N89 - 22230

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THE ROLE OF BORON AND FLUIDS IN HIGH TEMPERATURE, SHALLOW LEVEL METAMORPHISM OF THE CHUGACH METAMORPHIC COMPLEX, ALASKA

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The possible role of boron (B) involvement in granite equilibria and generation of melts during crustal metamorphism has been a focus of speculation in recent literature (1,2,3). Most of the evidence for such involvement derives from experimental data which implies that the addition of B will lower the temperature of the granite solidus (4,5). Also the presence of tourmaline has a minor effect on the temperature of the solidus (6). Further indirect evidence that B may be involved in partial melting processes is the observation that granulites are commonly depleted in B (7), whereas the B content of low grade metapelites can be high (up to 2000 ppm, 8 & 9). Our measurements of the whole-rock B contents of granulites from the Madras region, India are low, ranging from 0.4 to 2.6 ppm, and Ahmad and Wilson (10) suggest that B was mobilized in the fluid phase during granulite facies metamorphism of the Broken Hill Complex, Australia. Thus, it appears that during the amphibolite to granulite transition, B is systematically lost from metasediments. The B that is released will probably partition into the vapor phase and/or melt phase.

Field data from a high temperature, shallow level regional metamorphic complex in the eastern Chugach Mountains of southern Alaska indicate localized partial melting has occurred in response to increased heat flux from intrusion of tonalite sills and plutons (11). In addition, the amount of tourmaline increased with increased metamorphic grade. However, in the migmatitic core of the complex, tourmaline is absent in the partial melt zones and rare in the host metasediment. The conditions of metamorphism (400 ^{o} to 600 ^{o}C outside the migmatitic core and 650 ^{o}C within the core at pressures of 2.5 to 3.5 kbar). and the presence of locally derived granitic melts, imply that B may be involved in the partial melting process. Approximately 3 wt % B_2O_3 is needed to lower the granite solidus from 700 ^{o}C to 650 ^{o}C (5). The breakdown of tourmaline may release the B necessary for fluxing the partial melting. The boron-rich fluid or melt is inferred to have escaped and is possibly represented by late stage tourmaline-bearing pegmatites and tourmaline-quartz veins. Below we present our preliminary results from whole-rock boron analysis and fluid inclusion observations done to explore the role of boron and fluids during the migmatization of the Chugach region.

The Chugach Metamorphic Complex (12,13,14) is developed in the Campanian to Maastrichtian Valdez Group, which is predominantly clastic argillite and graywacke with minor tuffaceous basalt deposited in either a trench setting or a deep sea fan. The entire region was metamorphosed to greenschist facies at 55-60 Ma, possibly by a combination of heat conduction from subducted hot, young oceanic crust (15) and heat advection from dewatering of fluids from sediments at depth in a subduction zone setting (16). The whole-rock boron content of the greenschist package is moderate and the concentration of the B is controlled by the host lithology (Table 1). The fluids involved in greenschist metamorphism are represented by hot, low salinity brines observed in fluid inclusions in first generation quartz veins. Later brines have both lower salinities and homogenization temperatures which may reflect cooling of the fluid and possibly mixing with meteoric fluids. The salinity decrease is correlated with a decrease in B content (Table 1). A similar relationship between B and Cl^- (salinity) has been observed in thermal waters (e.g. Yellowstone, 17).

The regional high temperature metamorphism followed the greenschist event in response to intrusion of tonalite sills and plutons at 55 Ma. Initial measurements of the Chugach whole-rock boron content of samples from the amphibolite facies and migmatitic core are low suggesting B has been lost. This may be related to the breakdown of tourmaline. However, some of the highest grade samples still have B contents similar to the greenschists (compare sample 96 with 7, Table 1). Additionally the B content of the intrusive tonalites (samples 11 and 103, Table 1) and the locally derived granitic melts (sample 98A1, Table 1) is low. The low boron in all these rock types and lack of tourmaline in the intrusive tonalites suggests that B is not present in sufficient quantity to have any affect on the solidus of the melts. However, some of the boron originally in the melt phase may have preferentially partitioned into a vapor phase leaving the tonalites and locally derived granites with low B content.

The majority of the fluid preserved as fluid inclusions in the Chugach Metamorphic Compex is CO_2-rich and the primary fluids have isochores which pass through peak metamorphic conditions. The B content of the host quartz veins is low (Table 1). One vein in the amphibolite facies region does preserve a transition from H_2O-CO_2 mixture to pure CO_2. The salinity of the H_2O component is not great enough to suggest fluid immiscibliity as a cause for the composition change at these metamorphic conditions (550 °C and 3 kbar). However, a possible explanation for the composition change is that the water has been incorporated into either the intrusive tonalites or locally derived melts. Thus, the CO_2 may represent a residual fluid. Olsen (18) describes a similar relationship for CO_2-rich fluids preserved in migmatites from Colorado.

These preliminary measurements imply that the boron content of rocks in the Chugach Metamorphic Complex is not sufficient to influence the processes of partial melting at low pressures. Further work is needed to constrain the mass balance of B during progressive metamorphism and evaluate the possiblity that both B and H_2O have been incorporated into melts which have since left the system.

TABLE 1. BORON CONTENT OF CHUGACH METAMORPHIC COMPLEX

Sample	Rock Type	Temperature (°C)*	Boron (in ppm)**
6	graywacke	400	46
10	graywacke	400	39
45B	graywacke	400	48
48B	graywacke	400	23
50B	graywacke	400	37
7	argillite	400	29
45A	argillite	400	18
48A	argillite	400	25
50A	argillite	400	18
8B	basalt	400	4.6
48D	basalt	400	2.7
64A	qtz vein	450, 3.5 wt %	2.6
64C	qtz vein	375, 2 wt %	0.7
64D	qtz vein	250, 0.5 wt %	0.4
8BV	qtz vein	375, 3.5 wt %	0.2
10BV	qtz vein	400, minor CO_2	0.9
89D	qtz vein	600, CO_2-rich	2.1
93R	qtz vein	550, CO_2-rich	2.3
12	schist	500	2.7
17G	schist	500	50
35	schist	575	8.5
45	schist	540	2.3
94L	schist	550	42
31D	schist	600	6.6
86E	schist	600	18
110	migmatite	650	6.7
96C	migmatite	650	46
98A2	migmatite	650	8.2
98A1	granite melt	--	7.6
103	tonalite	--	6.7
108	tonalite	--	2.3
11	tonalite	--	3.0
105	tourmaline-selvage	--	210

Table 1 (cont'd)

* Temperature is either estimated from mineral assemblage data or for quartz veins is derived from the fluid inclusion isochore and the composition is given with salinity in wt % NaCl equivalent.
** Boron measured by prompt gamma neutron activation analysis (PGNNA) at the McMaster University reactor centre. Precision is approximately 10% for concentrations above 10 ppm and falls to 30%-50% near the detection limits (< 0.5 ppm).

Acknowledgements: We would like to thank B. Weaver for samples from the Madras granulites. We also appreciate the help and assistance of LS Hollister, G Plafker, and WK Nokleberg. This work was supported by NSF grant EAR 85-12172 and the U.S.G.S. Trans Alaskan Crustal Transect (TACT) project.

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