12th International Kimberlite Conference Extended Abstract No. 12IKC-021, 2024

Updated geochronology of the central Slave craton – duration, pulses and time-integrated source variability

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Introduction

The discovery of kimberlites - volatile-rich ultramafic magmas and one of the major sources of natural diamonds - is very challenging as they are volumetrically insignificant compared to other rocks found in Earth's crust. Even after discovery, their economic potential can be highly variable. It is extremely difficult and very costly to confidently predict their diamond potential as it is often below parts per million level and very heterogeneously distributed. Among various other exploration tools, geochronology has played a key role in diamond exploration, and this is particularly true for kimberlites of the Lac de Gras (LDG) area, central Slave craton, Canada, which host the highly economic Ekati and Diavik diamond mines. Recent improvements in geochronology techniques have resulted in a key finding that multiple kimberlite eruption events with very different diamond potential have occurred within the same locality or in close vicinity, as reported for some bodies from the Renard kimberlite cluster, Quebec, the Victor kimberlite cluster in northern Ontario, and the Fort à la Corne kimberlite field in Saskatchewan. Moreover, from a petrogenetic perspective, its is crucial to understanbd the overall span of kimberlite activity at the scale of a given body, cluster and field, if the various genetic models are to be thoroughly evaluated.

The central LDG kimberlite field is one of the most intensively dated kimberlite fields on Earth. In the 30 years since the first emplacement ages for LDG kimberlites were reported, an episodic increase has occurred in the number of kimberlites dated in this district. Still, among more than 300 kimberlites which have been reported from central LDG, less than 20% have been dated so far and only a handful of them are found to be economic. However, a pulsed nature of kimberlite eruption with variable diamond potential is clearly emerging from this growing age database. Most of the kimberlites in the geochronology database are from Ekati with fewer from the Diavik property. In this study, we report new U-Pb perovskite age results of 10 samples from 5 closely spaced bodies at Diavik. We also include 3 samples from various drill holes from the DO-27 kimberlite. These new additions to the LDG geochronology database, for kimberlites with varied diamond potential and diamond source, help us paint a clearer picture of the correlation between multiple eruption events and their economic potential in the central LDG district, both within same pipe or different pipes within a cluster or in the LDG field.

Samples

Kimberlite samples used in this study are mostly coherent/hypabyssal kimberlite (CK/HK) collected during exploration from 2019 – 2022 on the Diavik property. The five Diavik property kimberlites include A4 and M24, located close to the mined A21 pipe; as well as C49, C13 and JY25 kimberlites that are located further from the Diavik cluster ofeconomic pipes. A4 is a relatively large body and 4 samples from various depths were chosen from this pipe while 2 samples came from M24. Geophysics indicates that the C13 kimberlite

possibly consists of a main body with NW satelite extension. One sample was chosen from each part of this C13 body. One sample from C49 and one from JY25, which is located just west of the much larger A180 body, complete the list of Diavik samples investigated in this work. In the southern portion of the LDG kimberlite field, three samples from various depths from the DO-27 kimberlite complex were also dated.

All of the kimberlites were processed using a Sel-Frag and groundmass perovskite with sizes varying between 30-75 µm were recovered from them. Perovskite recovery from DO-27 was particularly challenging due to their alteration and minuscule sizes (<30 um). Overall the analytical technique for U-Pb geochronology followed the procedure described in Sarkar et al. (2015) and Sarkar et al. (2018). Most of the emplacement ages reported here are a weighted average $^{206}Pb/^{238}U$ age from each sample.

Results and Discussion

The new data from the 10 Diavik samples define a range of emplacement ages between 62 and 70 Ma, except one sample of M24 (~ 58 Ma), thus exceeding those of the main economic cluster of Diavik area, which is around 55 Ma. All four samples from different CK units of the A4 pipe are almost identical within uncertainty around 67-70 Ma. Two samples from C49 and one from C13 are also similar with ages around 67.5 Ma. Two M24 samples gave younger ages than the other Diavik samples studied here, with one (57.3 Ma) having an emplacement age within uncertainty of the economic A21 cluster (55.7 ± 2.1 Ma; Graham et al., 1999). In contrast, the JY25 body, dated at ~ 80 Ma, represents the oldest of the post-Paleozoic Lac de Gras kimberlites discovered so far (excluding Eddie which is ~320 My, Sarkar et al., 2015).

For DO-27, ages from three samples are separated by ~13 Myr, with the oldest being over 71 Ma. Although the uncertainty on the calculated $^{206}Pb/^{238}U$ ages for this body are relatively high, mostly due to poor recovery of perovskite, small grain size and very high portions of non-radiogenic common Pb (up to 90%), these ages are outside their respective uncertainties. This age range at DO-27 is thus - perhaps - another example of protracted kimberlite magmatism within a single complex, as shown in numerous other examples e.g. Star and Orion South pipe in the Fort à la Corne kimberlite and the Renard kimberlite (Ranger et al., 2018).

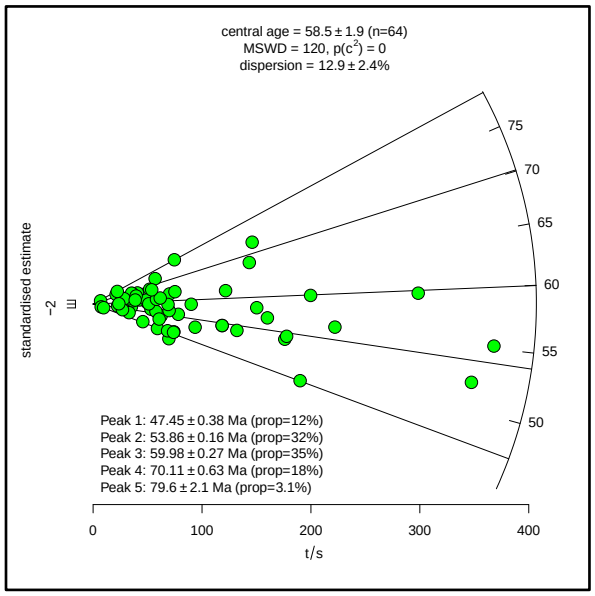

Fig 1 - Radial plot (age on circumference, relative precision on x-axis) of all central Lac de Gras kimberlite emplacement ages excluding Eddie. The Gaussian mixture modelling shows five distinct age pulses and their proportions of the overall database.

The new data, combined with previous data (Creaser et al., 2004; Sarkar et al., 2015; Heaman et al., 2019) provide emplacement ages on over 60 kimberlite bodies at Lac de Gras. The combined data show a total age range of almost 35 Myr (45 Ma to 80 Ma) for post-Paleozoic central Slave kimberlites (Fig. 1) . This new dataset can be used to further test the isotopic evolution of the source of LDG kimberlites with temporal trends recently found by Tovey et al., (2021), with the Mark kimberlite (47.5 Ma; Davis and Kjarsgaard, 1997) and the JY25 kimberlite from Diavik (~80 Ma, this study) providing anchors to such trends.

This updated dataset can also be statistically tested to identify any temporal patterns and pulses of kimberlite magmatism in central Lac de Gras area. Mixture modelling of the combined data identifies 5 age clusters among the central Slave kimberlites: ~ 79.6 Ma (~ 3% of the data), ~ 70 Ma (18%), 60 Ma (35%), 53.9 Ma (32%) and 47.5 Ma (~ 12%) (Fig 1). While the younger pulses of 47.5 Ma, 54 Ma, 60 Ma and 70 Ma were identified in the previous studies (Creaser et al., 2004; Sarkar et al., 2015), the oldest 80 Ma pluse, although relatively small, is a new addition. The correlation of economic potential and emplacement age has given rise to the current idea of a "Diamond Window" that stretches between the two youger pulses at 47.5 Ma and 54 Ma. The older ages of the newly dated bodies from Diavik in this study are generally sub-economic in nature, thus in-keeping with the trend, with the potential exception of JY25. The JY25 kimberlite (~80 Ma) has better diamond potential than the 60 My bodies. Similarly, for the sub-economic DO-27 deposit, although the youger pulses fall within the present "diamond window", the older pulse of 71 Ma is definitely outside. Thus, the older JY25 together with the older DO-27 age hints at varying economic potential for kimberlites in the 70 to 80 Ma age range in the Lac de Gras field, which warrents further work, though neither locations appear to be as economic as the main Ekati and Diavik mined pipes.

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