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Enriched crustal and mantle components and the role of the lithosphere in generating Paleoproterozoic dyke swarms of the Ungava Peninsula, Canada

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ABSTRACT

Paleoproterozoic mafic dyke swarms (2.5–2.0 Ga) of the Ungava Peninsula can be divided in three chemical groups. The *main group* has a wide range of Fe (10–18 wt.% Fe_2O_3) and Ti (0.8–2.0 wt.% TiO_2) contents, and the most magnesian samples have compositions consistent with melting of a fertile lherzolitic mantle at ~1.5 GPa. Dykes of a *low-LREE (light rare earth element) subgroup* (La/Yb ≤4) display decreasing Zr/Nb with increasing La/Yb ratios and positive $\varepsilon Nd_{2.0\ Ga}$ values (+3.9 to +0.2) that trend from primitive mantle towards the composition of Paleoproterozoic alkaline rocks. In contrast, dykes of a *high-LREE subgroup* (La/Yb ≥4) display increasing Zr/Nb ratios and negative $\varepsilon Nd_{2.0\ Ga}$ values (−2.3 to −6.4) that trend towards the composition of Archean crust. A *low Fe–Ti group* has low Fe (<11 wt.% Fe_2O_3), Ti (<0.8 wt.% TiO_2), high field strength elements (HFSE; <6 ppm Nb) and heavy rare earth elements (HREE; <2 ppm Yb) contents, but are enriched in large ion lithophile elements (LILE; K/Ti = 0.7–3) and LREE (La/Yb >4). These dykes are interpreted as melts of a depleted harzburgitic mantle that has experienced metasomatic enrichment. A positive correlation of Zr/Nb ratio and La/Yb ratio, negative $\varepsilon Nd_{2.0\ Ga}$ values (−14 to −6), and the presence of inherited Archean zircons further suggest the incorporation of a crustal component. A *high Fe–Ti group* has high Fe (>14 wt.% Fe_2O_3) and Ti (>1.4 wt.% TiO_2) contents, along with higher Na contents relative to the main group dykes. Dykes of a *high-Al subgroup* (>12 wt.% Al_2O_3) share Fe contents, $\varepsilon Nd_{2.0\ Ga}$ values (−2.3 to −3.4), La/Yb and Th/Nb ratios with Archean ferropicrites, and may represent evolved ferropicrite melts. A *low-Al subgroup* (<12 wt.% Al_2O_3) has relatively lower Yb contents (<2 ppm) and fractionated HREE patterns that indicate the presence of garnet in their melting residue. A comparison with ~5 GPa experimentally-derived melts suggests that these dykes may be derived from garnet-bearing pyroxenite or peridotite. The $\varepsilon Nd_{2.0\ Ga}$ values (−0.3 to −2.0) of these dykes lie between the compositions of Archean granitoids and Paleoproterozoic alkaline rocks, signifying their petrogenesis involved both crustal and mantle components.

Paleoproterozoic dykes containing a crustal component occur within, or close to, an isotopically enriched Archean terrane (T_{DM} 4.3–3.1 Ga), whereas dykes without this component occur in an isotopically juvenile terrane (T_{DM} <3.1 Ga). The lack of a crustal component and the positive $\varepsilon Nd_{2.0\ Ga}$ values of dykes intruding the latter suggest that the crust they intruded was either too cold to be assimilated, or that its lower crust and/or lithosphere were Paleoproterozoic in age. In contrast, the ubiquitous presence of a crustal component and the diversity of mantle sources for dykes intruding the enriched terrane (lherzolite, harzburgite, pyroxenite) suggest a warmer crust with underlying heterogeneous lithospheric mantle.

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1. Introduction

Proterozoic mafic (dolerite) dyke swarms are common to all Archean cratons and provide probes of the chemical composition and evolution of the Earth's mantle. Their message is, however, complicated by uncertainties about the relative roles of asthenosphere and lithosphere in their origin, as well as the effects of crystal fractionation and the assimilation of enriched crustal and/or mantle components (Tarney, 1992; Patchett et al., 1994; Condie, 1997). The magmas of many Proterozoic dykes have trace element characteristics that are similar to those of continental flood basalts (CFB), with light rare earth element (LREE) and large ion lithophile element (LILE) enrichments, and Nb–Ta depletions relative to primitive mantle values. Petrogenetic models for the generation of such trace element signature typically range between two end-members, i.e. contamination of asthenospheric magmas by crust, or enriched lithospheric mantle sources (Tarney, 1992 and references therein). It is difficult to distinguish between these end-members on the basis of chemistry alone because the trace element signature of the continental crust (enriched in LILE and REE, but depleted in Nb–Ta) is similar to that of metasomatized mantle (Tarney and Weaver, 1987; Boily and Ludden, 1991; Seymour and Kumarapeli, 1995; Condie, 1997). Furthermore, radiogenic isotope analyses have not clearly resolved the problem, as

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some studies have concluded that enriched and heterogeneous lithospheric mantle is the source for CFB (Hart, 1985), whereas others propose an important role for crustal contamination (Carlson et al., 1981; Peng et al., 1994; Baker et al., 2000).

This paper presents a synthesis of the chemical data acquired on Paleoproterozoic dyke swarms emplaced between 2.5 and 2.0 Ga in the Ungava Peninsula of Canada (Figs. 1 and 2). We show that the Nd signature of enriched mafic dykes is inherited from an Archean crustal component, but that trace element systematics require the existence of two enriched components, one representing the Archean crust and the other a metasomatized lithospheric component. We argue that these dyke swarms reflect the composition of the continental

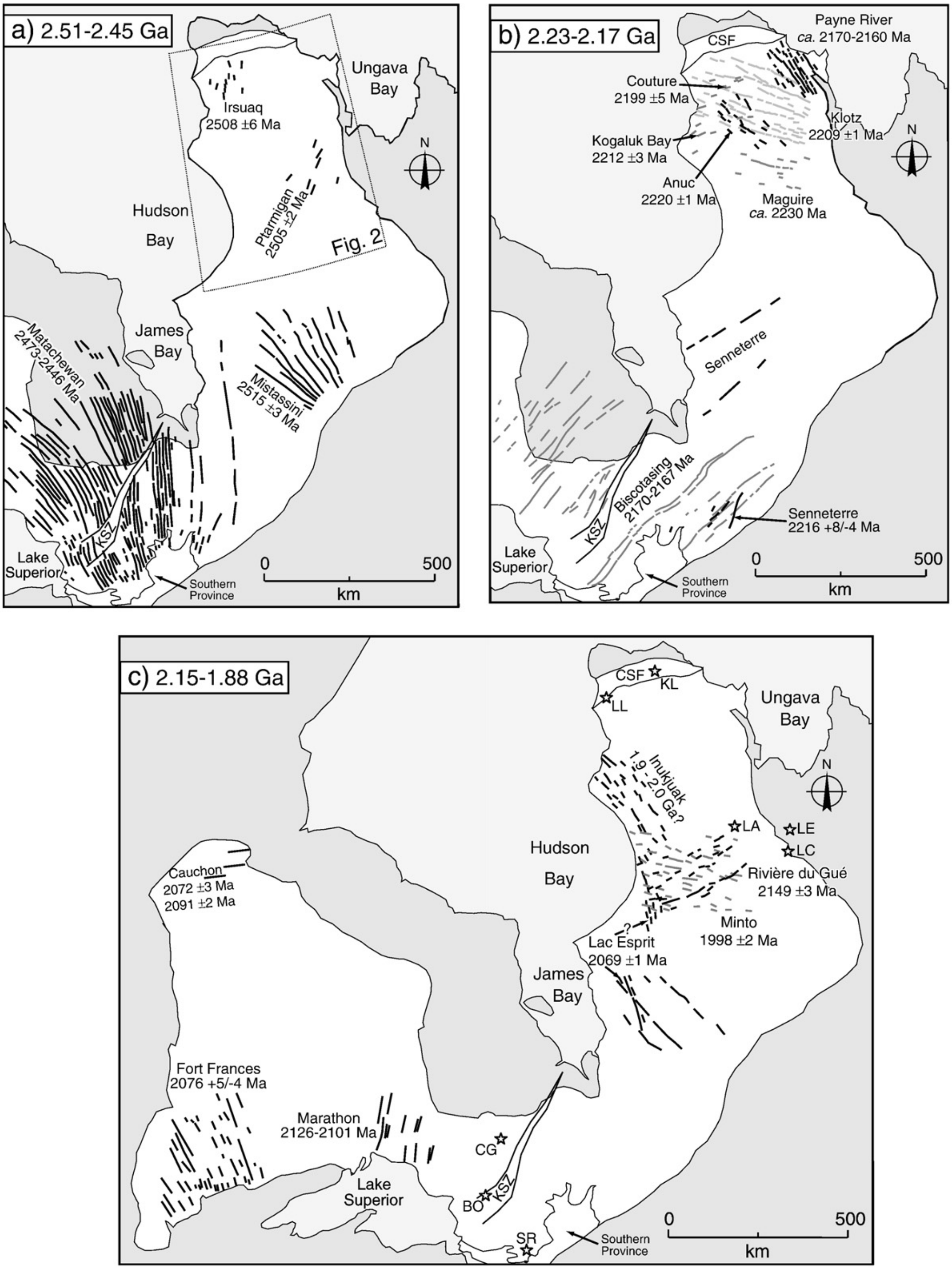

Fig. 1. Schematic distribution of mafic dyke swarms (modified from Buchan et al., 2007; Maurice, 2008) and alkaline rocks of the Superior Province emplaced over a) *ca.* 2.51–2.44 Ga (age for the Mistassini dykes from an internal report by M.A. Hamilton, Jack Satterly Geochronology Laboratory); b) *ca.* 2.23–2.17 Ga (the different dyke colors distinguish distinct swarms) and c) *ca.* 2.15–1.88 Ga. Acronyms for alkaline rocks as follows: KL, Kenty Lake; LA, Lac Aigneau; LC, Lac Castignon; LE, Lac Lemoyne; LL, Lac Leclair; CG, Cargill; BO, Borden; SR, Spanish River. The inset in a) shows the location of Fig. 2 and corresponds to the Ungava Peninsula.

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