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# Constraints on the origin of intrusion breccias: Observations from the Paleoproterozoic Boundary Intrusions in the Flin Flon area

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## Summary

The Boundary Intrusions in the Flin Flon area are a set of felsic to ultramafic breccia-laden intrusions in the upper crust emplaced at approximately 1842 Ma during the Trans-Hudson Orogeny. The breccia morphology, which includes chaotic breccias, and mosaic breccias at intrusion margins, offers insight into the fragmentation processes, which include dyke crack-tip propagation, mechanical and thermal lamination, stoping, or release of volatiles during ascent. Fragment roundness and angularity, and degree of assimilation provide constraints on distance travelled or time in the magma. Ascent rates of magmas with variable size xenoliths range from 0.01 m/hr to 1.84 km/hr. The matrix and intrusive fragments yield calc-alkaline arc signatures, and the magmas came from a complex, garnet-free mantle source that underwent assimilation and fractionation processes.

## Introduction

The Boundary Intrusions are a suite of felsic to ultramafic dykes and sills, many of which are brecciated and exhibit a variety of breccia textures, with fragments comprising volcanic country rock and earlier crystallized phases of Boundary Intrusions (Syme, 1975, Syme and Forester, 1977, O'Hanley and Kyser, 1994). The intrusions were emplaced prior to greenschist grade metamorphism and deformation during the Trans-Hudson Orogeny during the latter stages of volcanism associated with island arc accretion (ca. 1842 Ma; (Heaman *et al.*, 1992). Breccia textures at the outcrop- and thin section-scale have been used to suggest possible fragmentation processes and rate of magma ascent during the development of the Boundary intrusions, and geochemical signatures of intrusive fragments and matrix offer insight to possible relationships between them and magma sources.

Field observations were made from four locations in the Creighton (SK), and Flin Flon (MB) area: Green Street (GS), Louis Lake (LL), Phantom Beach, and Club Lake, although only the GS and LL intrusions were chosen for detailed outcrop mapping. Samples were cut for thin section analysis, and analyzed for whole rock major and trace element geochemistry using theSaskatchewan Research Council Geoanalytical Laboratories. Details of field observations, petrographic and analytical data, and interpretations can be found in Normore (2020).

## Results and Interpretations

The GS intrusion was emplaced in volcanic rocks of the Flin Flon formation with the most northerly section containing a largely polymictic, chaotic-textured, matrix-supported intrusion breccia. The margins of the dyke exhibit mosaic and jigsaw textures indicative of hydraulic brecciation. The

LL intrusion is a chaotic-textured, matrix-supported breccia and the contacts with the Louis formation volcanic rock are not exposed. Thepresence of layered blocks indicates the intrusion may have been emplaced as a sill, but are also cut by a clast-supported breccia. Intrusion morphology and breccia textures suggest possible processes for fragment generation include dyke crack-tip propagation, mechanical and thermal delamination, and stoping. Fragment populations for all intrusion breccias include mafic to ultramafic intrusives and locally derived volcanics, ranging from angular to rounded to disaggregated, with the intrusive fragments exhibiting greater degrees of rounding and disaggregation. This may suggest the intrusive fragments have had longer residence times or traveled greater distances within the magma than the volcanic xenoliths. Fragment size can reach up to 2 m in diameter with an average diameter typically between 10 and 30 cm. Settling rates of fragments within the magmas are calculated using similar methods to those employed by Morin and Corriveau (1996) and Ferreira *et al*., 2014. Resulting magma ascent velocities range from 0.01 m/hr to 1.84 km/hr for the GS intrusion, and is more variable in the complex LL intrusion.

Petrography of mafic to ultramafic intrusive fragments, some intact and some with irregular boundaries, within the GS intrusion exhibit textures which may suggest different stages of disaggregation and incorporation into the magma matrix. In addition, comparison of actinolite crysts "floating" in the intrusion matrix to actinolite-replaced phenocrysts in fragments may also indicate disaggregation of intrusive fragments.

Whole rock geochemistry for the matrix of the GS and LL Boundary intrusions and the mafic to ultramafic intrusive fragments show the samples display calc-alkaline island arc signatures. High field strength element (HFSE) patterns suggest an enriched and complex mantle source for all samples, with the resulting magma possibly affected by magma mixing. HFSE ratios may also indicate contamination by crustal assimilation for the GS intrusion. Low MORB-normalized $TiO_2$/Y ratios (<1) suggests that the magma source for the Boundary intrusions was at shallow depths with higher water contents (<50 km) where garnet is not a factor in retaining yttrium relative to titanium. Similarities in trace element patterns and higher Zr/$TiO_2$ ratios suggest fractionation within the sample suite for the GS area.


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