Petrogenesis and Evolution of Peraluminous Mount Douglas Leucogranites, Southwestern New Brunswick, Canada: Extreme Fractionation Linked to Sn-W-Mo-Polymetallic Mineralization

David LENTZ and Nadia MOHAMMADI

University of New Brunswick, Fredericton, NB, E3B 5A3, Canada

1 Introduction

The Mount Douglas intrusive suite is a texturally heterogeneous assemblage of granitic rocks that forms the eastern part of the Saint George Batholith, southwestern New Brunswick, Canada. Based on the field relationships, geochemical characteristics, and ages, the Mount Douglas suite together with the Mount Pleasant, True Hill, Beech Hill, Kedron, Pleasant Ridge, and Sorrel Ridge granitic stocks are distinguished as the Late Devonian (370–360 Ma) granitic series (GS) (McLeod, 1990; Whalen et al., 1996). This body forms an area about 30 km * 20 km, and extends from Red Rock Lake to Mount Douglas. Previous research show that the Mount Douglas (MD) suite has undergone extreme differentiation and offers considerable potential for endogranophile-element deposits (McLeod, 1990). Those studies illustrate that the MD suite has evolved from a magma chamber in a three-stage process and contains three compositionally distinct units, including Dmd1, Dmd2, and Dmd3, chronologically. Our study mainly focuses on the petrochemical aspects of these units and trying to find petrogenetic linkage between Dmd1, Dmd2, and Dmd3. Metal behavior during the evolution of this magmatic system is another purpose that has been done using McLeod’s analytical data (1990) of MD suite.

2 Major and Trace Elements Studies

The samples from the MD are characterized by high content (wt.%) SiO2 (68-78), K₂O (3.5-7.8), (Fe₂O₃+FeO)/MgO ratio (average 8.7), and alkalis, low CaO, and MgO, and very low P₂O₅ and TiO₂. The Dmd3 shows the highest amount of SiO₂ with average 76.4 wt. %. Based on their aluminum saturation indices (ranging from 1.03-1.60), they are peraluminous, and belonged to the alcalic-calcic and calcic-alkaline series. According to the classification from Frost et al. (2001), Dmd1 sample are magnesian granites; however the Dmd2 and Dmd3 samples range from magnesian to ferroan granite, respectively, reflecting increasing fractionation.

With regards to their trace elements, the MD leucogranites are strongly enriched in the incompatible elements, such as F, Li, Rb, Cs, U, Th, and Nb; this enrichment is correlated with an obvious depletion in compatible elements (e.g., Ca, Mg, Ti, Sr, Ba, and Eu). Compared to the Dmd2 and Dmd3, the Dmd1 has the lowest amounts of incompatible trace elements, the smallest negative Eu anomalies, as well as Ba, Sr, P, and Ti; however, they have an enriched chondrite-normalized REE patterns [(La/Yb)N = 4.3–21.8]. The Dmd3 shows a flat "birdwing shape" REE patterns, which are characterized by large negative Eu anomalies (from Dmd1 to Dmd3, negative Eu anomalies increase) and the lowest (La/Yb)N (ranging from 5.9-10.2) ratios, showing the highly evolved affinity of Dmd3. These data are consistent with the major element data (e.g., high SiO₂ and K₂O, very low CaO and TiO₂). Normalized to the least-evolved sample of the MG granites (Dmd1), the Dmd3 unit is the most enriched in Rb, Th, U, Ce, Ta, Pb, Nd, Sm, Dy, Y, Yb, and Lu, and show extremely reduction in Ba, Sr, P, Zr, Eu, and Ti content (Fig. 1a), reflect fractionation from Dmd1 to Dmd3.

3 Petrogenesis and Tectonic Setting of the Mount Douglas Leucogranite Suite

Using trace elements shows that most samples from the MD granites are within-plate granites (WPG, A-type) to syn-collisional granites (SCG, S-type), however, several Dmd1 samples show their affinities to volcanic-arc
granites (I-type). On the plot of Nb vs. Sr (Fig. 1b), the samples mainly fall in the field between fractional crystallization and assimilation-fractional crystallization (r= 0.2) curves. Rb-Ba-Sr diagram (Fig. 1c) shows a clear progressive differentiation from Dmd1 to Dmd3. Geochemical discrimination diagrams (Fig. 1d) illustrates that granitoid samples of Dmd2 and Dmd3 mostly fall in the transition zone between FG (fractionated felsic granites) and A-type granites, and Dmd1 samples mainly plot in the field of OGT (unfractionated M-, I-, and S-type granites). It cannot be concluded the possibility of variable degrees of partial melting of the same source since compatible elements, such as Ba, Sr, and Eu don’t show a large variation in each unit. Comparing the Mount Douglas Granites with the Late Devonian Mount Pleasant Granites (MPG) may give the result that they are similar in geochemical composition (McLeod 1990; Yang et al., 2003).

4 Metal Behaviour during Fractional Crystallization

One of the most important factors affecting mineral occurrences is metal behaviour during magmatic evolution. For this study, Ta has been considered as most incompatible for defining D values using Allegre method (Allegre et al. 1977). Based on their D values, LREE [La, Ce, Nd, and Sm], HREE [Tb, Dy, Tm, Yb, and Lu], Pb, U, Sn, Rb, Th, Nb, and Y behave as incompatible elements; however, the other elements, such as Zr, Sr, Ba, Eu, Zn, Cs, W, Cu, Mo, Li, Sc, Hf, Ti, and P act as compatible elements during magmatic evolution. Decreasing K/Rb, Nb/Ta, and Zr/Hf ratios, and increasing Ti/Sc ratio from Dmd1 to Dmd3 possibly reflect increasing of fluid involvement during formation of the units toward the last-stage unit (Dostal and Chatterjee, 2000).

5 Conclusion

Petrochemical data show that the subunits of Mount Douglas Granites, Dmd1, Dmd2, and Dmd3, have within-plate geochemical character with possibility of hybrid I- and S-type affinity. It seems that they have been produced by fractional crystallization of the same parental magma with different magmatic evolution. Indeed, they might have a single genetic group with different fractionation, in which this fractionation increases from the early unit (Dmd1) to the late unit (Dmd3). Extreme fractional crystallization and fluid involvement during formation of these units have been the most important factors affecting the magma evolution, producing three different units, compositionally. Significant mineral occurrences might mostly be associated with the latest and most highly differentiated phases (Dmd3) as it includes the highest
amount of incompatible elements, including Sn. Although W and Mo act as compatible elements comparing to Ta, their concentration increase accompanied with the degree of fractionation. On the other hand, these metals show a significant enrichment in the MD granites, and their compatibility may be the result of leaching or partitioning out during volatile exsolution. Therefore, the most highly evolved unit (Dmd3), and then Dmd2 might be considered for exploration of Sn, W, Mo, and as well U and Pb deposits.

Acknowledgments

This project supported by NB Energy and Mines, a President’s Doctoral scholarship (NM), and a NB Innovation Fund award (NM). DL is supported by a NSERC Discovery grant.

References


