

# Current Thinking on Waste Rock Mixing to Mitigate Acid Rock Drainage and Metal Leaching Potential

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# Outline

- Timescales for mine waste management
- Premise of geochemical waste rock mixing
- Scale considerations for mixing
- Some risk factors and guidance

For a schematic cross section refer to **Figure 4-1** in Denholm, E. and Hallam, R., 1991. *A review of acid generation research at the Samatosum Mine. In Proceedings of the Second International Conference on the Abatement of Acidic Drainage (Vol. 2, pp. 561-578).*

# Timescales for Mine Waste Management

- Management technologies that allow slow incremental release of contaminant load over geological time are preferable to technologies that “halt” weathering.
- Waste mixing may be able to achieve this objective under some circumstances.

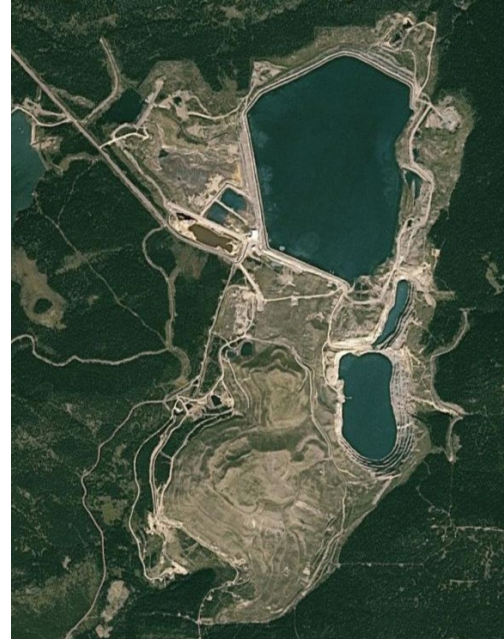
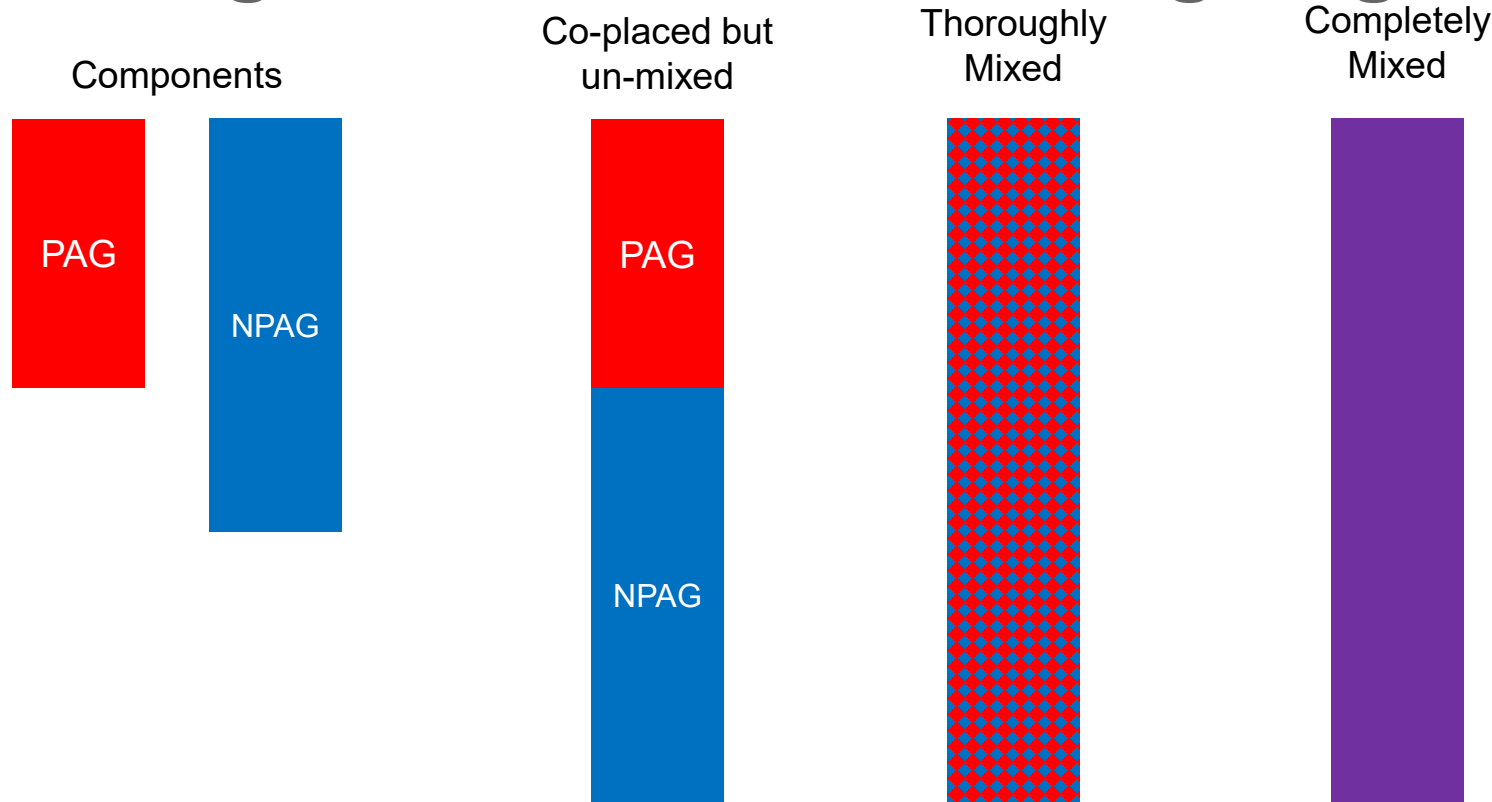


Image: Google Maps

# Premise for Geochemical Waste Rock Mixing

- Objective is to mix reactive waste rock with less reactive waste rock to slow down weathering reactions and result in a low likelihood of future worsening water quality.
- Focus is mainly on mitigating severe decrease in pH (i.e. from near neutral to below 5).

# Premise for Geochemical Waste Rock Mixing – Continuum of Mixing Degree



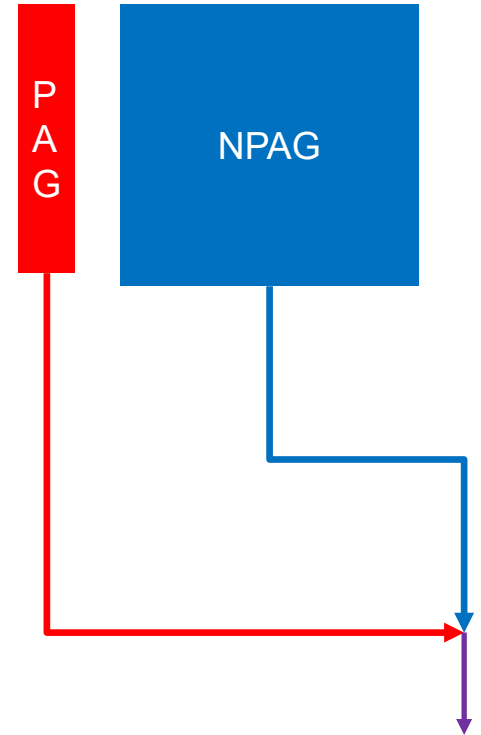
# Premise for Waste Rock Mixing

Mehling, P.E., Day, S.J. and Sexsmith, K.S., 1997, May. Blending and layering waste rock to delay, mitigate or prevent acid generation: a case review study. In *Proceedings of the Fourth International Conference on Acid Rock Drainage* (Vol. 2, pp. 951-969)

Degree of Mixing	Name	Mitigation Achieved
Unmixed	Non-blend	Due to mixing of waters
Partly mixed	Non-ideal blend	Reaction of acidic contact water with acid neutralizing minerals
Thoroughly mixed	Ideal blend	Oxidation occurs under non-acidic conditions.

# Premise for Waste Rock Mixing – Non-Blend

- Wastes are co-placed but acid neutralization occurs by mixing of acidic and basic waters.
- Neutralization occurs if alkalinity (e.g.  $\text{HCO}_3^-$ ) in basic waters overwhelms acidity in acidic waters ( $\text{H}^+$ ,  $\text{Fe}^{2+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Al}^{3+}$  etc.)
- Final  $\text{pH} < 8$ , limited precipitation of some metals (Cd, Co, Ni, Zn),
- Performance depends on relative flow volumes and chemistry of waters.



# Premise for Waste Rock Mixing – Non-Ideal Blend

- Accelerated oxidation occurs in the PAG material.
  - High solubility of metals associated with sulphides (Fe, Cu, Zn etc).
  - Strong reaction with silicates resulting in leaching of Al, Ca, Mg, K, Na.
- Neutralization by carbonate causes pH to increase precipitating Fe, Al likely leading to inefficient carbonate utilization.
  - Fe precipitates can sequester metals.

Co-placed but  
un-mixed

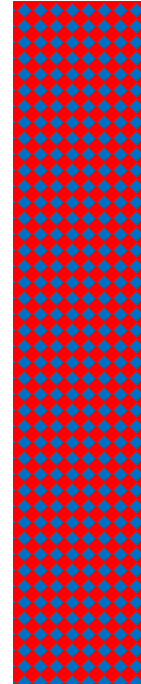




# Premise for Waste Rock Mixing – Ideal Blend

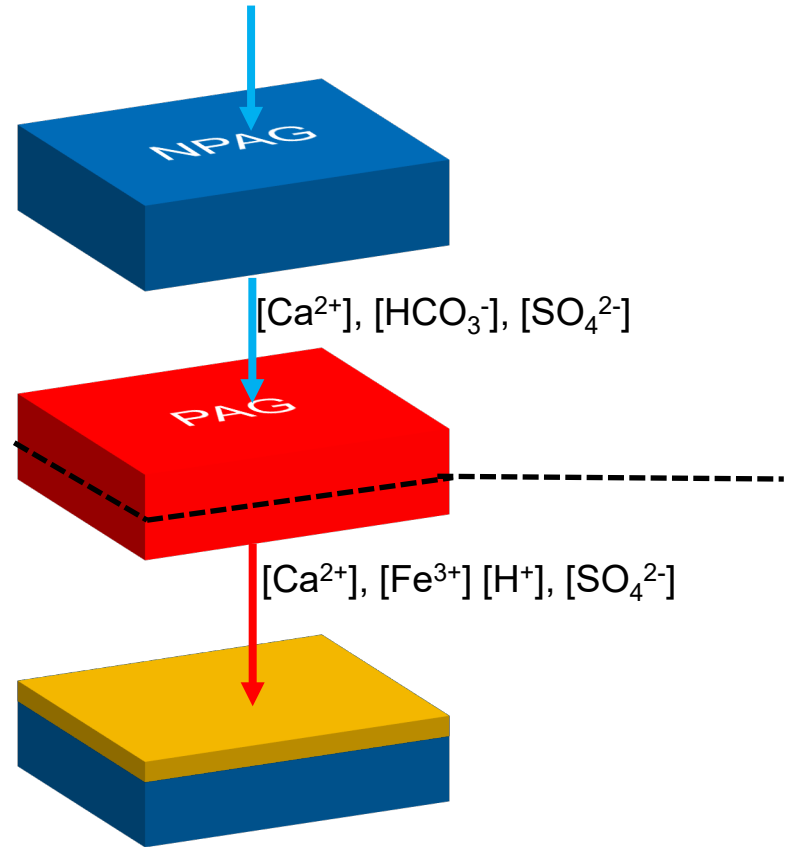
- Weathering occurs as if completely mixed.
- Iron does not migrate beyond iron-sulphides grain which are replaced by iron (ferric) oxide.
- Weathering processes are dominantly basic with acidity being consumed at the sulphide oxidation site.
- Oxidation rates are not allowed to accelerate.
- Metals are sequestered directly into the sulphide oxidation products.

Thoroughly  
Mixed



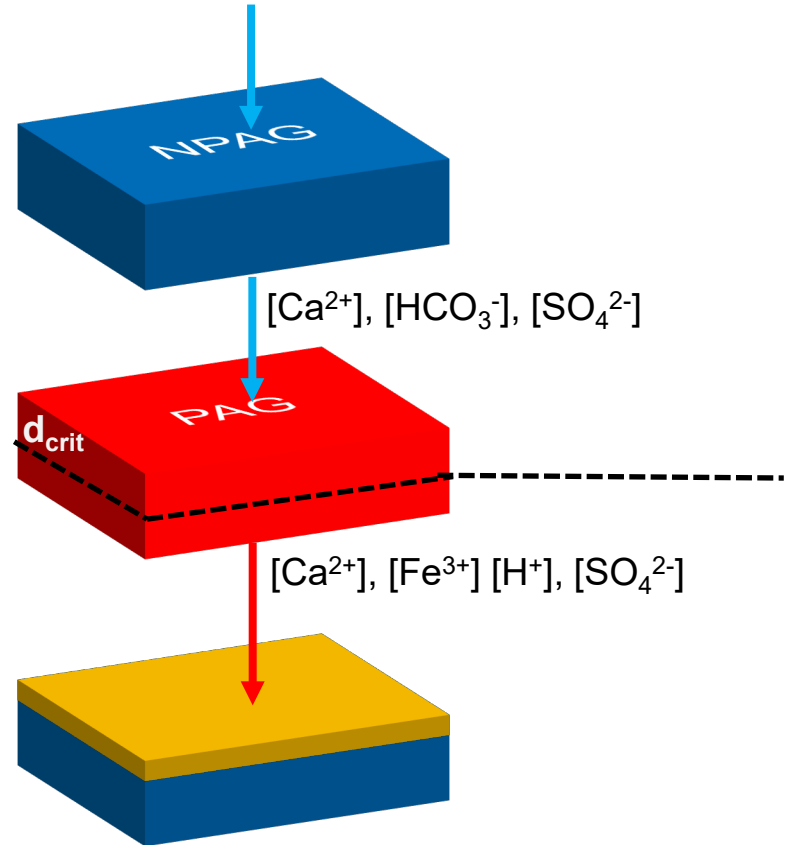
# Scale Considerations

- What defines ideal vs non-ideal?
- Dissolved  $\text{HCO}_3^-$  leaches from NPAG due to dissolution of carbonates.
- In PAG,  $\text{HCO}_3^-$  is progressively consumed by  $\text{H}^+$  from iron sulphide oxidation.
- If  $\text{HCO}_3^-$  is completely consumed in the PAG, acid water emerges.



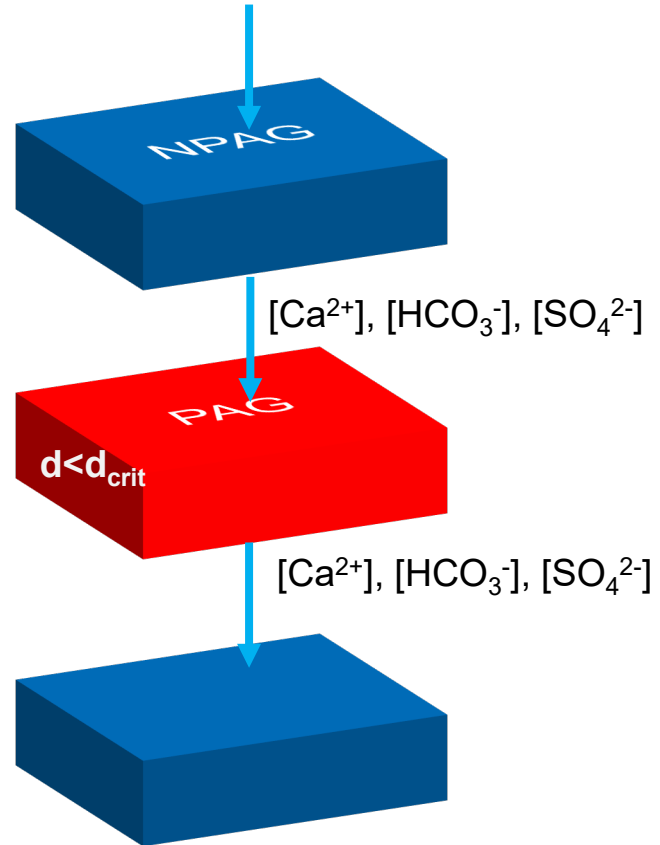
# Scale Considerations

- Dependency on rate of acid generation in PAG, and the rate of  $\text{HCO}_3^-$  delivery from NPAG.
- Scale relationship (d) for ideal blend described by:
  - $d < d_{\text{crit}} = 0.48 \frac{B \cdot I}{\rho \cdot R}$ 
    - B – alkalinity (mgCaCO<sub>3</sub>/L)
    - I – Infiltration (L/m<sup>2</sup>/year)
    - R – Rate of acid generation under basic conditions (mgSO<sub>4</sub>/kg/year)
    - ρ – Density (kg/m<sup>3</sup>)



# Scale Considerations

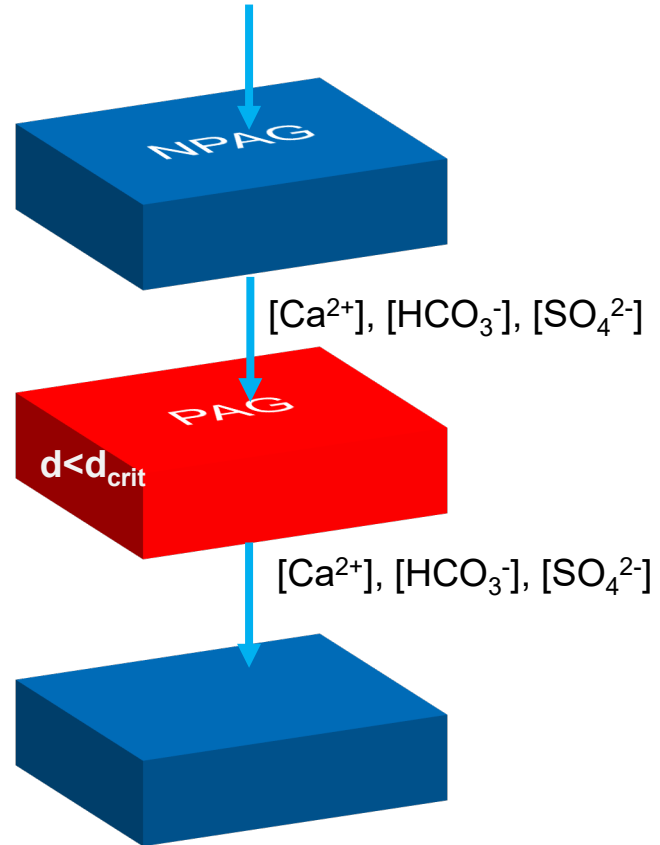
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# Scale Considerations

Implications of the scale equation:

- More reactive PAG wastes demand a greater degree of co-mingling than less reactive PAG wastes because  $d_{\text{crit}}$  is lower.
- Less soluble carbonates are less effective in delivering alkalinity.
- Rate of alkalinity delivery will be slower for drier climates.



# Some Risk Factors and Guidance

- Mass balance
- Reactivity of PAG materials
- “Metal” leaching
- Source of  $[\text{HCO}_3^-]$
- Placement method

# Risk Factors – Mass Balance

- Mass balance NP/AP must always exceed the individual sample threshold for acid generation (e.g. NP/AP>2).
- NP must be determined from Ca+Mg carbonate content. NP from silicates cannot be included in mass balance.
- Ideal blend implies most effective utilization of neutralization potential but mass balance needs to allow for imperfect mixing.
- Target mass balance NP/AP needs to be greater for more reactive PAG materials.

$$\text{NP/AP} = \frac{\text{NP}_{\text{PAG}} \cdot \text{M}_{\text{PAG}} + \text{NP}_{\text{NPAG}} \cdot \text{M}_{\text{NPAG}}}{\text{AP}_{\text{PAG}} \cdot \text{M}_{\text{PAG}} + \text{AP}_{\text{NPAG}} \cdot \text{M}_{\text{NPAG}}}$$

# Risk Factors – Reactivity of PAG Materials

- Calculation of  $d_{crit}$  for highly reactive (e.g. massive sulphide) PAG materials indicate values of the order of millimetres.
- Therefore, mixing for these materials will require something other than conventional placement to ensure close contact with NPAG.
- Mixing to achieve an ideal blend is more applicable to low sulphide (~1% or less) materials.



# Risk Factors – “Metal” Leaching

## Metals

- Non-ideal blending increases the risk of accelerated oxidation rates and increased metal leaching,
  - Zn, Cd, Co and Ni require higher pHs than achieved by carbonate neutralization to precipitate
  - However, iron precipitates can be very effective for sequestration of metals.

## Sulphate

- Non-ideal blending also increases the risk of mobilization of magnesium, potassium and sodium from silicates thereby increasing sulphate solubility.

# Risk Factors – Source of $[\text{HCO}_3^-]$

- Limestone is a good source  $\text{HCO}_3^-$  but mass balance calculations yield low limestone volume requirements to achieve target NP/AP.
- Achieving  $d_{\text{crit}}$  for limestone may require crushing to result in thorough dispersal but this creates other potential issues (premature dissolution, susceptible to Fe and Al oxide blinding).
- Preferred alkalinity sources are moderately calcareous waste rocks.

# Risk Factors – Placement Methods

- Placement methods need to consider  $d_{crit}$  and hydrologic factors (flowpaths).
- Layered PAG and NPAG waste rock types at the Samatosum Mine generated ARD for several reasons. Layering resulted in lateral flow, and the PAG layers were about 1000 times too thick to result in an ideal blend.
- End-dumping over high faces results in thin layering and mixing.

For a schematic cross section refer to **Figure 4-1** in Denholm, E. and Hallam, R., 1991. *A review of acid generation research at the Samatosum Mine. In Proceedings of the Second International Conference on the Abatement of Acidic Drainage (Vol. 2, pp. 561-578).*

# Where are we at?

- Waste rock mixing may be a long term stable solution for management of PAG waste rock.
- While understanding is growing, it is poorly understood and infrequently applied.
- The objective of blending should be to minimize the risk of long term degradation of water quality due to acid or metals breakthrough by “thoroughly mixing” (“ideal blend”).

