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# Geochemical signatures of uraninite from iron oxide-copper-gold (IOCG) systems of the Great Bear magmatic zone, Canada

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Comparative Analysis

As presented by Fryer and Taylor (1987), Pagel et

I. (1987), Maas and McCulloch (1990), Hidaka et

lercadier et al. (2011), chondrite-normalized REE

patterns of uraninite are diagnostic for deposit

types, reflecting distinct genetic conditions

(different combinations of fluid chemistry, T

source materials, etc.). Recent technological

advances permitting in-situ analysis (SIMS and

LA-ICP-MS methods) have facilitated analysis of

least-altered grains with greater accuracy and

and affiliated systems are most similar to

al., (1992), Fayek and Kyser (1997), Hidaka and

Gauthier-Lafaye (2001), Cuney (2010) and



Representative chondrite-normalized REE patterns of uraninite from

### Introduction

during formation of these younger deposits (Kidd and Haycock, 1935; Lang et al., 1962; Gandhi et al, 2013).

The GBMZ is interpreted as an continental arc that is composed of volcanic, volcanic and volcaniclastic rocks intruded by several Hildebrand et al., 1987; Azar, 2007).

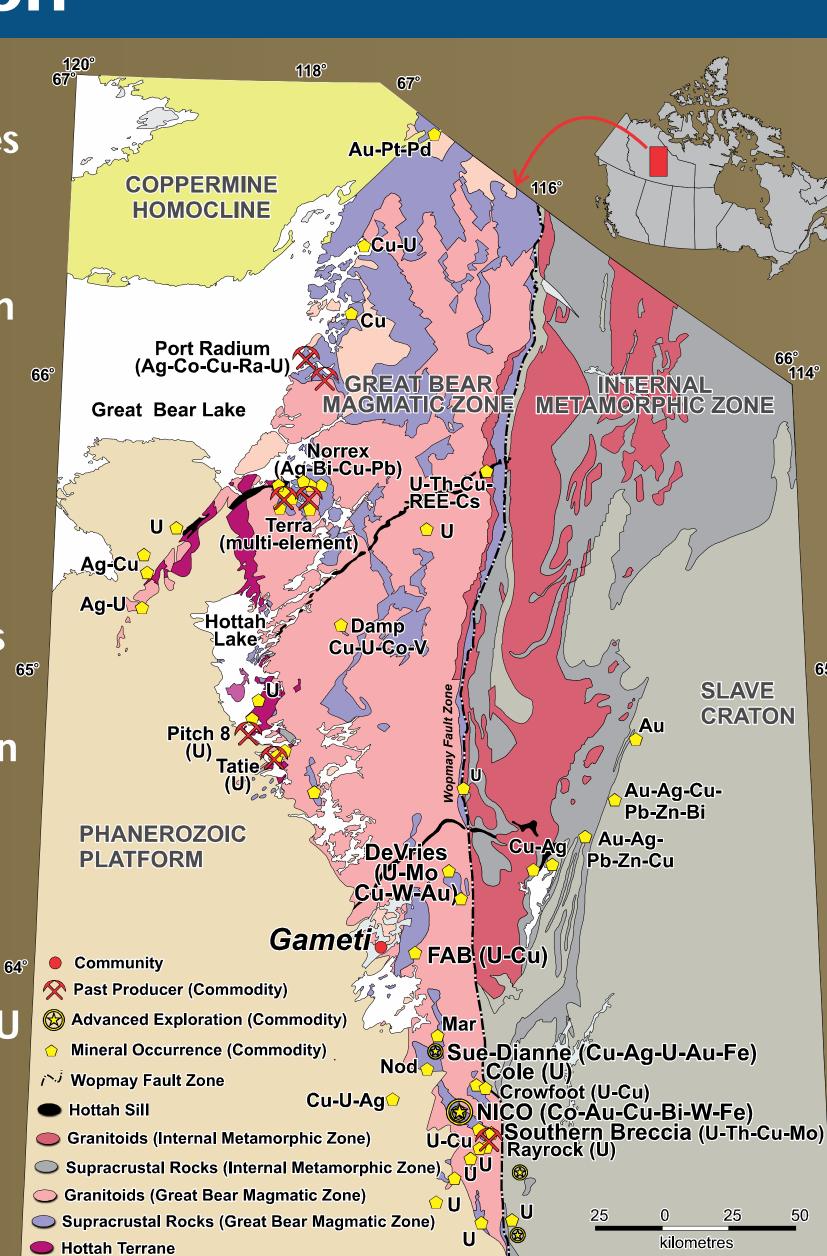


Figure 1. The GBMZ continental arc is situated on the western margin the Wopmay orogen. It developed on the composite Hottah terrane overlying the ca. 1.88 Ga Treasure Lake Group sedimentary basin following the short lived Calderian orogeny (Gandhi et al., 2001;

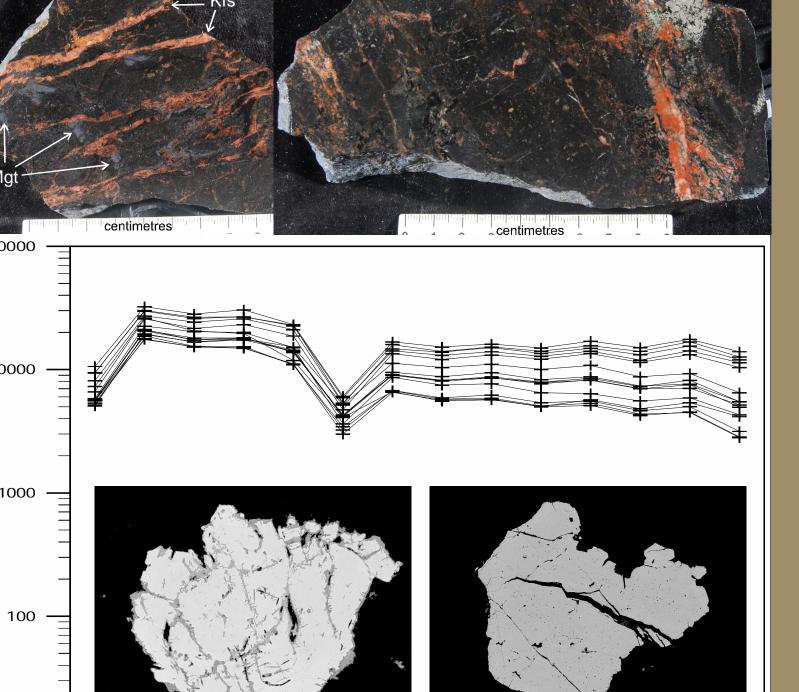
### Geochemical signatures of uraninite in IOCG and affiliated systems from the GBMZ and East Arm

The Fab Lake magnetite-group IOCG system is located in the south central GBMZ (Fig. 1) within a succession of rhyolitic to andesitic shoshonitic rocks.

Alteration assemblages: Na, Na-Ca-Fe, Ca-Fe and Ca-Fe-K overprinted by hightemperature K-Fe assemblages.

These gave rise to magnetitecemented hydrothermal crackle breccias developed in tension fractures, extensive amphibole + magnetite-bearing replacement fronts and K-feldspar + magnetite alteration

Uraninite forms anhedral grains in magnetite+K-feldspar veins associated with chalcopyrite and pyrite.



Top: Photographs of Ca-Fe and K-Fe altered, U-bearing samples fro the Fab prospect. Middle: chondrite-normalized REE patterns o uraninite from the Fab IOCG prospect. Chondrite normalization value of McDonough & Sun (1995). Insets: Representative BSE-images of uraninite grains with variable coffinite alteration along the grain

The Southern Breccia is a 3 km-long

Alteration: Na (albite), Ca-Fe (amphibole + magnetite), K-Fe (Kfeldspar/biotite + magnetite/ilmenite) K±Fe (K-feldspar + biotite) and Mg-Fe

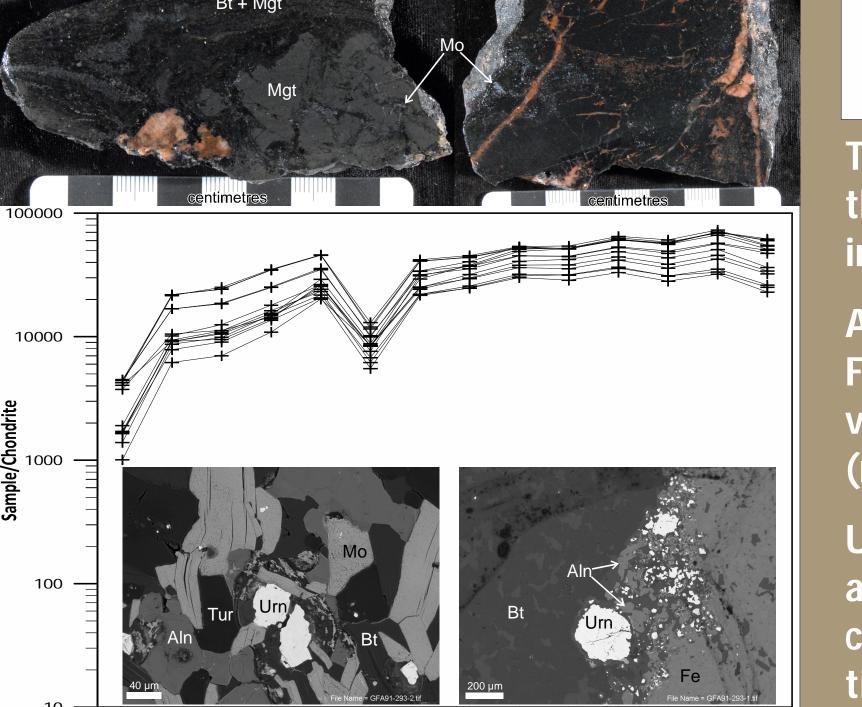
Late, northeast-trending brittle faults remobilized U into earthy hematite+ chlorite+K-feldspar veins.

The Nori occurrences at DeVries Lake (Fig.1) are within foliated and altered metasiltstones in the Central GBMZ.

Alteration is stratabound to discordant high 1 K-Fe (biotite + K-feldspar + magnetite).

Uraninite is in veins of biotite + magnetite accompanied by K-feldspar, tourmaline, molybdenite, allanite-(Ce), pyrite and chalcopyrite (Gandhi, 1993; Ootes et al., 2010; Acosta-Góngora et al. 2011).

Mild LREE depletion may relate to co-

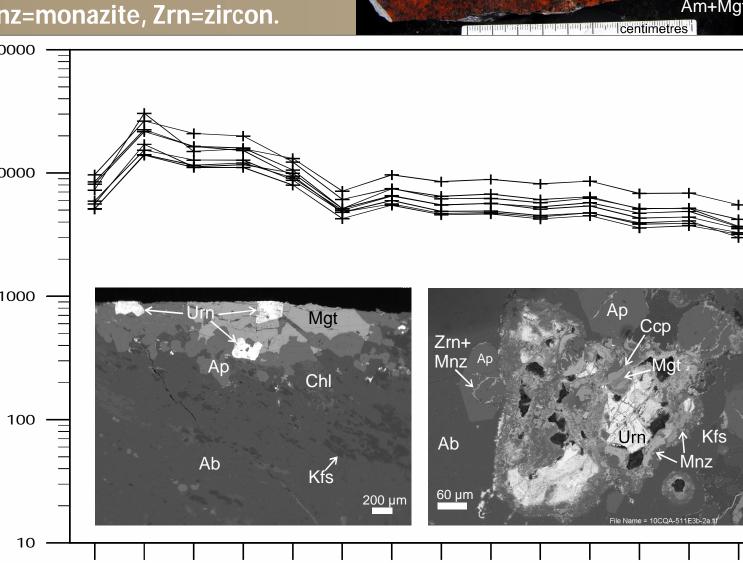


mples from the Nori prospect. Middle: REE patterns of uraninit g chondrite normalization values of McDonough & Sun (199! Insets: Representative BSE-images of uraninite (Urn) grains with allani Aln), biotite (Bt), tourmaline (Tur), molybdenite (Mo) and magnetite

ight: Location of the East Arm and photograph of U-bea prospect. Bottom: REE patterns of uraninite from the Ri Sun (1995). Inset: Representative BSE-image of uraninite eur hosted within intergrown magnetite+biotite groundmagnetite

The Ridley iron oxide-apatite (IOA or Kiruna-type) veins are located in the East Arm of Great Slave Lak

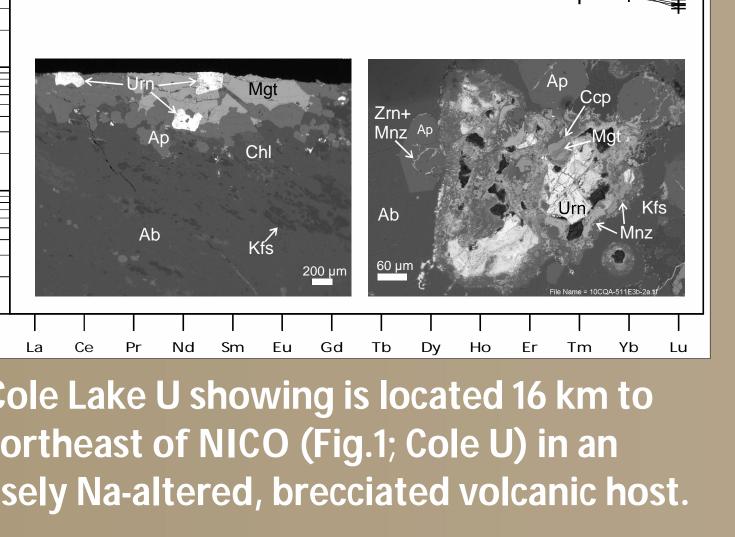
The prospects are characterized by lenses of pegmatitic actinolite + magnetite + apatite ± K feldspar veins with erratically distributed uraninit chalcopyrite, pyrite and carbonate hosted within a fractured and variably Na-altered quartz monzonit laccolith that intrudes sedimentary rocks of the East Arm Basin (Badham, 1978; Jefferson 2013; Potter



The Cole Lake U showing is located 16 km to ne northeast of NICO (Fig.1; Cole U) in an ntensely Na-altered, brecciated volcanic host.

Alteration assemblage: Na overprinted by Ca-Fe±K (amphibole + magnetite + K-feldspar) veining that transitions into HT K-Fe (magnetite + K-feldspar) assemblages.

Uraninite occurs in magnetite, K-feldspar, amphibole and apatite veins with trace chlorite, zircon, monazite, chalcopyrite,



#### Preliminary Interpretations REE concentrations in uraninite determined by LA-ICP-MS from IOCG and affiliated occurrences produce remarkably consistent chondrite-normalized REE patterns that are inferred to reflect precipitation from high temperature fluid(s) (>350°C) and are remarkably

precision. REE signatures of uraninite from IOCG Mercadier et al., (2011; intrusive, syn-metamorphic, Cigar Lake, SIMS method) and this study (Key Lake; LA-ICP-MS method)

intrusion related U deposits, wherein the dilational nature of the uraninite crystal structure at

crystallization (Mercadier et al., 2011). The REE pattern of remobilized uraninite (e.g. Southern

Breccia) mimics that of the host rocks, reflecting precipitation from lower T fluids. It distinctly

nigh-T (>350°C) permits inclusion of large amounts of REEs without fractionation during

contrasts the flat pattern with deep Eu anomaly of primary high-T uraninite.

similar to those of intrusion-hosted, magmatically precipitated uraninite. Moderate to high Th contents in uraninite also mirror magmatic-derived compositions, ranging from 0.25 to 12.9 wt. % Th.

• Strongly negative Eu anomalies are interpreted to reflect scavenging of metals during high temperature Na alteration under reducing conditions and subsequent precipitation from fluids that evolved and equilibrated through progressive Na (albite), Ca-Fe (amphibole + magnetite) and ultimately K-Fe (K-feldspar/biotite + Fe-oxides) alteration phases (Fig. 2).

 Mineral parageneses record precipitation of U minerals during K-Fe alteration accompanied by significant changes in fluid conditions and compositions. During this transitional stage of IOAA evolution, magnetite-dominant (reduced) K-Fe alteration was overprinted by hematitebearing (oxidized) K-Fe alteration.

 Alteration of uraninite to coffinite at most of the occurrences also points to increasing silica activity in the residual fluids, consistent with field observations of epithermal-style veins peripheral to the IOAA systems.

 Secondary (interpreted as re-mobilized) uraninite is characterized by chondrite-normalized REE patterns similar in slope to those of the altered host rocks (e.g. Southern Breccia), typical of lower temperature, vein-type U mineralization (Mercadier et al., 2011).

## **IOCG - IOAA Zoning Model**

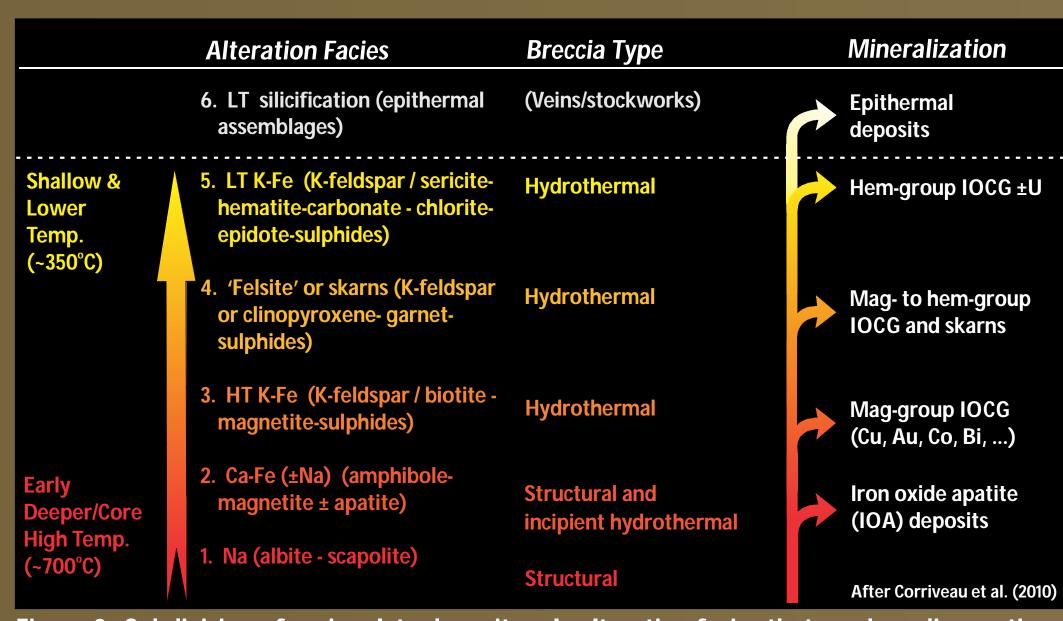


Figure 2. Subdivision of regional- to deposit-scale alteration facies that produce diagnosti lithological, mineralogical, chemical, and geophysical characteristics (Belperio et al., 200 Benavides et al., 2008; Corriveau et al., 2010; Skirrow, 2010).

the PhD studies of JFM. Modified from poster presented at GSA 2013.

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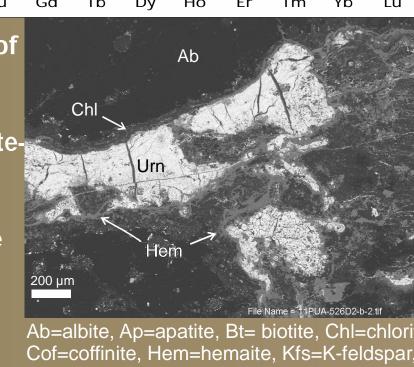
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IOCG deposits are polymetallic hydrothermal mineral occurrences that contain economic Cu and Au concentrations with potential enrichment in Ag, U, REE, Bi, Co, Ni, P, Nb, etc., set in abundant low-Ti iron-oxide (magnetite, hematite) gangue minerals or associated alteration. The sulphidedeficient ore includes native elements and lowsulphur base-metal sulphides and arsenides, such as chalcopyrite, bornite, chalcocite, pyrrhotite and arsenopyrite (Corriveau, 2007; Corriveau and Mumin, 2010). All IOCG deposits are enclosed within regional-scale, alteration haloes of intensely iron oxide-alkali-altered metasomatized rocks and breccias (Fig. 2).

Uraninite, brannerite and coffinite occur within magnetite-bearing K-Fe alteration with ± pyrite ± chalcopyrite ± molybdenite ± bismuthinite ± galena in magnetite + ilmenite + K-feldspar ± biotite-cemented breccias developed



La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb

Potter, E.G., Corriveau, L., Montreuil, J-F., Yang, Z., and Comeau, J-S, 2014. Geochemical signatures of uraninite m iron oxide-copper-gold (IOCG) systems of the Great Bear magmatic zone, Canada; Geological Survey of © Her Majesty the Queen in Right of Canada 2014. This publication is available for free download through



Although the Olympic Dam deposit contains the world's largest recoverable U resource, very little is known regarding the processes and timing of U enrichment in iron oxide-copper-gold (IOCG) systems. The Great Bear magmatic zone (GBMZ) in the Northwest Territories of Canada is an ideal natural laboratory to study U in iron oxide-alkali-altered (IOAA) systems. Reexamination of excellent glaciated 3D exposures of the weakly to un-deformed/ unmetamorphosed IOAA systems has shown these systems to encompass not only IOCG deposits (magnetite, magnetite-hematite and hematite group IOCG deposits; cf. Williams, 2010), their alteration and breccia zones, but also the wide spectrum of affiliated deposits that form within such systems such as iron oxide-apatite (IOA or Kiruna-type) deposits (Williams et al., 2005; Potter et al., 2013a), iron oxide-uranium (IOU; Hitzman and Valenta, 2005; Skirrow et al., 2011), some skarns (Gandhi, 2003; Williams, 2010; Corriveau et al., 2011) as well as alkaline intrusion-hosted IOCG deposits (Groves et al., 2010). The GBMZ also hosts historic polymetallic U-bearing vein @ systems (e.g. Port Radium, Rayrock) attesting to the availability of U

1873 – 1865 Ma, predominantly intermediate to felsic suites of sub-63° Phottah Terrane generations of felsic plutons from 1870 – 1855 Ma (Gandhi, 1988; Gandhi et al., 2001; Bennett and Rivers, 2006; Ootes et al., 2013;

corridor of U-rich polymetallic showings developed within the al zone of the Lou IOAA system which also hosts the co-genetic NICO Au-Co-Bi-Cu magnetite-group IOCG deposit (Montreuil et al., accepted).