Age, and tectonic history of the Murmac Bay Group psammopelite, eastern Beaverlodge Domain based on U-Pb SHRIMP and chemical monazite dating

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Introduction

The southwestern Rae Province in Saskatchewan is flanked by the Taltson Magmatic Zone in the west and the Snowbird Tectonic Zone in the east (Figure 1). This portion of the Rae Province is divided into multiple domains, each with long and varied histories. Affects of the 1.94-1.92 Ga culmination of the Taltson-Thelon orogeny are well documented in the west of the province and into Alberta and Northwest Territories (McDonough et al., 2000), with ca. 1.93 Ga metamorphic ages reported from as far east as the Zemlak Domain (Ashton et al., 2009). In contrast, the rocks of the Tantato Domain appear devoid of the ca. 1.93 Ga record and rather contain abundant evidence for ca. 1.90 Ga high-pressure high-temperature metamorphism (e.g. Baldwin et al., 2003).

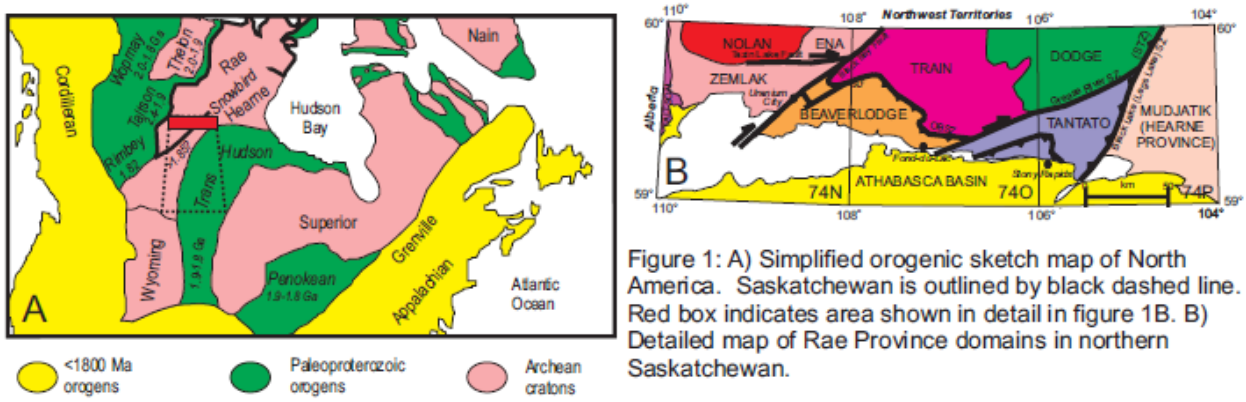

Figure 1: A) Simplified orogenic sketch map of North America. Saskatchewan is outlined by black dashed line. Red box indicates area shown in detail in figure 1B. B) Detailed map of Rae Province domains in northern Saskatchewan.

The Beaverlodge Domain, situated between the Zemlak and Tantato domains, serves as a place to test the apparently contrasting metamorphic histories across Rae Province in Saskatchewan. The western Beaverlodge Domain experienced granitoid plutonism at ca. 3.0 Ga, 2.6 Ga, and 2.33 Ga (Van Schmus et al., 1986; Hartlaub and Ashton, 1998; Hartlaub et al., 2007). These plutonic rocks form the basement to the Murmac Bay Group; a package of quartzite, mafic volcanic, minor carbonate, komatiitic rocks and psammite to pelite (Hartlaub and Ashton, 1998; Ashton et al., 2000). Deposition of the Murmac Bay Group was originally considered to have occurred after 2630 Ma (Hartlaub et al., 2005). Recent studies of psammitic to psammopelitic sediments have indicated deposition of a least the pelitic component occurred after 2170 Ma (Ashton et al., 2009). Regional deformation has created an early migmatitic to gneissic foliation (S1), an early east southeast-trending set of isoclinal folds (F2), local northwest-trending folds (F3), northeast-trending folds (F4), and minor north-trending late folds (F5). Metamorphic grade is lowest in the southwest Beaverlodge Domain where it is amphibolite facies and increases to granulite facies both to the north and east.

In the eastern Beaverlodge Domain rocks are granulite facies equivalents of those described in the west (Ashton and Card, 1998; Ashton et al., 2006; Ashton et al., 2007). The psammopelite

is more voluminous than observed in the west, however, this is considered due to deposition in a deeper water environment (Ashton and Card; 1998). A SHRIMP geochronological study of detrital zircon provides a maximum deposition age of 2030 +/- 16 Ma from the youngest detrital zircon. A metamorphic zircon age of 1907 +/- 5 Ma constrains the lower age limit for deposition. This is similar to the results reported from the west (Ashton et al., 2009) and further supports correlation of the psammopelite with the Murmac Bay Group.

The geographically central location of the rocks of the eastern Beaverlodge Domain provides an opportunity to further explore the apparently contrasting metamorphic histories between the western Beaverlodge Domain and the Tantato Domain. A detailed petrographic and in-situ chemical monazite geochronological study of these granulite-facies rocks was warranted to test the working hypothesis that two major events affected these rocks at ca. 1.93 Ga and 1.90 Ga related to the Thelon-Taltson orogeny and thermotectonism along the Snowbird tectonic zone respectively. The psammopelite was an attractive choice for a detailed study of these regional events as their <2030 Ma depositional age excludes complications introduced by ca. 2.6 Ga, 2.55 Ga and 2.34 Ga metamorphic events recorded in the southern Rae Province (Baldwin et al., 2003; Berman et al., 2005). Furthermore, as the psammopelite records D1 through D5 deformation, collection and study of oriented samples aimed at obtaining absolute timing of fabric development was possible.

Results of Chemical Monazite Geochronological Study

In situ monazite geochronological study was performed on six oriented thin sections of psammopelite from the eastern Beaverlodge Domain (See also Knox et al., 2008). Monazite grains with distinct chemical signatures could be linked to deformational events and metamorphic reactions were preferentially dated.

Results have been divided based on age and/or monazite composition and relationship of age domain to structural elements: 1) 2.15 – 2.0 Ga, 2) 1.99-1.94, 3) 1.94-1.91 Ga, 4) 1.91 -1.90 Ga, and 5) 1.90-1.85 Ga.

1) The oldest group of monazite ages ranges from 2.15-2.0 Ga is characterized by low Th. Grains in this category are found both shielded within garnet as well as in the matrix. This group does not have a distinct chemical or age signature and therefore does not define a single event. The oldest grain is low-Th and is dated at 2146 +/- 65 Ma, which is older than the minimum age of deposition. These grains are interpreted as detrital monazite that has resisted resetting during regional metamorphism (Knox et al., 2008).
2) Monazite grains dating from 1.99-1.94 Ga are oriented in the S1/2 foliation and are found in the matrix and within garnet. The composition of these grains is variable but interpreted to have grown along the prograde metamorphic path and correspond to the timing of formation of the gneissic to migmatitic regional foliation and early isoclinal folding (S1/2, F2). The ages from 1.96-1.94 Ga show a relative decrease in Y indicating garnet growth had begun during this time.
3) By far the largest population of dated monazite grains falls within the 1.94-1.91 Ga range. Although the majority of ages are ~1.93 Ga this grouping represents a continuous span of ages from 1.94-1.91 Ga (Figure 2). This age population has a chemical signature characterized by generally low Y and moderate Th and suggests formation during garnet growth in the presence of anatectic melt. Domains of this age are found shielded in garnet, in corderite reaction rims around garnet and within the matrix. In addition, many of the grains are aligned within the S1/2 foliation. These grains date high-grade metamorphism associated with D2 deformation. Dumond et al. (2008) similarly concluded that high-grade metamorphism was occurring at this time in the vicinity of the Grease River shear zone.
4) The slightly younger 1.91-1.90 Ga monazite have low-Y and moderate-Th compositions. They are chemically similar to 1.94-1.91 Ga monazite but are texturally distinct forming rims

on older monazite cores (e.g. core ca. 1.93 Ga with younger rim) and more rarely grains of the same age. Texturally this population is also observed to be aligned in a northeast orientation and in some cases overprinting minerals previously aligned in this northeast S4 orientation. This group of monazite is present in the matrix and in corderite reaction rims surrounding garnets. The composition of the grains indicates the presence of stable garnet during growth and thus signifies continuation of high-grade metamorphism during 1.91-1.90 Ga. Therefore, this range of ages is considered to date the formation of the northeast F4 folds and associated metamorphism.

5) The ca. 1.90-1.85 Ga monazite population is represented by a small number of overgrowths on older cores (Figure 2). Grains of ca. 1.90-1.85 Ga are relatively enriched in Y with low Th and are found exclusively within the matrix and cordierite reaction rims surrounding garnet. Several domains of this age have been documented in a northeast orientation. These grains therefore appear to be generated during continued regional stress creating the northeast F4 folds during the retrograde metamorphic path as garnet breakdown to cordierite was occurring. Regional cooling and uplift during this time has also been documented by Dumond et al. (2008) in the Grease River shear zone.

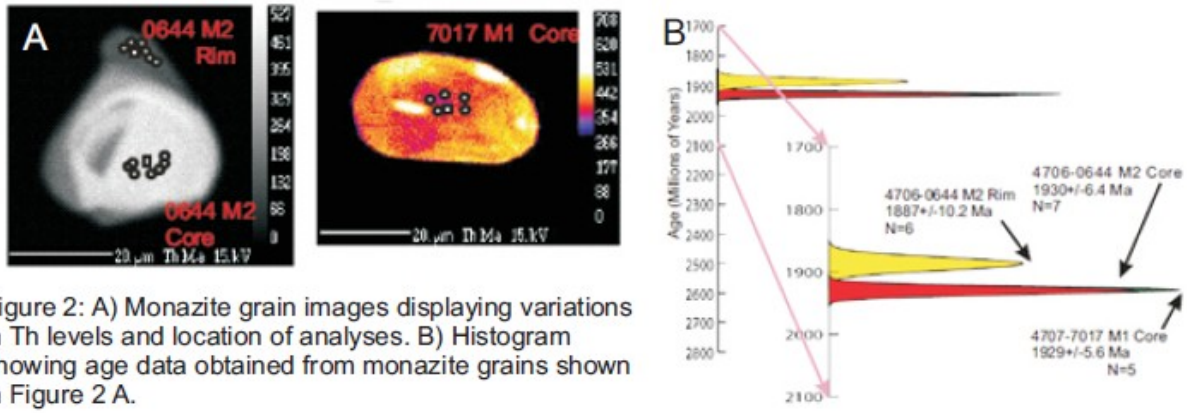

Figure 2: A) Monazite grain images displaying variations in Th levels and location of analyses. B) Histogram showing age data obtained from monazite grains shown in Figure 2 A.

Discussion and Conclusions

Rocks of the eastern Beaverlodge Domain include higher grade equivalents of the ca. 2.6 and 2.3 granitoid plutons, and a deeper water facies equivalent of the Murmac Bay Group (Ashton and Card, 1998; Ashton et al., 2008; 2009). The 2030 Ma maximum age for deposition of the psammopelite in the Fond-du-Lac map area agrees with more recent data from the western Beaverlodge Domain (Ashton et al., 2009). In addition, this 2030 Ma age is very similar to results from the Snowbird Lake area where deposition is constrained to be post-2070 Ma and pre-1910 +/- 10 Ma (Martel et al., 2008). Similar metasediments in the Dodge Domain (Gilboy, 1979; Knox and Ashton, 2009) could be correlative

The psammopelite from the Fond-du-Lac map area records an extended monazite history that allows for elucidation of post-2030 Ma deformational and metamorphic events. With monazite ages spanning from ca. 2.15 Ga to 1.85 Ga it appears that resetting (or complete resetting) of monazite age domains, even for non-shielded grains, appears incomplete. Low-Th monazite grains (2.15-2.0 Ga) are interpreted to be of detrital origin. A 1.99-1.94 Ga monazite population represents growth along a prograde metamorphic path and records garnet growth beginning at ~1.96 Ga. An overwhelming population of monazite growth took place during high-grade metamorphism at 1.94-1.91 Ga. A large percentage of the results from this monazite population are ca. 1.93 Ga, which is interpreted to be the timing of peak D1-D2 fabric formation and accompanying granulite-facies metamorphism. Dumond et al. (2008) also document a granulite facies metamorphic event in the eastern Beaverlodge Domain at ca. 1.93 Ga. The unique orientation of 1.91-1.90 Ga monazite grains allows for recognition of a distinct population of zircon grains that record the timing of northeast-trending F4 folding. Although it appears that

the eastern Beaverlodge experienced high-grade metamorphism from ca. 1.94 to 1.90 Ga, two distinct thermotectonic events are structurally and chemically distinguishable. In-situ chemical monazite geochronology of oriented sections provided a useful tool to distinguish the ages of the multiple deformational events.

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