

Geochemical Characterization of Tourmaline across Pegmatite - Country Rock Boundaries in the Southwestern Maine Pegmatite Field

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INTRODUCTION AND GEOLOGIC SETTING

The Oxford Pegmatite Field of southwestern Maine, part of the Central Maine Synclinorium region, is associated with several granitic plutons that resulted from the Acadian orogenic events related to the arrival of coastal terranes (Personal Communication: C. V. Guidotti and C. A. Francis, 1996). The field is dominated by the Sebago batholith in the south and by several smaller plutons in the north (Wise, 1995).

Mount Mica and Black Mountain are the sites of two well-zoned complex rare element pegmatites (Francis et al, 1995). Both of these pegmatites contain tourmaline crystals, and tourmaline is also found in the immediately surrounding country rock. Mount Mica is located northeast of the Sebago batholith and intrudes an amphibolite facies pelitic schist. Black Mountain is in close proximity to both the Rumford and Whitecap Mountain plutons and is intruded into a quartzite.

The complete characterization of chemical and isotopic signatures across the contact zone between a pegmatitic body and its surrounding country rock allows examination of element and fluid mobility. Samples of tourmaline were collected across the contacts at both Mount Mica and Black Mountain and were analyzed for elemental composition using a variety of techniques. Analysis and comparison of the chemical trends allowed us to observe the geochemical effects of interaction between magmatic fluid and surrounding country rock, to examine the extent of fluid migration, to determine whether the process of intrusion and alteration had differed at each site, and finally to evaluate the mechanisms of fluid flow to some extent in each case.

The two pegmatites show very different effects on the surrounding rock, primarily due to the difference in textures of the country rock. At Mount Mica the intrusion is parallel to the cleavage direction of the schist making it very difficult for fluid to migrate perpendicularly through the wall of the pegmatite and penetrate the country rock, thus there is a lower abundance of tourmaline included within the surrounding rock. The exceptions to this are where the fluids were able to move into cracks in the country rock producing pods of pegmatitic rock within the country rock. Black Mountain differs in that there is more uniform distribution of the tourmaline in the host rock showing that fluids could move more freely. These factors need to be considered when looking at the difference in chemical trends between the two localities. An alternative interpretation of our data is that the pre-intrusive and/or pre-metamorphic chemical composition of the country rock varied between the two locations. Further evaluation of the coexisting phases at each locality should help discriminate between these hypotheses.

METHODS

In the field we collected a total of eight samples from Mount Mica of which three were from within the country rock, one was from a pegmatitic pod in the country rock and four were from within the body of the pegmatite. At Black Mountain we collected one pegmatite sample and five country rock samples. We also used thirteen samples which had been previously collected from within the pegmatite, for which we are indebted to Mike Wise of the Smithsonian Institution and to project co-leader Darby Dyar. These samples were sent away for SEM / microprobe, particle-induced gamma-ray emission, Mossbauer, and oxygen and hydrogen isotope analyses. We received data back determining Si, Al, Ti, Fe²⁺, Fe³⁺, Mg, Mn, Ca, Na, K, F, Li, B, H, ¹⁶O, and ¹⁸O contents for each sample.

RESULTS & DISCUSSION

In a publication by Henry and Guidotti (1985), it was shown that the kind of host rock a given tourmaline came from could be predicted by plotting it on an Al, Fe(tot), Mg ternary diagram. The samples we analyzed from within the pegmatites at both Mount Mica and Black Mountain plot in the Li-rich pegmatite field section of Henry and Guidotti's ternary diagram, and the samples from the country rock plot as being from an Al-saturated metapelite (Fig. 1). This indicates that the tourmaline in the country rock shows very little of the pegmatite composition. This chemistry could be a result of the breakdown of biotite or of other Mg-rich aluminosilicates. Biotite is known to break down in the presence of boron-rich solutions (London et al, 1996), in which tourmaline is capable of growing.

•Elemental Data

The elemental trends of the tourmaline samples collected across the contact were generally similar at the two localities. Specific elements for the most part increased or decreased similarly at both pegmatites as the samples were taken from further into the country rock. Most of these trends may be explained by assuming that the growing tourmaline crystal incorporates elements which are in abundance in its immediate surroundings. The more statistically significant trends include a general increase in Mg and Ca and a decrease in Fe as tourmaline was sampled from farther into the country rock.

A comparison of the inverse Mg - Fe trends is consistent with the crystal chemistry of tourmaline. Both elements are able to fill the Y-site, and as more Mg becomes available through the breakdown of biotite, there is less Fe in this site. This demonstrates a relatively straightforward substitution. At Black Mountain, the Mg content jumps up at the contact and increases steadily and the Fe count decreases steadily with distance into the country rock. At Mount Mica the Mg count jumps and the Fe count drops right at the contact, but both stay at approximately constant levels as distance into the country rock increases. This supports the conclusion that fluid interaction with country rock is more extensive at Black Mountain than at Mount Mica. Also, the incorporation of Mg occurs to a greater extent at Black Mountain, actually changing the character of the tourmaline in the wall rock to the Mg enriched form of tourmaline, dravite, from the Fe-rich schorl immediately within the pegmatite.

Another notable trend is the B - Si relationship (Fig. 2). There is a clear inverse correlation between the two and odd behavior at the contact at both Black Mountain and Mount Mica. The two localities record opposite directions in the trends, again suggesting a difference in the character of interaction of the pegmatitic fluids with their surrounding country rocks. The tourmaline close to the contact had quartz cores and some samples had an almost graphic texture. This is typical of tourmaline found in the country rock surrounding a B-enriched pluton (London et al, 1996). It should be noted that even though the B content within the tourmaline increases with distance into the wall rock at Black Mountain, the overall B content of the whole rock does not, as the tourmaline is much more abundant close to the contact than farther away. At Black Mountain, where fluid interaction appears to have been much more extensive, the crystallization of tourmaline in the country rock probably tied up any Mg or Fe from the wall rock that otherwise would have mixed with the melt and entered the pegmatite (London et al, 1996). The clear correlation between the Si and B levels at both sites suggests a complex substitution that merits further study.

•Isotope Data

Tourmaline is a mineral well-suited for stable isotope work because it does not accommodate lighter or heavier isotopes preferentially. The stable isotope data for samples from our two sites show opposite trends, most likely due to the difference in the constricting effects the differing country rocks had on the pegmatitic fluid. At Black Mountain the hydrogen isotope trend indicates a highly metamorphic source in the core and a more igneous source at the rim of the pegmatite and into the country rock. This isotopic signature suggests an exchange of hydrous fluids between the pegmatite and the country rock. The source of the hydrogen is most likely the breakdown of biotite in the presence of the boron rich fluid. The hydrogen isotope data from Mount Mica shows the opposite trend, suggesting that the pegmatite body did not have extensive interaction with fluids from the country rock. The trends of both localities converge towards the same value, which is most likely the isotopic composition of similar original pegmatitic fluids.

The only available oxygen isotope data from Black Mountain is from the country rock samples which show a trend of more metamorphic character farther into the country rock. At Mount Mica the oxygen isotope data are more complete and shows the same basic trend with the samples from within the pegmatite having a considerably smaller $d^{18}O$ value. Overall the $d^{18}O$ values from tourmaline samples at Mount Mica are higher than those at Black Mountain even in the whole rock samples from the country rock.

Derivation of Tourmaline Host Rock

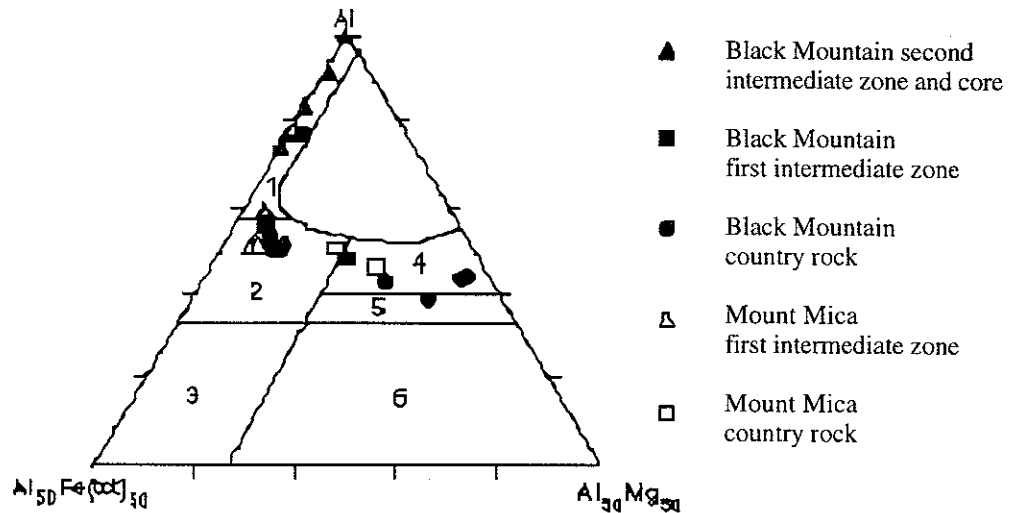


Figure 1. Al - Fe(tot) - Mg diagram (in molecular proportions for tourmaline samples from Black Mountain and Mount Mica, Maine). The fields are defined as follows: (1.) Li-rich granitoid and their associated pegmatites and aplites. (2.) Li-poor granitoids and their associated pegmatites and aplites. (4.) Metapelites and metapsammites coexisting with an Al-saturating phase. (5.) Metapelites and metapsammites not coexisting with an Al-saturating phase. Fields (3.) and (6.) are Fe³⁺-rich quartz tourmaline rocks, calc-silicate rocks, and metapelites which are not represented in our samples.

Si - B Relationship across the contacts at Mount Mica and Black Mountain

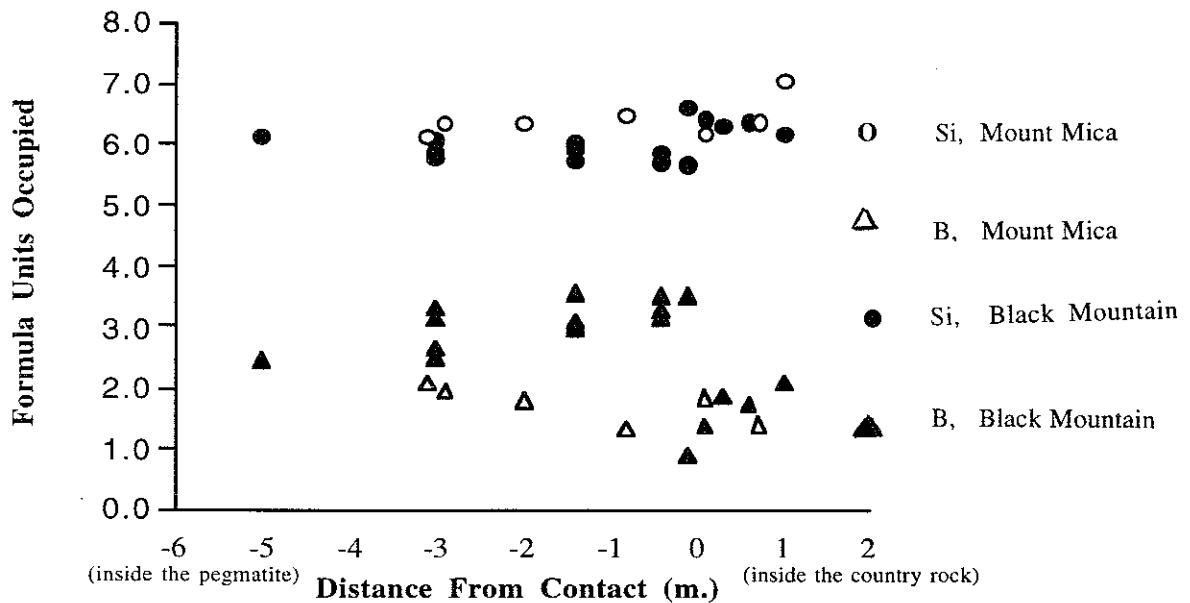


Figure 2. The inverse relationship between Si and B in tourmaline sampled from Mount Mica and Black Mountain.

A complete comparison of the isotopic data cannot be made until the oxygen isotope data from the Black Mountain pegmatite samples is received. The existing data imply that the pegmatitic fluids interacted more with the country rock at Black Mountain than at Mount Mica.

CONCLUSION

Our data support the conclusion that the character of interaction between the pegmatites and the country rocks which they intruded differed at our two study sites. Chemical and isotopic signatures indicate a greater degree of interaction at Black Mountain than at Mount Mica, most likely due to the differences in texture of the two country rocks. Where interaction did occur, the breakdown of biotite in the presence of a B-rich fluid and the incorporation of the resultant freed Mg into tourmaline crystals is indicated. Where fluid interaction was extensive with the wall rock, the crystallization of tourmaline played a dominant role in incorporating dissolved elements from the wall rock, so that the chemical signature of the wall rock did not seem to affect the composition of the pegmatitic body to the extent that the pegmatite affected the immediate country rock. At both Black Mountain and Mount Mica pegmatites, tourmaline samples demonstrated a very strong inverse correlation between B and Si content which certainly merits the effort of future study.

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