Mining Sustainability by Water Treatment, Tailings Repurposing and Slag Recycling

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Population 40,000
Close to 2 NP’s
Mining Sustainability by Water Treatment, Tailings Repurposing and Slag Recycling

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- Jessica Young
- Jamie Young

Montana Tech
THE UNIVERSITY OF MONTANA
OUTLINE

- Anti-Mining Sentiment
- Mining Sustainability
- Metallurgical Research
- Conclusions
- Acknowledgements
Anti-Mining Sentiment

It’s local and global:
East/Midwest
Montana
Nevada
California
Wisconsin
Honduras
Philippines
Nepal
Romania
Peru
Vatican
The Mining Industry needs more:

- Accountability
- Transparency
- Credibility

In general, there are 6 challenges:

- Social
- Political
- Economic
- Government
- Environment
- Health & Safety
OUTLINE

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Mining Sustainability

Suggests the need to minimize:
- Water consumption
- Energy consumption
- Land disturbance
- Waste production

and the criticality to conduct:
- Soil, water and air treatment
- Mine closure
- Land reclamation

Current needs met; future generations uncompromised

Environmental stewardship
- Social responsibility
- Integrated economy
OUTLINE

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METALLURGICAL RESEARCH

- Artisanal Mining (Example: Peru)
- Water (Cyanide, As/Se, ARD, Remediation)
- Slag (ARD Treatment, Recycling)
- Tailings (Lunar Soil, Resource Recovery)
- Energy Reduction (Electrowinning)
- Spent Materials (SPL Waste Minimization)
- Process Development (Au Thiosulfate, REEs)
METALLURGICAL RESEARCH

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Water
(Natural Remediation)
Modeling BPLW
(Deep Water, Pore Water and Sediment)

Collect Core Sample

Siphon/Filter Off Deep/Pore Water

Split & Section the Core

Analyze the Water & Solid Contents
Chemical Control by Mineral Solubility

Aluminum Solubility

- **Muscovite**
- **KAl_2AlSi_3O_10(OH)_2(s)**

Silicon Solubility

- **Surface Water (pH ~ 2.5)**
- **Deep Water (pH ~ 3.3)**

Ferric Iron Solubility in Pore Water

- **Schwertmannite**
- **Fe_8O_8(OH)_6SO_4**

Potassium Solubility

- **Jarosite**
- **KFe_3Al_2(SO_4)_3(OH)_6**

Graphs showing solubility versus pH for aluminum, silicon, iron, and potassium minerals.
Chemical Control by Mineral Solubility

Mineral

A - Kaolinite
B - Muscovite
C - K-Feldspar
D - Orthoclase
E - Albite
F - Anorthite
G - Annite

Amorphous SiO$_2$

Deep Water ~pH 3.3

pH

$\log_{10}$ SiO$_2$
What if the silicate mineral was slag?

- H - Fayalite
- I - Psuedowollastonite
- J - Ackermanite
- K - Rankinite

Graph showing the pH and pSiO2 relationship with slag phases: Amorphous SiO2
Silicate Slags (in Montana)

Source of Silicate (and lime)

Act as pH-Buffers (replace lime)

Available everywhere (active and inactive smelters)

Rhone Poulenc - Pseudowallastonite, CaSiO₃
ASARCO - Olivine-type, CaFeSiO₄
ARCO - Fayalite, Fe₂SiO₄

<table>
<thead>
<tr>
<th>Slag</th>
<th>Ca (%)</th>
<th>Fe (%)</th>
<th>Si (%)</th>
<th>Fe/Si</th>
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</thead>
<tbody>
<tr>
<td>Rhone Poulenc</td>
<td>30.3</td>
<td>0.4</td>
<td>19.0</td>
<td>~ 0</td>
</tr>
<tr>
<td>ASARCO</td>
<td>14.0</td>
<td>22.6</td>
<td>22.7</td>
<td>~ 1</td>
</tr>
<tr>
<td>ARCO</td>
<td>2.6</td>
<td>30.9</td>
<td>15.8</td>
<td>~ 2</td>
</tr>
</tbody>
</table>
Slag Remediates!
Slag (Recycling)

Variables
- Temperature
- Time
- Carbon Amount
- Slag Site
- Flux Addition

Responses
- Iron Recovery
- Glass Hardness
- Glass Density
ANACONDA SLAG

<table>
<thead>
<tr>
<th>Glass One</th>
<th>Temp (°C)</th>
<th>Carbon(g)</th>
<th>Time(min)</th>
<th>Recovery(%)</th>
<th>Hardness(VH)</th>
<th>Specific density(g/cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1410</td>
<td>12.5</td>
<td></td>
<td>73.7</td>
<td>92.23</td>
<td>646.9</td>
<td>2.71</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Glass Two</th>
<th>Temp (°C)</th>
<th>Carbon(g)</th>
<th>Time(min)</th>
<th>Recovery(%)</th>
<th>Hardness(VH)</th>
<th>Specific density(g/cc)</th>
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</thead>
<tbody>
<tr>
<td>1500</td>
<td>15</td>
<td></td>
<td>67.5</td>
<td>66.89</td>
<td>692.1</td>
<td>2.92</td>
</tr>
</tbody>
</table>
Tailings
(Lunar Soil)

Fine Powder
Lunar Regolith
Broken Rock
NASA Flowsheet - Road Norite (SMC Tails)

1. Road Norite
2. Crush to -600 μm
3. Screen at 75 μm
4. -600/+75 μm
5. Paramagnetic Material
6. RE Belt Separator
7. Nonmagnetic Material
8. Electrostatic Separator
9. Tails
10. Pyroxene Separate
11. Hydrated Silicates
12. Wet Grind to 80% Passing 45 μm
13. Flotation (Collector)
14. Plagioclase Separate
NASA Flowsheet - Spent Sand (Casting)

Mineral Formula

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Formula</th>
<th>Lunar Soil</th>
<th>Calculated Wt. %</th>
<th>NASA XRD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase</td>
<td>(Na, Ca)(Si, Al)(_2)O(_8)</td>
<td>75</td>
<td>75.01</td>
<td>79</td>
</tr>
<tr>
<td>Orthopyroxene</td>
<td>(Mg, Fe, Ca)(Mg, Fe, Al)(_2)O(_6)</td>
<td>10</td>
<td>11.09</td>
<td>12</td>
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<tr>
<td>Clinopyroxene</td>
<td>(Ca, Na)(Mg, Fe)(Si, Al)(_2)O(_6)</td>
<td>5</td>
<td>3.31</td>
<td>1</td>
</tr>
<tr>
<td>Olivine</td>
<td>(Mg, Fe)(_2)SiO(_4)</td>
<td>10</td>
<td>9.99</td>
<td>8</td>
</tr>
</tbody>
</table>

Spent Sand

Leaching with H\(_2\)O

Wet Grind to 80% Passing 45 \(\mu\)m

Filtration & Drying

Dissolved KHCO\(_3\)

Filtration & Drying

Filtrate

Olivine Separate (with 3% Clinopyroxene)
Minerals and metals are pillars of society

Minimal dependence on foreign supply

Importing commodities = exporting pollution

Environmental Stewardship is mandatory

The Mining Industry is becoming Socially Responsible

Sustainability will lead to an Integrated Economy

More innovative research on resources is needed!
ACKNOWLEDGEMENTS

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All of the mining friends and companies that have supported us through the years

Undergraduate and graduate students who did the research, including my daughters

Collaborators and faculty who made it possible
GO PACK GO!