Petrogenesis and Tectonic Setting of Mafic Meta-igneous Rocks from Hope Bay and Elu Greenstone Belts, NE Slave Craton

H. Mvondo*, D. Lentz
Department of Geology, University of New Brunswick, Fredericton, NB, Canada
hmvondo@unb.ca

and

M. Bardoux
Newmont, Vancouver office, Vancouver, BC, Canada

Summary

In the northeastern part of the Slave Craton (Bathurst Block), the NE-striking Elu Belt (EB) is linked to the adjacent N-striking Hope Bay Belt (HBB) by an arcuate E-W connection zone termed the Elu Link (EL). The EL provides new insights into key geological relationships in the ca. 2700-2600 Ma EB and HBB. A preliminary geochemical study of mafic meta-igneous rocks from EL and HB belts shows they are similar and represent tholeiitic to calc-alkaline basalts and basaltic andesites. These rocks represent three magmatic suites, mainly Ti-depleted flat REE, Ti-enriched flat REE, and Ti+LREE enriched magmatic systems. Like mafic rocks in the Yellowknife belt, rocks in the EL and HBB are inferred to have derived from deep to shallow mantle sources and emplaced in a back-arc setting over attenuated continental crust.

Introduction

Elu and Hope Bay are ca. 2700-2600 Ma greenstone belts in the northeastern Bathurst Block of the Slave Craton. The NE-striking Elu Belt (EB) is deflected westwards in the south to form an E-W connection zone, termed the Elu Link (EL), with the N-striking adjacent Hope Bay belt (HBB). Unlike EB, HBB has been the focus of intensive exploration and mapping projects that resulted in discovery of important gold deposits including Doris, Madrid, and Boston. The HBB and EB are connected, although it is not clear if the two belts record the same geologic history or if they could represent different, juxtaposed greenstone belts. This project aims at correcting this lack of information by documenting critical geologic affinities between the two belts. This paper presents preliminary geochemical data from the mafic meta-igneous from EL and HBB. We argue the two belts formed from the same magmatic rocks emplaced in a back-arc basin over an attenuated continental crust, i.e., like the Yellowknife belt (Goodwin et al., 2006).

Geological framework

The Slave Craton (SC) is an Archean granite – greenstone - metasedimentary terrane bound to the east and the west by the Paleoproterozoic Thelon and Wopmay orogens, respectively. HBB in the SC Bathurst Block is comprised of greenschist-grade, thick mafic-pillowed flows and subordinate metasedimentary rocks, felsic volcanic to volcaniclastic intercalations, and syn- to late-volcanic ultramafic intrusions bound or cut by low- to medium-grade metamorphic felsic granitoid rocks. Felsic metavolcanic rocks in the EB yielded a U-Pb zircon ages between 2716 and 2663 Ma, against 2672+4/-1 to 2608 ± 5 Ma U-Pb zircon age for felsic intrusions and 2649.5+2.9/-2.5 Ma U-Pb zircon and 2589 Ma titanite ages of migmatitic gneisses SE of HBB (Bevier and Gebert, 1991; Hebel, 1999). HBB is cut by Neoarchean to Protorozoic diabase dykes (Bevier and Gebert, 1991). Similarly, metavolcanic rocks with subordinate iron formation and metapsammite intercalations, all intruded by mafic and felsic syn- to late-tectonic bodies and dolerites occur in EL. Two main fabric-forming deformation phases D1 and D2 are variably recorded in EL and HBB. D2 is a vertical general flattening strongly overprinting pre-existing D1 deformation imprints.

Analytical methods

Petrographic data were obtained from the study of thin sections and XRD analysis of samples using University of New Brunswick's Bruker D8 Advance Spectrometer. In addition, samples were analyzed using the pressed pellet technique by Wavelength-Dispersive X-ray Fluorescence Spectrometry at Memorial University and for INAA analysis at Actlabs in Ontario. In both cases, MRG and MA-2C standards were used for quality data control. The results were recombined considering elements with the least absolute analytical error. To minimize analytical errors in the determination of certain elements, an additional data arrangement was made using ICP-MS results obtained by Newmont Mining from a commercial laboratory (ACME) in Vancouver. The following results are based only on the recombined data of 7 samples from EL, and the mean and standard deviation of 63 samples from an unpublished MSc thesis (Shannon, 2008) in HBB.

Results

Petrographic description of HBB rocks is summarized in Sherlock and Sandeman (2004) and references therein. Mafic meta-igneous rocks of the EL include massive and pillowed flows, amphibolites, meta-gabbros, and dolerites. In this study, a brief presentation of those petrologic aspects is presented where relevant to the interpretation of geochemical data. Massive flows are fine- to medium-grained schistose to "striped" rocks with local foliation parallel epidote-rich veins and unevenly embedded small size (< 15 cm) pillows. In reverse, the pillowed flows show abundant large size (30-50 cm) flattened pillows separated by < 5 cm thick rusty selvages. The main mineral assemblage in both cases includes chlorite (30-50 vol.%), albite (20-25 vol.%), and quartz (8-25 vol.%) defining varied textures. Amphibolites forming small enclaves or large veined septa within felsic granitoids have a similar composition, suggesting they were derived from mafic metavolcanic rocks. Metagabbros are coarse-grained massive rocks mainly composed of chlorite (6-55 %), albite (15-40 %), amphibole (ca. 15 %), and quartz (ca. 14 vol.%). Fine- to medium-grained dolerites show a similar composition with minor quartz and minor phlogopite. In all these rocks, chlorite generally derives from amphibole and/or biotite. Amphibole has magnesio-hornblende and ferro-tschermakite composition in metagabbros, and magnesio-hornblende and tirodite in metavolcanic rocks and dolerites, respectively. Magnetite, sulfides, zoisite, sericite, and calcite occur in amounts <1 %. Also, titanite and phlogopite occur in metavolcanic rocks and amphibolites, whereas zoisite and magnetite may reach up to 20 % and 10 % in meta-gabbro, respectively. Sulfides generally include pyrite, chalcopyrite, and arsenopyrite, with sphalerite locally occurring in meta-gabbro.

On a Zr/TiO_2-Nb/Y diagram, suitable for the classification of altered rocks (Hall and Plant, 1992), most of the EL and HBB mafic meta-igneous rocks straddle the boundary between sub-alkaline basalt and basaltic andesite fields (Fig. 1a). The Zr/P_2O_5-TiO_2 plot shows the rocks mainly have a tholeiitic affinity (Fig.1b), with alkali-basalt signature likely due to fractionation. They yield 48.07 ± 2.05 wt.% SiO_2, 1.04 ± 0.28 wt.% TiO_2, and 14.59 ± 1.60 wt.% Al_2O_3 mean contents permitting to distinguish; 1) low-titania (< 1.00 wt.% TiO_2) and medium- to low-alumina (≤14.00 wt.% Al_2O_3) and 2) high-titania (1.00 wt%<TiO_2<2.00 wt.%) and medium-alumina (14.00 wt%<Al_2O_3<18.00 wt%) magmatic suites. Titanium-depleted and Ti-enriched rocks show variable Zr (99 ± 77 ppm) contents sympathetic with Fe- and Mg-tholeiites, respectively (Hall and Plant, 1992). The dolerites are particularly highly Ti-enriched (> 2.00 wt.%TiO_2) and moderately Al-depleted (<14.00 wt.% Al_2O_3). All these features agree with 50.80 ± 4.01 wt% SiO_2, 1.22 ± 0.50 wt%TiO_2, 15.17 ± 2.01 wt% Al_2O_3, and 77 ± 34 ppm Zr contents indicated by MHBR.

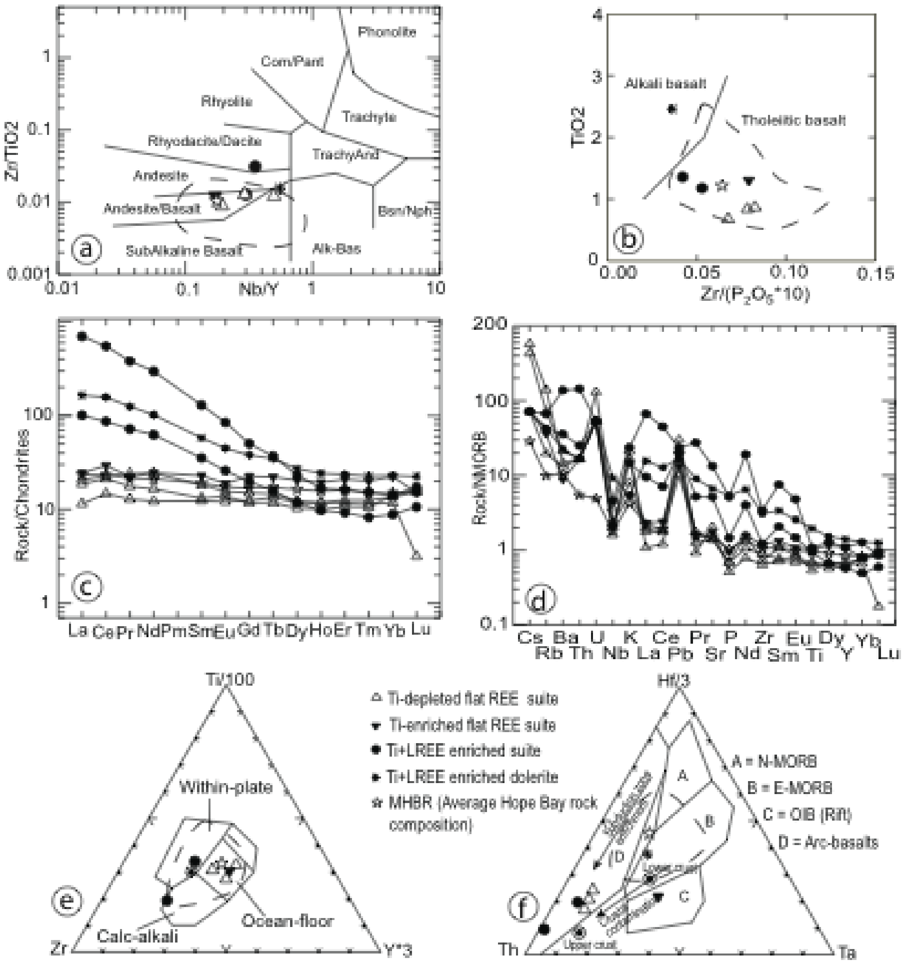

Figure 1: Classification of the MHBR and EL rocks using (a) Nb/Y vs Zr/TiO_2 and (b) TiO_2 vs $Zr/(P_2O_5*10)$ diagrams after Winchester and Floyd (1976, 1977); (c) Chondrite-normalized REE diagram, and (d) N-MORB-normalized spider diagram; (e) Zr-Ti-Y ternary (Pearce and Cann, 1973), and (f) Th-Hf-Ta ternary (Wood et al., 1980) tectonic setting discrimination diagrams. Dotted line/field indicates the plotting area of the 63 HBB rock samples.

Varied Mg# [$Mg/(Mg+Fe^{2+})$] calculated on the basis of $Fe^{3+}/Fe^{2+} = 0.2$ in both HBB+EL rocks (15.20 ± 5.80 and 19.70 ± 4.92, respectively) denote important fractionation of their protolith magmas, with EL rocks relatively Mg-enriched. Indeed, very low (< 0.7) to high (> 1) La/Nb ratios suggest that these rocks originated from both enriched and depleted mantle sources (Sun and McDonough, 1989). Also, the Ti-depleted suite and MHBR on a chondrite-normalized REE plot yield flat REE pattern with slight positive Ce anomaly, whereas Ti-enriched rocks, including the dolerites, distinguish into flat REE with no Eu anomaly and LREE-enriched suites comparable to Island-Arc Tholeiites (IAT) and related high-K calc-alkaline basalts, respectively (Fig. 1c). Conversely, N-MORB-normalized profiles regardless of the rock group depict highly incompatible element enrichment including Th+Ce, and significant Nb (Ta) and Ti depletion characteristic of magmas generated in active subduction margin settings (Fig. 1d).

Using Ti/V ratios and Ti-Zr-Y ternary diagram shows most samples grouping into the Mid-Ocean Ridge Basalt (MORB) and Volcanic-Arc Basalt (VAB) fields with a few plotting as Within-Plate Basalts (WPB) (Fig. 1e). The Th-Hf-Ta ternary plot confirms this distinction of magmas (Fig. 1f).

Discussion

N-MORB- and chondrite-normalized plots show that both EL+HBB rocks principally have VAB affinity contrasting with VAB, WPB, and MORB settings highlighted by Ti-Zr-Y and Th-Hf-Ta diagrams. MORB + VAB affinities are ascribed to contaminated shallow mantle-derived melts, whereas WPB signature reveals partial melting of deep mantle in the garnet stability field. In other words, HBB+EL mafic meta-igneous rocks are derived from mixed magmas of both shallow and deep mantle sources. Together with high Th+Ce and relative Nb+Zr enrichment exhibited by the rocks, these geochemical features could be attributed to a back-arc basin emplacement setting with an attenuated continental crust. This interpretation is consistent with the local geology and, within the Slave Province, is analogous to the interpreted setting of the Yellowknife greenstone belt (Goodwin et al., 2006).

Conclusion

Mafic meta-igneous rocks of HBB and EL belt are interpreted to have derived from the same magmatic protoliths, including tholeiitic- to calc-alkaline basalts and basaltic andesites. All these rocks pertain to varying magmatic lineages represented by Ti-depleted flat REE basalts, Ti-enriched flat REE basalts, and Ti+LREE-enriched basalts. Like the better studied Yellowknife greenstone belt in the southern Slave craton, rocks in the HBB and EL are thought to have evolved from deep and shallow mantle-derived melts emplaced in a back-arc setting over attenuated continental crust.

Acknowledgements

We are grateful to the Canada – Nunavut Geoscience Office for financially supporting this work. Newmont is also thanked for its significant financial and logisticical support for the field work.

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