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The northern and southern sections of the western ca. 1880 Ma Circum-Superior Large Igneous Province, North America: The Pickle Crow dyke connection?

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ABSTRACT

The ca. 1880 Ma Circum-Superior Large Igneous Province (LIP) consists of a number of discontinuous segments known to cover a significant portion of the margin of the Superior Province craton in North America. New geochemical and isotopic data from western segments of this LIP support a common origin for the these segments and suggest that magmatism in the Lake Superior region may have been fed through the ~600 km long Pickle Crow dyke from a source north of the Fox River Belt in northeastern Manitoba. The Fox River Belt, Pickle Crow dyke and sections of the Hemlock Formation in the Lake Superior region possess trace element signatures which are similar to those of more recent oceanic plateaux. The Hemlock Formation displays a heterogeneous geochemical signature. This chemical heterogeneity can in part be explained by lithospheric contamination and possibly by source heterogeneity. The tectonomagmatic setting in which these igneous rocks were formed could have involved a mantle plume. Evidence supporting a plume origin includes high MgO volcanic rocks, high calculated degrees of partial melting and geochemical signatures similar to those of oceanic plateaux.

1. Introduction

The Canadian Shield consists of an amalgamation of Archaean cratons and Proterozoic orogens (Hoffman, 1988). The largest craton in the Canadian Shield is the Superior Province which covers an area of up to ~2.4×10^6 km^2 (Card, 1990; Kerrich et al., 1999; Percival and Easton, 2007; Stott, 1997) and is also the largest of the ~35 known cratons worldwide (Bleeker, 2003). The geological assemblage of the Superior Province is comprised of volcano-plutonic, metasedimentary, plutonic and high-grade gneiss subprovinces but also includes a number of greenstone belts and mafic dyke swarms (Buchan and Ernst, 2004; Card, 1990) which are of possible mantle plume origin (Ernst and Buchan, 2003). Additionally, a series of igneous rocks are also found around the Superior Province margins over a composite strike length of ~3000 km (Fig. 1).

These marginal igneous suites of the Superior Province are mostly ultramafic–mafic volcanic rocks and sills and were grouped together by Baragar and Scoates (1981) into what they called the Circum-Superior Belt because of their lithological, stratigraphical, gravitational and magnetic similarities. More recent U–Pb zircon/baddeleyite geochronology has shown that these igneous rocks are essentially coeval, with the majority of magmatism occurring between 1885 and 1870 Ma (see Ernst and Buchan, 2004; Heaman et al., 2009; Rukhlov and Bell, 2010). The extent and short duration of this magmatism and the recognition of several coeval mafic dykes and carbonatite complexes within the craton interior prompted Ernst and Bleeker (2010) to classify the magmatic rocks as a large igneous province (LIP). This study shall hereafter refer to this LIP as the Circum-Superior LIP.

A lack of modern, high-quality whole-rock major and trace element and isotopic geochemical data from many segments of this Circum-Superior LIP has hitherto hindered attempts to assess if the various segments can be correlated and have a common magmatic origin. Therefore this paper presents new elemental and isotopic data from igneous segments on the western side of the Superior Province, namely the Fox River Belt in northeastern Manitoba, the Pickle Crow dyke stretching across most of Ontario and the Hemlock Formation within the Marquette Range Supergroup in the Lake Superior region (Fig. 1). The main objective of this study is to characterise the geochemical and isotopic compositions of the mantle

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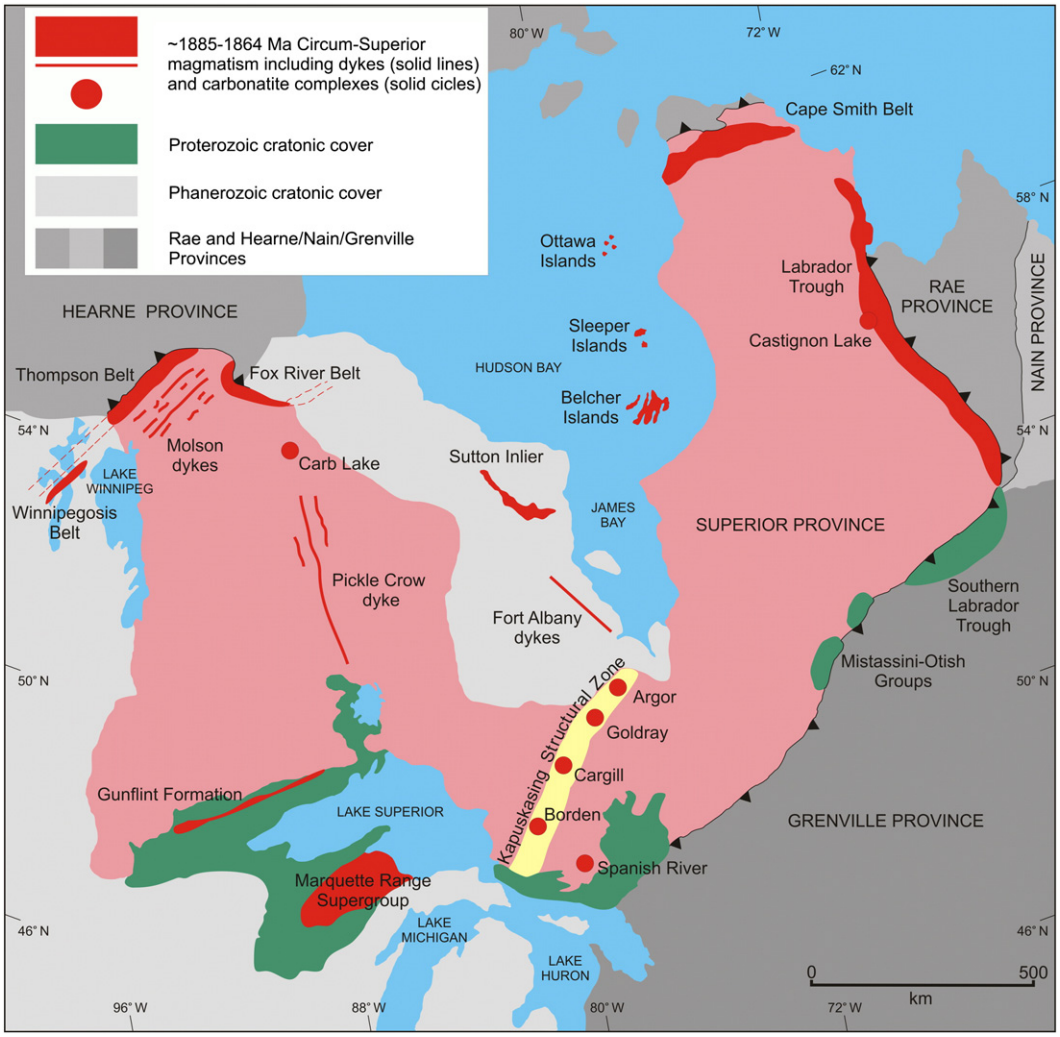

Fig. 1. Map of the Superior Province showing the location of the various segments of the Circum-Superior Belt and the Circum-Superior LIP. Adapted from Baragar and Scoates (1981). The Rae and Hearne Provinces are assigned the same shade of grey as these two provinces are often combined in the literature to constitute the Churchill Province.

sources of the Fox River Belt, Pickle Crow dyke and Hemlock Formation and to test whether the western portion of the Circum-Superior LIP could have had a co-magmatic origin.

There is not a strong consensus on the geodynamic origin and setting of the Fox River Belt. Scoates (1981) proposed that the Fox River Belt magmatism was the result of rifting of continental crust underlying an intracratonic basin at the edge of the Superior Province. Whereas Halden (1991) suggested a marginal basin as the geodynamic environment in which the rocks formed, with the size of the marginal basin being such that its closure did not necessarily require the close proximity of a subduction zone or oceanic crust subduction beneath the Superior Province. In contrast, Buchan et al. (2003) and Desharnais (2005) have argued for a mantle plume origin for the Fox River Belt. There is also a debate concerning the geodynamic origin of the Hemlock Formation. Ojakangas et al. (2001) and Southwick and Morey (1991) suggested that the Hemlock Formation volcanic rocks are related to the rifting stage of the Penokean Orogeny which occurred at ~1.88–1.85 Ga as the Wisconsin Magmatic Terrane collided with the southern Superior Province (Schulz and Cannon, 2007). Hoffman (1988) and Schneider et al. (2002) proposed that the volcanic rocks were erupted in foredeep basins created by the oblique subduction of the Superior Province margin during the Penokean Orogeny. Ueng et al. (1988) interpreted the Hemlock Formation to have formed in a rifting environment analogous to the North Atlantic Ocean while Fralick et al. (2002), Hemming et al. (1995), Schulz and Cannon (2007) and Van Schmus (1976) suggested that the Hemlock Formation erupted in a back-arc basin formed by extensionally-driven subsidence. Controversially, Buchan et al. (2003) postulated that the Hemlock Formation magma may have been transported from a source near to the Fox River Belt to the Lake Superior region through the Pickle Crow dyke (and probably related nearby subparallel dykes). A comparison of the geochemical and isotopic compositions of the Fox River Belt, Pickle Crow dyke and Hemlock Formation should be able to test the validity of the model of Buchan et al. (2003).

2. Regional geology and magmatic rock types

The Circum-Superior LIP consists of a number of discrete segments of volcanic and intrusive sequences unevenly distributed mainly around the Superior Province margin and also within the craton interior (Fig. 1). These segments include the Cape Smith Belt, eastern Hudson Bay area, Sutton Inlier, Fox River Belt, Thompson Nickel Belt, Winnipegosis Belt, Molson dykes, Pickle Crow dyke, Lake Superior area, Labrador Trough and possibly a number of carbonatite complexes which are largely confined to the Kapuskasing Structural Zone. For this study only the Fox River Belt, Pickle Crow dyke and Hemlock Formation of the Lake Superior area will be considered in more detail.