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Characterization of transpressive deformation in shear zones of the Archean North Caribou greenstone belt (NW Superior Province) and the relationship with regional metamorphism

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ABSTRACT

The 2.7–3.0 Ga North Caribou greenstone belt (NCGB), host to the Musselwhite BIF-hosted gold deposit, possesses abundant shear zones on its northern margins, which appear to have formed under amphibolite facies conditions. Protracted deformation and regional metamorphism are coeval with widespread magmatism and accretion events during crustal amalgamation of the Western Superior Province, and are responsible for folding the ore-hosting BIF and channeling fluids. The importance of shear zones in behaving as conduits for fluids during the tectonic evolution of the NCGB is not well known and their relationship with metamorphism is equivocal, yet higher-grade, syn- to post-tectonic metamorphic minerals seem to correlate with loci of higher strain. Structural analyses support oblique transpressive collision that produced steeply-dipping planar and shallowly-plunging linear fabrics with dominant dextral kinematics, that trend broadly parallel to the doubly arcuate shape of the belt. Electron backscatter diffraction analyses were conducted on strategic samples across one shear zone in order to characterize crustal conditions during transpressive deformation. The Dinnick Lake shear zone cuts through mafic metavolcanics and at its core is an L-tectonite granite composed of recrystallized quartz. Whole rock geochemistry shows little variation in Ca, Na, Mg and K (often used as indicators of hydrothermal alteration) from surrounding less deformed units, suggesting deformation in a dry environment. Microstructural analysis indicates subgrain rotation recrystallization and deformation by prism a- and c-slip in quartz, as well as aligned hornblende that suggest deformation temperatures above 500 °C. Quartz in mafic rocks along the margins of the shear zone also exhibits a basal a-slip component, indicating a slight decrease in strain or temperature. Although the NCGB exhibits some first-order evidence of vertical tectonism (dome and keel geometries), the dominant strain record within shear zones is that of horizontal (oblique transpressive) displacement. This is in agreement with other greenstone belts in the Western Superior Province where vertical tectonism and horizontal tectonism were coeval.

1. Introduction

The Archean North Caribou greenstone belt (NCGB) in northwestern Ontario is part of the nucleus of Canada's Superior Province (termed North Caribou Superterrane, NCS), which is characterized by east–west trending belts that represent remnants of microcontinents and oceanic basins (Percival et al., 1994; Biczok et al., 2012; Fig. 1). The NCGB comprises 3.0–2.7 Ga metavolcanic–metasedimentary assemblages and is host to the Musselwhite lode gold deposit (Fig. 1). The ore occurs in moderately metamorphosed banded iron formation units, along highly strained, near-vertical limbs of isoclinal folds and within fold hinges. The margins of the NCGB are defined by discrete deformation zones, which were likely reactivated throughout the amalgamation of the Western Superior Province during the Neoarchean Uchian orogeny (Percival et al., 1994; Breaks et al., 2001; Percival et al., 2006; Kalbfleisch, 2012). Percival et al. (2006) among others suggested that growth of the Superior Province is a consequence of horizontal tectonism, in contrast with models proposing vertical tectonism to explain the formation of arcuate greenstone belts typical of the Western Superior and other Archean granite–greenstone terrains (e.g. Lin and Jiang, 2001; Lin and Beakhouse, 2013). Significant vertical displacement has been documented in several Superior greenstone belts such as Hemlo and Cross Lake, supporting a dome and keel model that would result in sagduction of greenstone belts between rising granitoid domes (Lin, 2005; Parmenter et al., 2006; Lin and Beakhouse, 2013). A

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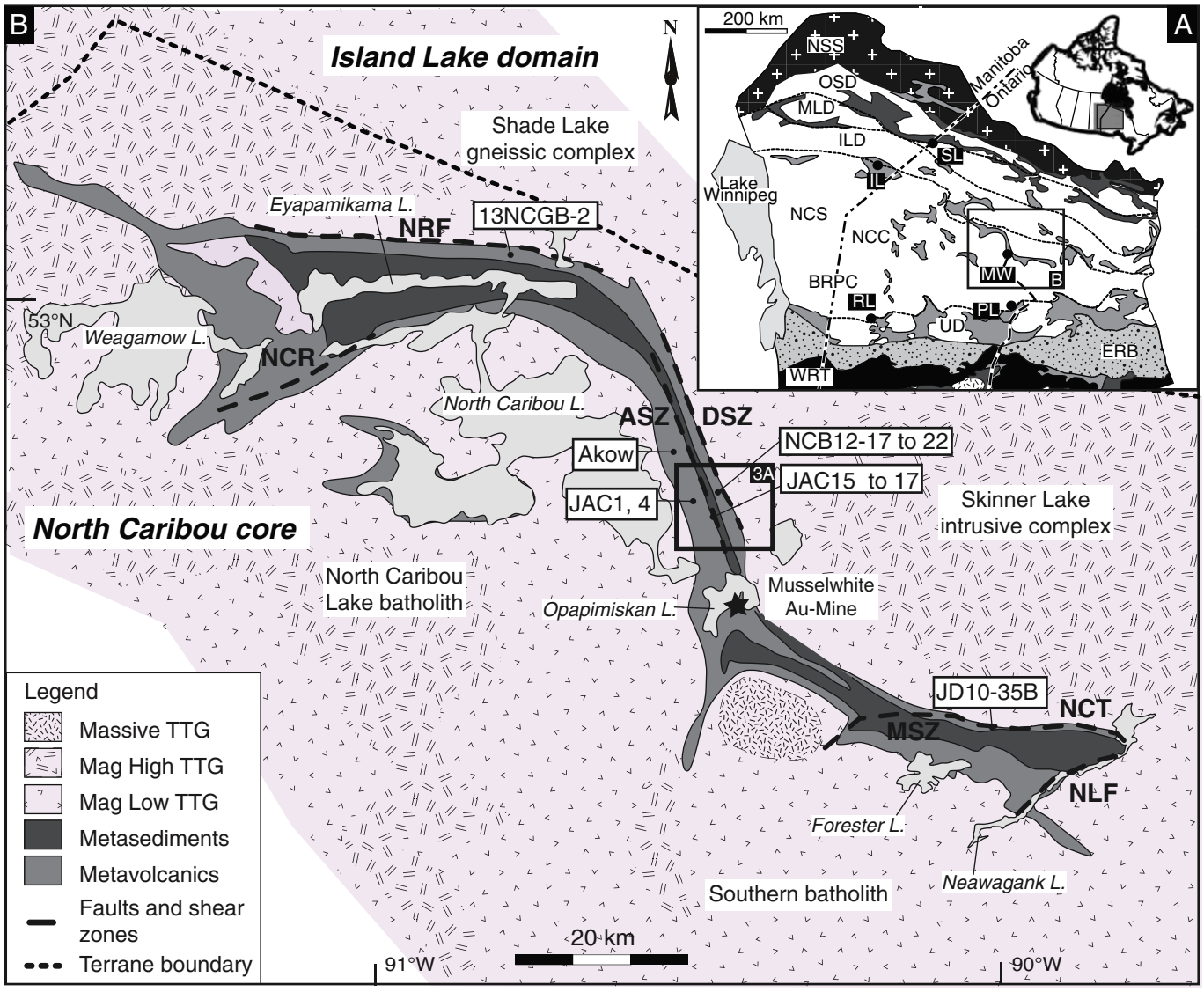

Fig. 1. Location and regional geological map of the North Caribou greenstone belt in Northwestern Ontario, Canada. A) Location of the NCGB in the Western Superior Province modified from Percival et al. (2006). Black box shows map area of Fig. 3A. NSS, Northern Superior superterrane; NCS, North Caribou superterrane; OSD, Oxford-Stull domain; MLD, Munroe Lake domain; ILD, Island Lake domain; NCC, North Caribou core; BRPC, Berens River plutonic complex; UD, Uchi domain; SL, Stull Lake; IL, Island Lake; MW, Musselwhite; RL, Red Lake; PL, Pickle Lake; WRT: Winnipeg River terrane; ERB: English River basin. B) Regional geological map of the NCGB surrounded by TTG granitoid suite classified by their aeromagnetic signatures (modified from Breaks et al. (2001)). Sample locations used for analyses are shown in white boxes. Musselwhite mine is represented by the black star. ASZ, Akow Lake shear zone; DSZ, Dinnick Lake shear zone; MSZ, Markop Lake shear zone; NCT, North Caribou–Totogan deformation zone; NCR, North Caribou River fault; NLF, Neawagank Lake fault; NRF, North Rim fault zone.

dominant vertical component is proposed to have been synchronous with a subordinate horizontal component, focused along crustal-scale shear zones at granite–greenstone contacts with a potential for channeling fluids and ore deposition. Yet studies of other Archean greenstone belts (e.g. Yilgarn craton of Western Australia, Bird River greenstone belt in Western Superior Province) indicate more complex systems with transpression-related shortening and shearing processes in the formation of shear zones and arcuate greenstone belts (e.g. Chen et al., 2001; Duguet et al., 2009; Zibra et al., 2014). Shear zones on the northern margins of the NCGB separate the Island Lake Domain (ILD) in the north from the North Caribou superterrane to the south, and are interpreted as a suture (Percival et al., 2006). Understanding the nature of tectonism at this important boundary will provide insights into Archean geodynamics and the evolution of the Western Superior Province, as well as on the potential for structurally-controlled orogenic gold deposits that are thought to originate from collisional systems during the Archean (Biczok et al., 2012).

The regional metamorphic grade of the NCGB and that of the host rock at the Musselwhite mine is notable from those observed in other greenstone belts of the Superior Province. Abukuma-type regional metamorphism in the NCGB is thought to have occurred at 2.75–2.69 Ga, reaching middle amphibolite facies conditions (Breaks et al., 1991; Kalbfleisch, 2012; Biczok et al., 2012; Kelly et al., 2013; Kelly and Schneider, 2015). Protracted tectonism in the belt created the complex metamorphic map pattern and a consequent metamorphic veil making it difficult to distinguish between metamorphic and ore-bearing hydrothermal signatures that are often similar (e.g. pervasive biotite that may be metamorphic or potassic alteration). Although deformation has important implications for mineralization in the NCGB (e.g. dilatant zones, fracture network for veining, tectonic

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