The collisional Snowbird tectonic zone revisited: new constraints on the Chesterfield Inlet segment provided by detrital zircon, metamorphic monazite, and ^{40}Ar-^{39}Ar geochronology

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Introduction

One of the most controversial aspects of the tectonic history of the western Churchill Province is the interpretation of the Snowbird tectonic zone (Stz). Originally postulated as a <1.9 Ga suture between Rae and Hearne cratons (Hoffman, 1988), others consider it an intracontinental feature that experienced ~600 Myr quiescence prior to a ca. 1.9 Ga extensional event (Flowers et al., 2006). Berman et al. (2007) supported the suture model with P-T-age data in the area of the northern Stz (Chesterfield Inlet segment; Fig. 1) that helped to delineate a 2000 km-long, high-P belt of ca. 1.9 Ga age. They suggested that a ca. 1.9 Ga suture lies to the south of Chesterfield Inlet, rather than along the original Stz defined by gravity anomalies marking high-P gabbro-anorthosite. Here this model is tested and refined with new data from three regions in the vicinity of the northern Stz.

Regional Setting

In the vicinity of Chesterfield Inlet (Fig. 1), the western Churchill Province is composed of three major crustal blocks: the Rae craton, Hearne craton, and Chesterfield block. The latter bears some affinities with Rae crust (Cross Bay complex) to the north (2.72-2.68 Ga volcanic and plutonic rocks, 2.62-2.58 Ga plutons), but is distinctly more juvenile (Fig. 1; Ryan et al., 2000). The Chesterfield block is thought to have been in position by 2.6 Ga, the age of a major stitching plutonic event which is lacking in the Hearne craton to the south.

Archean volcanic and sedimentary rocks in the western Chesterfield block (e.g. the MacQuoid supracrustal belt; Fig. 1; Davis et al., 2006) record a significant ca. 2.56 – 2.50 Ga metamorphic event (Berman et al., 2000) with a static high-P (~10 kbar) overprint at 1883 $\pm$ 5 Ma (Berman et al., 2007). In the eastern Chesterfield block, psammitic and pelitic rocks are interpreted as Paleoproterozoic because they do not record the ca. 2.5 Ga event and a metapelite from Barbour Bay (Fig. 1) contains ca. 2.3 Ga detrital zircon (Berman et al., 2007). Six samples from this eastern region define a low- to moderate-P (4-6 kbar) tectonothermal event at 1890 $\pm$ 4 Ma (Berman et al., 2007).

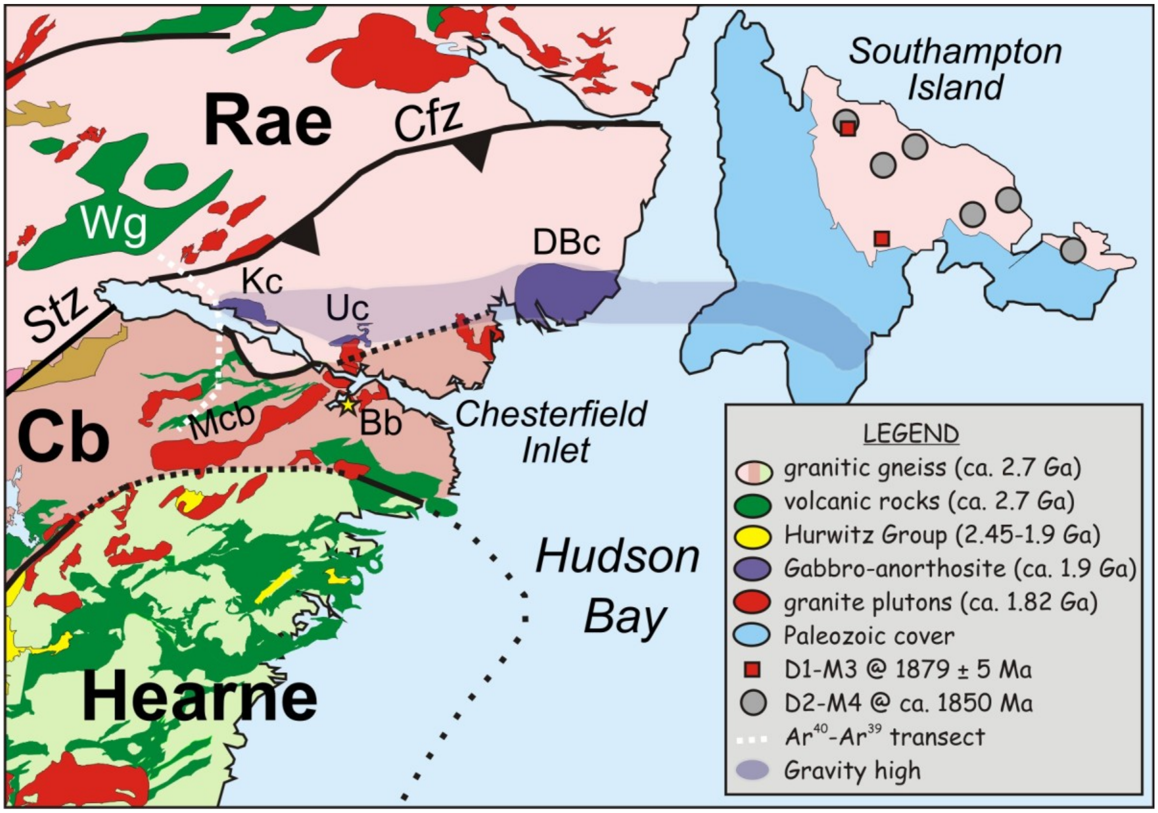

Figure 1: Regional geology around the northern (Chesterfield Inlet) segment of the Snowbird tectonic zone. Abbreviations: Bb = Barbour Bay, BLsz = Big Lake shear zone, Cb = Chesterfield block, Cfz = Chesterfield fault zone, DBc = Daly Bay complex, Kc = Kramanituar complex, Mcb = MacQuoid Lake supracrustal belt, Sc = Southampton gabbro inlier; Uc = Uvauk complex. Symbols: yellow star = sample location at Barbour Bay, grey circles = localities recording D_2-M_4 at ca. 1850 Ma, red squares = localities recording D_1-M_3 at ca. 1880 Ma

Barbour Bay: detrital zircon constraints

A SHRIMP detrital zircon study was undertaken on a metapsammite layer (cummingtonite-garnet-plagioclase-quartz) within metapelite at Barbour Bay on the south side of Chesterfield Inlet (Bb, Fig. 1). Ninety-nine SHRIMP analyses of 74 different zircon grains define three distinct populations (Sapers, 2008): (1) ca. 2.69 Ga high Th/U (0.3 – 1.2) zircon that occurs as separate grains and cores, both of which exhibit oscillatory zoning consistent with an igneous origin; (2) ca. 1.9 Ga (1902 +40/-27 Ma robust median ^{206}Pb/^{238}Pb age; 1873 ± 24 Ma weighted mean ^{206}Pb/^{238}U age), low U (< 38 ppm), low Th/U (0.001 – 0.1) zircon that occurs as distinct rims on ca. 2.69 Ga cores (population 1) and as unzoned grains up to 200 μm long with fractured boundaries; and (3) ca. 1.9 Ga (1904 ± 7 Ma weighted mean ^{207}Pb/^{206}Pb age), high U (137 - 1036 ppm), low Th/U (0.003 – 0.03) zircon that occurs as heterogenous grains with complex zoning. Textural and chemical features suggest that population 1 is igneous in origin. Populations 2 and 3 could be igneous or metamorphic, but their very different U concentrations suggest that they did not crystallize *in situ*. Instead all three groups are interpreted as detrital zircon grains. The age of deposition of the metapsammite sample is constrained between 1898 ± 6 Ma (based on multiple analyses of the youngest zircon) and 1890 ± 4 Ma (the age metamorphic monazite, Berman et al., 2007).

The strong bimodal (ca. 2.7 and 1.9 Ga) age distribution of the Barbour Bay metapsammite requires a restricted, local source region, with two lithologies providing (a) zircon with 2.69 Ga cores and 1.9 Ga low-U rims, and (b) 1.9 Ga high-U zircon. The most likely source region lies on the north side of Chesterfield Inlet where ca. 2.68 Ga tonalite gneiss has been intruded by 1902 $\pm$ 2 Ma gabbro-anorthosite within the 10-12 kbar, granulite-facies Kramanituar complex (Fig. 1; Sanborn-Barrie et al., 2001). Leucogranite dykes dated at 1.9 Ga (Sanborn-Barrie et al., 2001) may have provided the high U, 1.9 Ga detrital zircon.

Southampton Island: Age of deformation and metamorphism

Further east on Southampton Island (Fig. 1), metasedimentary rocks comprise Archean and presumed Proterozoic sequences. Thermobarometric and *in situ* SHRIMP monazite geochronology reveal a complex, polycyclic history with two main deformation events. Two samples located along the western side of exposed basement (red squares on Fig. 1) define moderate-P (~8 kbar) D_1-M_3 at 1879 ± 5 Ma. Six samples located across the exposed basement (grey circles) constrain D_2-M_4 at ca. 1850 Ma. Four samples also record a post- D_2, M_5 event at 1818 $\pm$ 4 Ma.

Regional ^{40}Ar-^{39}Ar constraints

^{40}Ar-^{39}Ar cooling ages were obtained for hornblende samples extending from the north side of the Chesterfield fault zone (Cfz) to near the inferred Cb – Hearne suture (Fig. 1). Between the Cfz and the proposed suture, ca. 1900 Ma cooling ages are preserved, ranging from 1918 $\pm$ 9 immediately south of the Cfz to 1882 $\pm$ 13 Ma south of Kramanituar complex. North of the Cfz and near a granite pluton close to the suture zone, hornblende ages are younger than 1843 $\pm$ 7 Ma.

Discussion

Berman et al. (2007) proposed that the Hearne craton arrived from southwest, creating a transpressional boundary along the central Stz and a compressional boundary in the vicinity of its Chesterfield Inlet segment (Fig. 1). The data reported here are consistent with this model and provide further refinements.

Charnockite dated at ca. 1935 Ma on Southampton Island (Sanborn-Barrie et al., 2008) and ca. 1917 Ma tonalite at Daly Bay (Berman et al., 2007) have geochemical signatures consistent with subduction-related magmatism, as predicted by this model. The width of the geophysically defined Hearne craton (Fig. 1) coincides with the length of the gravity signature of ca. 1.9 Ga high-P, granulite-facies gabbro-anorthosite complexes along the north side of Chesterfield Inlet and on Southampton Island (Fig. 1), suggesting that they were geodynamically linked with the Hearne. In this model, gabbro-anorthosite magmatism formed in response to response to extension induced by rollback of the subducting Hearne slab. Subsequent collision with the Hearne craton could account for the spatial restriction of the ca. 1880 Ma D_1 event to the western side of exposed basement on Southampton Island (Fig. 1).

Associated exhumation was rapid, as evidenced by cooling of Kramanituar complex through rutile closure by 1896 $\pm$ 2 (Sanborn-Barrie et al., 2001), and by detrital provenance showing rapid erosion of similar lithologies into the Barbour Bay basin. The ^{40}Ar-^{39}Ar data reveal that ca. 1900 Ma cooling and exhumation affected a crustal block that extends north to the Chesterfield fault zone. Rapid cooling and exhumation may have resulted from a first stage of extensional faulting, followed by northwest-vergent thrusting along the Chesterfield fault zone. Continued plate convergence is considered to have driven this thrusting, as well as tectonic thickening that induced monazite growth at ca. 1890 Ma and ~5 kbar in the Barbour Bay area and at ca. 1880 Ma at the deeper levels exposed on Southampton Island and in the MacQuoid supracrustal belt. Taken together, these data support the model that the northern Stz formed in a ca. 1.9 Ga convergent tectonic setting that culminated in collision of the Rae and Hearne cratons.

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