



# Duration and periodicity of kimberlite volcanic activity in the Lac de Gras kimberlite field, Canada and some recommendations for kimberlite geochronology



Chiranjeeb Sarkar<sup>\*</sup>, Larry M. Heaman, D.G. Pearson

Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton T6G 2E3, Canada

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## ABSTRACT

Establishing the emplacement ages and distribution pattern of Central Slave kimberlites has played a key role in diamond exploration within the Lac de Gras kimberlite field. Nonetheless, emplacement age information is lacking for approximately 80% of the known kimberlites in this field making the assessment of emplacement age patterns difficult. This study expands the number and geographic coverage of kimberlite emplacement ages within the Lac de Gras field to re-assess the absolute timing, duration, and possible number of pulses of kimberlite eruption. U–Pb perovskite ages for eight previously undated kimberlites and an additional thirteen kimberlites, which were previously dated by either the Rb–Sr or U–Pb methods, fall within the age range of 75–45 Ma, as previously suggested for kimberlite magmatism in this area. We report the first Carboniferous age kimberlite in the Central Lac de Gras field – the Eddie kimberlite – with a U–Pb perovskite age of  $321.0 \pm 3.0$  Ma. A compilation of 57 kimberlite emplacement ages from the central Lac de Gras field was evaluated using probability density and mixture modeling methods. Five short-duration (4–5 Ma) periods of kimberlite magmatism are recognized at 48, 54, 61, 66 and 72 Ma; the three younger pulses have been previously recognized and remain relatively unchanged. The 54 Ma pulse represents the major kimberlite eruption event containing ~40% of the currently dated kimberlites in Lac de Gras field. A detailed evaluation of the temporal–spatial evolution of Lac de Gras kimberlites reveals that the oldest diamond-poor kimberlites (75–60 Ma) were emplaced in the northern and eastern parts of the field whereas the younger (55–48 Ma) economic kimberlites are concentrated in the center of the field.

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## 1. Introduction

Kimberlites occur in all major Archean cratons including: the Kaapvaal craton (Southern Africa); Siberian craton (Russia); Slave, Sask, Wyoming and Superior cratons (North America); North Atlantic craton (Greenland); North China craton (China); and Dharwar craton (India). However until quite recently, much of our knowledge about the nature and origin of kimberlites was based on numerous studies of southern African kimberlites (Clement et al., 1984; Dawson and Hawthorne, 1973; Erlank et al., 1987; Fesq et al., 1975; Le Roex et al., 2003; Mitchell, 1986; Nowell et al., 2004; Smith et al., 1985; Spriggs, 1988; Wagner, 1914). During the last two decades, a large number of kimberlites have been discovered in other countries; for example, prior to 1990 there were less than 30 kimberlite localities reported in Canada whereas today there are more than 600, with new discoveries every year. As this inventory of kimberlite occurrences has increased there have been significant modifications to the views

on their origin and emplacement mechanisms (Fipke et al., 1995; Heaman and Kjarsgaard, 2000; Heaman et al., 2003; Porritt et al., 2008; Sparks et al., 2006, 2009; Tappe et al., 2013). In addition to petrogenetic and geochemical studies, constraining the timing and patterns of kimberlite emplacement has become important for understanding global mantle processes responsible for kimberlite magmatism (e.g., Heaman et al., 2003; Zurevinski et al., 2011). For example, Heaman and Kjarsgaard (2000) noted that a corridor of Triassic–Jurassic kimberlite magmatism in central and eastern Canada with a distinct age progression coincided with independent evidence for the synchronous passage of the Great Meteor mantle plume hotspot track (Morgan, 1983). This observation is consistent with a mantle plume origin for, at least, these kimberlite fields. The rate of kimberlite eruption (uniform versus pulsed) and whether there are temporal windows of economic diamond-bearing kimberlite activity are additional questions that may be addressed via improved kimberlite geochronology. As more comprehensive geochronology studies of kimberlite magmatism are conducted, it is becoming clear that the magmatic history in a number of fields is protracted, spanning periods of 10–30 m.y.; for example, the emplacement of 12 kimberlites in the Kirkland Lake field occurred

<sup>\*</sup> Corresponding author.

E-mail address: [chiranjeeb.sarkar@ualberta.ca](mailto:chiranjeeb.sarkar@ualberta.ca) (C. Sarkar).

over a 13 m.y. period between 165 and 152 Ma (Heaman and Kjarsgaard, 2000); and kimberlite magmatism in Siberia occurred between 340–400 and 420–460 Ma (Smelov and Zaitsev, 2013). Lastly, precise geochronology is increasingly required by industry to accurately resolve the timing of economically significant intrusive phases within multi-intrusion kimberlite complexes and clusters. Here we focus on better constraining the age range of kimberlite activity within the Lac de Gras kimberlite field, Northwest Territories, Canada, with a view to establishing more firmly whether the most economic kimberlites erupted in distinct time periods.

## 2. Geochronology of the Lac de Gras kimberlite field

The Slave province is an Archean cratonic region covering approximately 210,000 km<sup>2</sup> of the North West Territories and Nunavut, Canada. Exposed rocks in Slave craton consist of 2.73 to 2.58 Ga basement gneiss complexes intruded by granitic plutons and overlain by several groups of supracrustal rocks (Davis et al., 1999, 2003). The Lac de Gras kimberlite field occurs in the central portion of the Archean Slave craton (Fig. 1; Kjarsgaard et al., 2002). The Lac de Gras field is part of an ~N–S corridor of Cretaceous/Tertiary kimberlite magmatism that extends sporadically for approximately 2000 km along strike from the NWT through Alberta to Montana (Heaman et al., 2003). In

addition to the Cretaceous/Tertiary magmatism, more than 600 Ma of kimberlite eruption history is recorded in the Slave craton, however the origin and geodynamic setting of this magmatism is poorly understood. In an early assessment of emplacement patterns Heaman et al. (1997, 2003, 2004) identified four distinct age clusters: a southwestern Siluro-Ordovician domain (~450 Ma), a southeastern Cambrian domain (~540 Ma), a northern domain that contains Jurassic, Permian and Neoproterozoic kimberlites, and a central Cretaceous/Tertiary domain (74–48 Ma) in the vicinity of Lac de Gras.

Although more than 270 confirmed kimberlites have been discovered in the Lac de Gras field, <20% of them have had their emplacement ages determined by radiometric methods so far. Of the existing ages, their emplacement history spans a period of ~30 m.y. (75–45 Ma; Creaser et al., 2004; Lockhart et al., 2004). Most of the kimberlites with known ages are from the central Lac de Gras field, predominantly from the Ekati kimberlite property. The first radiometric age was reported from the Mark kimberlite (47.5 ± 0.5 Ma), determined using the Rb–Sr phlogopite isochron technique (Davis and Kjarsgaard, 1997). Later, Creaser et al. (2004) completed an extensive Rb–Sr phlogopite geochronology study and proposed the existence of four distinct periods of kimberlite magmatism at ~47–48, 51–53, 55–56 and 59–61 Ma, based on ~40 Rb–Sr phlogopite ages. Only one study (Lockhart et al., 2004) has reported a summary of U–Pb perovskite ages for seven different Ekati kimberlites. There are two intriguing features of the published

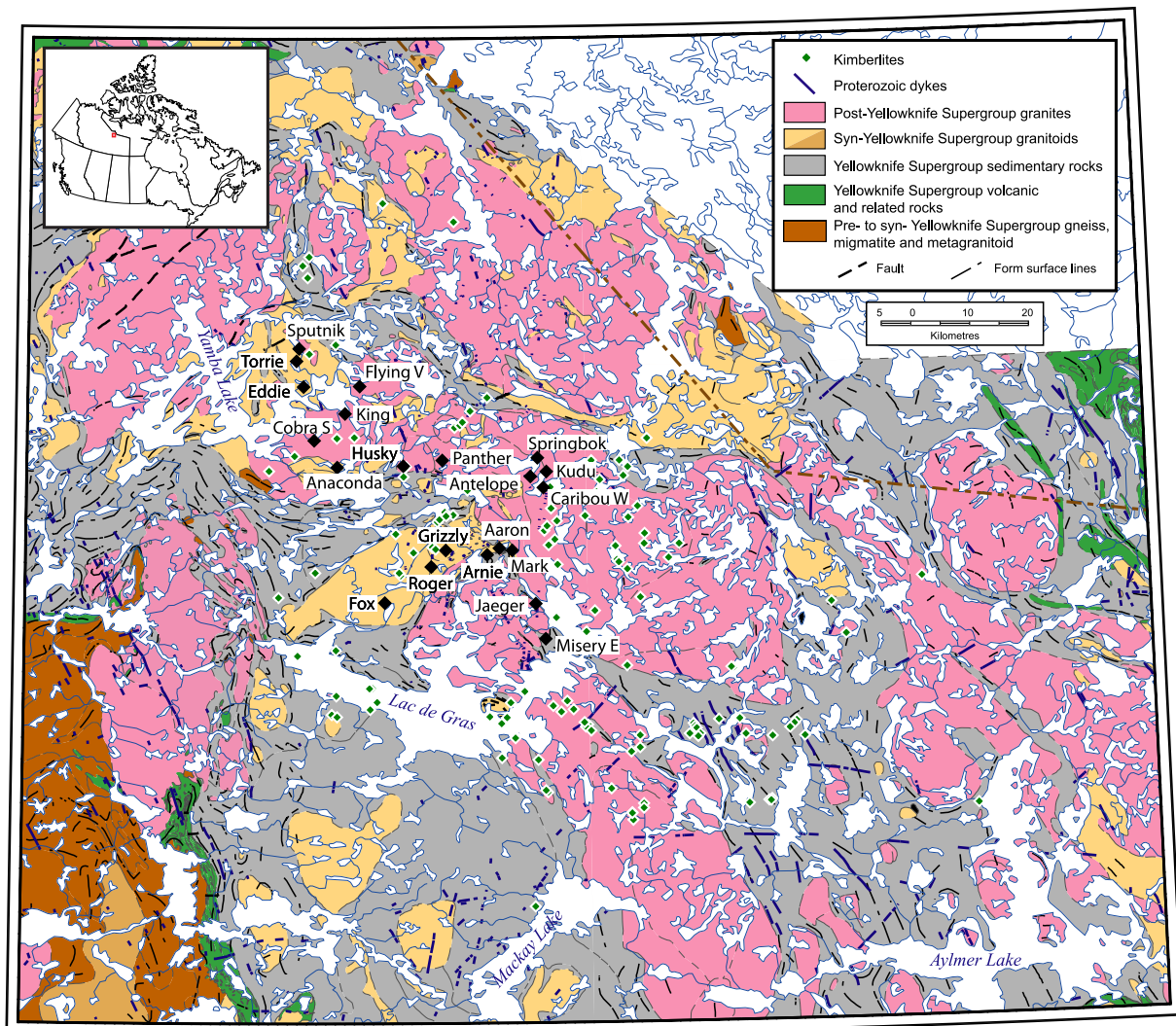


Fig. 1. Generalized geological map of central Lac de Gras area, modified from Kjarsgaard et al., 2002. Diamond symbols represent occurrences of kimberlites in the field. Black diamonds represents the locations of kimberlites used in this study.

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