

**TINTINA**RESOURCES

*Lisa Bithell Kirk, Ph.D., P.G.,  
Principal Geochemist*

*Katharine Seipel,  
Sr. Environmental Scientist*

*Lauren Bozeman,  
Geologist*



Environmental  
Geochemistry

**Black Butte  
Copper  
Project**

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# Objectives of Environmental Geochemistry Program

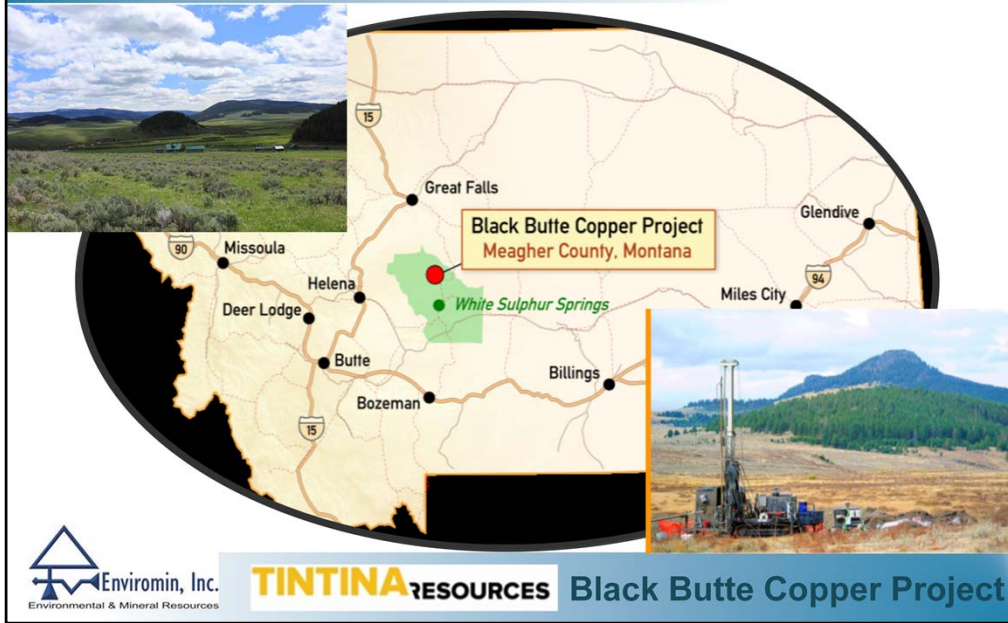
- Assess potential for acid rock drainage
  - By lithology, S%
- Describe metal mobility
- Evaluate
  - Risk of asbestiform mineral occurrence
  - Kinetic factors influencing leachate chemistry
  - Mineral residence of constituents of interest
- Guide facility design
  - 2012 Johnny Lee Exploration Decline
  - Construction materials
  - Waste rock disposal
  - Tailings geochemistry
  - Prediction of future groundwater quality



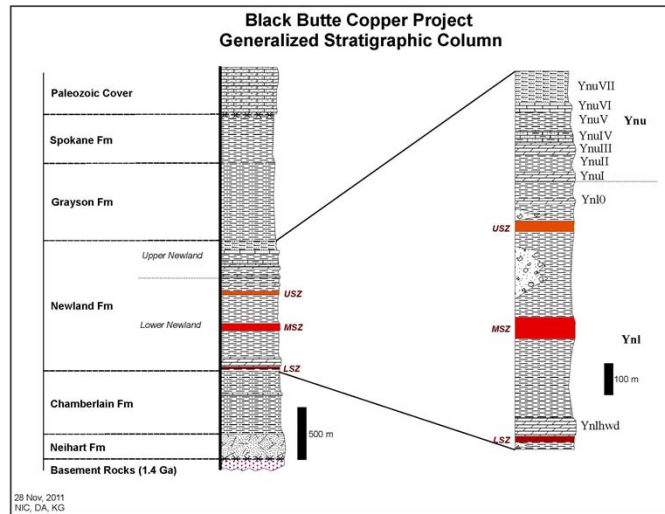
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# Location Map



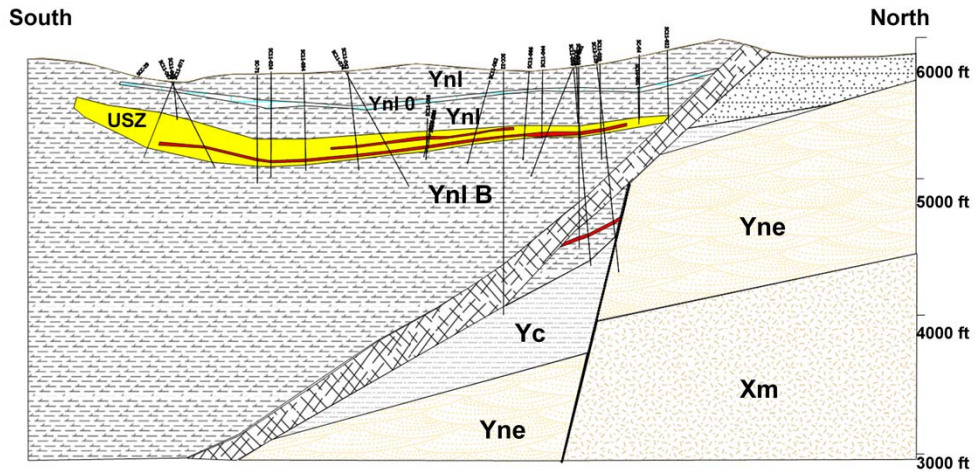
# Mid-Proterozoic Belt Sediments



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# Stratigraphic Cross Section of Proposed Mine Area



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## Waste Rock Lithologies

- Lower Newland
  - Upper Sulfide USZ
  - Undifferentiated Ynl
  - Dolomite/Dolomitic Shale Ynl O
  - Basal Conglomerates Ynl B
- Neihart Quartzite Yne
- Chamberlain Shale Yc
- Igneous Dike IG



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## Static Geochemical Testing

- Multi-element ICP-MS following 4-acid digestion (ICP)
- Acid Base Accounting (ABA)
- Net Acid Generation (NAG)
- Synthetic Precipitation Leachability Procedure (SPLP) (EPA1312)
- Mineral Liberation Analysis (MLA)
- Asbestiform Mineralogy (AM)



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## Summary of Static Testing to Date

<u>Lithotypes</u>	<u>ICP</u>	<u>ABA/NAG</u>	<u>SPLP</u>	<u>MLA</u>	<u>AM</u>
<i>USZ</i> <sup>1</sup>	3669	49	13	1	2
<i>Ynl</i>	1171	57	14	1	2
<i>Ynl O</i>	69	10	8	1	1
<i>Ynl B</i> <sup>2</sup>	1584	17	20	1	2
<i>Yne</i>	43	8	0	0	0
<i>Yc</i>	69	9	0	0	0
<i>IG</i>	37	8	8	0	1

<sup>1</sup>Initial USZ tests on ore and waste

<sup>2</sup>Additional static ABA/NAG data pending for *Ynl B*

Geochemical testing of tailings not yet conducted, but will be designed according to Tintina's operational management plan.



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# Static Testing Procedure

- Exploration ICP summary statistics guided sample selection
  - 8-18 samples from each waste unit for further testing
    - ABA and NAG
    - 1-2 samples for AM and MLA
    - SPLP initially, but problematic
  - Preliminary analysis of 1 sample from each rock type twinning
    - Archived crushed reject
    - Freshly crushed
  - Results of static testing informed decisions for kinetic testing

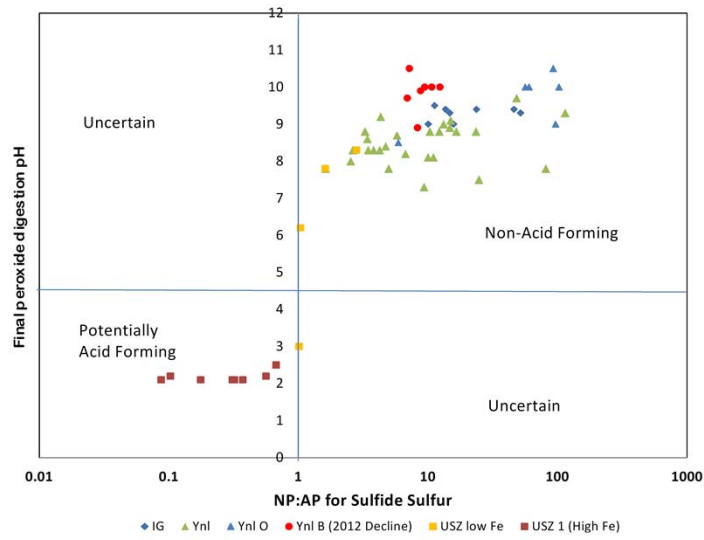


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# Johnny Lee Decline

## NP:AP versus NAG pH

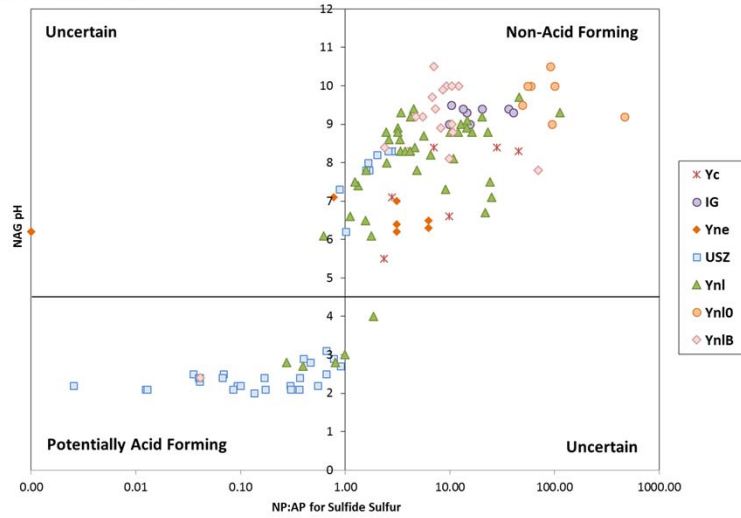


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# Site Wide Acid Generation Potential

NP:AP versus NAG pH

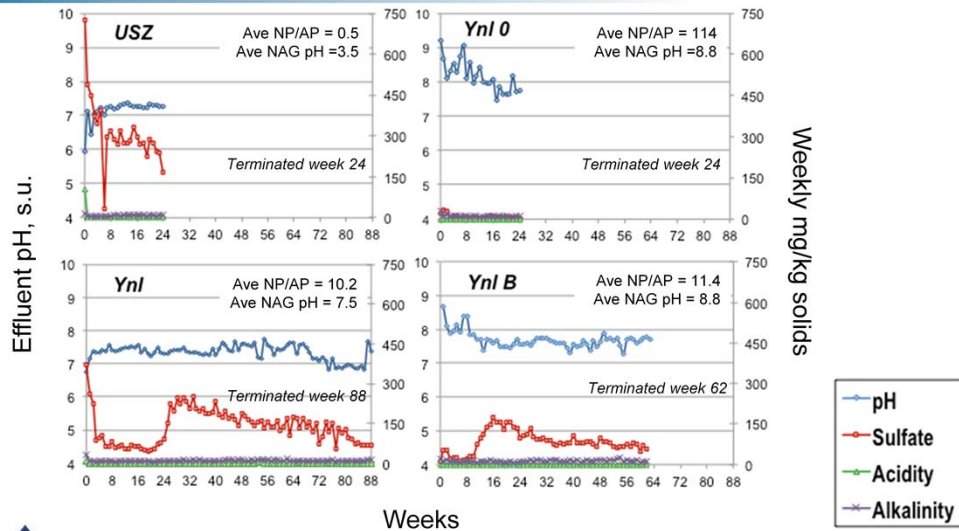


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Note from Katie: I did not hear constructive results from Vince, but Jerry provided me a comprehensive database last week, and I have double checked that these lithotypes are accurately reported here.

# Humidity Cell Testing: Weekly

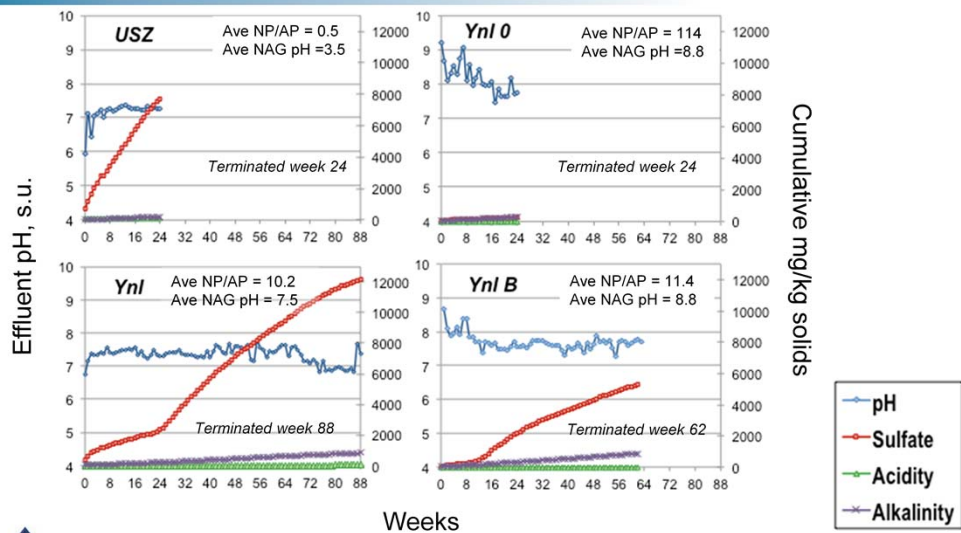


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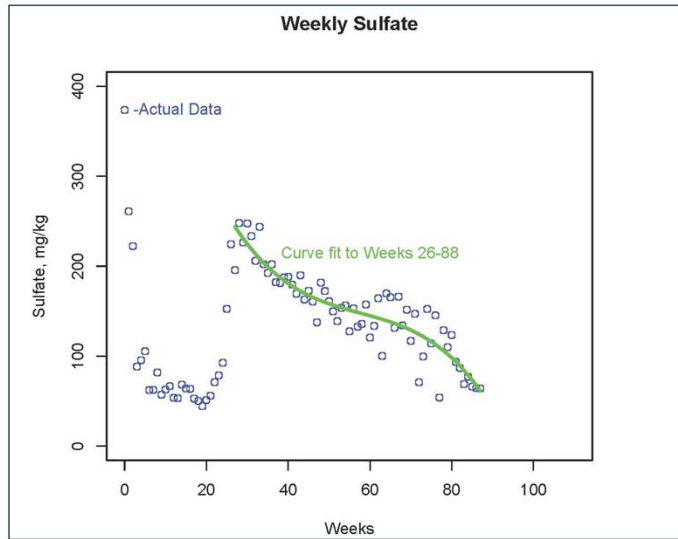
Not sure we should say “focus on tailings” in USZ text box... waste rock, versus ore issue here?

# Humidity Cell Testing: Cumulative



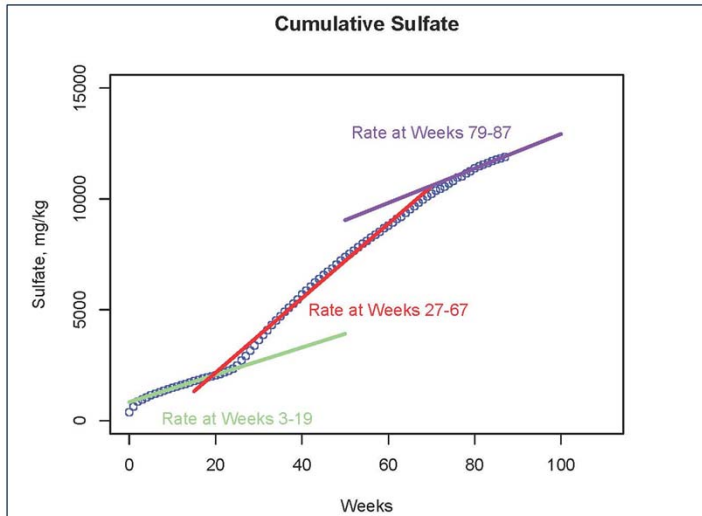
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# Ynl HCT: Weekly Sulfate Trend



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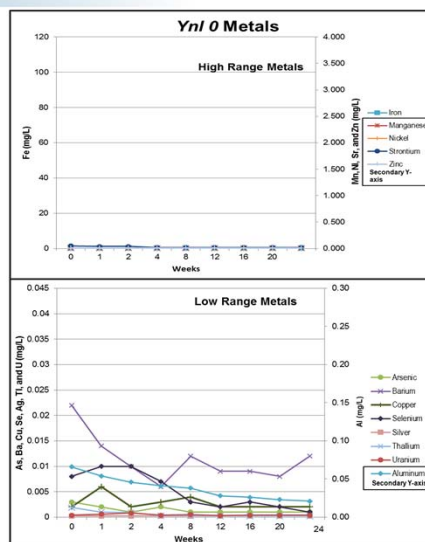
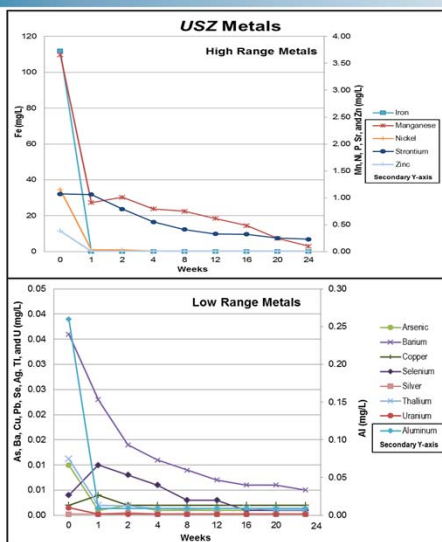
# Ynl HCT: Cumulative Sulfate Trend



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# HCT Metals

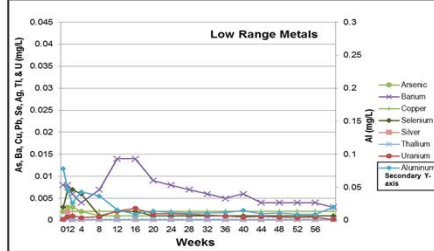
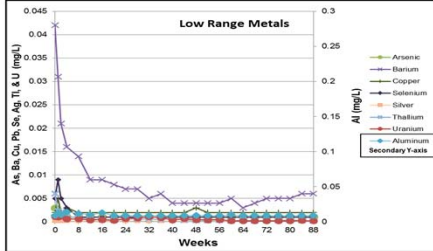
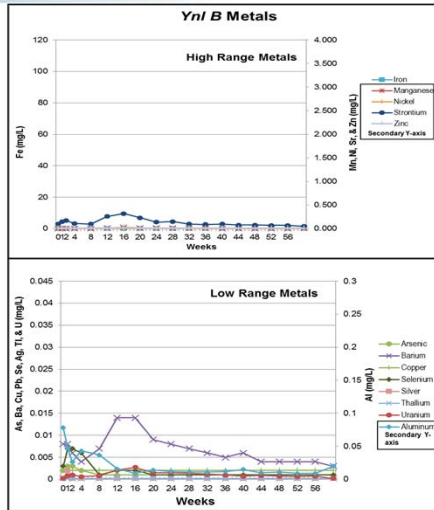
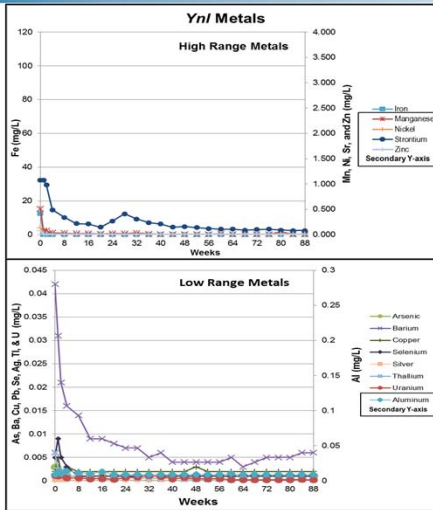


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# HCT Metals, *continued*



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# Kinetic Testing

- *USZ*
  - 1 HCT offline after 24 weeks
  - Additional kinetic testing in planning phase
- *Ynl 0*
  - 1 HCT offline after 24 weeks
  - Sufficiently characterized, no further testing planned
- *Ynl B*
  - 1 HCT offline after 62 weeks
  - Additional kinetic testing in planning phase
- *Ynl*
  - 1 HCT offline after 88 weeks
  - Sufficiently characterized, no further testing planned
- *Yc*
  - ABA Data: Average NP:AP=10.13, Average NAG pH= 7.7
  - HCT or MWMP being discussed
- *Yne*
  - ABA Data: Average NP:AP= 3.7, Average NAG pH= 6.5
  - HCT or MWMP being discussed

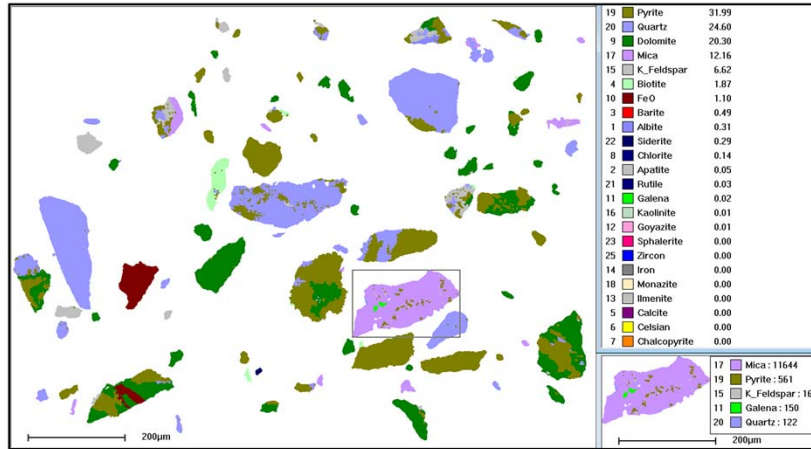
\*Results of static testing informed selection for kinetic testing



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# Mineralogy- USZ



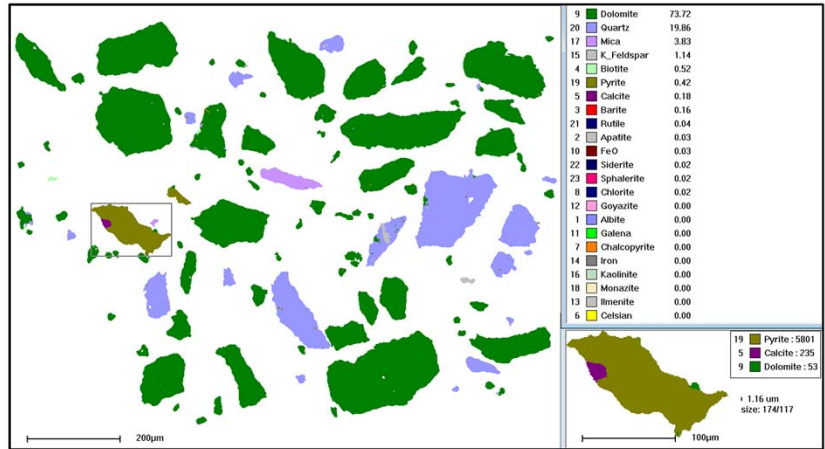
Classified MLA image from the USZ (-100 mesh). The particle inset shows the mineral surface area in pixels, concentration palette abundances in surface area percentage.



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# Mineralogy- Ynl 0



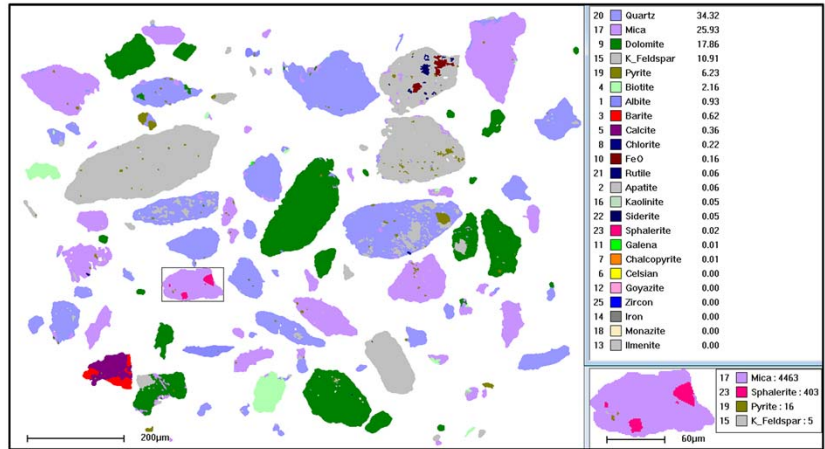
Classified MLA image of Ynl 0 (-100 mesh). Particle inset shows phase area in pixels and the concentration palette displays concentration as surface area percentage.



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# Mineralogy- Ynl



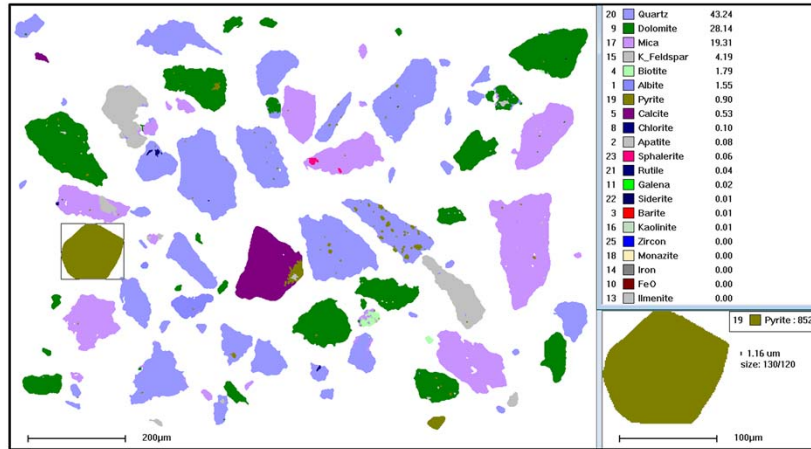
Classified MLA image from Ynl (-100 mesh). Particle inset shows mineral abundance in pixels and concentration palette shows mineral content in area percentage.



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# Mineralogy- Ynl B



Classified MLA image of Ynl B (-100 mesh). Particle inset shows phase area in pixels and the concentration palette displays concentration as surface area percentage.



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## Asbestiform Minerals

- No asbestiform minerals detected:
  - *IG*
  - *USZ* (2 samples)
  - *Ynl* (2 samples)
  - *Ynl 0*
  - *Ynl B* (2 samples)
- Testing underway for:
  - *Yc*
  - *Yne*



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## Acid Generation Potential

- High for the Upper Sulfide portion of the *Ynl*
- Neutral pH after kinetic testing up to 88 weeks for
  - *Ynl 0*
  - *Ynl*
  - *Ynl B*
- Static testing of *Yne* indicates inert chemistry
- Additional kinetic testing required for *USZ*, *Yc*, *Ynl B* to address spatial distribution



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# Metals

## KINETIC WORK

- Selenium Weeks 0 to 4,
  - *USZ, Ynl, Ynl 0, Ynl B*
- Thallium most Weeks
  - *USZ, Ynl, Ynl 0*
  - *NOT Ynl B*
- Trace Cd, Fe, Ni week 0
  - *USZ, Ynl*
  - Artifact of crushing, but may be released due to oxidation under acid conditions.

## GROUNDWATER

- Arsenic
- Copper
- Strontium
- Thallium

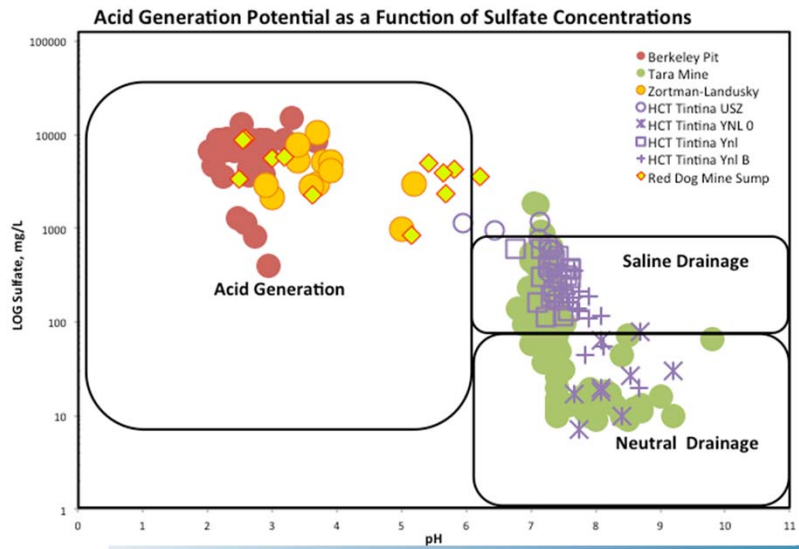
Only TI is observed in kinetics – different oxidation condition in test than in field? GW more reduced?



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# Ficklin Plot – Sulfate Comparison

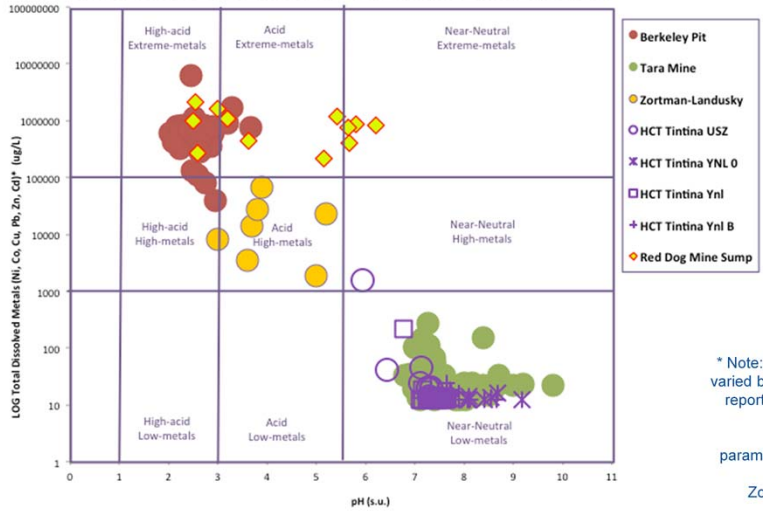


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# Ficklin Plot– pH and Metal comparison

Acid Generation Potential as a Function of Dissolved Base Metal Concentrations



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## Ongoing Work

- Complete waste rock characterization
  - How much of 2012 Johnny Lee Exploration Decline represented overall mine?
    - Revisited lithotypes deposit wide to assess sufficiency of characterization
    - Added untested lithologies
  - Modify metal mobility method to MWMP if kinetics not required
- Characterize tailings
  - Saturated kinetics?
  - Paste geochemistry? Cementation?
  - Closure design – biomineralization approaches



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