Punctuated, long-lived emplacement history of kimberlites from the Renard cluster, Superior Province, Canada indicated by new high precision U-Pb groundmass perovskite dating

I.M. Ranger[1], L.M. Heaman[1], D.G. Pearson[1], C. Laroulandie[2], I. Lépine[2] and V. Zhuk[2]

[1] *University of Alberta, Edmonton, Canada, iranger@ualberta.ca, larry.heaman@ualberta.ca, graham.pearson@ualberta.ca*

[2] *Stornoway Diamond Corporation, North Vancouver, Canada, claroulandie@stornowaydiamonds.com, ilepine@stornowaydiamonds.com, vzhuk@stornowaydiamonds.com*

Introduction

A number of Neoproterozoic (~680-550 Ma) kimberlites and related intrusions have been identified in eastern North America and southwest Greenland (e.g. Tappe et al., 2016). In eastern Canada these intrusions are known to occur in at least three clusters (Figure 1); the ca. 610-550 Ma ultramafic lamphrophyre intrusions from the Torngat Mountains to Aillik Bay in Labrador (e.g. Tappe et al., 2008 and references therein), the ca. 629 Ma Wemindji kimberlite sills near James Bay (Letendre et al., 2003) and the ca. 656-551 Ma Otish kimberlite field in north-central Québec (Moorhead et al., 2003; Birkett et al., 2004; Fitzgerald et al., 2009; Tappe et al., 2016). An intriguing aspect of this magmatism that has been alluded to previously (e.g. Heaman et al., 2004) is that it broadly coincides with the timing of the breakup of the Rodinia supercontinent and the opening of the Iapetus Ocean (ca. 760-550 Ma; Cawood et al., 2001). However, in detail the connection between kimberlite magmatism and the rifting history of northeast Rodinia remains unclear.

In this study we have conducted a detailed multi-sample ID-TIMS U-Pb perovskite age investigation of Renard kimberlite pipes in the diamondiferous Renard cluster, located within the Otish mountains region of north-central Québec. One of the main challenges at Renard is establishing the exact emplacement age and intrusion history of these kimberlites. For example, published U-Pb perovskite dates for hypabyssal kimberlite from within the same pipe (e.g. Renard 2) yield a range of ages from 640.5±2.8 Ma to 655.8±6.0 Ma (Fitzgerald et al., 2009; Tappe et al., 2016).

Geologic Setting and Previous Geochronology

The diamondiferous Renard cluster comprises a core of nine kimberlite bodies (Renard 1 to 10 with Renard 65 combined), two dyke systems (Lynx and Hibou) and several anomaly dykes which erupted through Archean crust of the eastern Superior Province. Most of the kimberlite bodies follow a ~2 km long NNW-trending alignment and the surface area of individual pipes vary between 0.3 and 3.1 ha (Farrow and Hopkins, 2015). The internal geology of Renard 2 and Renard 3 were described by Fitzgerald et al. (2009) and Muntener and Scott Smith (2013), respectively, with the remaining kimberlite bodies described by Farrow and Hopkins (2015).

The Renard kimberlites are considered to be Group I kimberlites and consist of hypabyssal kimberlite (e.g. dykes) and one or more pipe-infilling units ranging from coherent to transitional to massive volcaniclastic kimberlite in each pipe (Kimberley-type pyroclastic kimberlite previously termed tuffisitic kimberlite) (Scott Smith et al., 2013; Farrow and Hopkins, 2015). For example, Fitzgerald et al. (2009) characterised the blue massive volcaniclastic kimberlite in Renard 2 as phlogopite kimberlite and the brown coherent kimberlite as monticellite phlogopite kimberlite. In addition, cm- to tens of meters thick hypabyssal kimberlite occur throughout the Renard pipes as dykes, irregular intrusions or possibly autoliths. These hypabyssal kimberlites also occur within the marginal breccia and/or cracked country rock. Fitzgerald et al. (2009) described the hypabyssal kimberlite intrusions in Renard 2. They range in primary groundmass mineralogy, primarily with varying amounts of phlogopite to monticellite.

A number of U-Pb perovskite dates by both TIMS and SIMS have been reported for Renard kimberlites. The first published U-Pb TIMS groundmass perovskite date of 631.6±3.5 Ma was reported for a Renard 1 hypabyssal kimberlite (Birkett et al., 2004). A slightly older U-Pb TIMS composite emplacement age of 640.5±2.8 Ma from Renard 2 and 3 was reported by Fitzgerald et al. (2009). Recent U-Pb perovskite age determinations by SIMS from hypabyssal kimberlite in Renard 2 (655.8±6.0 Ma) and Renard 3 (653.8±5.9 Ma) (Tappe et al., 2016) expanded the previously known range of kimberlite magmatism in the Renard cluster to ca. 656-632 Ma. These studies highlight a significant discrepancy between the U-Pb perovskite TIMS and SIMS dating results for the same pipe. Unfortunately the sampling details of hypabyssal kimberlites in Renard 1-3 were not described in the previous studies, even though the complexity of these bodies requires this detail in order to understand the significance of the ages. In addition, the Otish field includes the much younger 550.9±3.5 Ma Lac Beaver hypabyssal kimberlite located ~90 km south of the Renard cluster (Figure 1; Moorhead et al., 2003).

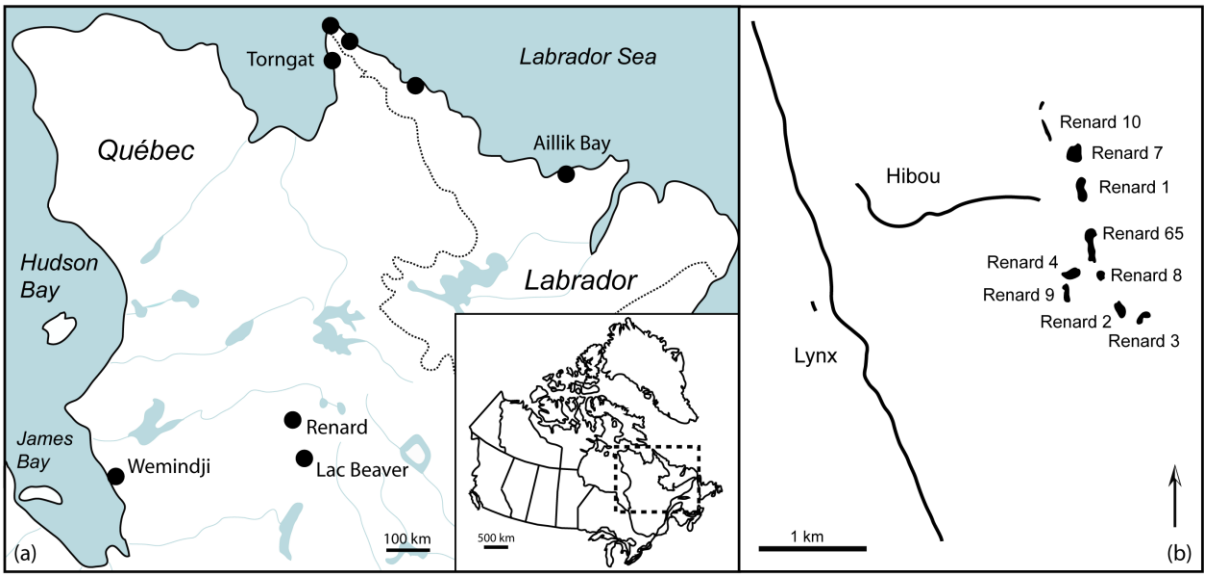

Figure 1. Simplified sketch of (a) the locations of kimberlite clusters and related intrusions in eastern Canada and (b) the Renard kimberlite cluster outlining Renard 1-10 and the Lynx and Hibou dyke systems in north-central Québec. Modified from a Natural Resources Canada reference map (2001), Tappe et al. (2008), and Farrow and Hopkins (2015).

Results and Discussion

This study provides new high-precision (±1-3 Ma; 2σ) ID-TIMS U-Pb groundmass perovskite dates for the Renard cluster. A more detailed investigation of the ages of the main pipe-infilling units versus hypabyssal kimberlite uncovered a novel result that offers an explanation for understanding complicated kimberlite geochronology where multiple U-Pb perovskite dates for a single pipe exist. There is clear evidence for multiple episodes of hypabyssal kimberlite magmatism at Renard, with a geologically significant range in emplacement dates. Interestingly this protracted kimberlite intrusion history is recorded even within some individual pipes.

For example, eight new U-Pb dates from Renard 2 indicate that the hypabyssal kimberlite has emplacement dates that span at least ~20 Myr from approximately ~652-632 Ma. Some hypabyssal kimberlites were emplaced both prior to and post the ~643 Ma emplacement of the coherent to massive volcaniclastic kimberlite main pipe-infilling units. These new age results demonstrate that hypabyssal kimberlite magmatism in the Renard 2 pipe took place at punctuated intervals over a protracted period of time. The findings of this study demonstrate that a single radiometric date obtained on hypabyssal kimberlite from one pipe may not be representative of the age of the main pipe-infilling units.

New high precision ID-TIMS U-Pb perovskite dates from the Renard kimberlite cluster indicate that the majority of this magmatism occurred much earlier than the kimberlite and ultramafic lamprophyre magmatism recorded in southwest Greenland and Labrador (ca. 610-550 Ma) (e.g. Tappe et al., 2008 and references therein). Furthermore, the timing of the majority of Renard kimberlite magmatism is distinct from the two proposed periods of Rodinia rifting (e.g. ca. 760-700 Ma and ca. 620-550 Ma, Cawood et al., 2001) and at least ~35 m.y. earlier than estimates for the birth of the Iapetus Ocean (Kamo et al., 1989).

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