ma indicate that half of the perovskite-dated kimberlites erupted between 65.6-61.3 Ma and possibly in the narrow reversal period of 64.0-63.6 Ma. The remaining perovskite-dated kimberlites were likely emplaced in the reversal period of 71.1-68.7 Ma.

DISCUSSION

Kimberlite volcanism appears to have occurred in a number of intrusive episodes, each lasting for about 0.5-1.0 Myr, and each episode being separated by a 1-3 Myr hiatus (Table 1). All ages groups are roughly equally distributed throughout the Ekati property (Figure 1).

The Ranch Lake kimberlite model age (52.1 ± 0.3 Ma) falls well within the observed Ekati age range (Table 1). This age relationship suggests that the Ranch Lake kimberlite represents the northwestern extent of the Lac de Gras kimberlite field.

Separate episodes of economic kimberlite magmatism are defined by the Lynx-A154 cluster at 55.4 ± 0.5 Ma

Table 1: Summary of NRM refined model ages and microdiamond grades of Ekati area kimberlites**.**

Kimberlite & Episode	Micro-diamond "Grade" (cpt)	NRM Polarity	Age (Ma)	Error (Ma)	Dating Methodology	Reference
Aaron	>1.0	Reverse	45.2	0.8	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Giraffe	>1.0	Normal	47.4	0.5	Phlog. single-point Rb-Sr	Geospec, 2002
[4]Brent	~0.4	Reverse	(47.1)	0.5	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Mark	~0.7	Reverse	47.95	0.05	Phlog. isochron Rb-Sr	Davis & Kjarsgaard, 1997
[1]Hawk	~0.1	Reverse	48.4	0.4	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Arnie	>1.0	Reverse	48.5	0.6	Phlog. two point Rb-Sr	Armstrong & Moore, 1998
[1]Brent	~0.4	Reverse	48.6	0.6	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Grizzly	~1.0	Reverse	51.5	3.5	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Point Lake	~1.0	Reverse	51.87	0.13	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Falcon	~1.0	Reverse	52.1	0.3	Phlog. single-point Rb-Sr	Geospec, 2002
[3]Ranch Lake	~0.3	Reverse	52.1	0.3	Phlog. isochron Rb-Sr	Geospec, 2002
[1]Leslie	~1.0	Normal	52.1	1.3	Phlog. isochron Rb-Sr	Colllerson, 1995
Zach	~0.4	Normal	52.8	0.5	Phlog. single-point Rb-Sr	Geospec, 2002
[1]**Panda**	>1.0	Normal	**52.7**	**3.7**	Phlog. isochron Rb-Sr	Collerson,1995
[1]**Beartooth**	>1.0	Normal	**53.0**	**0.4**	Phlog. single-point Rb-Sr	Geospec, 2002
[1]**Koala North**	>1.0	Normal	**53.1**	**0.3**	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Cardinal	>1.0	Reverse	54.7	1.2	Phlog. single-point Rb-Sr	Geospec, 2002
Bison	~0.2	Reverse	54.8	0.6	Phlog. single-point Rb-Sr	Geospec, 2002
[2]**A154 South**	>1.0	Reverse	**54.8**	**0.3**	Phlog. isochron Rb-Sr	Graham et al, 1999
[2]**A418**	>1.0	Reverse	**55.2**	**0.3**	Phlog. isochron Rb-Sr	Graham et al, 1999
[1, 2]**A154 North**	>1.0	Reverse	**55.6**	**0.3**	Phlog. isochron Rb-Sr	Graham et al, 1999
[2]**A21**	>1.0	Reverse	**55.7**	**2.1**	Phlog. isochron Rb-Sr	Graham et al, 1999
[1]**Lynx**	>1.0	Reverse	**56.8**	**3.5**	Phlog. single-point Rb-Sr	Geospec, 2002
Panther	~0.0	Reverse	58.3	4.4	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Crab	~0.3	Reverse	58.4	0.5	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Shark	~1.0	Reverse	58.7	0.7	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Rooster	~0.1	Reverse	59.1	1.2	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Antelope	<0.1	Reverse	59.4	1.5	Phlog. single-point Rb-Sr	Geospec, 2002
Rattler	<0.1	Reverse	59.7	0.9	Phlog. single-point Rb-Sr	Geospec, 2002
Cobra South	<0.1	Reverse	59.7	0.7	Phlog. single-point Rb-Sr	Geospec, 2002
Glory	>1.0	Reverse	61.3	2.5	Phlog. single-point Rb-Sr	Geospec, 2002
[1]Rufus	<0.1	Normal	61.1	0.2	Phlog. single-point Rb-Sr	Geospec, 2002
King	<0.1	Reverse	63.9	3.4	Perovskite single-point U-Pb	Geospec, 1999
Springbok	<0.1	Reverse	63.9	2.6	Perovskite single-point U-Pb	Geospec, 1996
Roger	0.0	Reverse	64.1	9.0	Perovskite single-point U-Pb	Geospec, 1996
Husky	<0.1	Reverse	64.1	4.0	Perovskite single-point U-Pb	Geospec, 1996
Caribou West	~0.0	Reverse	68.2	3.8	Perovskite single-point U-Pb	Geospec, 1996
Jaeger	<0.1	Reverse	69.1	6.4	Perovskite single-point U-Pb	Geospec, 1996
Roger	0.0	Reverse	71.0	9.2	Perovskite single-point U-Pb	Geospec, 1996
Kudu	0.0	Reverse	74.7	6.8	Perovskite single-point U-Pb	Geospec, 1996

[1]NRM refined age, [2]Diavik Diamond Mines Inc., [3]Tahera Corporation, [4] inconsistent model age with NRM polarity

and by the Panda-Koala cluster at 53.1 ± 0.3 Ma. The 55.4 Ma Lynx-A154 kimberlites have a reverse remanent magnetisation and produce a neutral to negative aeromagnetic signature (Graham et al, 1999). In contrast, the 53.1 Ma Panda-Koala kimberlites have normal remanent magnetisation and appear in aeromagnetic data as weak to moderately strong positive anomalies.

It is important to recognize that kimberlites from other age groups are located near the two economic clusters (Figure 1), including the perovskite-bearing ones, which have very low microdiamond content (Table 1). This suggests that the older kimberlites may not be economically significant. It appears likely that the early to mid 50's Ma kimberlite magmas had a better capacity to sample and to carry diamondiferous mantle to surface, but that does not rule out the possibility of finding a high grade kimberlite within an age group that is generally characterized by low grade kimberlites. Diamond quality and diamond content are normally related to their mantle source-rocks, and the magmatic processes that preserve or dilute them en route to surface, rather than purely temporal considerations.

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