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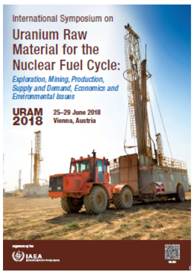

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Geochemical signatures of U-bearing metasomatic deposits of the Central Mineral Belt, Labrador, Canada.

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INTRODUCTION

The Central Mineral Belt (CMB) of Labrador hosts multiple U±Cu±Mo±V prospects and deposits, including some with affinities with albitite-hosted uranium deposits and others with iron-oxide-copper-gold (IOCG) deposits [1, 2, 3]. Extensive exploration campaigns during the mid-2000s generated a large amount of industry geophysical and geochemical data.

Worldwide, IOCG deposits hosts significant polymetallic resources with the Olympic Dam deposit being the largest uranium producer in the world. Over the past decade, the demonstration of a diagnostic evolution of alteration facies within IOCG systems has led to the development of geochemical tools useful to detect prospective areas [4]. In the CMB, geological and mineralogical characteristics analogous to those of IOCG systems include pervasive regional sodic alteration prior to brecciation and iron oxide ± K-feldspar alteration and subsequent mineralization. Thus, it is worthwhile to explore potential links between IOCG and the CMB uranium mineralization as means to advance exploration models.

The Central Mineral Belt uranium geochemistry database (CMBUG; [5]) consists of over 40 000 data entries compiled from Geological Survey of Newfoundland and Labrador data files and drill core geochemistry submitted in mineral assessment reports for the period 2002 to 2011. In this work, we provide a general characterization of the CMBUG data in terms of their alteration types, along with a preliminary principal component analysis done on a smaller data suite of the CMBUG.

GENERAL GEOLOGY

The regional geology of the CMB described herein is summarized from [1, 6, 7, 8, 9, 10, 11, 12, 13],]. The Archean Nain Province gneisses are the basement to the variably deformed tonalite, granodiorite and granite intrusions of the Kanairiktok Intrusive Suite (KIS), both of which are transected by 2.23 Ga Kikkertavak dykes.

The Paleoproterozoic (younger than 2.2 Ga) metavolcanic and metasedimentary packages of the Moran Lake and Post Hill groups unconformably overly the Archean gneisses and KIS intrusions. The Post Hill Group (northeastern CMB) is overlaid by mixed sedimentary and bimodal volcanic rocks of the Aillik Group. The Moran Lake Group (southwestern CMB) is unconformably overlain by the Bruce River Group, which consists of conglomeratic arkose and sandstone covered by a thick sequence of 1.7 Ga felsic volcanic rocks. The youngest supracrustal sequences in the CMB are the Letitia and Seal Lake groups. The ca. 1.3 Ga Letitia Lake Group is dominated by alkaline volcanic rocks that are overlain by sedimentary and mafic volcanic rocks of the Seal Lake Group.

The Archean intrusions and Paleoproterozoic sequences were metamorphosed (up to amphibolite facies) and variably deformed by at least three orogenic episodes (Makkovikian: ca. 1.8–1.7Ga; Labradorian: 1.7–1.6 Ga; Grenvillian: ca. 1.0 Ga).

The CMB U±Th±Cu±Pb±Zn mineralization occurs within all the Archean to Paleo- to Mesoproterozoic intrusive (e.g. Two Time prospect), volcanic (e.g. Moran Lake Upper C and Michelin deposits) and sedimentary (e.g. Anna Lake prospect) rocks. Mineralization styles include breccia- (e.g. Two Time and Moran lake Upper

C zone) and fracture-hosted (e.g. Anomaly No. 17 prospect) plus disseminated (e.g. Anna Lake prospect) mineralization. However, in most cases ore-bearing events are preceded by moderate to pervasive sodic metasomatism (e.g. Michelin deposit) and iron oxide replacements or breccia infill (mainly hematite).

ANALYTICAL METHODS

The major and trace element analyses compiled in the CMBUG were obtained from various laboratories mainly using 'total digestion'(TD) techniques. The TD techniques rely on a mixture of three to four different acids to attempt to fully dissolve samples followed by inductively couple mass spectrometry analysis to provide relatively complete geochemical results. Although TD techniques are typically effective, incomplete digestion of the sample is still possible due to the presence of highly resistive minerals. Thus, the TD is best considered a 'near-total'digestion. In addition, elements that may volatilize during TD (e.g. As, Se, Te and U) may be underrepresented in the analyses. Less commonly, samples in the CMBUG were analyzed by a mixture of lithium metaborate/tetraborate fusion, instrumental neutron activation analysis (INAA) and X-ray fluorescence (XRF) techniques. The combination of these techniques allow a better quantification of major and trace elements contained in resistive minerals (e.g. magnetite; rare-earth bearing minerals).

DATA DISTRIBUTION

The CMBUG encompasses over 40 000 data points from multiple locations within the CMB. However, over 95% of the data are from six main areas: Moran, Jacques Lake, Snegamook, Michelin, Anna Lake, Kitts-Post Hill and Kanairiktok (see figures 1 and 2 in [5]). These areas may represent one or many prospects and/or deposits. For example, the Moran dataset includes the Moran Lake Upper C Zone deposit and Moran Lake B and Armstrong prospects. On the other hand, the Jacques Lake dataset only comprises samples from the Jacques Lake deposit. In this report, data characterization is restricted to the aforementioned main locations and no further geographical distinction was considered.

ALTERATION CHARACTERIZATION

The alteration facies hosting uranium mineralization in the CMB were evaluated through the [4] alteration discrimination plot. For this purpose, only samples having non-zero Al, Na, K, Ca, Mg and Fe concentrations are selected. To better illustrate the data description below we refer the reader to figures 1, 5 and 6 in [14].

In general, the CMBUG samples present significant scatter with most samples plotting in the least altered and Na and Fe-(Mg) alteration fields. In the Snegamook and Jacques Lake areas, most samples are Na-altered and a lower portion of those data plot mainly within the unaltered and K alteration fields. In the Anna Lake, Kanairiktok, and Michelin areas, most samples plot within the least altered and Na alteration fields, with less significant clusters consistent with K, Ca-K-Fe and K-Fe altered rocks. The Moran Lake data accounts for the greatest portion of the CMBUG database and shows the largest scatter. Similar to other CMB locations, most samples are contained in the least altered, Na and Fe-(Mg) alteration fields, with a relatively minor portion plotting within the K, Ca-K-Fe, K-Fe, Fe-rich Ca-K-Fe and Ca-Fe alteration fields. Notably, it is observed that distribution of high uranium contents is not associated to a particular type of alteration type, instead uranium mineralization is found in almost all fields on the alteration plot, including that representing least altered rocks.

In IOCG deposits, sodic alteration is commonly associated with deeper and higher temperature parts of the hydrothermal system that evolve in time and over distance to Ca-Fe and K-Fe alteration assemblages [2, 3, 4, 15, 16]. Generally, rocks contained in the K-Fe field are considered as geochemically 'mature'and economically fertile in terms of base, precious and speciliazed metals. In the CMB, the data suite as a whole does follow the prograde path of IOCG evolution, rather it either evolves from the Na to Fe-(Mg) alteration or from the Na to K alteration which is typical of telescoping of alteration facies. Such telescoping leads to significant overprints that result in a shift of major elements contents into the least altered field. However, it is possible that mineralization hosted in veinlets, fracture-coatings and/or disseminated in relatively unaltered rocks could also account for the high uranium content of rocks in the least altered field.

In summary, the preliminary interpretations of the data distribution in the alteration plot are that: i) Na alteration is the most common alkali alteration in the CMB; ii) emplacement of iron oxide minerals is generally decoupled from potassium (few samples located in the K-Fe alteration field); and iii) the mineralization is not necessarily strictly associated with alkali or iron oxide altered rocks. However, the latter may result from alteration overlaps that shift the major element composition of mineralized rocks to the least altered field. Furthermore, as the CBUG relies on industry data submitted for analysis (i.e., targeting a specific style of mineralization such as the uranium-bearing Na+/-Fe style observed at the Michelin deposit), there is potential for sampling bias in the data. As such, it is possible that certain alteration facies are underrepresented in the database.

PRINCIPAL COMPONENT ANALYSIS

The statistical characterization of whole-rock geochemistry requires data treatment prior to analysis. The centred log-ratio transformation overcomes the closure constraint inherent to geochemical data [17]), which allows the use of multivariate statistical tools (e.g. principal component analysis) to identify geochemical processes. A suite of ca. 5000 whole rock analyses obtained from TD were transformed using the centred log-ratio technique prior to principal component analysis (PCA).

As a whole, base metals tend to co-variate roughly together with cobalt, vanadium and iron forming a subgroup distinct from cadmium, chromium, zinc, copper and nickel. The association of the iron, cobalt and vanadium is likely related to the incorporation of the latter two elements in iron oxides such as magnetite and hematite. From the PCA it is also remarkable that alkali alteration related elements (e.g. potassium and sodium) do not correlate directly with uranium, as is also suggested by the alteration plot. However, this lack of association, especially with sodium, might be masked by the fact that proportionally, the sodium alteration in the CMB is more common and regionally widespread in comparison to the local occurrences of uranium mineralization. In addition, uranium might have been remobilized and concentrated along structural traps (e.g,. unconformity, shear zones) even though it was first precipitated within the iron oxide alkali-calcic alteration systems

CONCLUSIONS

Evaluation of the data in the alteration plot indicates that: i) sodic alteration is the most common alkali alteration in the CMB; ii) the emplacement of iron oxide minerals is generally decoupled from potassium; and iii) uranium mineralization is not necessarily associated to alkali or iron oxide altered rocks. Nevertheless, alteration type overlaps may shift the major element composition of mineralized rocks to the least altered field. The absence of an association of uranium and other base metals with alkali elements is also recorded by PCA. However, further statistical analysis based on the individual alteration types and by geographical location of the CMBUG is necessary to fully characterize the mobility of uranium and base metal elements and their association with alteration facies.

This report is a contribution to NRCan's Targeted Geoscience Initiative (TGI) program, under the metal pathways and traps in polymetallic (U +/- Fe, Cu, Au, REE) metasomatic ore systems activity.

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Country or International Organization

Canada

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