Spinel + quartz granites and associated meta-sedimentary enclaves from the Taltson magmatic zone, Alberta, Canada: a view into the root zone of a high-temperature, S-type granitic batholith.

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Introduction

The Taltson magmatic zone (TMZ) makes up the southern part of the early Proterozoic (ca. 1.9–2.0 Ga) Taltson-Thelon orogen, a north-south trending belt that extends for more than 2000 km along strike from central Alberta to the Arctic Ocean (Hoffman, 1988; Ross *et al.*, 1991). The TMZ is dominated by felsic plutonic rocks, in particular by peraluminous grantoids (Bostock *et al.*, 1987; Goff *et al.*, 1986). The present study focuses on the petrology of a spectacular outcropping of one such granitoid body and its associated enclaves. The rocks are unusual in that both the granites and the enclaves contain the high-temperature mineral assemblage, spinel-quartz-cordierite-garnet$\pm$sillimanite. The aim of this study is to document the pressure-temperature conditions indicated by this assemblage and to assess the magmatic and metamorphic processes leading to its development. Descriptions of rocks from other parts of the TMZ (Bostock *et al.*, 1987; Grover *et al.*, 1993) suggest that processes documented at this outcrop may be representative of those that operated over much of the TMZ.

Petrographic Descriptions and Chemical Analyses

The outcrop is located on the Slave River in northernmost Alberta, near the town of Fort Smith. It consists of a medium-grained alkali feldspar granite which hosts numerous meter-sized, lozenge-shaped enclaves of pelitic composition paragneiss. The enclaves can be broadly subdivided into two groups, a mafic variety rich in cordierite, garnet, spinel and alkali feldspar and a felsic variety rich in quartz and poor in feldspar. Both groups of enclaves have migmatitic textures and contain variable amounts of quartz-alkali feldspar or quartz-rich leucosomes.

The granite and the enclaves possess nearly identical mineral assemblages and differ primarily

TABLE 1. Representative whole-rock and mineral chemical analyses

sample#	ROD-1	PR6	PR3	ROD-1	SEP2-9	ROD-1	SEP2-9	ROD-1	SEP2-9
rock type	granite	enclave	enclave	granite	enclave	granite	enclave	granite	enclave
analysis	w.r.	w.r.	w.r.	garnet	garnet	spinel	spinel	cordierite	cordierite
SiO_2	73.40	49.12	79.91	37.51	37.92	0.12	0.11	48.02	48.81
TiO_2	0.16	1.30	0.61	ND	ND	ND	ND	ND	ND
Al_2O_3	15.59	29.21	9.37	21.28	21.82	54.28	57.51	32.49	33.92
Cr_2O_3	ND	ND	ND	ND	ND	0.20	0.69	ND	ND
V_2O_3	ND	ND	ND	ND	ND	0.18	0.49	ND	ND
FeO*	0.71	10.71	4.88	35.05	33.10	39.74	35.00	10.60	9.16
MnO	0.01	0.18	0.06	0.99	0.55	0.13	0.06	0.07	0.11
MgO	0.26	3.21	1.41	4.61	6.42	2.51	5.26	6.38	7.91
ZnO	ND	ND	ND	ND	ND	1.09	0.46	ND	ND
CaO	0.92	0.35	0.70	0.67	0.65	ND	ND	ND	ND
Na_2O	3.20	1.50	1.61	ND	ND	ND	ND	0.26	0.14
K_2O	6.21	4.75	1.90	ND	ND	ND	ND	0.03	0.00
P_2O_5	0.11	0.07	0.02	ND	ND	ND	ND	ND	ND
Total	100.56	100.40	100.46	100.10	100.28	98.24	99.57	97.94	100.04

in their mineral textures and modal proportions of minerals. Garnet and cordierite occur as elongate, irregularly-shaped grains in the enclaves and as equant and euhedral grains, respectively, in the granite. Anhedral grains of green spinel occur in both rock types in apparent textural equilibrium with other minerals. Spinel-quartz interfaces are, however, characterized by narrow (10–20 μm) reaction rims of cordierite which we interpret as a retrograde feature. Mesoperthitic alkali feldspar is ubiquitous but plagioclase (An_{22}) is found as minor phase only in the granite. Sillimanite is widespread in the enclaves and occurs as a trace phase in some granite samples. Trace corundum occurs as inclusions in a few spinel grains. Notably, all rocks at the outcrop are characterized by a paucity of primary hydrous phases; reddish-brown biotite occurs as a trace phase (generally < 1%) only in some enclave samples.

Pressure-temperature calculations

A total of five representative samples of granites and enclaves were chosen for thermobarometric analysis. To minimize the effects of retrograde Fe-Mg exchange, mineral analyses of garnet, cordierite and spinel were selected, wherever possible, from grains completely surrounded by non-ferromagnesian phases. We calculated pressures and temperatures using the TWEEQU thermobarometry program of Berman (1991) (version 1.02). Activity calculations were made on the basis of solution models provided by Berman (1990) and Fuhrman and Lindsley (1988) for garnet and plagioclase, respectively, and on ideal on-sites mixing models for spinel and cordierite. Because of the presence of plagioclase, the largest number of equilibria can be calculated for the granite samples (three or more linearly independent equilibria).

Calculated pressures and temperatures generally range from 5–7 kbar and 830–940°C, depending on the choice of end-member phases. Most of this variation can be attributed to the selection of Fe- versus Mg-cordierite end-members and to the cordierite hydration model. In general, higher pressures and temperatures are associated with calculations using hydrous Mg-cordierite. We note that more recent experimental calibrations of some of these equilibria (Nichols *et al.*, 1992) and quartz-garnet oxygen isotope temperatures determined for samples from this outcrop (940–1000°C; Farquhar *et al.*, this volume) are more consistent with the upper end of this P–T range. We take these results to represent minimum estimates of peak metamorphic/magmatic conditions.

Implications for granitoid petrogenesis

The petrologic, geochemical and thermobarometric considerations noted above lead us to propose the following:

1) The rocks of the outcrop represent an S-type magma that has incorporated and transported part of its melt-depleted source material. This hypothesis is supported by the strongly peraluminous nature of the granite (indicating derivation from a pelitic source) and the highly refractory chemical character of the mafic enclaves (Table 1). It is also consistent with the observation that mineral compositions in the granite and the enclaves are similar. Interestingly, the mineral compositions in the two rock types are not identical and indicate some partitioning of elements (e.g., Fe-Mg) between melt and restite.

2) The abundance and large size of the enclaves suggest that granitic body is relatively near its source region. Because the granites crystallized at 5–7 kbar, this in turn suggests extremely high geothermal gradients in the TMZ at ca. 1.95 Ga.

3) The high temperatures (> 900°C) documented at the Slave River outcrop suggest that these rocks are better analogues of the source regions of high crustal level S-type plutons (and volcanics) than are much lower temperature migmatite terrains (e.g., see Clemens and Wall, 1984).

4) The high magma temperatures account for the occurrence of these extraordinarily anhydrous granites. Any residual water was likely removed via a melt phase or an anhydrous fluid. Indeed, the removal of water and complete crystallization of melt probably accounts for the preservation of high-temperature information in the granites and enclaves (see Pattison, this volume).

Additional O, Nd and Pb isotopic studies currently underway will provide additional constraints for understanding the evolution of these high-grade rocks.

References

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