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The S-type Ladybird leucogranite suite of southeastern British Columbia: Geochemical and isotopic evidence for a genetic link with migmatite formation in the North American basement gneisses of the Monashee complex

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Abstract

The 62–52 Ma Ladybird granite (LBG) suite is a peraluminous, leucocratic, S-type, quartz monzonitic to granitic suite which occurs as batholiths, stocks, dikes, sills, and pegmatite veins predominantly in the high-grade rocks of the Shuswap complex, in southeastern British Columbia. The emplacement of the LBG was synchronous with the production of abundant migmatites within Thor–Odin dome of the Monashee complex, an exposure of North American basement, exhumed from depths of ca. 26–33 km by Eocene extensional faults. The LBG and the leucosome in migmatites from Thor–Odin dome have similar major and trace element patterns, and are both characterized by zircons which have inherited Precambrian cores. Whole rock Nd isotope compositions show a range of values for the LBG with $\varepsilon Nd_{(55\ Ma)}$ values from −5.0 to −17.2. The $\varepsilon Nd_{(55\ Ma)}$ for the leucosome samples range from −9.5 to −23.6, overlapping with those of the granitic suite. These data support the interpretation of a genetic link between formation of the LBG suite and melting of North American basement rocks, such as those exposed in the core of Thor–Odin dome. The leucosome samples have lower high field strength element (HFSE) concentrations and positive Eu anomalies, whereas the LBG samples have higher HFSE concentrations and negative Eu anomalies. The similar trace element characteristics suggest that the leucosome from the migmatites and the LBG are related, whereby most of the leucosome samples are cumulates and the LBG samples represent evolved or residual melts. The initial $^{87}Sr/^{86}Sr$ isotope values for both the LBG and leucosome samples have a large range. However, the initial Sr isotopic ratios for the LBG suite are lower than those of the leucosome samples, with $^{87}Sr/^{86}Sr_{(55\ Ma)}$ ranging from 0.70603 to 0.73688 and 0.74256 to 0.76593, respectively. This isotopic discrepancy suggests either: a) isotopic disequilibrium during partial melting in the mid- to lower crust where the leucosome formed, b) the distribution of Sr during partial melting was controlled by different melt-producing reactions, and/or c) isotopic heterogeneity in the source rocks. At least part of the LBG suite likely formed via melting of North American basement rocks that were dominantly of sedimentary origin. Melting of the Proterozoic supracrustal metasedimentary rocks overlying North American basement may also have contributed to the formation of the different phases of the suite found at the regional scale. However, the abundant leucosomes in the basement rocks of Thor–Odin dome may mark the paths along which anatectic melt migrated in the structurally overlying Ladybird granites of the South Fosthall pluton.

Keywords: Leucogranite; Migmatite; Partial melting; Anatexis; Leucosome; Geochemistry

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1. Introduction

A relationship between the formation of migmatites and the generation of granites has long been postulated (see Mehnert, 1968; Misch, 1968); although the nature of that relationship is often debated (Sawyer, 1987; Le Breton and Thompson, 1988; Clemens, 1990; Brown and D'Lemos, 1991; Jung et al., 2000; Kalsbeek et al., 2001; Solar and Brown, 2001). Exposures of migmatites and related peraluminous, crustally derived granitic intrusions have provided, in certain instances, evidence of a link between migmatites and granitic plutons (i.e. Barbey et al., 1996; Sawyer, 1998; Kalsbeek et al., 2001; Solar and Brown, 2001; Johannes et al., 2003). This link is further supported by the interpretation that the leucosome portion of most migmatites were derived from partial melts and that migmatites may represent initial stages of crustal anatexis (Ashworth, 1985; Sawyer, 1987; Brown et al., 1995; Barbey et al., 1996; Jung et al., 2000; Kriegsman, 2001).

The relationship between spatially associated, coeval migmatites and granite plutons can be as follows: a) leucosome in migmatites may represent a link between high-grade metamorphism and large-scale granitic intrusions (Brown and D'Lemos, 1991); b) leucosome may have fed, or represent crystal fractionation from, the spatially and temporally related granitic bodies (Kalsbeek et al., 2001; Solar and Brown, 2001; Johannes et al., 2003;); c) leucosome may represent healed pathways that granitic melts followed during emplacement in the crust (Sawyer, 1987; Barbey et al., 1996; Sawyer, 2001); d) migmatites may represent the arrested stage of granite formation (Le Breton and Thompson, 1988; Obata et al., 1994); e) migmatites may represent contact metamorphic effects induced by emplacement of temporally associated plutons (Pattison and Harte, 1988; Jung et al., 2000); or, f) there may be no genetic relationship between migmatite formation and spatially associated granites (White and Chappell, 1990). As there are a variety of possible interpretations of spatially and temporally associated migmatites and plutons, various field and laboratory methods are necessary to evaluate any relationship.

This paper evaluates the potential genetic link between coeval migmatites and Paleocene–Eocene S-type leucogranites in the Omineca Belt of southeastern British Columbia. Precambrian North American basement rocks of the Monashee complex are exposed in structural culminations that were exhumed during early Tertiary extension and tectonic denudation (Fig. 1; Parrish et al., 1988). The Monashee complex consists of high-grade Paleoproterozoic basement rocks and overlying cover rocks which are now largely migmatitic and represent the deepest exposed structural level in the southern Canadian Cordillera. In Thor–Odin dome, of the southern part of the complex, the basement rocks underwent progressive deformation and anatexis. The basement gneiss in the core of the dome underwent anatexis at ca. 56 to 54 Ma based on U–Pb zircon geochronology studies (Vanderhaeghe et al., 1999; Hinchey, 2005; Hinchey et al., in press). The production of leucosome was coincident with emplacement of part of the structurally overlying Ladybird granite suite (LBG) which ranges in age from ca. 62 to 52 Ma (Parrish et al., 1988; Carr, 1992) based on U–Pb zircon geochronology studies. Genetic linkages have been proposed between the melting of basement para- and orthogneiss and the extensive formation of the granitic bodies. Vanderhaeghe et al. (1999) and Hinchey and Carr (2003) have suggested that the melt from which the leucosome in the structurally deeper migmatites was derived may also have been the source of the LBG. The leucosome in the diatexite migmatites of Thor–Odin dome are a suitable source for the LBG because they were a component of a melt (Hinchey et al., in press) which would have enabled large-scale magma transport, their volumetric extent is comparable to that of the plutonic suite, and they have similar compositions as the LBG. These characteristics are associated with diatexite migmatites that are likely to represent source melts of parental granites (Sawyer, 1996).

2. Regional geology

The Canadian Cordillera formed as a result of the Paleozoic to Paleogene accretion of fragments of allochthonous and parautochthonous oceanic sequences, continental slivers, volcanic arcs and sedimentary sequences to the western edge of ancestral North America (Monger, 1989). Mesozoic to Paleogene crustal thickening occurred during convergence between accreted terranes and the North American plate (Fig. 1; Monger et al., 1982; Monger, 1989; Gabrielse and Campbell, 1991). By the Middle Jurassic accreted terranes had begun overriding the pericratonic terranes as well as both the Proterozoic and the Paleozoic to early Mesozoic platformal sedimentary sequences that had accumulated on the paleomargin of North America (Monger et al., 1982). By the mid-Cretaceous, a 50 to 60 km thick crustal welt and a foreland basin had formed, and during the Cretaceous the Rocky Mountain fold and thrust belt (Foreland belt) formed (Price, 1986, and references therein). Crustal thickening and burial of the North American sedimentary sequence and the