Characterization of Waste Rock Borrow Material for Use as Rock Armor to Reduce Tailing Impoundment Side-slope Erosion

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Mission Mine Tailing Reclamation

• Approximately 1200 acres of tailings
  – 350 acres of side-slopes
• Rock armor slopes per bankruptcy agreement (Previous reclamation highly eroded)
• Waste rock is cheapest source, but need:
  – Erosion resistant material
  – Non-acid generating, low metal leaching
  – 775,000 tons of material per 12 inches of depth
• Revegetation not a primary criteria
Natural Side-Slopes (Sonoran Desert)
Natural Side-Slopes (Sonoran Desert)
Study Objectives

- Identify rock armor sources with > 50% material > 0.5 inches (12.5 mm); geochemically not reactive
- Waste rock borrow material assessment:
  - Identify potential borrow material based on previous geochemical data
  - Characterize particle size distributions (PSDs) and geochemical characteristics of various waste rock sources
  - Evaluate potential phyto-toxicity, revegetation potential
- Erosion analysis of borrow material:
  - Erosion modeling (RUSLE2)
  - Rock armor field erosion test
Acid Base Accounting (ABA)

• ABA provides indication of propensity of material to produce acid mine drainage
  • Acid-neutralization potential (ANP) = assets
  • Acid-generating potential (AGP) = liabilities
  • Net neutralization potential (NNP) = ANP – AGP = equity
• Favorable rock armor ABA criteria: NNP > 0 (ANP/AGP > 1)
Waste Rock Armor Sources

• Potentially acceptable rock types
  – Volcanics (low Acid Generating Potential (AGP), low Acid Neutralization Potential (ANP))
  – Argillite (moderate AGP and ANP)
  – Arkose (mix of high and low AGP, moderate ANP)

• Six different source areas
Waste Rock
Characterization Approach

• Test pits and trenches
  – Visual logging of material types and oxidation levels
  – Digital images of rock piles and trench walls

• Composite and selected sample testing:
  – Split-Net imaging – Particle Size Distribution (PSD) (n=189)
  – Laboratory PSD (n=28)
  – pH and Acid-Base Accounting (ABA) (n=111)
  – Soil fertility and leachable metals (n=39)
Trenching on MND West
Split-Net Image Analysis
Characterization Results

• Initial Screening
  – WR3 Argillite: Significant oxidation and highly variable NNP
  – WR3 Volcanics: 50% material < 0.2 inches
  – SOD Area: 50% material < 0.4 inches and Negative NNP
  – In-Pit Argillite: Negative NNP
  – MND North Argillite, MND West Argillite, SXND Arkose meet screening criteria

• Mean Particle Diameter
  – MND North Argillite: 0.9 inches
  – MND West Argillite: 0.8 inches
  – SXND Arkose: Coarse = 1.5 inches; Fine = 0.3 inches
  – Mean diameter minus one standard deviation still meets criteria
  – More SXND Arkose material > 3.7 inches compared to MND Argillite material
# Geochemical Data

<table>
<thead>
<tr>
<th></th>
<th>Pyrite Sulfur (%)</th>
<th>CaCO₃ (tons/1000 tons)</th>
<th>pH (91% samples pH &gt; 7)</th>
<th>ANP/AGP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MND North Argillite (n=27)</strong></td>
<td>2.1%</td>
<td>119</td>
<td>7.7</td>
<td>1.73</td>
</tr>
<tr>
<td><strong>MND West Argillite (n=35)</strong></td>
<td>2.1%</td>
<td>94</td>
<td>7.6</td>
<td>1.37</td>
</tr>
<tr>
<td><strong>SXND Arkose (n=24)</strong></td>
<td>1.1%</td>
<td>56</td>
<td>7.8</td>
<td>1.83</td>
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<tr>
<td><strong>Alluvium (n=10)</strong></td>
<td>0.15%</td>
<td>98</td>
<td>7.6</td>
<td>34</td>
</tr>
</tbody>
</table>
Soil Fertility and Metals Data

• All samples showed moderate salinity (4 to 5 dS/m)
• High copper values above potential phytotoxicity thresholds
• Zinc and boron above potential phytotoxicity thresholds in some samples
• Native plant species adapted to high-salinity or copper conditions may not be adversely affected
EROSION ANALYSIS
Erosion Analyses

• Model potential erosion under various scenarios (using PSD data and RUSLE2)
  – Fine, average and coarse argillite material
  – 150 to 600 foot slope length
  – Furrowing and revegetation
  – Vary percentage of “gravel” cover

• Implement argillite field erosion test pads
  – 12 inches argillite over 12 inches alluvium
  – Unripped, Ripped (6 inches and 24 inches)

• Simulated rainfall with water truck spray:
  – 2 inch rain over 30 minutes (Test #1)
  – 4.5 inch rain over 60 minutes (Test #2)
Erosion Modeling Results

- Predicted annual Argillite erosion rates increase with slope length (2X from 150 ft to 600 ft)
- Furrowing along the contour on average decreases the predicted erosion by about 10%
- Increasing the gravel cover by 10% reduces predicted erosion rates by approximately 25%
- Coarse Argillite best
- Limit Argillite use to 3:1 slopes < 300 ft
Erosion Test Results

- No significant differences in PSD between pre-and post-test ripping plots
- Argillite ripped to 24 inches was most erosion resistant
- Cascading and rilling observed where ripping not perpendicular to slope, or shallow furrows
- Ripping treatments did not show effective mixing of the alluvium and argillite rock armor material
Conclusions

• Waste rock armor that is erosion resistant and geochemically inactive is available

• Side-slope reclamation design
  – One foot of alluvium base over tailings (extra ANP, potential for rooting medium)
  – One foot of rock armor material

• Full-length slope design (no benches):
  – MND West and North Argillite areas for use on slopes < 300 feet
  – SXND Arkose areas for use on slopes > 300 feet
  – Need to segregate visibly oxidized waste rock

• Revegetation potential?? – recommend salt tolerant seed mix
THE REAL EROSION TEST
Erosion on alluvium

- July 27 – 2.75 inch event (1 hour)
- July 30 – 2.52 inch event
Arkose