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CRITICAL METALS IN MINERAL SYSTEMS WITH IRON OXIDE COPPER-GOLD (IOCG) AND AFFILIATED DEPOSITS

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Field exposures of mineral systems,
Great Bear magmatic zone (CA)

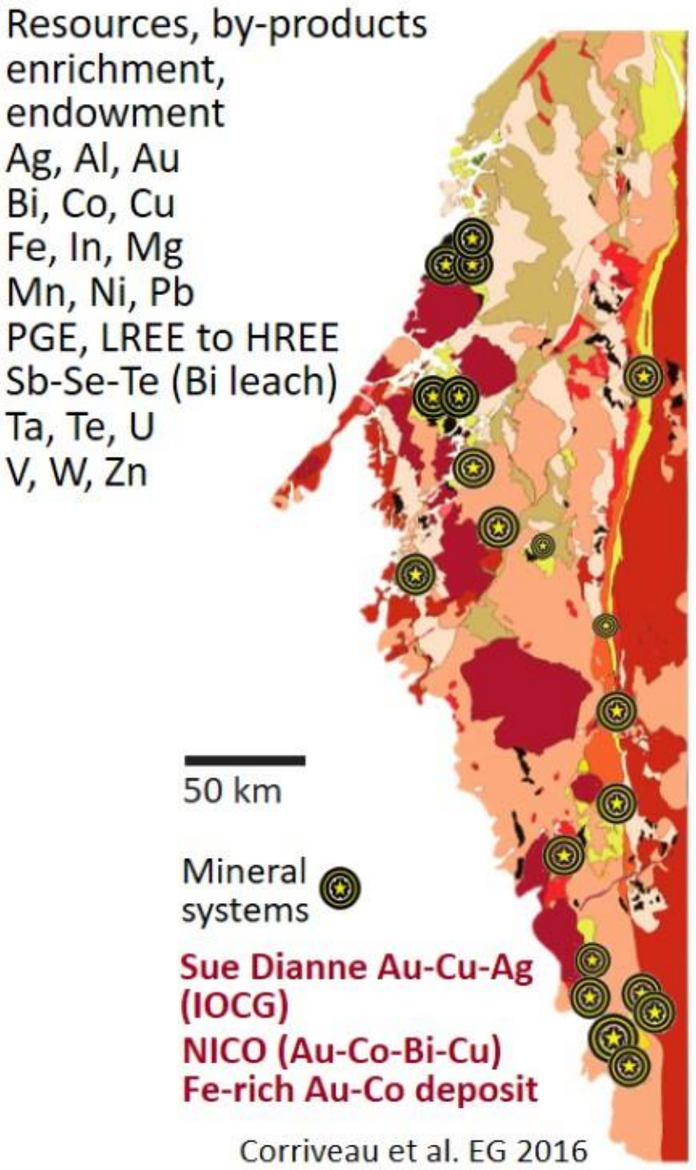
Critical Minerals Mapping Initiative Update
American Geoscience Institute, 2022

Canada

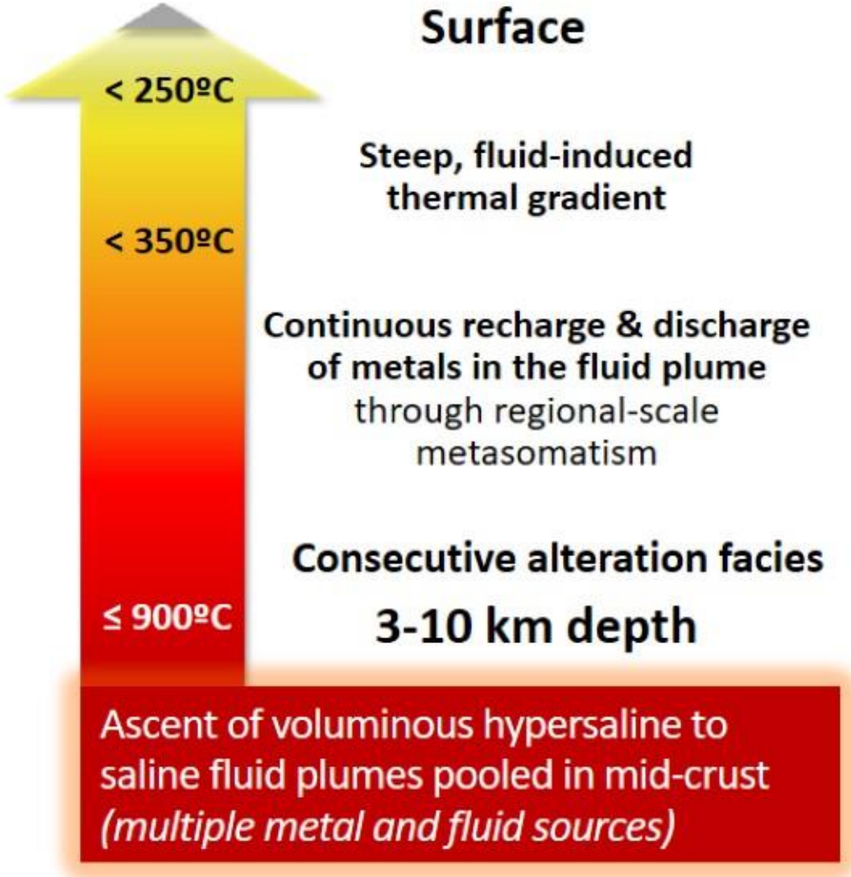
Archetype IOCG deposit: Olympic Dam (11 Bt of resources in Cu-U-Au-Ag + Co-REE-Re…)
Archetype field exposures of systems: Great Bear magmatic zone (CA)

Depth to surface evolution of metasomatic iron and alkali-calcic (MIAC) mineral systems with IOCG and affiliated deposits in a pristine, extremely well exposed Paleoproterozoic setting

Corriveau et al. 2010b, 2016, GAC SP 52 in press



Corriveau et al. EG 2016



CORRIVEAU et al. 2022

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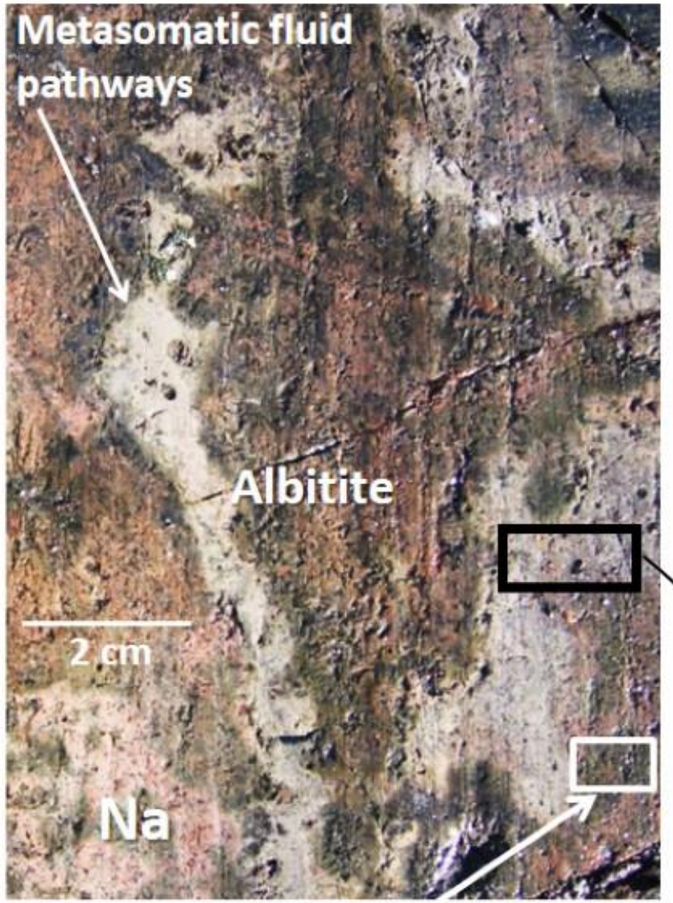
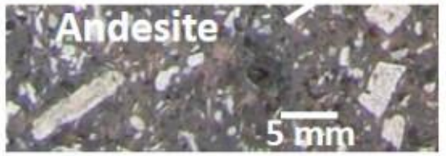
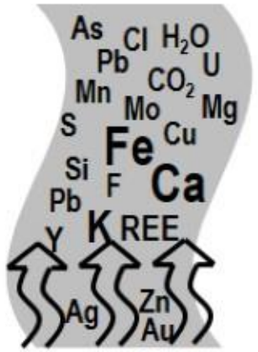
Timeline + depth to surface evolution of alteration





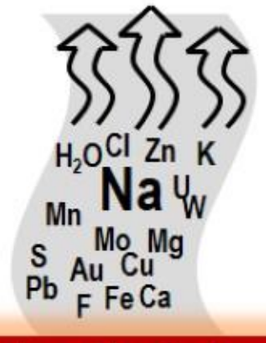
Fluids recharged in metals in host rocks



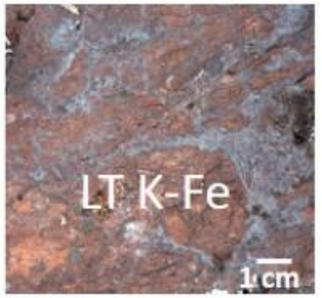
Na precipitates
Al + some Si is retained
Other elements leached

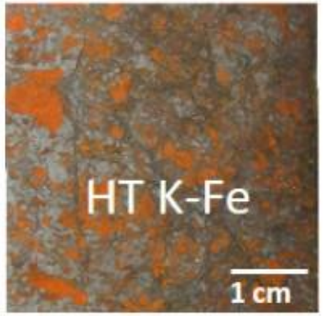
Reaction of highly saline fluids with host rock

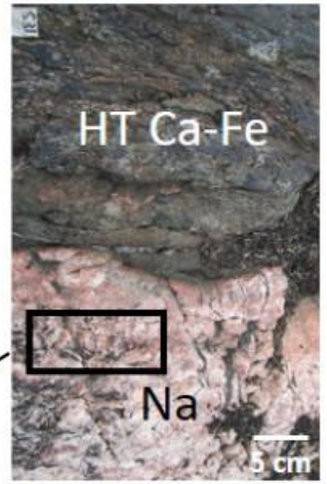
≤ 900°C



Ascent of hypersaline fluid plume







Alteration facies

6 **LT Si,K,Al,Ba,±Fe**
(vein, epithermal)

5 **LT K/Ca/Mg(H-CO_2,F)-Fe**
Hem, Kfs, Ms, Chl, Cb, Fl, Brt
Cu Sul
Cu, Ag, Au, LREE, U, Mo, W, Co

4 **K felsite and/or K skarn**
Kfs or Cpx, Grt, Kfs, **base metal Sul**

3 **HT K-Fe**
Kfs, Bt, Mag, **Cu Sul**
Au, Ag, Co, Cu, REE, U

2-3 **HT Ca-K-Fe**
Amp, Mag, Bt, Kfs, **Co-As-Sul**
As, Au, Bi, Co, Ni, ± Cu

2 **HT Ca-Fe (peak temperature)**
Amp. Mag, Ap, Ep
Fe, LREE+HREE, Th, V, W

1-2 **Skarn**
Cpx-Grt, W

HT Na-Ca-Fe
Ab-Amp-Ap-Cpx-Scp

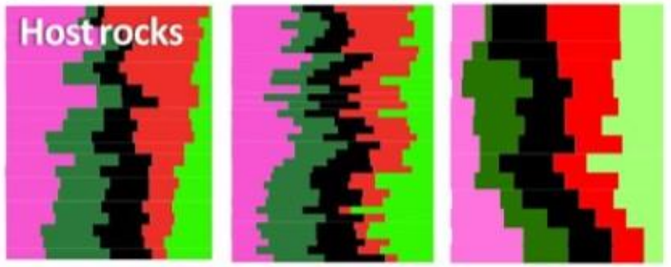
1 **Na albitite**
Ab-Scp

Corriveau et al. GAC SP52 in press

Metasomatic chain reactions through the upper crust

Form metasomatic iron and alkali-calcic (MIAC) mineral systems with consecutive alteration facies and associated deposit types

Igneous + sedimentary host rocks contain 3-4 dominant cations



Molar proportions from whole-rock analysis

Na Ca Fe K Mg

MIAC alteration facies contain 1-3 dominant cations

- Strong coupling/decoupling of cations & metals as fluid plume ascends

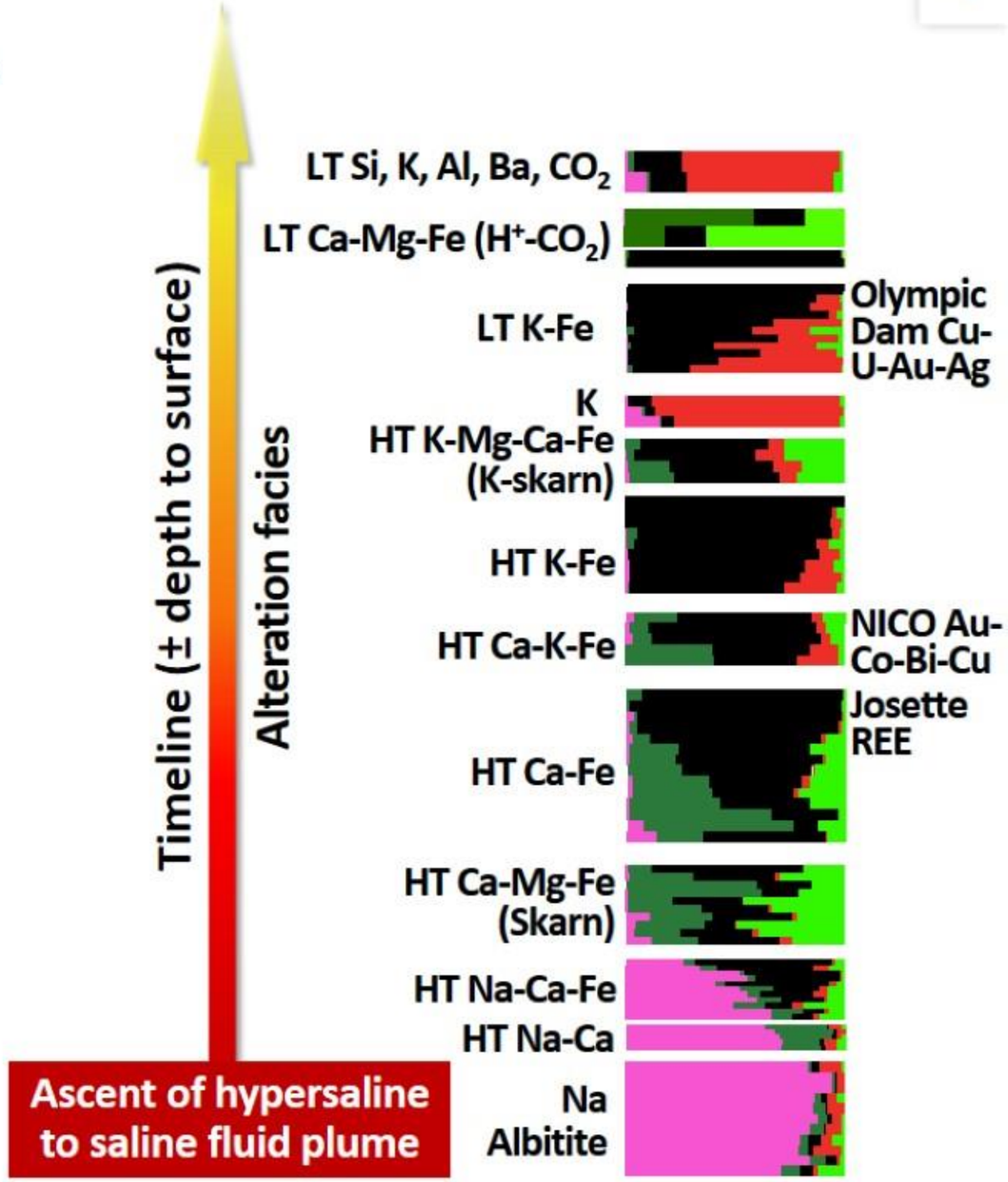
Na alteration facies = albite = $NaAlSi_3O_8$ = albitite

Na to Na-Ca → Ab / Ab-Scp

Intense **albitization** totally changes bulk composition and proportions of Na-Ca-Fe-K-Mg of host rocks to form albitite

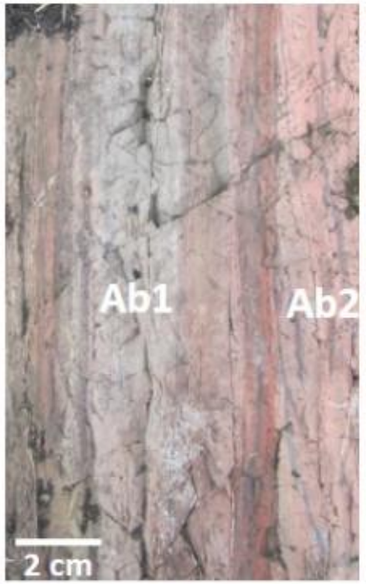
Na (+Al-Si) **is dominant**

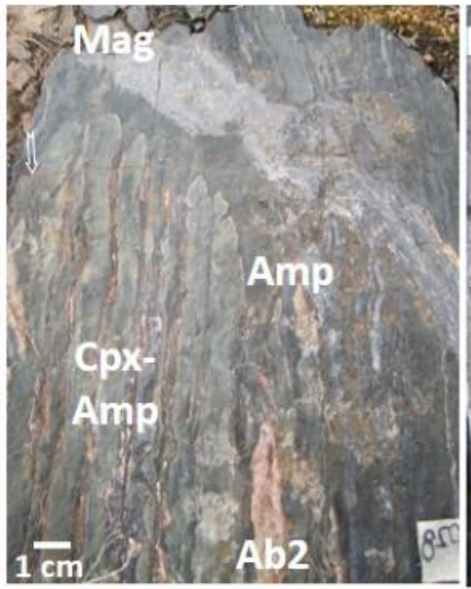
Other cations transferred to the fluid plume

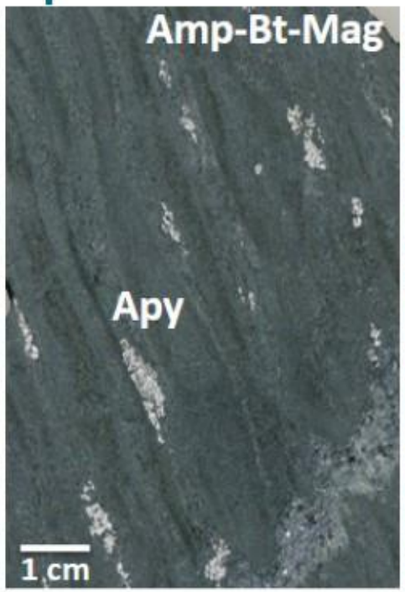


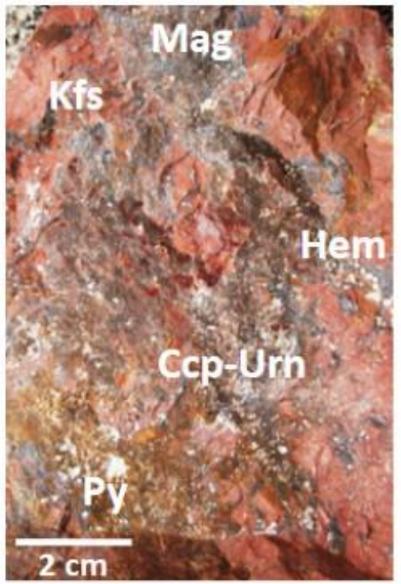
Corriveau et al. GAC SP52 in press

NICO deposit (CA): 33Mt at 1.02g/t Au, 0.12% Co, 0.14% Bi, 0.04% Cu at Facies 2-3 HT Ca-K-Fe

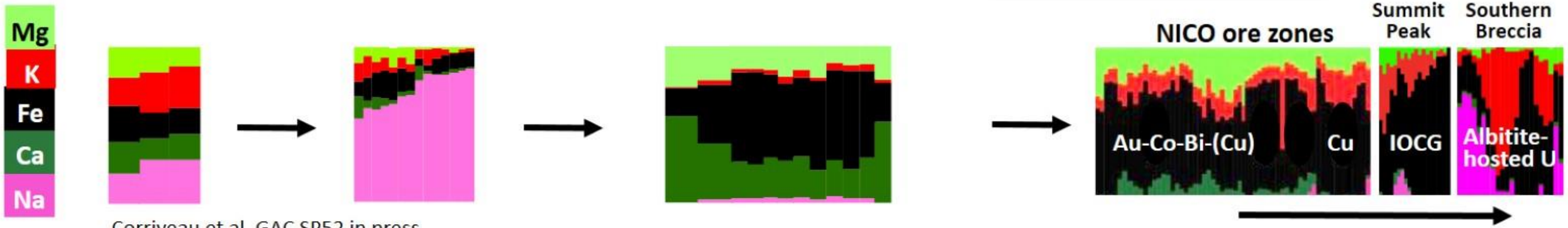








Host siltstone | **Facies 1 Na** | **Facies 1-2 skarn** | **Facies 2 HT Ca-Fe** | **Facies 2-3 HT Ca-K-Fe** | **Facies 3→5 HT→LT K-Fe**

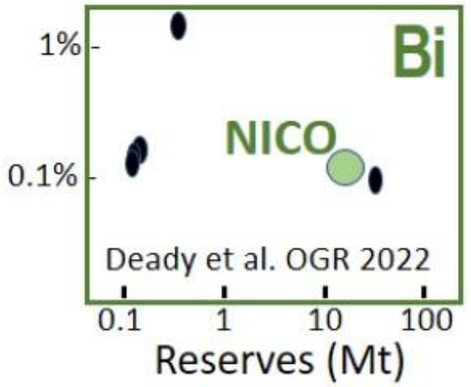


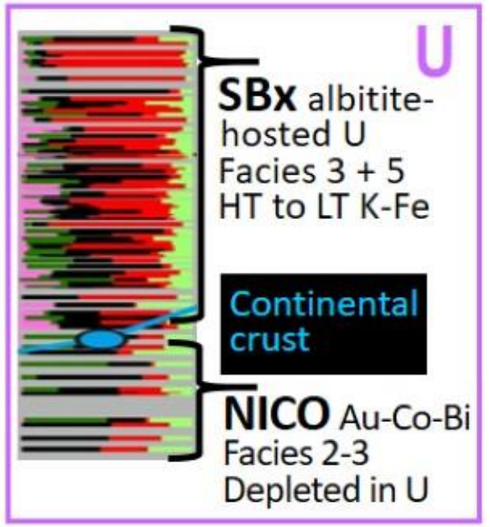
Corriveau et al. GAC SP52 in press

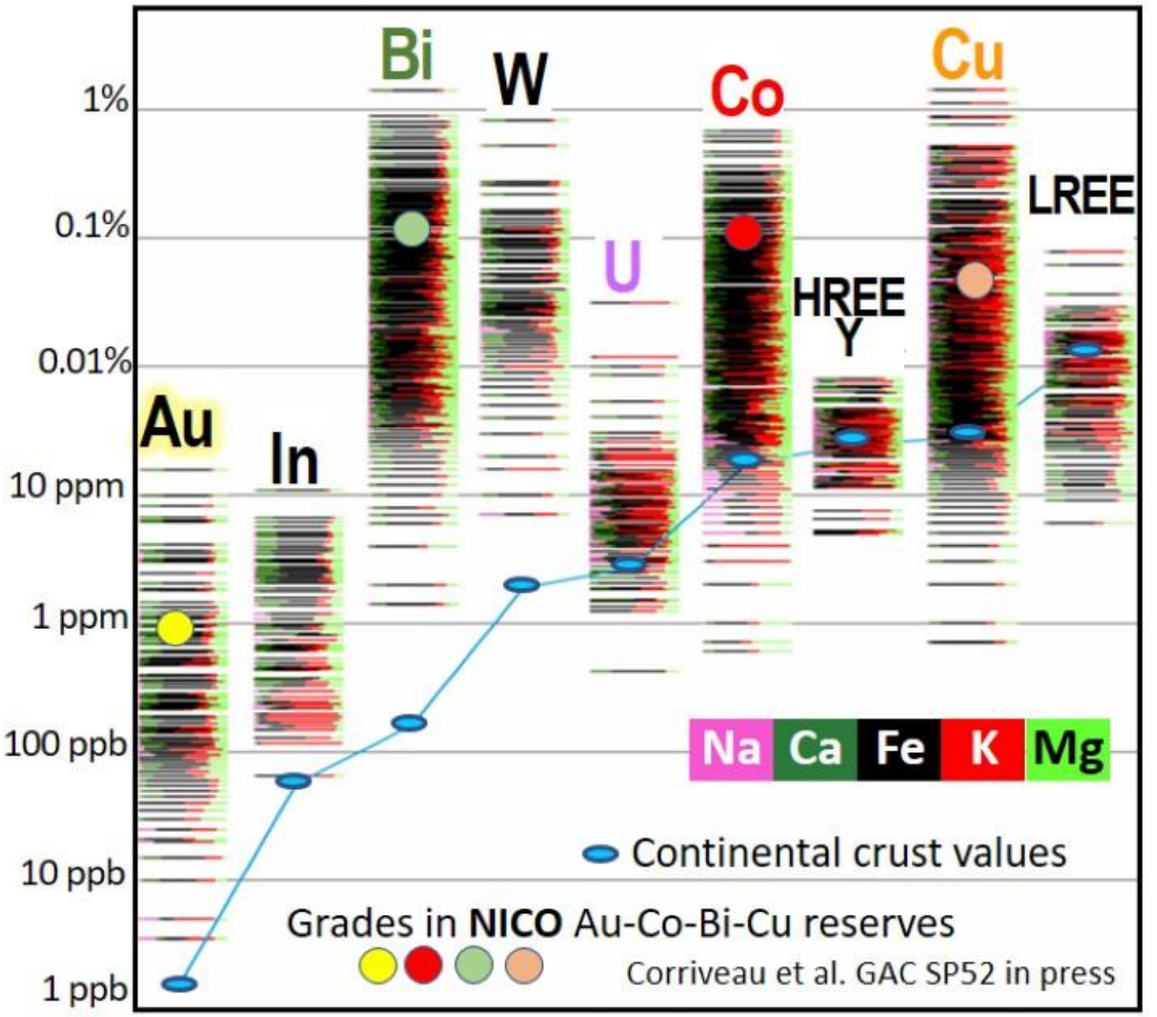
Facies 2-3 HT Ca-K-Fe: critical metal rich Fe-rich Au-Co-Bi deposits

NICO (CA): 33 Mt at 1.02 g/t Au, **0.12% Co**, **0.14% Bi**, 0.04% Cu (**reserves**[1])

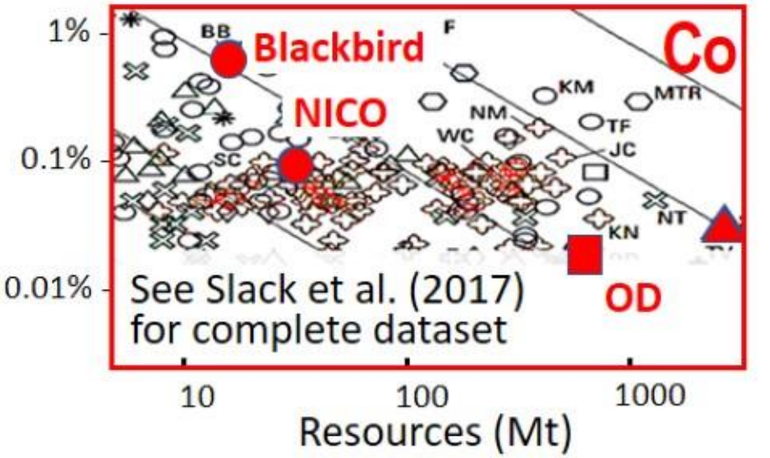
Blackbird (US): 16.8 Mt at 1.04 g/t Au, **0.73% Co**, 0.14% Cu (resources[2])







Ranges of composition in **NICO deposit and host system**



Fe-rich Au-Co±Bi±Cu

Olympic Dam IOCG
Not updated

Sudbury magmatic Ni-Cu

Fe-oxide Au-Co-Bi-Cu NICO + Fe-silicate Blackbird (US)

Primary cobalt resources

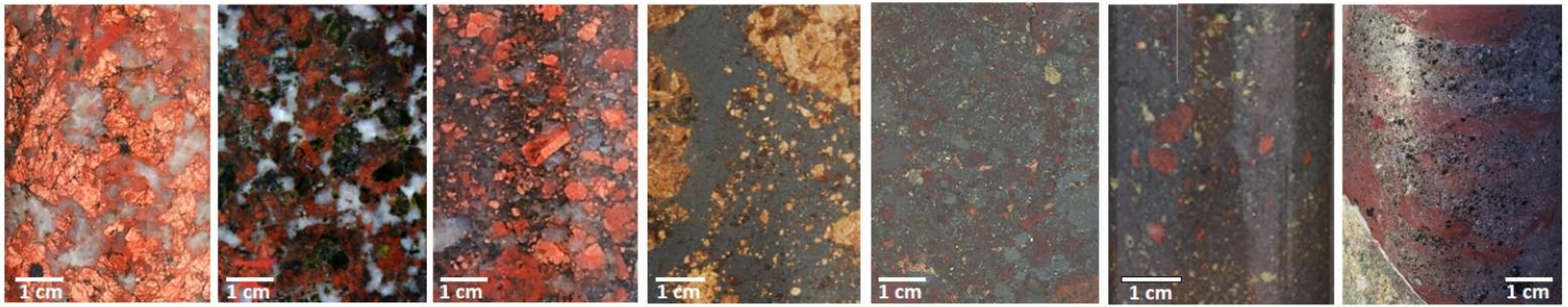
Cobalt enrichment relative to continental crust **>>>>** than that of the Olympic Dam Cu-U-Au-Ag and Sudbury Ni-Cu deposits

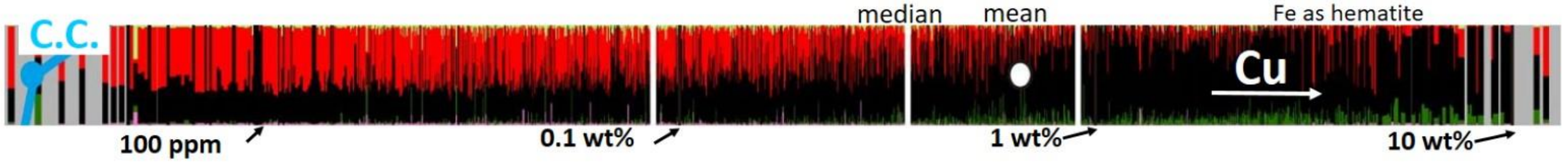
Data: representative surface and decline samples of host mineral system and representative samples from the muck piles across the NICO ore zone from Corriveau et al. (2015); samples from drill cores (96-01–06, 96-11, 96-13, 96-16, 96-17, 96-24, 96-25, 96-30) in Mumin (1997).

[1] Burgess et al. (2014); [2] Slack (2013)

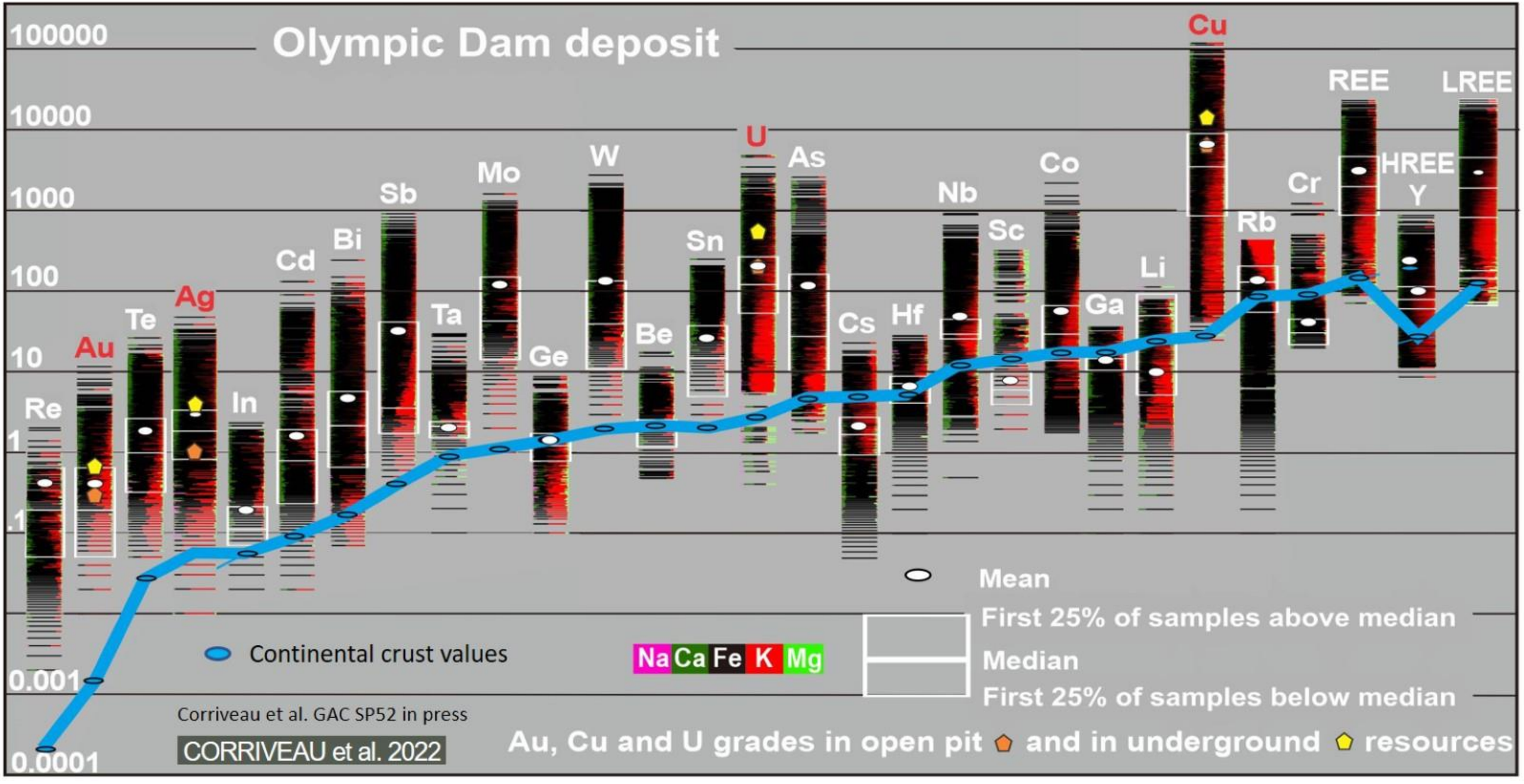
Canada

Precipitating 10,100 Mt @ 0.62% Cu, 0.21 kg/t U_3O_8, 0.28 g/t Au, 1 g/t Ag at the **Olympic Dam IOCG deposit** (AU)



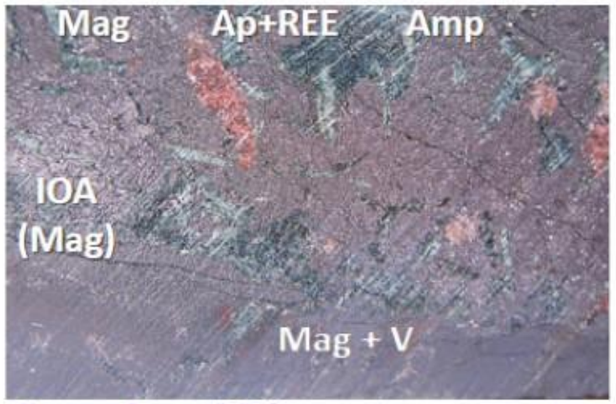


Corriveau et al. GAC SP52 in press


Olympic Dam deposit
100000
10000
1000
100
10
1
.1
0.001
0.0001
Re
Au
Te
Ag
In
Cd
Bi
Sb
Ta
Mo
Ge
W
Be
Sn
U
As
Cs
Hf
Nb
Sc
Co
Ga
Li
Cu
Rb
Cr
REE
HREE
Y
LREE
Mean
First 25% of samples above median
Median
First 25% of samples below median
Continental crust values
Na Ca Fe K Mg
Corriveau et al. GAC SP52 in press
CORRIVEAU et al. 2022
Au, Cu and U grades in open pit and in underground resources

REE deposits: Remobilization of primary REE endowment of iron oxide-apatite (**IOA**) deposits precipitated at the **HT Ca-Fe** facies leads to **resources** of **6.9 Mt at 2.72 % REE_2O_3** (i.e. 1.83% LREE, 0.89% HREE) at the Josette deposit (QC) and historic resources of 0.2 Mt at 12 % REE_2O_3 at the Pea Ridge deposit (MO)

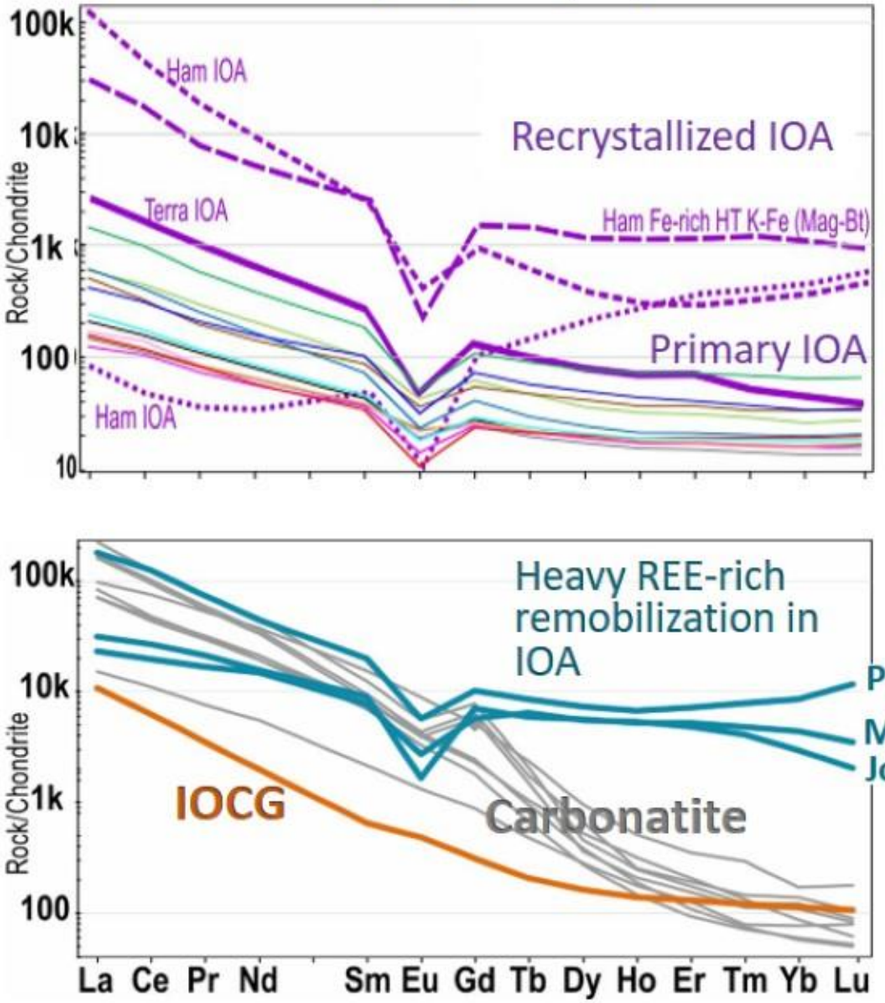
Facies 2 HT Ca-Fe



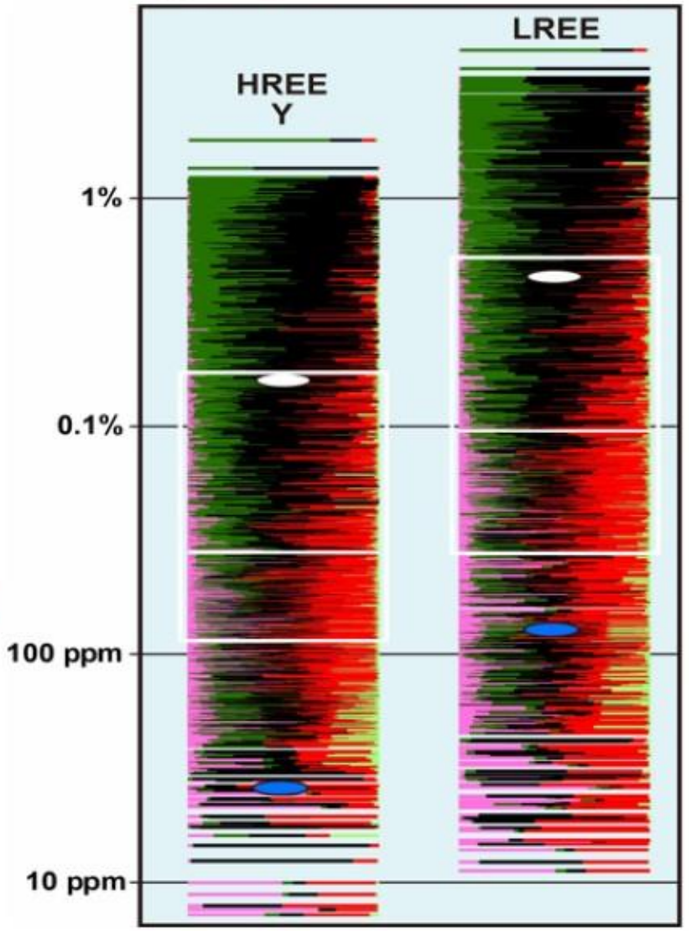
Great Bear IOA

Josette REE vein-type ore in IOA

Great Bear IOA prospects (NT)



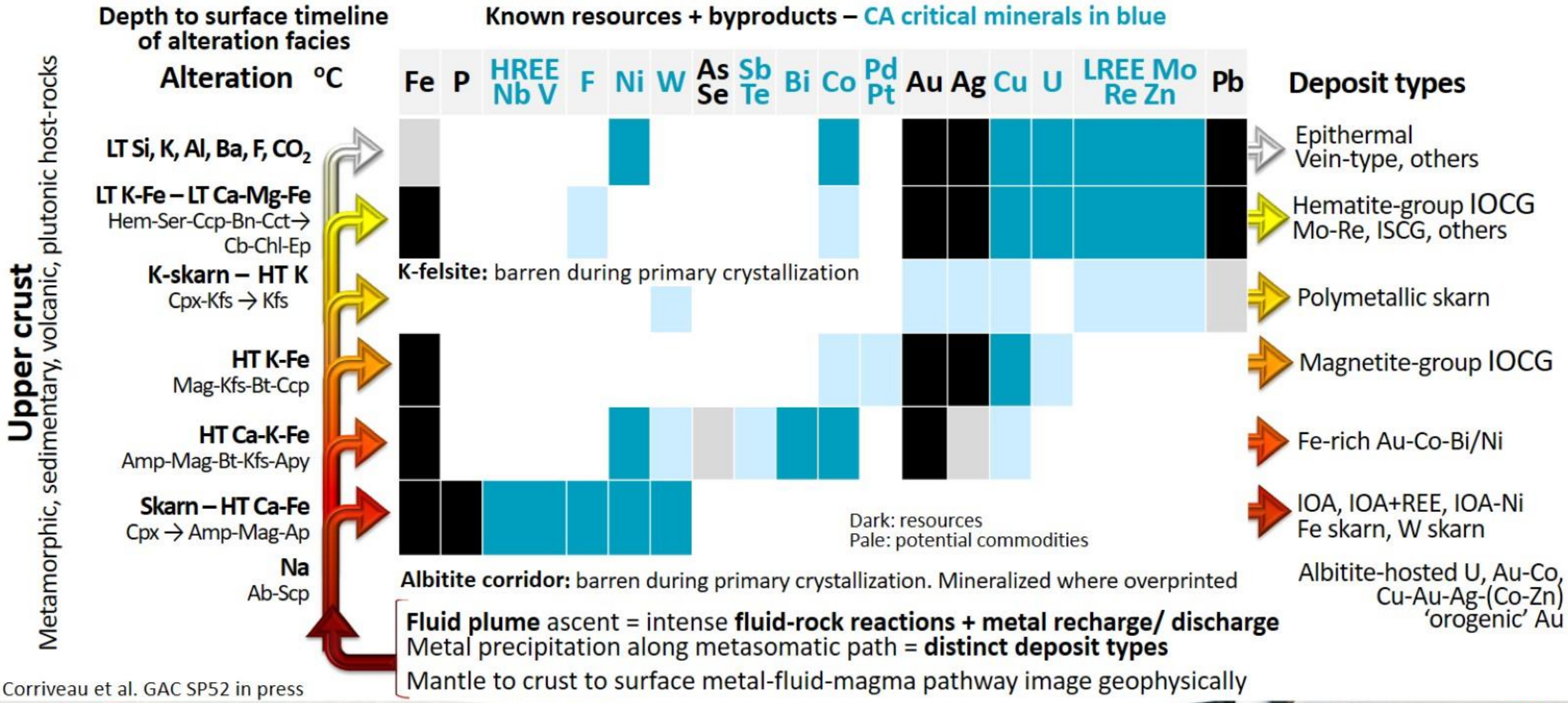
Kwyjibo system and Josette deposit



See Corriveau et al. in press; Sappin and Perreault 2021; Data: Magrina et al. 2005; Perreault and Artinian 2013; Weng et al. 2013; Corriveau et al. 2015, Day et al. 2016a, b; Taylor et al. 2019

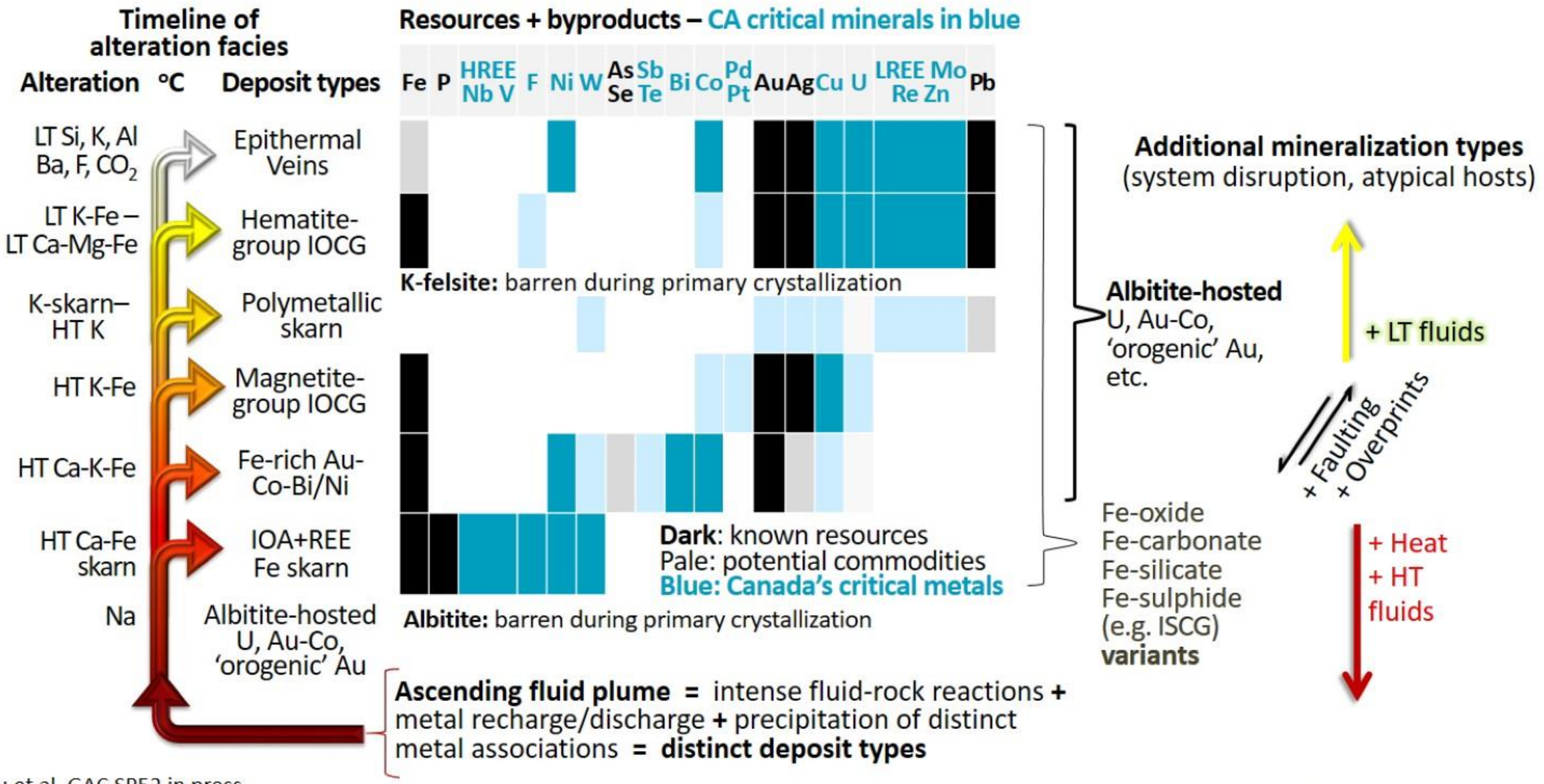
Foundation of wealth:

Critical metals in metasomatic iron and alkali calcic (MIAC) mineral systems



Corriveau et al. GAC SP52 in press

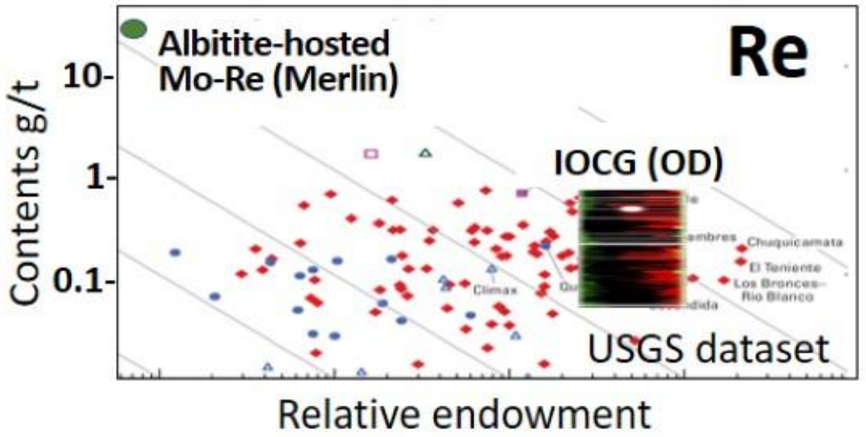
Foundation of wealth: MIAC systems and their critical metal resources



Corriveau et al. GAC SP52 in press

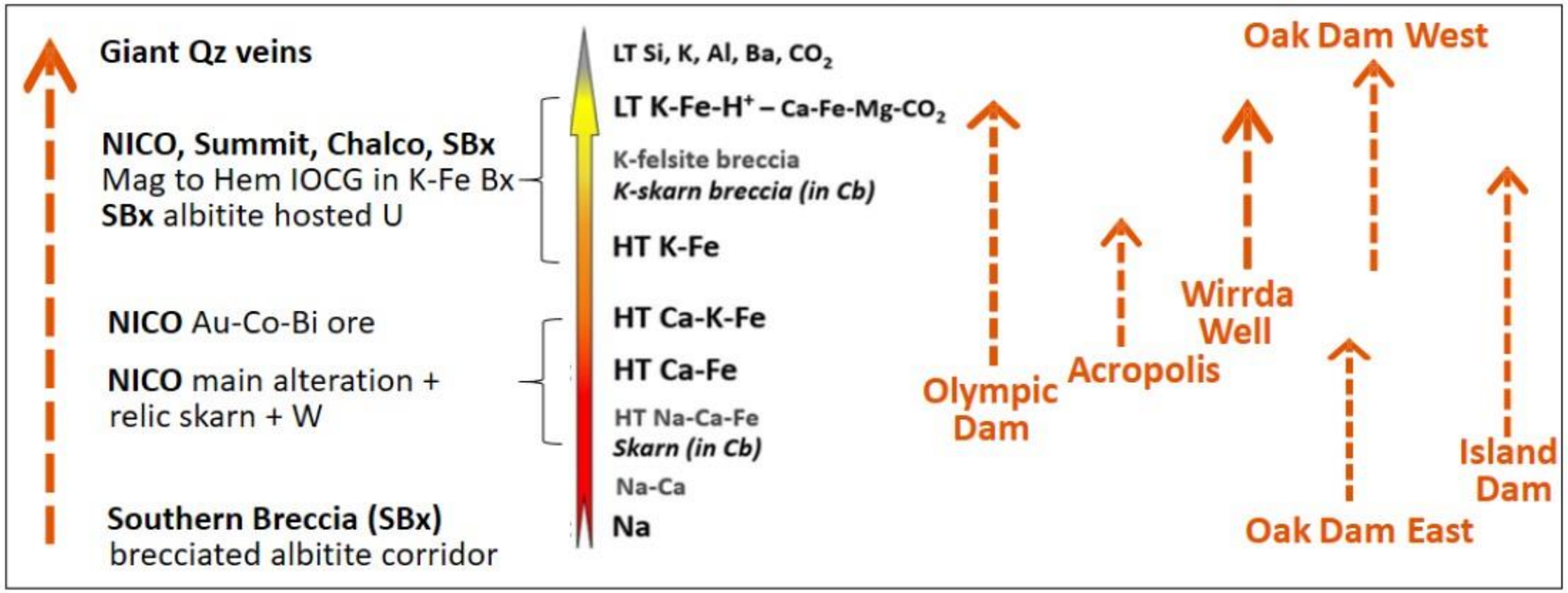
Alteration facies: record the metal pathways to ore

+ vector to the realm of potential mineralization types within deposits and systems



Systems can precipitate extremely high contents of any commodities
e.g. Merlin reserves
6.4 Mt at 1.5% Mo, 26 g/t Re

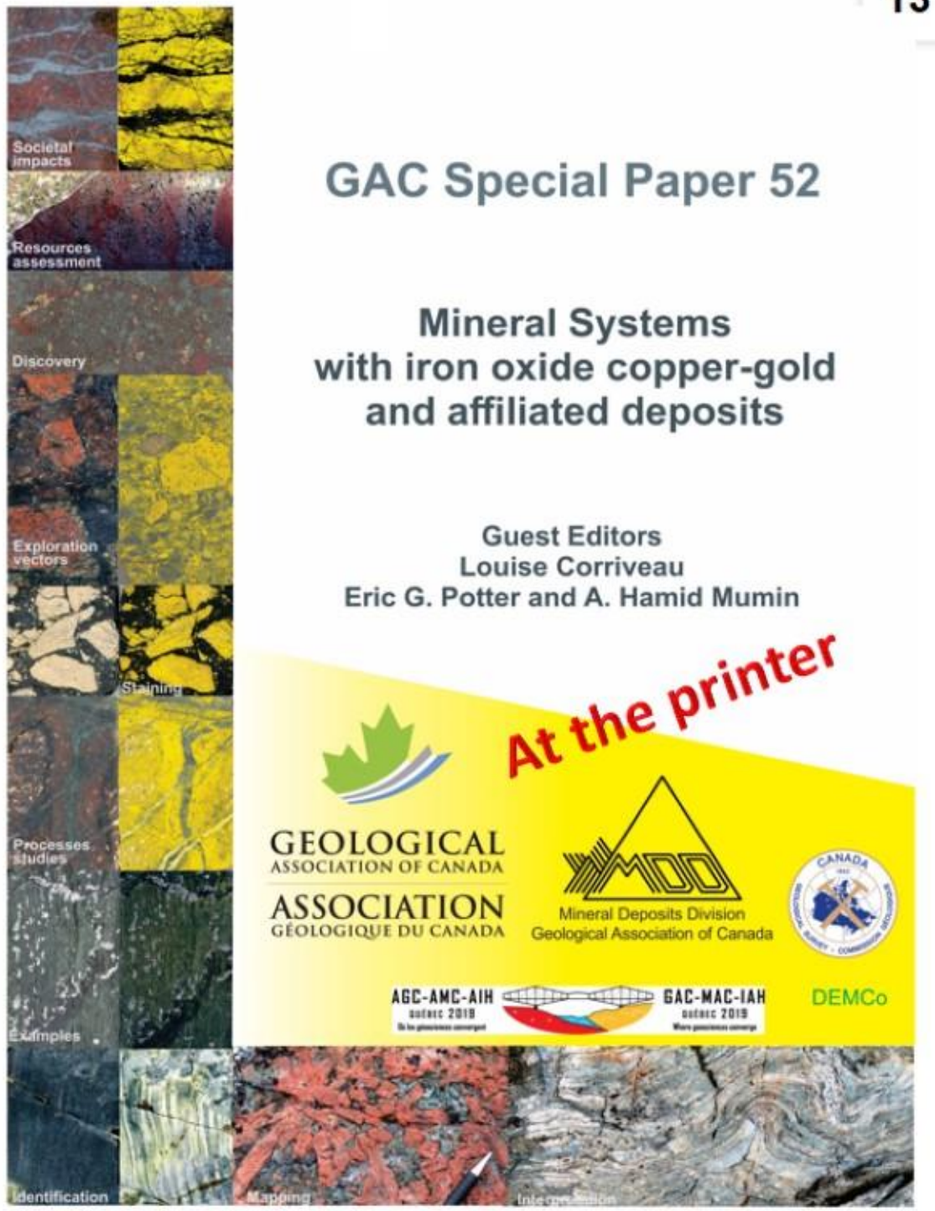
Critical metal associations vary as systems evolve



Merci! Masi! Thank-you!

Geological Survey of Canada (GSC), Northwest Territories Geological Survey (NTGS), Tłı̨chǫ Government, Community Government of Gamètì, Aurora Research Institute, Wek'eezhii Land and Water Board (WLWB), Tłı̨chǫ field assistants and cook, GSC field assistants and grad students, Jean Wetrade Gamètì School, Tłı̨chǫ and Sahtu First Nations land-use planners, Dillon Consulting, Sahtu Government, Protected Areas Strategy Coordinator, Traditional Knowledge Researcher, Fortune Minerals, Alberta Star, Hunter Bay Resources, Diamonds North, Energizer Resources, Honey Badger Exploration, DEMCo (Denendeh Exploration and Mining Company), BRGM, Geological Survey of South Australia, BHP-Olympic Dam, TGI 3 to 6 and GEM IOCG-MIAC activities participants and their collaborators, authors, reviewers and editors of GAC Special Paper 52, Indian and Northern Affairs Canada, Resource Management Office and Contaminants & Remediation Directorate, Polar Continental Shelf, Prince of Wales Northern Heritage Centre, Discovery Mining Services, Air Tindi, Arctic Sunwest, Aurora Geosciences, Great Slave Helicopter, Manitoulin Transport, Norpo Construction Ltd, Weaver and Devore, Tli Cho Landtran Transport.

Targeted Geoscience Initiative Program (Geological Survey of Canada) and **Critical Mineral Mapping Initiative** (Geoscience Australia, Geological Survey of Canada, USGS)
GEM task shared agreement with **Fortune Minerals** (Robin Goad, CEO, NICO deposit)



For more information

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Cited references can be found in Corriveau et al., 2021, Metasomatic iron and alkali-calcic (MIAC) system frameworks: A TGI-6 task force to help de-risk exploration for IOCG, IOA and affiliated primary critical metal deposits. Geological Survey of Canada, Scientific Presentation 117, 103 p. https://doi.org/10.4095/329093

Canada