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**GEOLOGICAL SURVEY OF CANADA
OPEN FILE 7643**

**Dataset of geochemical data from iron oxide alkali-altered
mineralizing systems of the Great Bear magmatic zone,
Northwest Territories**

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Abstract

The Great Bear magmatic zone is a Paleoproterozoic calc-alkaline to shoshonitic volcano-plutonic belt in the Northwest Territories of Canada. The region hosts regional-scale iron oxide and alkali-alteration mineral systems with polymetallic iron oxide copper-gold (IOCG) deposits and prospects as well as iron oxide±apatite, skarn and albitite-hosted uranium mineralisation. In the course of phase-three Targeted Geoscience Mapping program and phase-one Geo-mapping for Energy and Minerals program as well as in 1973 for the Bear Province lithogeochemical survey project, a total of 1720 samples were collected across these iron oxide alkali alteration systems between 2005 and 2012 and their chemical composition analysed by complementary methods. In this Open File, we report over 3500 lithogeochemical analyses (including analyses from distinct laboratories, duplicates and standards). In these samples, metals above the NORMIN cut-off grades for mineral showings include base, precious, strategic and specialised metals including rare-earth elements as well as uranium and thorium. The format chosen for the data set is tailored for geographic information systems (GIS); all samples are georeferenced and as such the data set locates all the anomalous metal concentrations encountered during the aforementioned projects. Metadata is being provided on the sampling protocols, the analytical methods, and the quality control results. This complete data set of analyses is also being published to serve as an electronic supplement to current and future scientific publications associated with these projects as well as a support for a subsequent open file where the best results per elements will be compiled. As such, this dataset provides the documentation for the commonalities observed in the chemical fingerprints of each hydrothermal alteration facies across the varied systems and anchor the refined lithogeochemical exploration methods developed for IOCG and affiliated deposits. In addition, the dataset can be used as baseline knowledge for the natural geological environment of the belt that guides the natural metal distribution in glacial sediments, soils, water and biomass.

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Introduction

Under phases three and four of the Targeted Geoscience Initiative (TGI-3) and phase one of the Geo-mapping for Energy and Minerals (GEM) program, the Geological Survey of Canada of Natural Resources Canada has collaborated closely with the Northwest Territories Geoscience Office, the Community Government of Gamètì, the Tłıchq Government, academia and private sector to highlight and further test the mineral potential of the Great Bear magmatic zone (GBMZ) in the Northwest Territories for polymetallic iron oxide copper-gold (IOCG) and affiliated deposits (Figure 1). The Northwest Territories Geoscience Office led a program of broad-scale systematic geological mapping across the central GBMZ and its bounding terranes. The Geological Survey of Canada headed the TGI-3 Deep Search project, the TGI-4 Uranium System project and the GEM Multiple Metals IOCG-Great Bear project, thematically focused on IOCG mineral potential of the GBMZ, ore deposit models, exploration methods and exploration technologies. The community of Gamètì, Fortune Minerals Limited and Alberta Star Corporation provided essential logistical support.

The TGI teams developed a conceptual model that placed the extraordinary range of IOCG deposits in terms of a systemic progression of hydrothermal alteration facies from depth to surface along very high geothermal gradients. A fundamental consequence of the severe chemical mobility associated with pervasive fluid infiltration and coupled dissolution-precipitation mechanisms during prograde and retrograde iron oxide-alkali alteration is the formation of multiple metals magnetite- and hematite-group IOCG deposits, and affiliated iron oxide±apatite deposits, skarn and albitite-hosted uranium deposits within a continuum to porphyry and epithermal deposit types (Corriveau et al. 2010a,b; Mumin et al. 2010). This model was validated across the GBMZ during the GEM program and provided a framework to re-assess the linkages among the diverse, seemingly disparate, metal associations and host rocks of the historic mineral showings (Skanderberg 2001). The host mineralising systems studied have elevated base (Fe, Cu, Pb, Zn, Ni), precious (Au, Ag, PGE), specialised/strategic (Bi, Co, Mo, V, Nb, Ta, HREE, LREE) and/or actinides (U, Th) metals. Between 2005 and 2011, the GEM and TGI-3 projects sampled a vast array of alteration types with and without known mineralisation across the belt for whole-rock geochemistry (Figure 2) and sent them for analysis at its partner laboratory, the Institut national de la recherche scientifique (INRS-ETE), as well as at commercial laboratories. The GEM program also supported strategic re-analysis of samples from the 2200 whole-rock powder collection derived from GSC's 1973 Bear Province lithogeochemical survey (project 730003). This belt-scale sampling survey targeted acid porphyry rocks of the Proterozoic Bear Province (Garrett 1974). The field description for these samples and some early geochemical data are published in Garrett (1975, 1990).

Current research based on the geochemical data provided in this Open File has enabled the GEM team to: 1) recognise new local IOCG, iron oxide±apatite and albitite-hosted uranium potential across the belt; 2) validate the predictive capabilities of IOCG/IOAA alteration facies mapping in areas of known mineralisation and past-producing mines as well as during regional field mapping; 3) infer the maturity and potential metal associations of prospective areas; 4) formulate lithogeochemical vectors (pointers) to mineralisation including alteration index and discriminant diagrams; and 5) provide case studies specifically for IOCG exploration in Canadian terrains (Corriveau et al. 2010a, b, 2011; Mumin et al. 2010; Acosta et al. 2013, 2014; McMartin et al. 2011; Hayward et al. 2013; Montreuil et al. 2013, 2014; Potter et al. 2013a, b). Finally, the dataset contributes baseline information of the natural metal and atypical rock composition distribution of the bedrock which in turn is a controlling factor in the chemical composition of glacial sediments, soils, water and biomass. To better highlight the current knowledge of the GBMZ, papers, maps and databases close to completion are being listed herein as in preparation and included in the reference list.

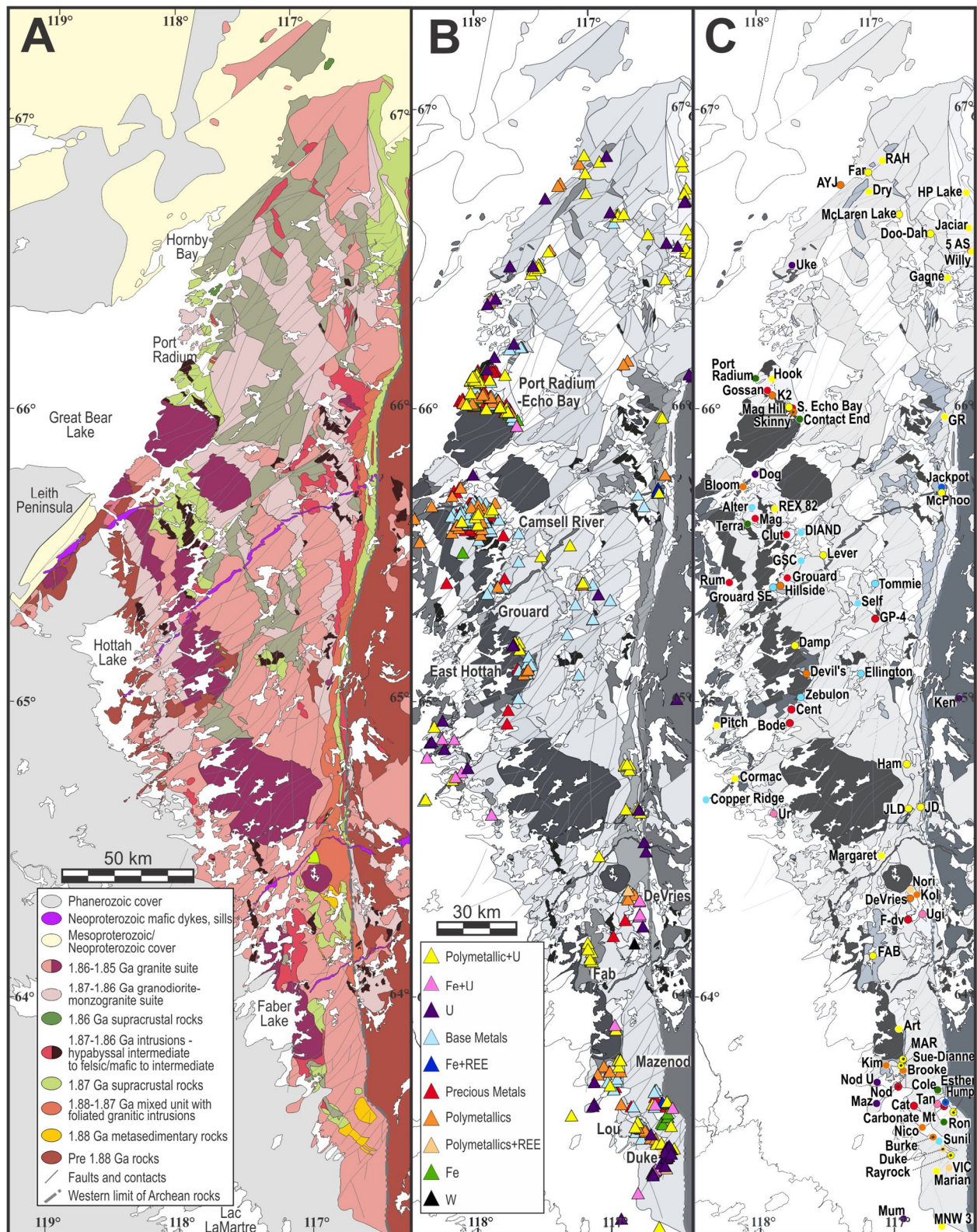


Figure 1: A Synthesis geological map of the Great Bear magmatic zone at the western margin of the Slave Craton from Corriveau et al. (in preparation a), derived from Hildebrand (2011, 2014), Jackson (2008), Jackson and Ootes (2012), Potter et al. (2013), Gandhi et al. (2014), and Hildebrand et al. (2014). **B** Metal associations of deposits, mineral prospects and showings from NORMIN database (www.nwtgeoscience.ca/normin) and Bretzclaff et al. (in preparation). **C** Location of representative prospects and geophysical footprints of IOAA systems and potential systems after Hayward et al. (2013).

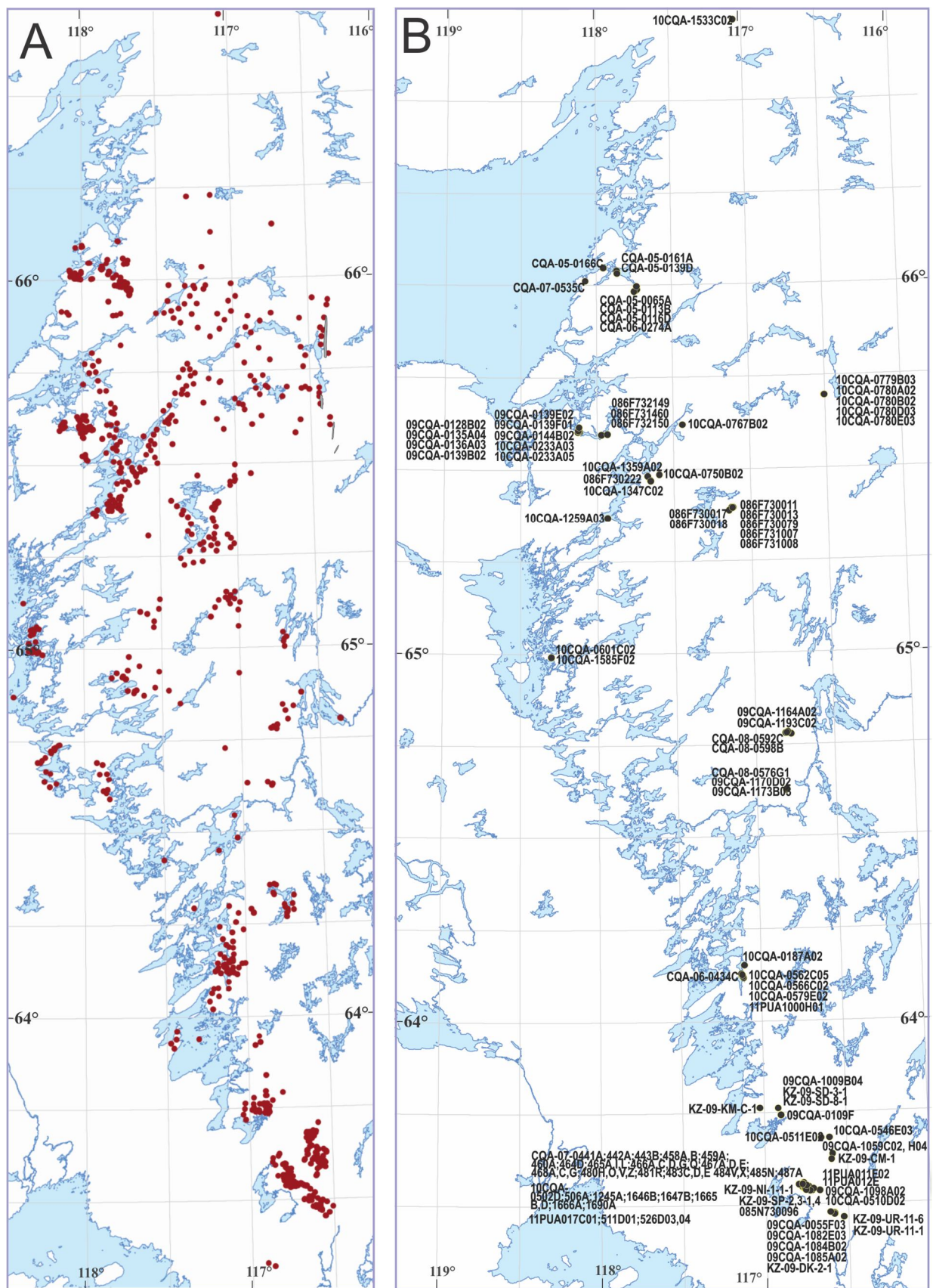


Figure 2: A Distribution of lithogeochemical samples for this dataset. B Samples with geochemical data above the NORMIN threshold to classify a metal occurrence as a showing (NWT Geoscience Office 2014).

Iron oxide alkali-altered (IOAA) systems overview

The extraordinary range of IOCG and affiliated iron oxide±apatite (IOA), skarns and albitite-hosted uranium deposits and prospects of the GBMZ in the Northwest Territories of Canada fall under the umbrella of the IOAA deposit type (Corriveau et al. 2010a, b; Porter 2010). Worldwide, IOAA districts commonly form in response to voluminous magma emplacement of continental calc-alkaline, shoshonitic and I- to A-type affinities (Williams et al. 2005; Mumin et al. 2010; Porter 2010). As large volumes of high-temperature (800 to 500°C), highly-saline fluids infiltrate precursor units, fluid-rock interactions result in continuous metal recharge of the fluids and selective discharge of their metals/cations through evolving physico-chemical properties of the fluid towards surface. The result is the development of systemic sets of alteration mineral parageneses across extreme regional-scale temperature gradients (from upper amphibolite-type temperature conditions to epithermal conditions) (Oliver et al. 2004, 2008; Corriveau et al. 2010b; Harlov and Austrheim 2012; Somarin and Mumin 2013). Intense alteration footprints can replace precursor rocks over tens of metres to kilometres and also include extensive veining, brecciation and stockworks. Ultimately, pre-existing units are thoroughly reorganised chemically over hundreds of cubic kilometres (Williams et al. 2005; Hayward and Skirrow 2010; Mumin et al. 2010; Porter 2010; Montreuil et al. 2013) and an extraordinary range of polymetallic deposits can form. Their oxide-rich rather than sulphide-rich ore zones incorporate atypical combinations of commodities (base, precious, rare, specialised/strategic and/or nuclear metals, and industrial minerals). Regional- to deposit-scale Na, Ca-Fe, K-Fe, Fe alteration, breccia and vein parageneses provide practical vectors and guides for exploration (Corriveau et al. 2010b).

The raw geochemical analyses presented in this Open File are from the IOAA systems of the GBMZ. This very large geochemical dataset on IOAA alteration haloes complements available data from IOA and IOCG deposits worldwide (e.g., Marschik and Fontboté 2001; Franchini et al. 2005; Tallarico et al. 2005; Benavides et al. 2008; Day and Granitto 2014). The data set also complements available geochemical data on the least-altered rock types of the GBMZ such as those of Badham (1973) and Hildebrand et al. (1987). In a future contribution, the analyses provided herein will be concatenated into an interpreted dataset where each element will be provided according to the best available analyses according to the QAQC provided herein.

The Great Bear magmatic zone is interpreted as a Paleoproterozoic continental volcanic arc formed between 1.87 and 1.84 Ga on the volcano-plutonic and sedimentary rocks of the Hottah terrane (Hildebrand et al. 2010) and the margin of the Archean Slave craton (Jackson et al. 2013). Many IOAA systems comprising IOCG and affiliated mineralisation and deposits were formed in the GBMZ between 1873 and 1868 Ma (Davis et al. 2011). Their alteration systems extend for up to 30 km by 10 km at surface, with geophysical signature extending to at least 5 km depth where modelled, and alteration grades from mild and sporadic to complete chemical, mineralogical and textural transformation of precursor (Mumin et al. 2007, 2010; Craven et al. 2013; Hayward et al. 2013). Pre-1.88 Ga hosts consist of metasedimentary rocks of the Treasure Lake Group as well as of units from the Hottah terrane basement at Hottah Lake such as the Zebulon Formation (Reichenbach 1991; Gandhi and van Breemen 2005). The 1.87 Ga precursor rocks consist of volcanic and volcanoclastic rocks of calc-alkaline to shoshonitic affinity and siliciclastic and chemical sedimentary rocks of the LaBine, Dumas and Faber groups, Ellington Lake Complex, and Nadin succession; carbonates are locally stromatolitic (this work; Badham 1973; Hildebrand et al. 1987, 2010, 2014; Gandhi et al. 2001, 2014; Azar 2007; Jackson 2008; Hildebrand 2011, 2014; Jackson and Ootes 2012; Jackson et al. 2013; Ootes et al. 2013; Potter et al. 2013a, b and references therein). Uranium contents of the igneous precursors are anomalously high throughout the GBMZ (Gandhi et al. 2001, 2014; Hildebrand et al. 2010; Ootes et al. 2013). Dykes and porphyritic intrusions that crosscut and were crosscut by IOAA alteration, albitites with hydrothermal zircons, and late-stage titanite-bearing carbonate veins circumscribe the development of the GBMZ IOAA systems and their IOCG

deposits to a ca. 7 m.y. time window at 1.87 Ga (Hildebrand 1986; Gandhi et al. 2001; Davis et al. 2011, unpublished data; Montreuil et al. submitted; Potter et al. submitted).

Hydrothermal alteration in the GBMZ IOAA systems follows a systematic evolution from sodic alteration in the early stages through metasomatic paragenesis consisting of high temperature (HT) calcic-iron minerals (amphibole, apatite, magnetite), evolving to HT potassic-iron minerals (biotite, K-feldspar, magnetite) and then to low temperature (LT) potassic-iron minerals (carbonates, chlorite, hematite, K-feldspar, sericite) and LT calcic-iron (epidote, carbonates, chlorite). In the near surface environments, epithermal alteration and quartz veins typically follow the main IOAA alteration stages and can concentrate the metals previously enriched in the IOAA system to which they are affiliated (Corriveau et al. 2010a, b). Each hydrothermal alteration facies formed in an IOAA system has a specific chemical signature and distinctive metal assemblage (Montreuil et al. 2013). Sodic alteration, the principal leaching stage, has a regional distribution with albitites forming plurikilometre-long corridors along sub-volcanic intrusions and fault zones (Hildebrand 1986; Reardon 1992; Mumin et al. 2007, 2010; Corriveau et al. 2010a, b, in preparation b; Montreuil et al. 2014). High temperature calcic-iron alteration is characterised by significant iron enrichment and can be associated with elevated rare-earth-element (REE) and vanadium contents that may lead to the formation of IOA deposits enriched in vanadium and/or REE (Mumin et al. 2010; this work). Calcic-iron-potassic, HT potassic-iron and LT potassic-iron alteration stages can be, where intense and spatially extensive, associated with IOCG and albitite-hosted uranium mineralisation.

Analytical procedures

Types of samples and sampling protocol

Style, mineral assemblages and textures of hydrothermally altered rocks, veins and breccias and least-altered precursor rocks were documented, sampled and photographed across areas targeted for fieldwork. The concentration of potassium (wt.% K), thorium (ppm eTh) and uranium (ppm eU) were measured across outcrops by portable gamma-ray spectrometers (Radiation Solutions Inc. RS-230 spectrometer equipped with a bismuth germanate detector) and volumetric magnetic susceptibility measurements by portable magnetic susceptibility meters (ZH instruments SM-30). These field measurements supported identification and description of alteration types, the identification of uranium and thorium mineralised zones, and optimised sampling for geochemistry. The prefix “e” (i.e., eTh or eU) denotes that uranium and thorium concentrations were determined indirectly from their daughter products (Bi_{214} and Tl_{208} respectively), assumed to be in equilibrium with their parent isotopes. The gamma-ray spectrometers and the magnetic susceptibility meters facilitated detection and systemic sampling of cryptic to intense potassic/sodic alteration zones, weak to highly anomalous uranium–thorium enrichment and depletion, and subtle to intense iron (magnetite) alteration in the various alteration types.

Samples collected for whole-rock geochemistry were taken on representative host rocks, breccias, alteration fronts (replacement-type alteration) or veins. Sample preparation started in the field, with samples chipped with a rock hammer on their own outcrop to remove weathering and avoid contamination. Crosscutting veins, altered fractures and superimposed or precursor alteration were avoided in order to document the alteration processes and geochemical signatures of individual alteration facies encountered in the IOAA systems. Chips were collected until a sufficient volume of visually uniform rock material was acquired for a representative sample according to grain sizes (Ingamells et al. 1973). Typically volumes of about 250 cm³ were sampled for fine-grained rocks and about 1000 cm³ for coarse-grained rocks. In most cases, the alteration sampled was very intense, pervasively and uniformly developed across the material selected. In contrast, representative hand samples (10x10x10 cm to

30x30x30 cm) were chosen to illustrate as many crosscutting relationships as possible to support detailed petrogenetic studies of IOAA alteration evolution. Hence, in no case can the heterogeneity of the hand specimen be considered to reflect the material analysed for geochemistry. Where the composition of vein material was to be established qualitatively (for veins too small to cut into a single geochemical sample), two samples were taken, one with veins and its host, and another of the host without veins for comparison purposes as exemplified by samples CQA-05-273H and 273i. A distinct sampling campaign took place for the collection of uranium mineralisation and followed a series of guidelines for safe handling and transportation of radioactive material. In addition, some key field relationships and units on flat outcrops were sampled using a portable diamond saw to optimise the sample collections and the associated research. Sub-samples were also collected at selected sites for indicator mineral recovery and this dataset was released separately (Normandeau and McMartin 2013). All the samples were carefully described and given a field alteration name corresponding to the IOAA alteration facies (Corriveau et al. 2010a, b, in preparation b). The sample descriptions will be published in a separate database (Corriveau et al. in preparation b). The sample series from 085N730001 to 086F732615 are re-analysed powders from GSC's 1973 Bear Province lithogeochemical survey (project 730003) (Garrett 1974, 1975, 1990). Sample locations in UTM NAD 83 and descriptions are provided in Appendix 1.

Analytical methods

Sample preparation

Except for the thorium and uranium-rich samples of the Southern Breccia and Fab uranium-rich prospects (09CQA and 10CQA series; high uranium contents were first identified by gamma-ray spectrometry in the field), all samples were crushed in a steel-plated jaw crusher, split and pulverised at INRS-ETE or ALS Minerals using an agate ball or ring mill. Potential pulverisation contaminants consist of Fe, Si, with very small traces (<10 ppm) of Cr, Al, Na, Fe, K, Ca, Mg, Ba, Ce, Sr, and Pb.

Geochemical analysis

Fusion and dissolution of rock powders derived from IOAA metasomatic rock types and mineralisation can be difficult given their atypical mineralogy and modes (including high modal content of highly resistive minerals), their multiple metal mineralisation and in some cases their nearly monomineralic nature. In such cases, the presence of solid residues impairs the ability to obtain accurate geochemical results. In addition, the diversity and atypical combinations of elements in alteration and mineralisation may be the source of unexpected interferences. Contrasting analytical protocols on representative suites of samples through non-destructive and destructive methods (integral unmodified pulverised rocks or chemically dissolved pulverised rocks with or without prior fusion) could thus point out to such problems.

Samples (2005-2011 sample series) were analysed through a combination of inductively coupled plasma mass spectroscopy (ICP-MS) for trace elements and inductively coupled plasma emission spectroscopy (ICP-ES) for major and some trace elements after lithium metaborate fusion and dissolution in dilute nitric acid at INRS-ETE laboratories in Quebec (Appendix 2). Some analyses have also been performed at AcmeLabs certified laboratories in Vancouver. They include ICP-MS analysis after multi-acid digestion for selected samples from the 2005-2009 collections (Appendix 3) and combinations of inductively coupled plasma mass spectroscopy (ICP-MS) for trace elements and inductively coupled plasma emission spectroscopy (ICP-ES) for major and some trace elements after lithium metaborate fusion and dissolution in dilute nitric acid as well as after aqua-regia dissolution for precious and base metals for selected samples from the KZ collection (Appendix 3). In addition, ICP-MS analysis after multi-acid digestion was performed at ALS Minerals for selected samples from the 2010-2011 collection (Appendix 4: methods ME-ICP61, 61a and ME-MS61u) and a few samples were analysed at ALS Minerals in Vancouver by ICP-MS and ICP-ES after after lithium metaborate fusion and dissolution in dilute nitric acid (Appendix 4: method ME-MS81U) (Linge 2007; Beauchemin 2008). The method ME-MS61u of ALS Minerals involves a

very aggressive four-acid digestion adapted to destroy all the resistive minerals that are potentially present in uranium-rich ore (Gandhi 1977; Porto da Silveira et al. 1991; Polito et al. 2009; Alexandre 2010), with detection limits comparable or better to fusion methods for many elements. Typical four-acid digestions involve a combination of heated HF, HNO₃, HClO₄, and HCl prior to element analysis. In addition, instrumental neutron activation (INAA) analyses were performed at Becquerel Laboratories (Appendix 5: BQ-NAA-1) in Toronto to investigate whether dissolution with and without fusion were complete or left unanalysed residues and if some methods were more suitable than others for these atypical rock types. Detection limits and analytical results are presented by the respective laboratories in Appendices 2 to 6. A summary of all laboratories and all methods used in this report are in Table 1.

Analyses for halogens (chlorine and fluorine) were performed between 2005 and 2008 by Dionex ion chromatography at the Geological Survey of Canada laboratories in Ottawa. Between 2009 and 2011, additional F analyses were done using fusion-Specific Ion Electrode at ALS Minerals (method F-ELE81a; 2010-2011 samples) and ACME (method 2A04-F; samples 2005-2009) laboratories in Vancouver (Canada). Chlorine for 2010-11 samples was analysed by neutron activation certified laboratory Becquerel (CL-method NAA06, Toronto) (Appendix 6)

Table 1 Summary of laboratories, methods and description

Laboratory	Laboratory method	Elements	Sample decomposition	Analytical Method
INRS-ETE		Major and trace elements	Lithium metaborate fusion and dissolution in dilute nitric acid	ICP-MS and ICP-AES
ACME	1EX	Major and trace elements	Four-acid digestion: HNO ₃ -HClO ₄ -HF, residue dissolved in HCl	ICP-MS
	GROUP 7TD	Base metals and some major elements	Four-acid digestion: HF-HClO ₄ -HNO ₃ -HCL	ICP-ES
	1DX	Precious and base metals	Aqua-regia digestion	ICP-MS
	2A12	TOT/S and TOT/C		Leco (Induction furnace)
	4B02	Trace elements	Lithium borate fusion and dissolution in dilute nitric acid	ICP-MS
	2A04	F	NaOH fusion, analysis by specific ion electrode	
ALS	ME-ICP61	Trace elements	Four-acid digestion: HNO ₃ -HClO ₄ -HF-HCl digestion, HCl leach	ICP-AES
	ME-ICP61a	High grade major and trace elements	Four-acid digestion: HNO ₃ -HClO ₄ -HF-HCl digestion	ICP-AES
	ME-MS61u	Major and trace elements and uranium in semi-resistate mineral forms	Four-acid digestion: HNO ₃ -HClO ₄ -HF-HCl digestion, HCl leach	ICP-MS
	ME-MS81U	Ultra-trace elements with uranium in resistate mineral forms	Lithium borate fusion and dissolution in dilute nitric acid	ICP-MS
	Au-AA23	Au	Fire assay fusion	AAS
	F-ELE81a	F	KOH fusion and ion selective electrode	WST-SIM
Becquerel	BQ-NAA-1	Trace elements		INAA
	CI-NAA06	Low grade chlorine		INAA
GSC - Ottawa		F, Cl, S total		Dionex Ion Chromatography

INRS-ETE laboratory

At INRS-ETE laboratories in Quebec City, access to all analytical equipment is controlled by electronic detectors. Equipment that is especially sensitive to contamination (e.g., ICP-MS) is located in a class 10000 clean room. Instrumentation for metal analysis in geological samples consist of an ICP-MS (Thermo Instruments X7), ICP-AES (Varian 725 (Radial)), and a fluxer (Fluxy, Corporation scientifique Claisse). All acids are of trace-metal grade and solutions are made with $>18\text{M}\Omega$ cm water. Handling and sample preparation are designed to minimise trace-element contamination. Multi- and single-element calibration standards are made from single-element, certified standards, traceable to NIST, purchased from SCP Science. Five certified reference materials are used: Sarm-1 (Bushveld granite), Sarm-5 (pyroxenite), BCR-2 (basalt Columbia River), BHVO-2 (basalt Hawaiian volcanic observatory) and W2 (diabase). Once performance of analytical equipment is tested, generally by analysing the signal given by a solution of known composition, it is calibrated with standard solutions. The calibration curve (7-10 points) is repeated each time that a new series of analyses is initiated. Every 15 samples, blanks (analytical and methodological) are reanalysed as well as duplicate, certified, and standard. Furthermore, for each analysis, we use internal standards to identify possible matrix problems or other problems. Internal standards may be used to correct results. No sample measurements are made if the control solutions give anomalous readings until problems have been clearly identified and resolved. The INRS-ETE laboratory is a regular participant in inter-laboratory comparative studies organised by the National Water Research Institute of Canada. Samples having suspect values are re-analysed. During the course of this project, several samples were re-analysed to confirm data when analytical results or dissolutions seemed unusual. In most cases, the end-results were that the composition of the 'problematic' metasomatic rock sample was highly atypical compared to volcanic, sedimentary, plutonic and normal metamorphic rocks as displayed in this dataset. The acquired knowledge was then integrated to adjust the analytical methods to the atypical mineralogical and compositional components of IOAA alteration. In addition, the laboratory expanded the realm of elements routinely analysed in order to include more potentially economic metals. Prior to this work, assay-type analyses were sent to commercial laboratories and the INRS laboratory focused on optimising trace-element reproducibility and accuracy not assay-grade metals.

QA-QC analysis

For each analytical method, QA-QC was assessed according to the precision of the certified material and duplicate analyses, analytical limitations of certain methods for specific elements, the detection limits for each element and the reproducibility of the results when the analytical methods are compared together (Appendices 2 to 5). Additional quality control involved comparison of the 1EX AcmeLabs (four-acid digestion + ICP-MS) analytical protocol with that of INRS (+ fusion ICP-AES, ICP-MS) and the Becquerel (INAA) data for CQA-05 to CQA-08 and 09CQA series for which enough material was available (Figures 3–6). Thirty-two samples of the Southern Breccia were also cross-analysed at ALS Minerals and INRS-ETE by ICP-MS (trace elements) and ICP-AES (major and some trace elements).

Compared with the fusion results (INRS-ETE), the analyses generated from four-acid digestion (AcmeLabs) tend to variably underestimate Al and K in some samples, especially when the concentrations of Al and K are greater than 6% and 3%, respectively (Figure 3). Digestion by four-acid methods yields more precise results for Ca and P at low concentrations (Figure 3) as well as for metals, in particular Bi, Cd, Pb, Zn, Co, Bi, Sn and Ni when the metal contents are low (Figure 4). However, at higher Ca and P concentrations, fusion coupled with acid dissolution and four-acid digestion yield comparable results (Figure 3). For some volatile trace elements that can be lost during loss on ignition (i.e., As, Rb, Cs, Au, Ag), INAA produces more precise values compared to multi-acid digestions and fusion techniques (not shown on figures). For REE, the fusion gives better results, especially for medium and heavy REE compared to four acid digestion and INAA (Figure 5 and Figure 6). Overall, for most major and trace elements, alkaline fusion techniques combined with ICP-MS and ICP-AES analysis provide the best analytical results. The relationships

described above are applicable only to the comparison of analyses of methods 1EX at AcmeLabs, BQ-NAA-1 at Becquerel and INRS analyses made between 2005 and 2009. They do not apply to analyses completed at INRS from 2010 to 2012, as well as analyses completed by ALS Minerals in 2010 and 2011. During this period, INRS significantly improved the analytical protocol for metals by lowering detection limits. The ALS Minerals method ME-MS61u gives results comparable to those obtained by fusion for most elements except Rb and Ta which yield more precise values by fusion at INRS-ETE and Zn which gives more precise values by the ALS Minerals method ME-MS61u (see Table 2 for correlation data). A comparison of problematic elements Al and K (INRS-ETE fusion vs. four-acid ALS-ME-MS61u, 2010-2011) indicates an improvement of previously underestimated values (four-acids by ACME), however K can be still underestimated, when the concentrations are greater than 6 % (Figure 7). These assessments provide also a framework for interpreting historical databases on IOAA systems done with these various methods and a framework for selecting the most appropriate methods according to the accuracy and precision required.

Table 2 Correlation coefficients for analyses at INRS-ETE (fusion) and those made with ALS protocol ME-MS61u (four-acid digestion).

Element	Correlation	Element	Correlation
Al	0.952	P	0.995
Ba	0.977	Pb	0.735
Ca	0.999	Rb	0.624
Ce	0.992	Sn	0.888
Cr	0.917	Sr	0.984
Cu	1.000	Ta	0.651
Fe	0.996	Th	0.956
Hf	0.942	Ti	0.998
K	0.896	U	0.988
La	0.993	V	1.000
Mg	0.999	W	0.998
Mn	0.992	Y	0.966
Na	1.000	Zn	0.776
Nb	0.972	Zr	0.943

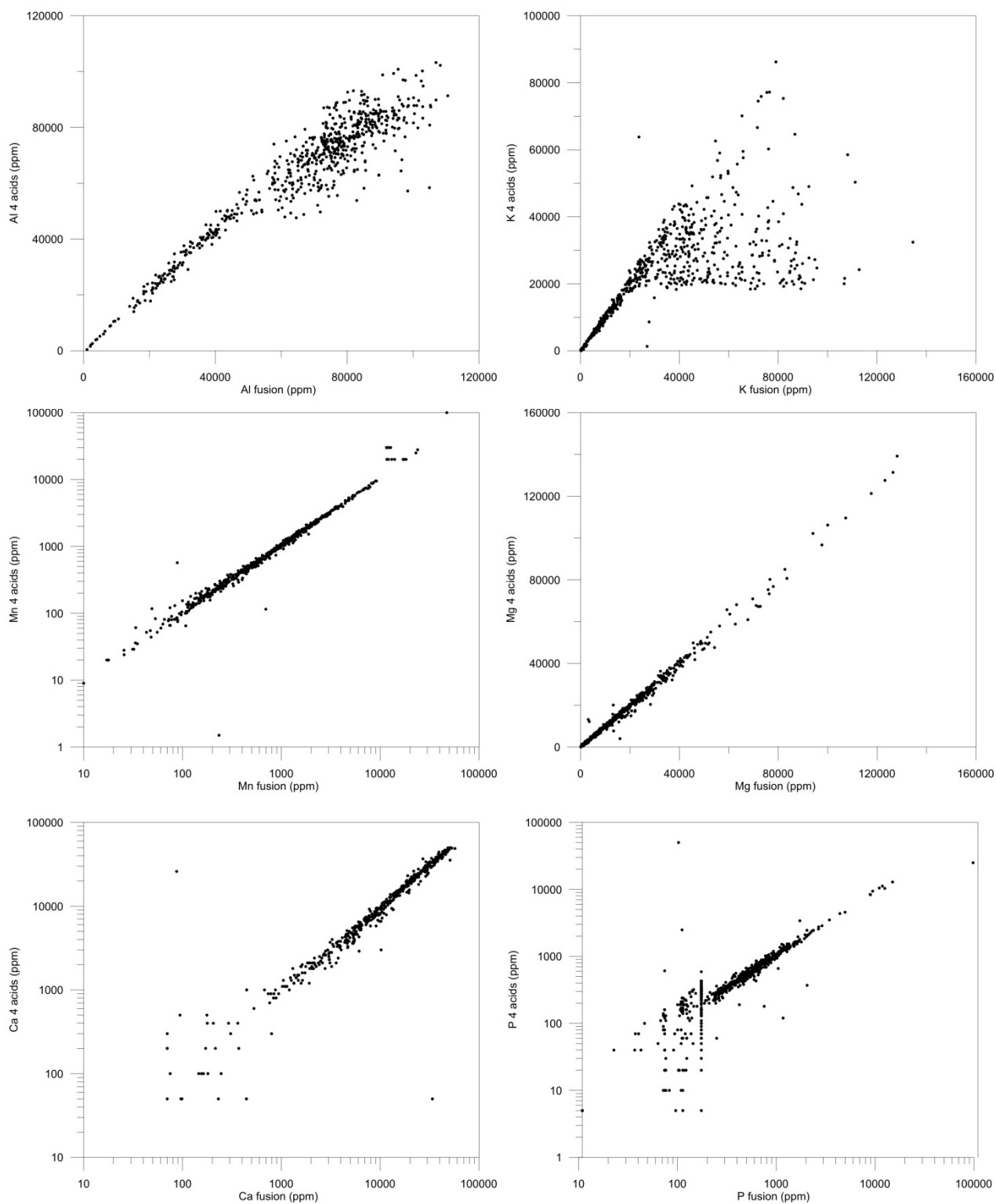


Figure 3: A Comparison of whole-rock major element analyses by ICP-MS after fusion and acid dissolution (INRS-ETE) versus four-acid digestion (ACME).

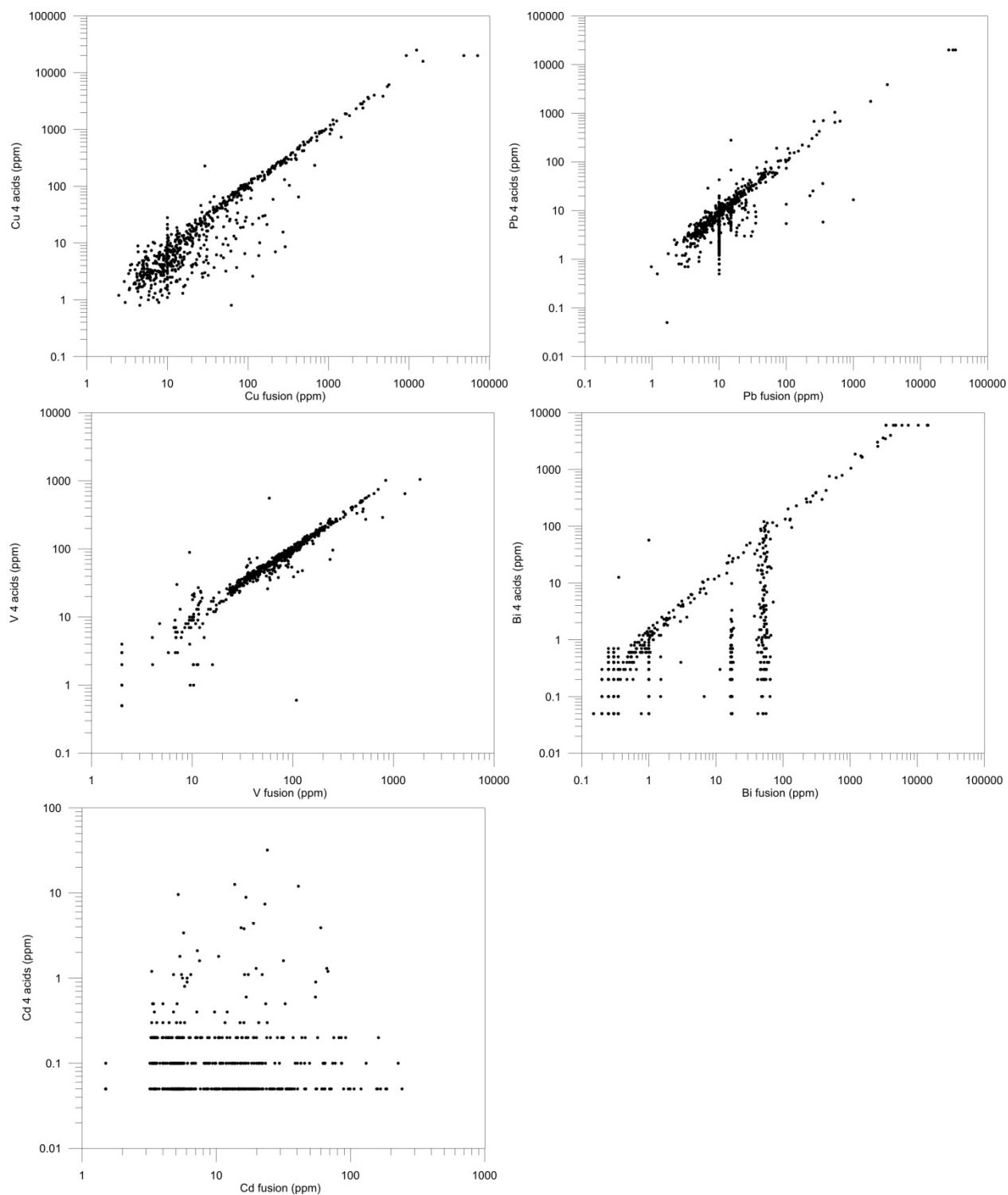


Figure 4: Comparison of metal values determined by ICP-MS after fusion and acid dissolution (INRS) versus four-acid digestion (ACME). Higher detection limits for metals (Bi, Cd, Cu and Pb) done at INRS by ICP-AES between 2005 and 2008 produced steps in the data, visible on the vertical axis.

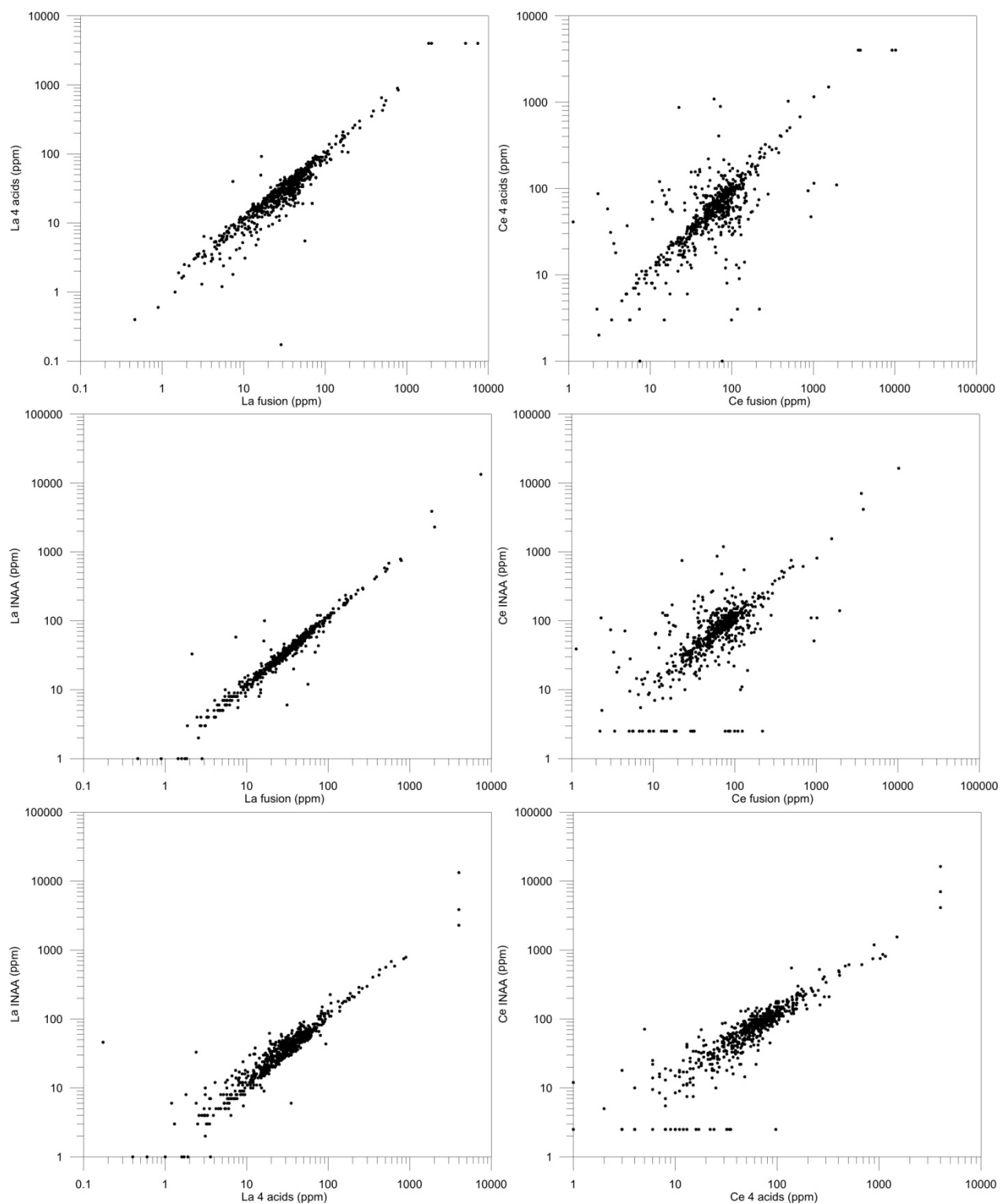


Figure 5: Comparison of light REE analyses by ICP-MS after fusion and acid dissolution versus four-acid digestion and INAA.

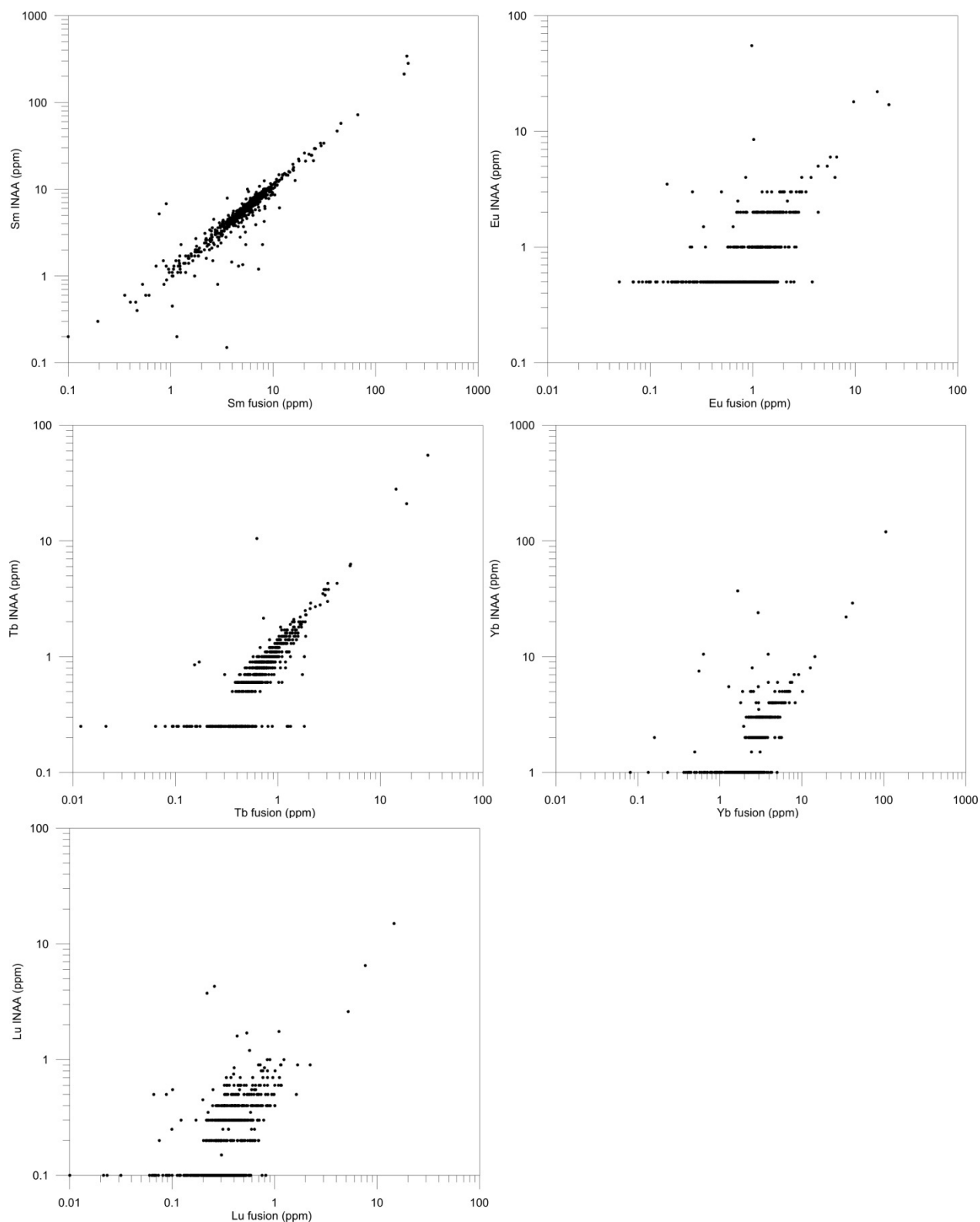


Figure 6: Comparison of medium and heavy REE analysis by ICP-MS after fusion and digestion versus INAA.

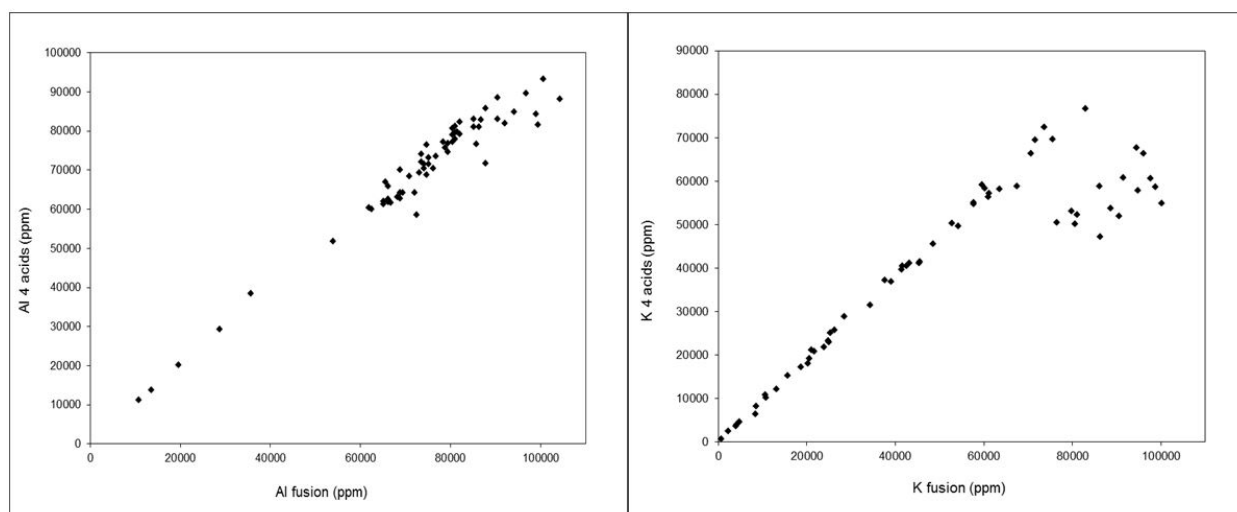


Figure 7: Comparison of Al and K analysis (2010-2011) by ICP-AES after fusion (INRS-ETE) and four-acid dissolution (ALS -ME-MS61u).

Summary

This Open File report releases an important dataset of whole-rock geochemical analyses from the GBMZ IOAA mineral systems. The dataset is presented in a format easily importable into geographic information systems (GIS) and consists of 1720 bedrock samples of iron oxide and alkali alteration associated with known mineralisation, alteration zones and least-altered bedrock. Analytical results (2005-2011 sample series) include geochemistry performed using a combination of ICP-MS for trace elements and ICP-ES for major and some trace elements after lithium metaborate fusion and acid dissolution at INRS-ETE in Quebec and ALS Minerals, and ICP-MS analysis after multi-acid digestion at AcmeLabs Laboratories and ALS Minerals. These datasets provide enough duplication to assess the best analytical method for each element in IOAA systems. In addition, caveats for each dataset and improvements made in some laboratories during the project have been documented. These caveats results from the extremely atypical composition the metasomatic rocks acquire during development of IOAA systems. In some cases, whole-rock compositions of alteration can reach extreme enrichment in some elements with potential for unusual peak overlaps in some methods. It can also lead to extreme depletion in other elements, approaching current analytical detection limits. Finally, the crystallisation of unusual resistate (hard to dissolve) minerals as minute inclusions and disseminations can lead to artificially low analytical results from fusion plus acid dissolution and multi-acid digestion methods. This Open File is not met to provide all scientific answers to these problems but to release in the public domain a thorough dataset of IOAA samples that can be applied to mineral exploration and research.

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