Critical Minerals Mapping Initiative

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U.S. Department of Interior, U.S. Geological Survey

Canada Geological Survey of Canada Natural Resources Canada

Queensland Government

Australian Government Geoscience Australia

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Deposit Classification Scheme for the Critical Minerals Mapping Initiative Global Geochemical Database

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Contents

Tables

Table 1. Critical Minerals of Each Country

Critical Minerals	Australia	Canada	United States
Aluminum (Al)		X	X
Antimony (Sb)	X	X	X
Arsenic (As)			X
Barite			X
Beryllium (Be)	X		X
Bismuth (Bi)	X	X	X
Cesium (Cs)		X	X
Chromium (Cr)	X	X	X
Cobalt (Co)	X	X	X
Copper (Cu)		X	
Fluorspar		X	X
Gallium (Ga)	X	X	X
Germanium (Ge)	X	X	X
Graphite	X	X	X
Hafnium (Hf)	X		X
Helium (He)	X	X	X
Indium (In)	X	X	X
Lithium (Li)	X	X	X
Magnesium (Mg), Magnesite	X	X	X

Critical Minerals	Australia	Canada	United States
Manganese (Mn)	X	X	X
Molybdenum (Mo)		X	
Nickel (Ni)		X	X
Niobium (Nb)	X	X	X
Platinum group elements (PGE)	X	X	X
Potash		X	X
Rare earth elements (REE)	X	X	X
Rhenium (Re)	X		X
Rubidium (Rb)			X
Scandium (Sc)	X	X	X
Strontium (Sr)			X
Tantalum (Ta)	X	X	X
Tellurium (Te)		X	X
Tin (Sn)		X	X
Titanium (Ti)	X	X	X
Tungsten (W)	X	X	X
Uranium (U)		X	X
Vanadium (V)	X	X	X
Zinc (Zn)		X	X
Zirconium (Zr)	X		X

Together there are 39 Critical Minerals

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Another Classification Scheme?

Why?

- Improve Communication
- Facilitate deposit comparisons
- Place deposit types in a systems framework

How?

- Met twice a month for a year
- Resolved System vs. Environment
- Compared deposit type names in each country…settled on 189

Table 2. Deposit Classification Scheme

System type/Genetically related features (N=40)

Deposit environment (N=12)

Deposit group (N=52)

Deposit type (N=189)

Linked to samples in the Global Geochemical Database

Synonyms

Examples

References (N=313)

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Genetically related features

is a proxy for *System type*

Porphyry copper system of Sillitoe, 2010 =
Calc-alkaline porphyry-epithermal system, CMMI

Arc, magnetite series, calc-alkaline volcano-plutonic center, magmatic fluid, alkali and hydrolytic metasomatism, and myriad deposit types.

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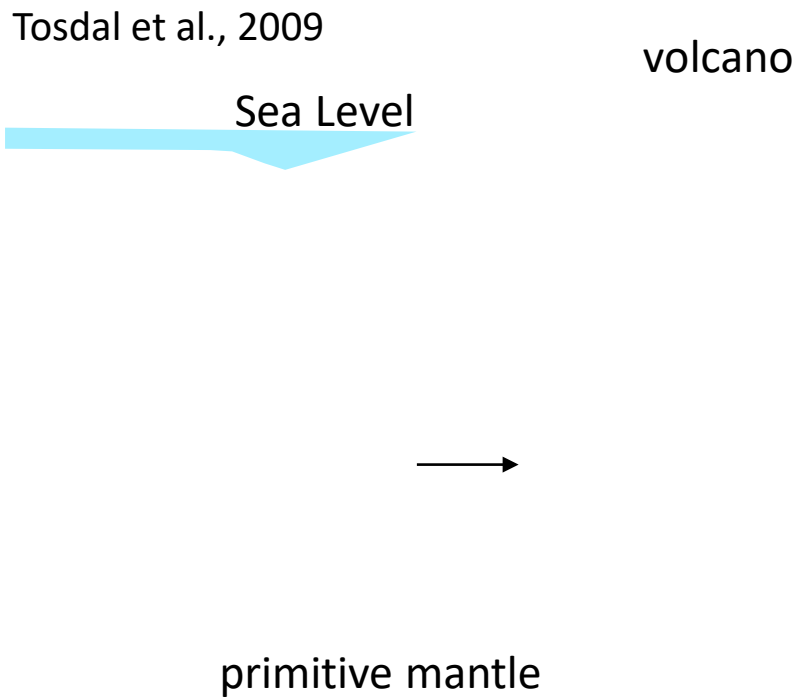
Example: *Subduction-related* Calc-alkaline Porphyry-Epithermal System: *Geotectonic models*

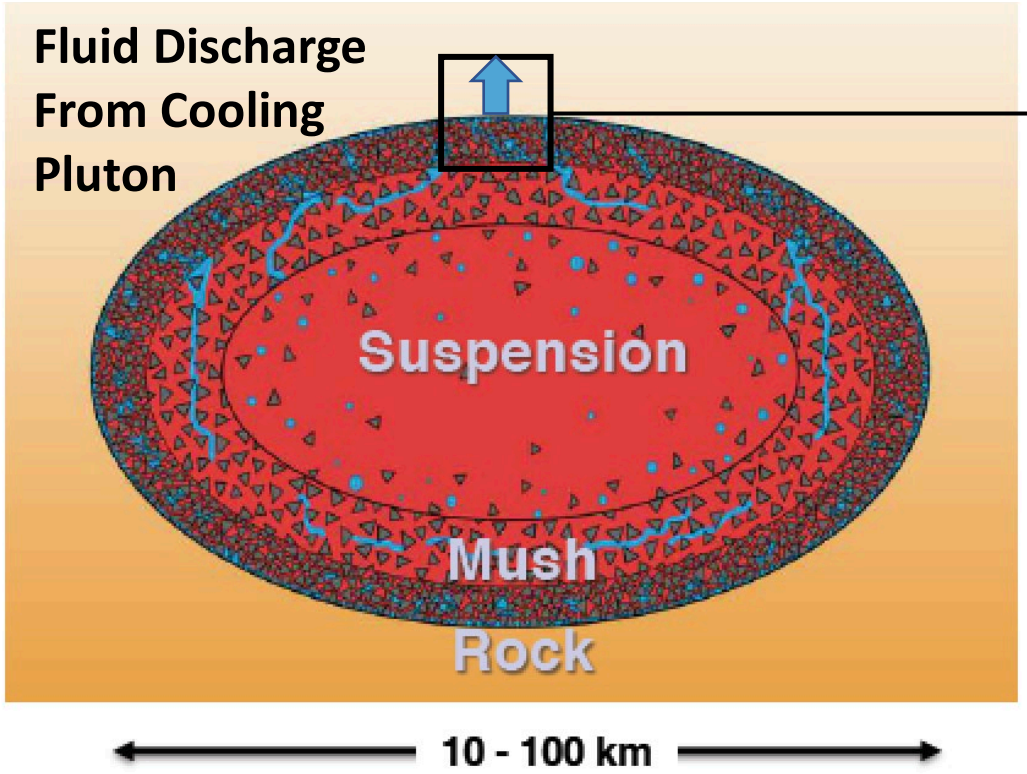
Dilles et al. 2015



Calc-alkaline Porphyry-Epithermal System: *Flow models*

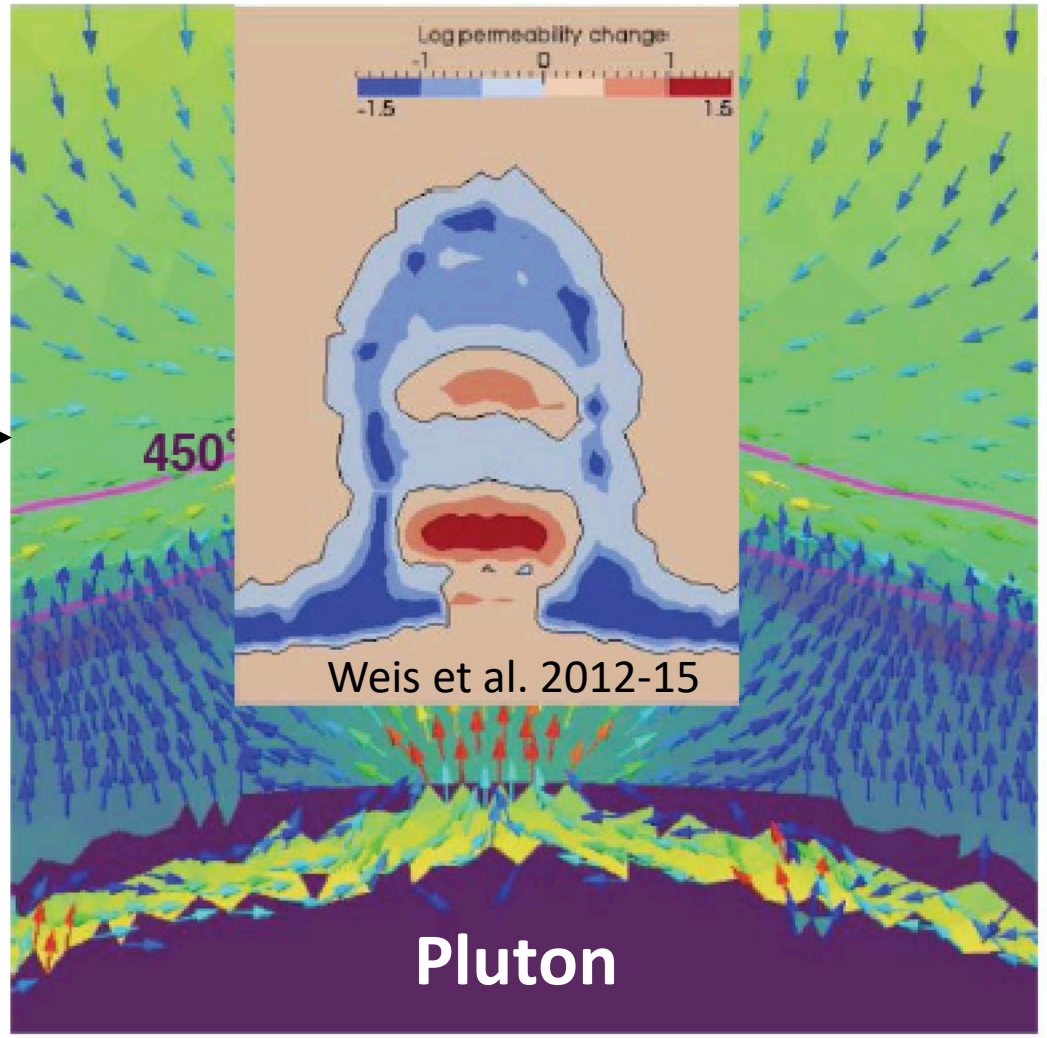
Heinrich et al., 2018

Lamy-Chappuis et al., 2020



Into Porphyry Stock

Meteoric water



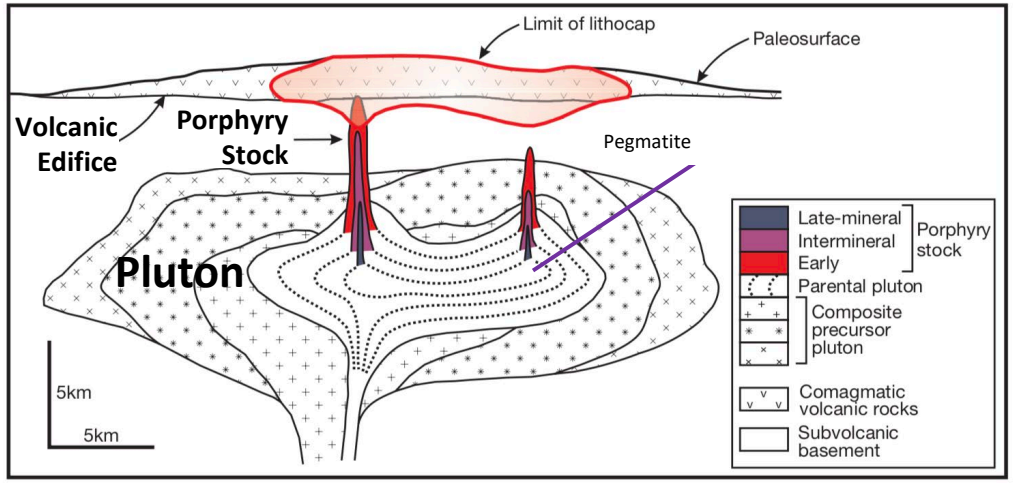
Weis et al. 2012-15

Calc-alkaline Porphyry-Epithermal System:

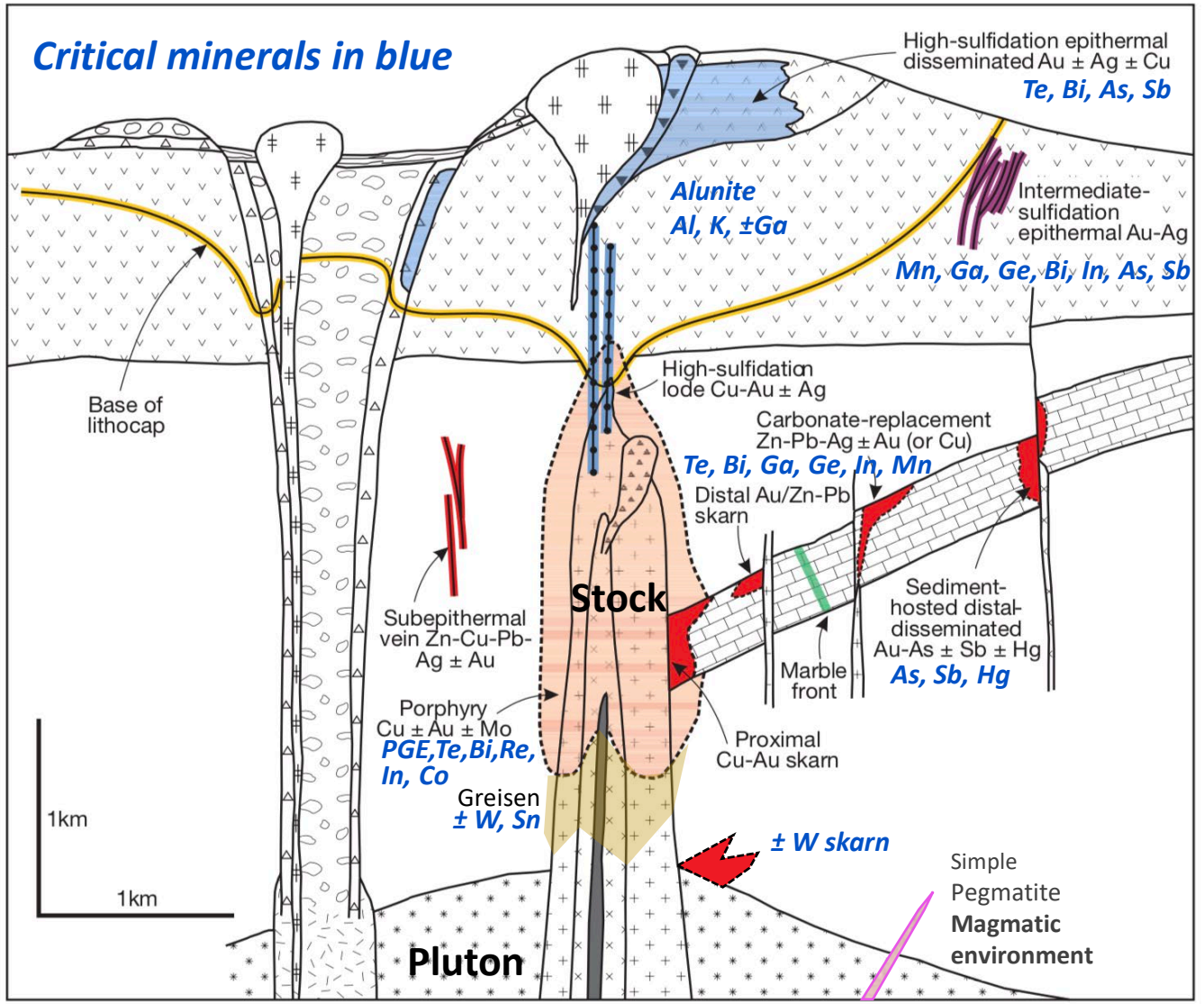
Cogenetic deposit types (same time, same place)

1 System type → many Deposit types

Magmatic hydrothermal environment



Trap part of the system



Adapted from Sillitoe, 2010

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Deposit environment *= Ore-forming environment*

- Erosional
- Supergene
- Infiltrational
- Basin evaporative
- Basin chemical
- Basin hydrothermal
- Metamorphic
- Metamorphic hydrothermal
- Regional metasomatic
- Volcanic basin hydrothermal
- Magmatic hydrothermal
- Magmatic

Deposit group term = *Key attribute of the deposit*

Most of the deposit type names consist of a term that describes a key attribute that is preceded or followed by one or more commodities that are typically recovered from the ore, e.g. *orogenic gold, porphyry copper, iron skarn*

In some cases, the deposit group term is preceded by a modifier that describes another characteristic that enables further discrimination, e.g. *epizonal orogenic gold*

Deposit type naming format

Optional modifier	+	Deposit group term	+	Commodity(s)
Epizonal		*Orogenic*		*Gold*
		Porphyry		*Copper*
		Skarn		*Iron*
High sulfidation		*Epithermal*		*Gold-silver*
		Carlin-type		*Gold*

Deposit Name Issues

- Same name for a System and its Deposit types (e.g. IRG, IOCG)

  Split out deposit types and assigned names

- Subtypes (e.g. Magmatic Ni-Cu-PGE deposits)

  Listed in Synonyms

- Deposit type occurs in multiple System types

  (e.g. Intermediate Sulfidation epithermal silver-gold)

  OK, because they can be distinguished by System type/GRF

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Uses of the classified Global GX Database

Identify the deposit types that have been poorly characterized.
Collect & analyze samples

Document the critical mineral signatures of each deposit type.
Focus exploration on specific deposit types

Identify individual deposits that are unusually enriched in critical minerals.
Prompt research to explain why

Compare critical mineral abundances in different deposit types
Mineralogy, Recoverability

Calculate the dollar value of potential critical mineral in ore.
Foster recovery

Place and quantify critical minerals in a systems framework
Resource assessments

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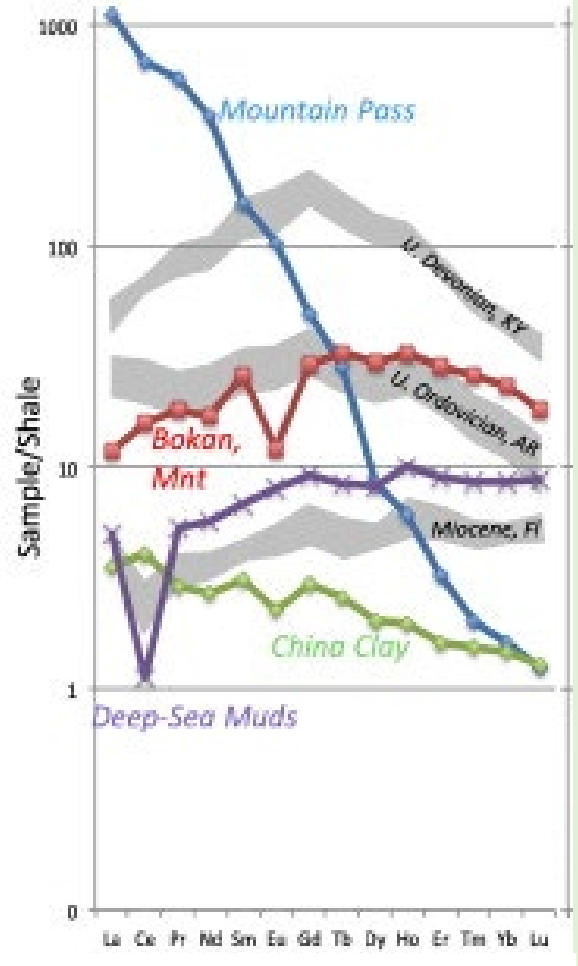
Phosphate Deposit REE comparisons vs. time

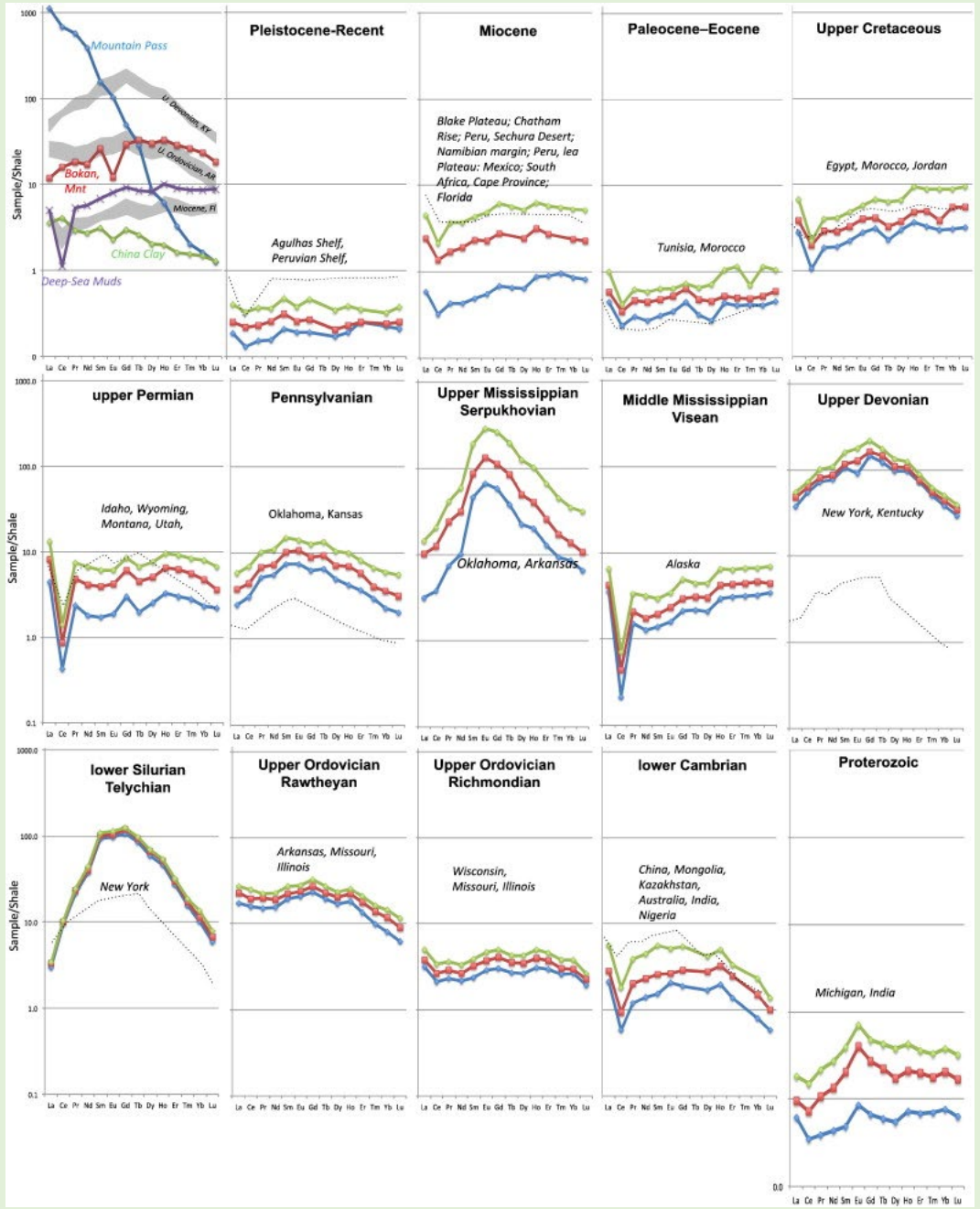
Emsbo et al. 2015



Deposit type:
Homogenous or Variable?

REE deposit types:
Compare Grade, Mineralogy, Evaluate Recoverability

We can apply this approach to other deposit types using the 60+ elements!



Utility of Critical Mineral/Primary Commodity Ratios

CM/PC in ore x tonnes PC = tonnes CM

Tonnes PC Production: Estimate tonnes CM in processed waste

$ value, recoverability, waste as a resource?

Tonnes PC Resource: Estimate tonnes CM future(?) production

$ value, recoverability, incentives?

CM resource maps

CM/PC in ore x PC grade = CM grade

Plot vs. deposit tonnes to make CM grade-tonnage models

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Utility of CM/PC ratios: CM tonnes & USD value

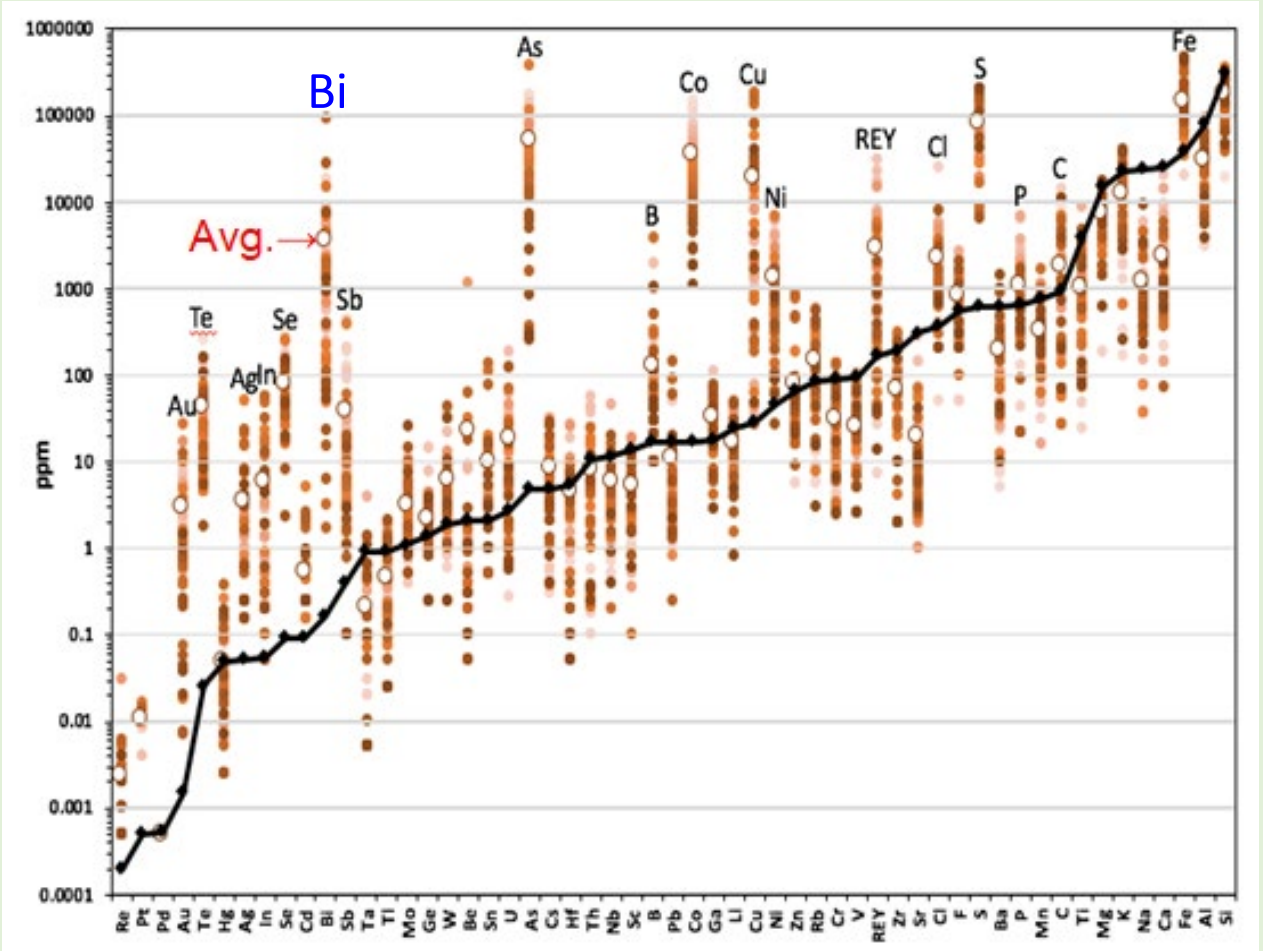
Composition of Co-Cu Ore in the Idaho Cobalt Belt relative to Upper Crust

USMIN: 6289 t Co produced 1939-1968

3785 Bi/37528 Co x 6289 t Co = 634 t Bi

= $4.2 million

Waste as a Resource



Legacy data from Slack, 2012 and Nash et al., 1988

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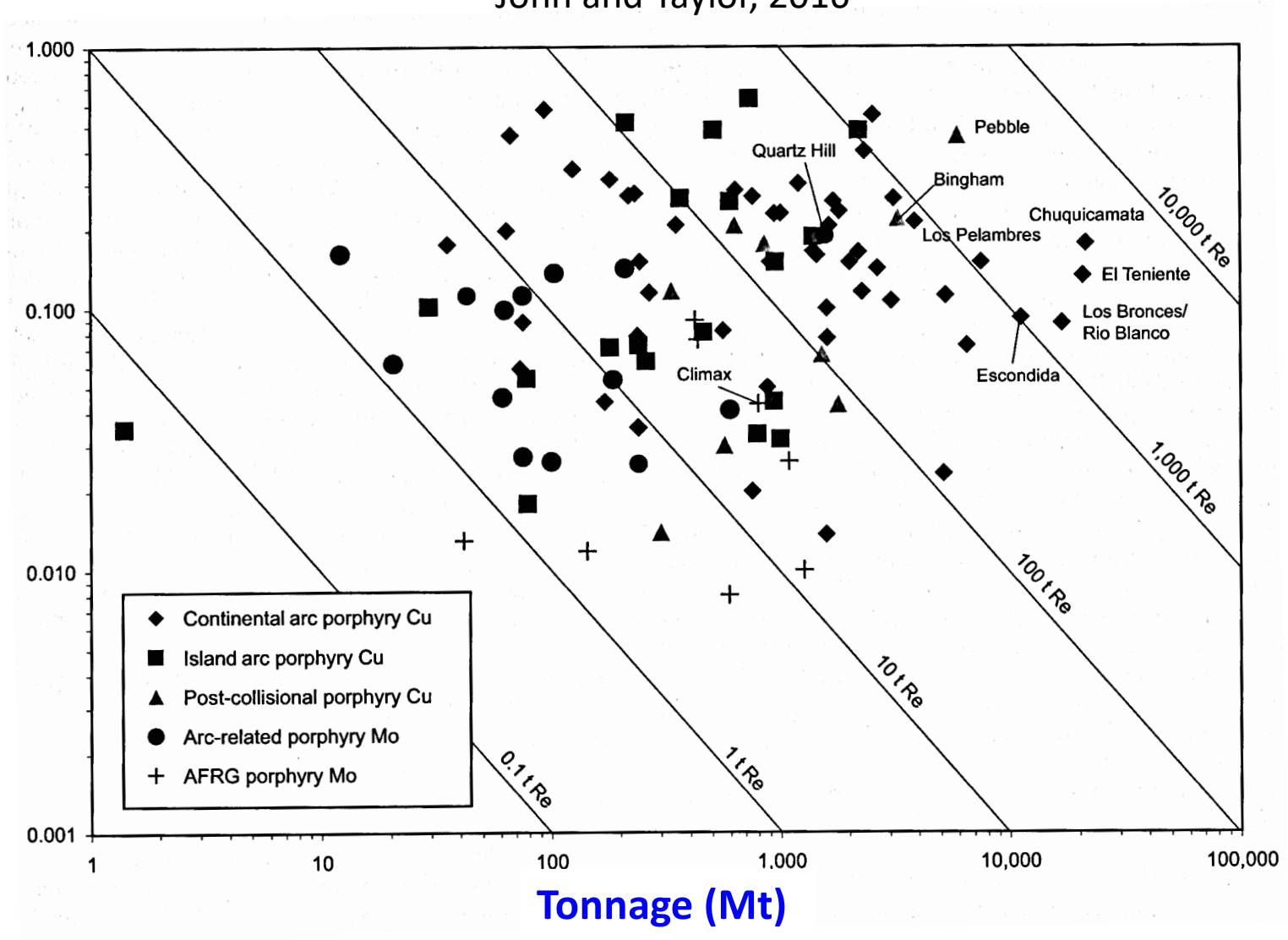
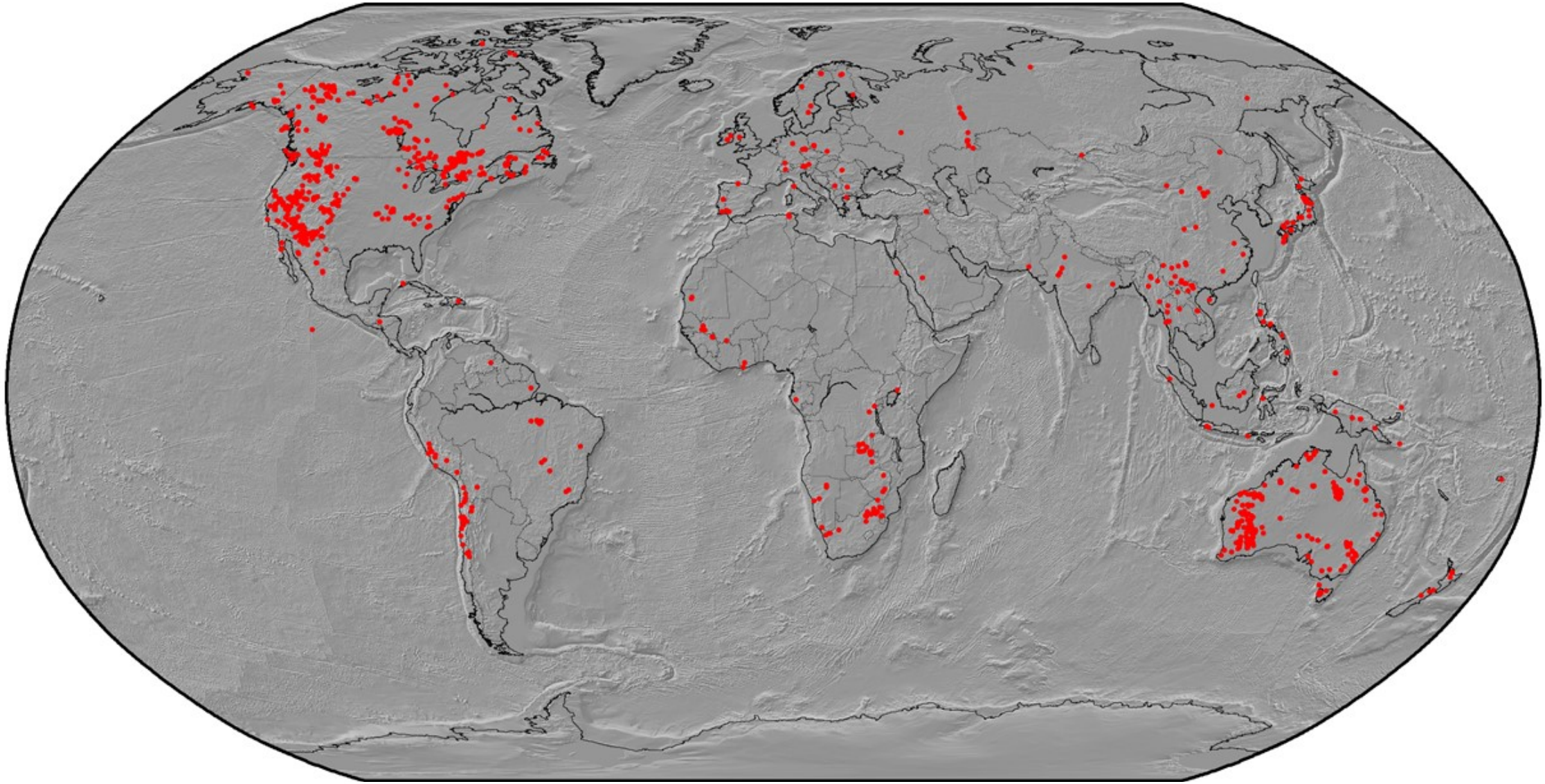
Utility of CM/PC ratios: *Re* G-T model - Porphyry deposits

John and Taylor, 2016



CMMI Global Geochemical Database



Ore sample location map

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