

Evaluation of Factors Affecting Porphyry Mine Drainage Chemistry

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WORKSHOP

*“Challenges and Best Practices in Metal Leaching
and Acid Rock Drainage”*

“Building and Using Drainage Chemistry Datasets
for Analog Sites”

Acknowledgements

Building analog datasets involves a lot of effort:

- Mining companies and others who sponsor the work.
- Water samplers. A small, grey, four-rotor drone with a cylindrical water sampling container attached to its front. It is shown in flight, moving towards the left, with motion lines behind it.
- Mine operators and regulators who provide data.
- Colleagues who organize, QA and interpret the data.

- Imperial Metals, Red Chris Project

Today...

1. The premise of the analog approach to drainage chemistry prediction
2. Building useful analog drainage chemistry datasets.
3. Learning from analog databases - Case example: BC porphyry dataset.

The Premise

Plumlee, G.S., Smith, K.S., Montour, M.R., Ficklin, W.H., and E.L. Mosier, 1999.
Geologic Controls on the Composition of Natural Waters and Mine Waters
Draining Diverse Mineral-Deposit Types. In: L.H. Filipek and G.S. Plumlee (Eds.),
The Environmental Geochemistry of Mineral Deposits, Part B: Case Studies and
Research Topics, Reviews in Economic Geology Vol. 6B, Society of Economic
Geologists, Inc., 373-432.

- “.....static and kinetic methods are widely used to help predict the compositions of mine waters, they have several potential limitations.
- “another approach to mine-drainage prediction.... is one in which the compositions of existing mine waters draining geologically-similar deposit types in similar climates are measured empirically.”



The Premise

- We have a much better likelihood of making accurate predictions from full-scale conditions than laboratory tests.



Building Analog Datasets

- Overall objective → types of data
- Sources of data.
- Minimum parameter lists.
- Data quality.

The overall objective should not only be to compile statistics on drainage chemistry....

but to understand water-rock-atmosphere-biosphere interactions.

- Analog data should be [contact water chemistry](#).

Types of Data

- Individual results, not summary statistics.
 - Important for internal chemical consistency
- Full scale data obviously preferred, but what about smaller scale test data?



Types of Data – Other than Full Scale

- Lab data:
 - Leach tests (e.g. SFE, MWMP), humidity cell and column leachates, columns are contact water chemistry but are highly dilute.
- Field tests:
 - Barrel tests, tests pile are contact water chemistry but have short flow paths compared to full scale.



Types of Data – Other than Full Scale

- Highly mobile ions (e.g. sulphate).
 - Small scale tests (including field tests) are affected by high dilution ratios and short flow paths.
- Heavy element cations (e.g. copper).
 - Small scale field tests provide useful contact water chemistry for non-acidic waters.
- Standard laboratory procedures can be modified to provide full scale analog data
 - Slower water application
 - Repeated contact (e.g. flow path experiments).

Types of Data – Full Scale



Known diluted waters are avoided.

Diluted Waters



X Underground mine drainage



X Pit lake



X Tailings pond & seeps

Types of Data – When to Sample?




Winter conditions –
less dilution

Sources of Data

- Directly from mine site personnel.
- Environmental monitoring reports.
 - Often compliance points rather than near source.
- MEND reports
- Publications
 - Statistical summaries and charts

Minimum Parameter Lists and Data Quality

- Reliable field pH measurements.
- Complete major elements (alkalinity, sulphate, Ca, Mg, K, Na)
 - For acidic waters, add Fe, Al.
 - Ion balances ($\pm 10\%$). 
- Other potentially important ions depending on setting
 - Cl, NO₃
- Filtered water analyses.
- Handling detection limits
 - Historical high detection limits add noise to datasets.
 - Accept only lowest detection limits.

Supporting Data

- Mineral deposit classification
- Geological setting
- Mineralogical and geochemical characteristics

The screenshot shows a web browser window displaying the MINFILE Mineral Inventory search page. The page header includes the British Columbia Ministry of Energy logo and navigation links. The main content area is titled "MINFILE Search" and shows a total of 13326 records. Below this, there are several tabs for different search criteria: Identification/Location, Mineral Occurrence, Host Rock, Geological Setting, Inventory, Production, Capsule Geology/Bibliography, and Import Numbers. The "IDENTIFICATION" section contains fields for MINFILE Name and MINFILE Number, along with a "Status" section with checkboxes for Anomaly, Developed Prospect, Past Producer, Producer, Prospect, and Showing. The "LOCATION" section includes two map selection lists: "BCGS Map" and "NTS Map", each with a list of map sheet numbers (e.g., 082E001 to 082E006 for BCGS and 082E01E to 082E03W for NTS). Below the maps, there are fields for "OR" (Other) and a section for selecting a bounding box using SE and NW coordinates, with options for NAD 27 and NAD 83 datums.

Analog Datasets

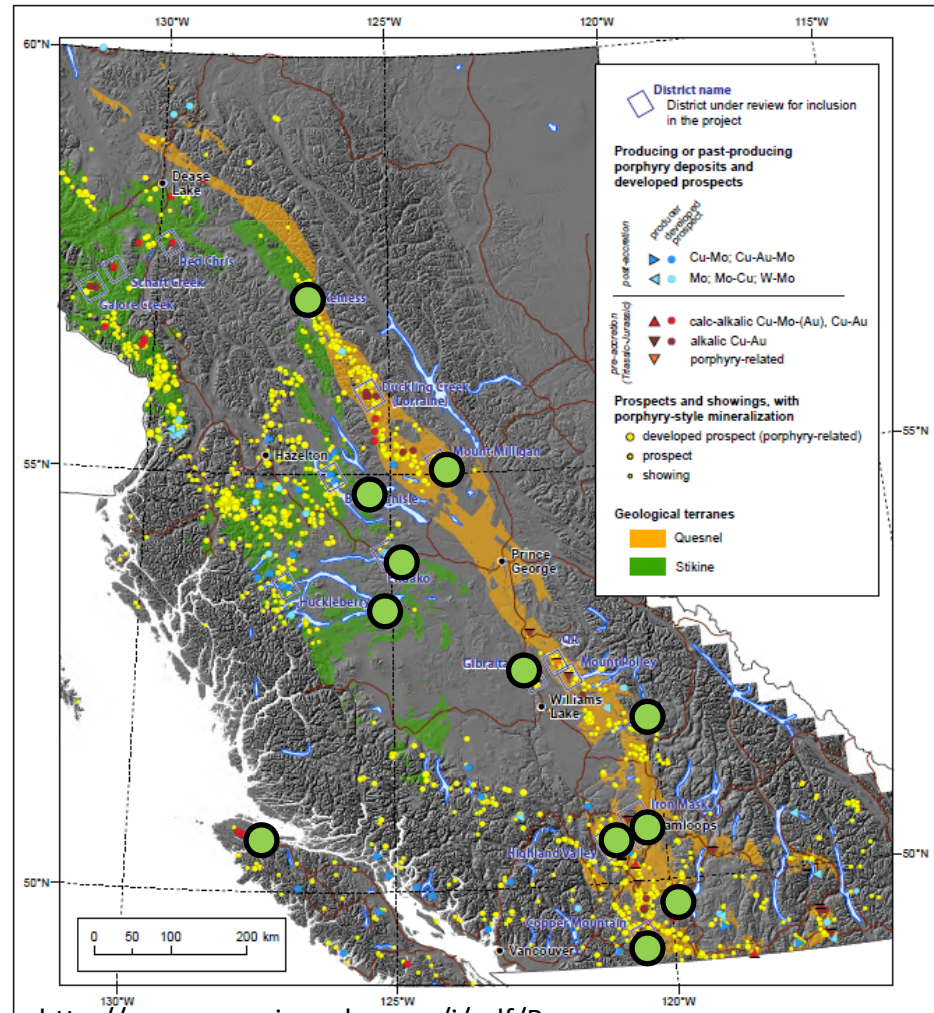
- Porphyries (e.g. Island Copper, BC)
- Coal (e.g. Tumbler Ridge area, BC)
- Kuroko-type volcanogenic (e.g. Britannia Mine, BC)
- Sedimentary exhalative (e.g. Anvil Range Complex, Yukon)
- Pluton-related Au (e.g. Brewery Creek Mine, Yukon).
- Layered ultramafic (e.g. Duluth Complex, MN)
- Unconformity roll front uranium (e.g. Rabbit Lake, SK)

Learning from Analog Datasets

- pH is usually the strongest master variable – examine data in context of pH (Plumlee et al. 1999).
- Interpret in context of known mineral solubilities.
- Interpret slopes of pH vs concentration.
 - Low pH: $M(OH)_3 + 3H^+ \leftrightarrow M^{3+} + 3H_2O$
 - Equilibrium Constant, $k = \frac{[M^{3+}]}{[H^+]^3}$
 - $\text{Log}[M^{3+}] = -3\text{pH} + k$, Slope of -3 on log-pH graph

Learning from Analog Datasets

- Porphyry mines (●)

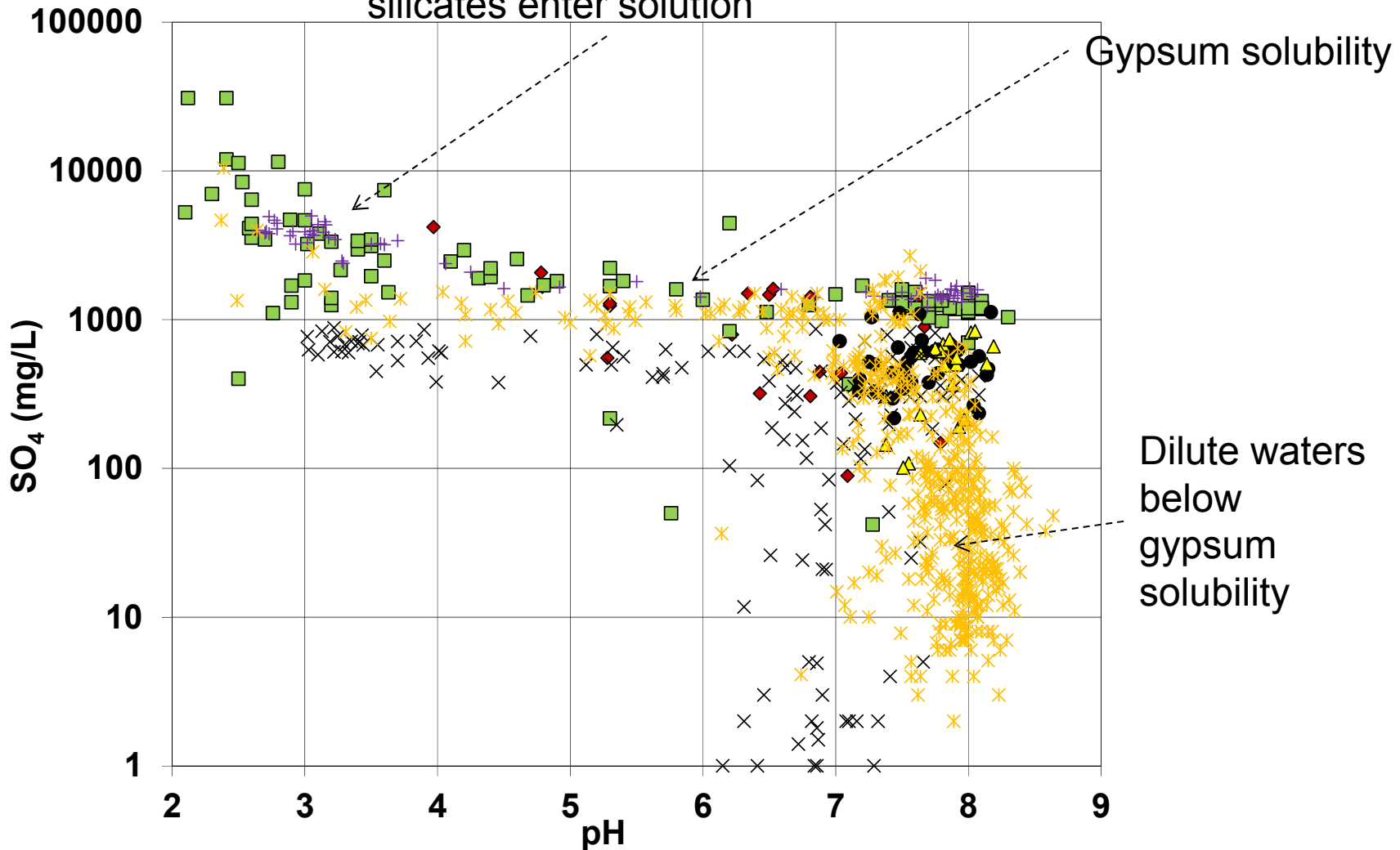


Learning from Analog Datasets

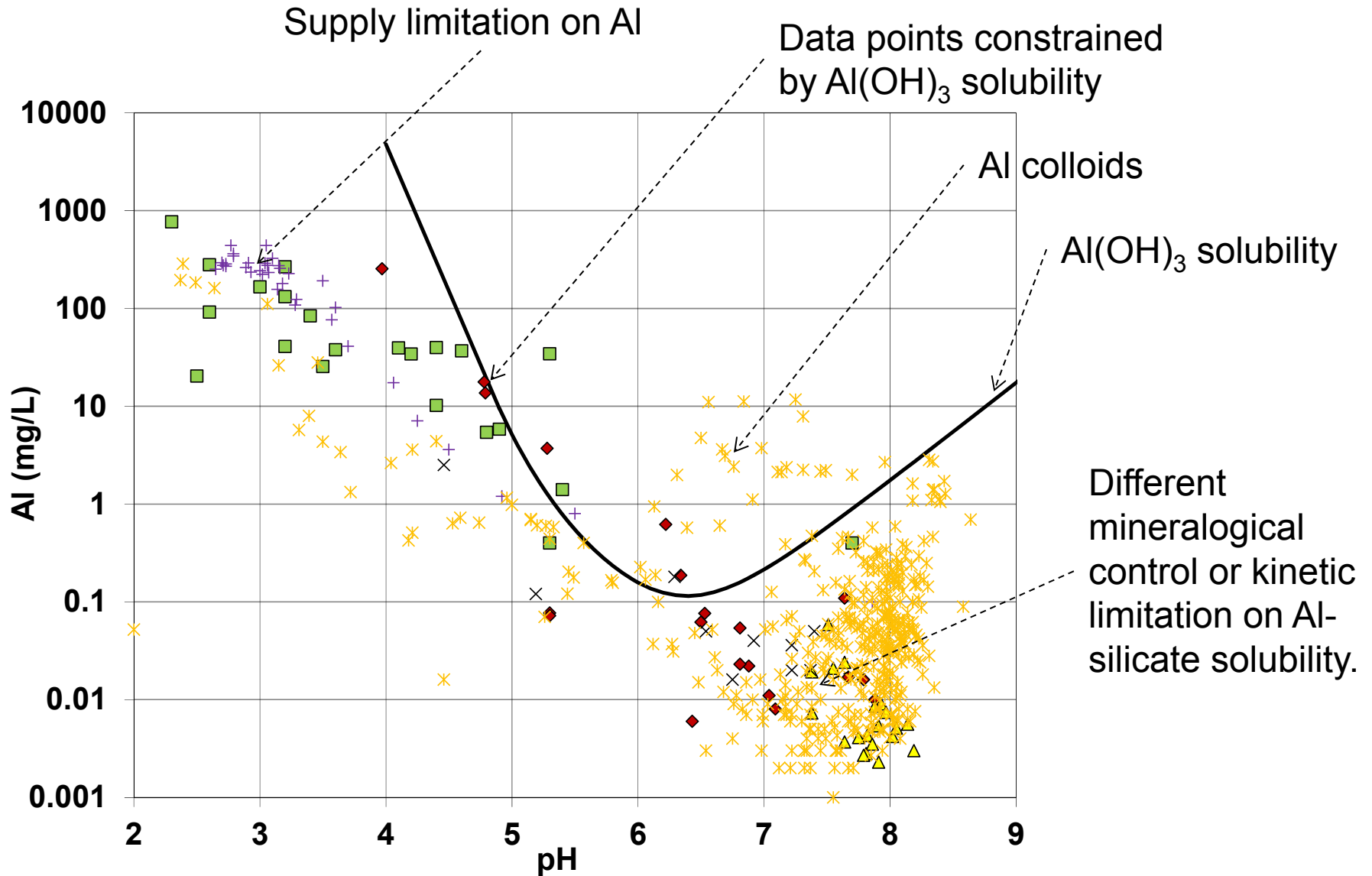
- Examples from the porphyry database
 - Strong mineralogical control – Sulphate
 - Strong mineralogical control with pH – Aluminum
 - Influence of host rock sulphide mineralogy - Zinc
 - Mineralogical control unknown but pH control – Arsenic.

BC Porphyry Dataset - Sulphate

Gypsum solubility
increases as ions from
silicates enter solution



BC Porphyry Dataset - Al

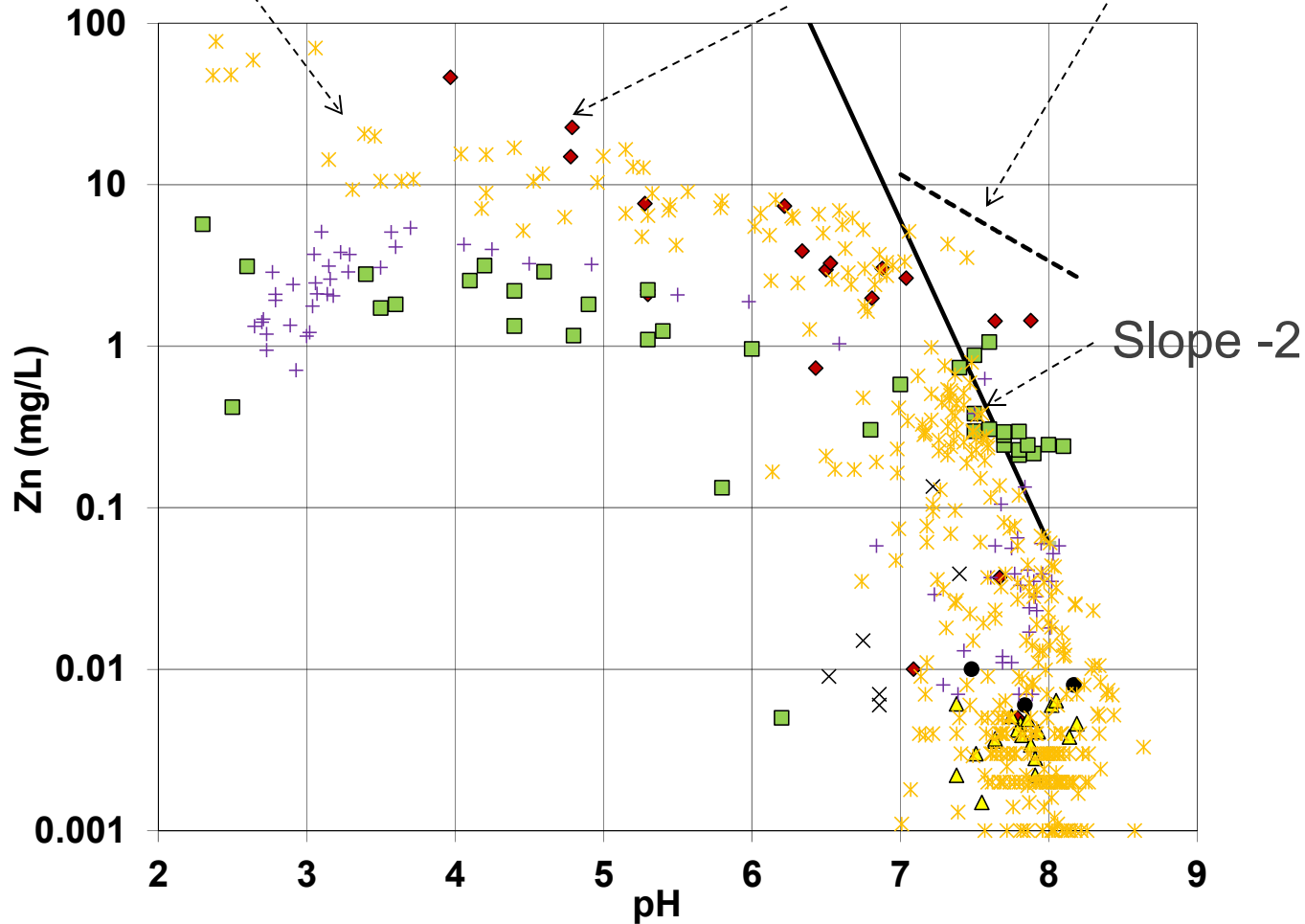


BC Porphyry Dataset - Zn

Non-porphphy waste rock

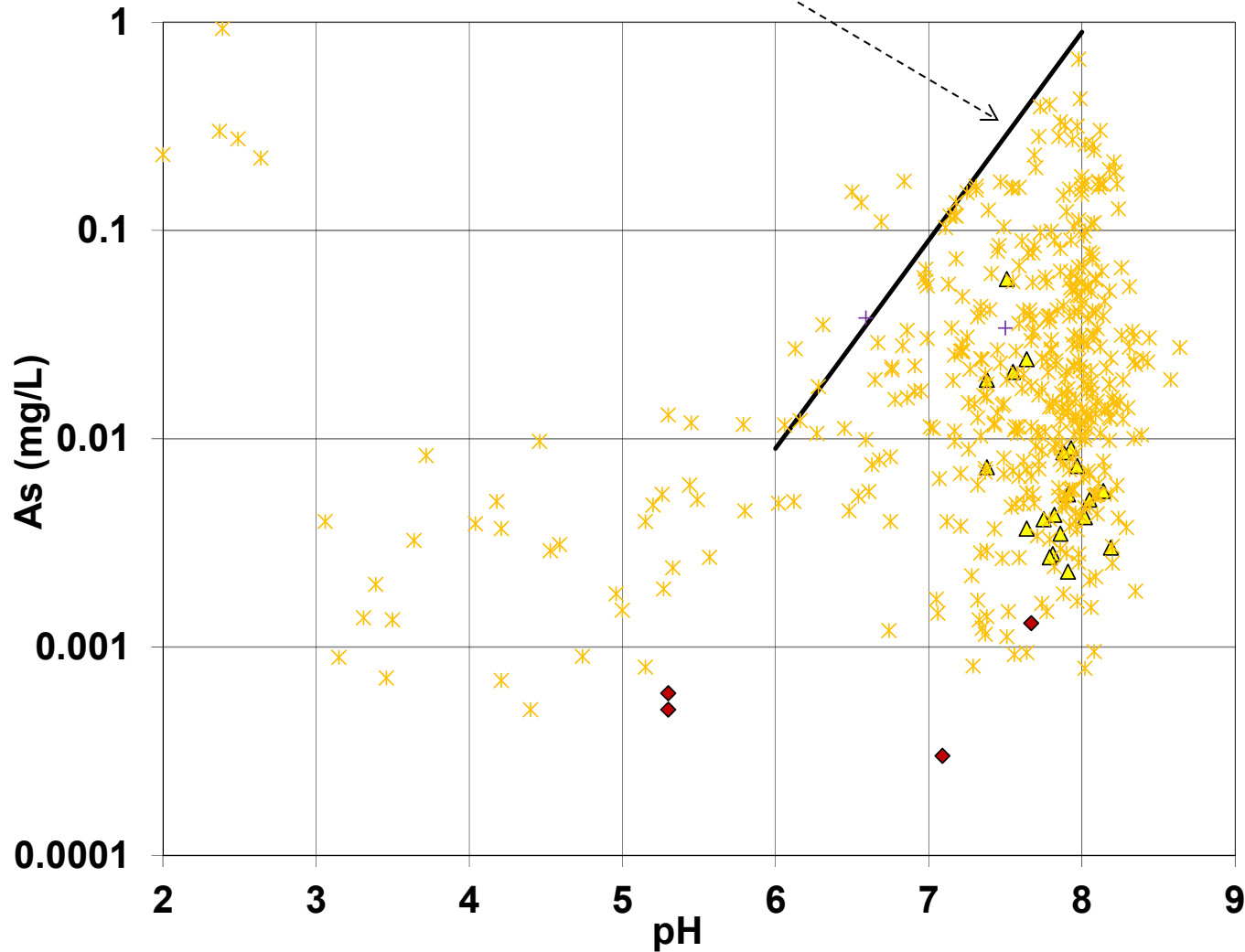
Waste rock containing ZnS

ZnCO₃ solubility (in the presence of calcite)



BC Porphyry Dataset - Arsenic

Slope +1: Solid As (e.g. sorbed) \leftrightarrow $\text{AsO}_4^- + \text{H}^+$



Conclusions

Analog datasets

- Selectivity about types of data – contact water.
- Minimum parameter lists.
- Quality control – ion balances, detection limits.
- Awareness of sources.
- Interpretation in pH context.

BC Porphyry database

- Consistent with primary mineralogy and mineralogical controls.

