Reactive Transport Modeling of Uncovered Tailings – Insights for Hyperarid Mine Sites

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BUILDING A BETTER WORLD

Outline

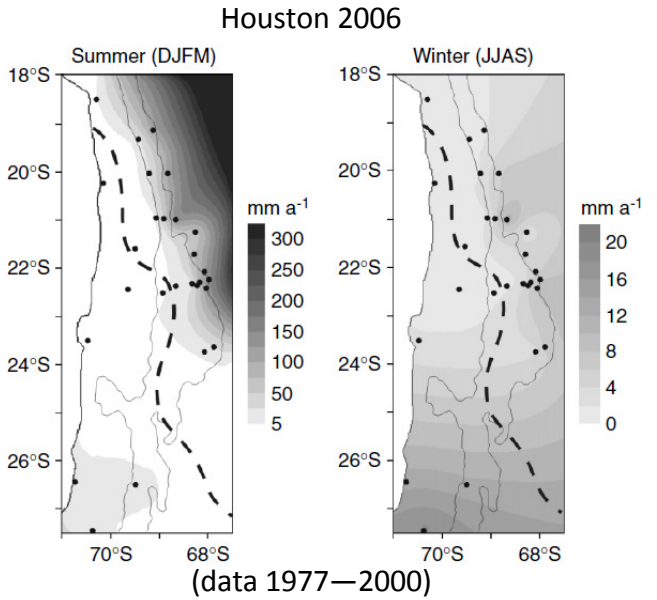
1. Introduction & Background
2. Conceptual Model
3. Numerical Model
   - — Site Conditions Modeled
   - — Sensitivity Analyses Modeled
4. Results
   - — Simulated versus Field Observations
5. Conclusions

Purpose

- How are geochemical reactions in uncovered, potentially acid generating (PAG) tailings affected by a hyperarid climate?
- How sensitive are the changes in porewater chemistry to tailing deposition processes and carbonate content?
- How do forward model simulations compare to empirical observations collected at uncovered tailings sites in northern Chile?

What is Hyperaridity?

- Definition based on ratio of annual precipitation *(P)* to potential evaporation *(PE)*
- Within the Atacama Desert climate is primarily hyperarid because *P/PE* < 0.05
- Hyperaridity in the Atacama is controlled by
  - Subtropical high pressure belt
  - Cold ocean from Humboldt current
  - Topographic rain shadow

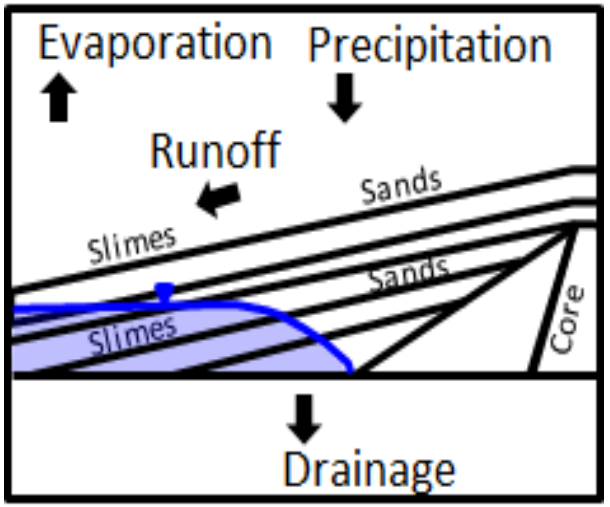


Does the climate affect ARD reactions?

- Conventional humidity cell tests (HCTs) are likely to over-estimate ARD reactions
  - HCTs add about 50% of annual *P* on a weekly basis (15 mm) and 70% of annual *P* is less than long-term mean (30 mm)
  - HCTs add forced air on the order of 3 mm/s while diffusive transport in tailings is likely on the order of 0.03 mm/s
- Based on these constraints, published kinetic rate law for pyrite oxidation was used to evaluate changes in porewater chemistry
  - Pyrite oxidation controlled by H^+ and O_2 concentrations

Conceptual Model

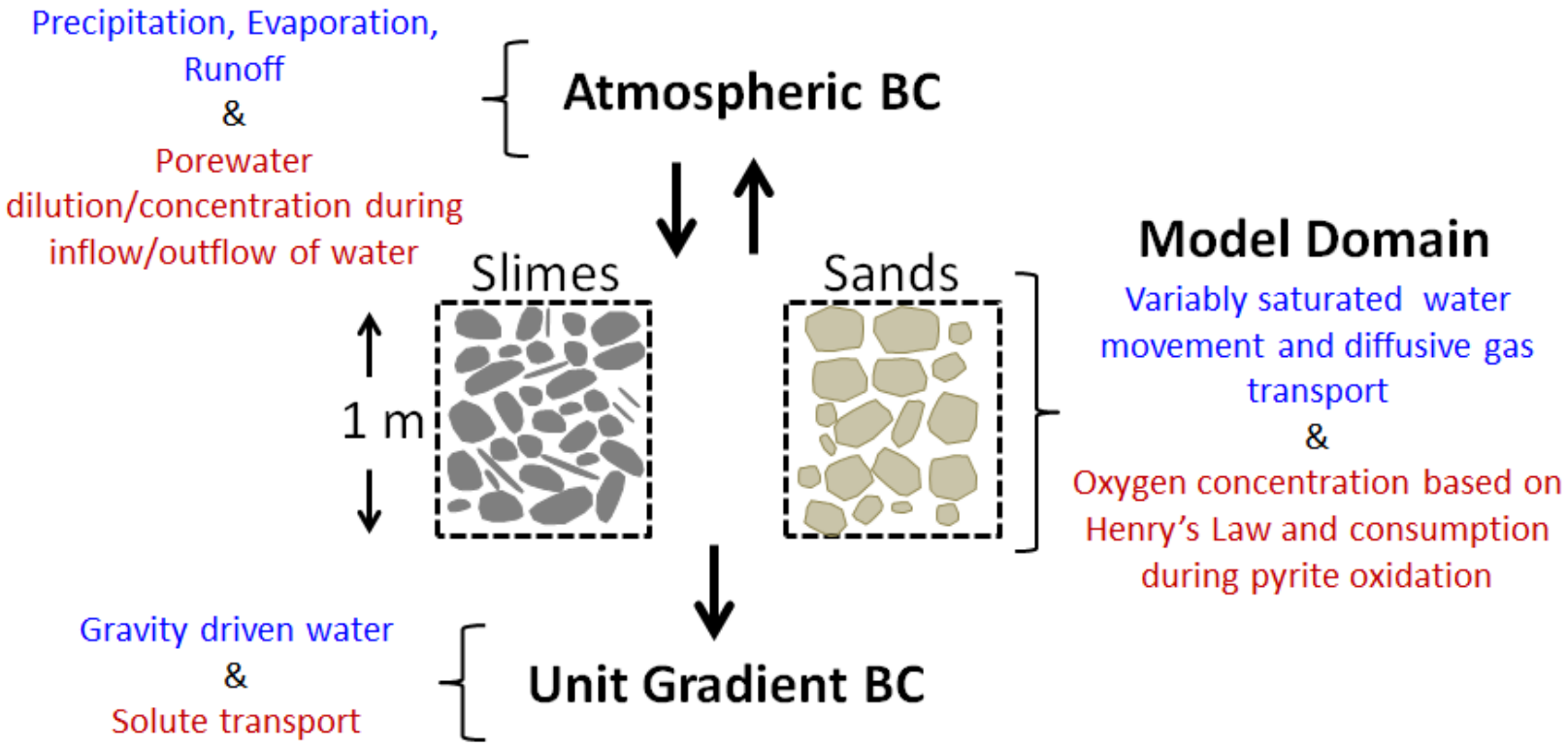
- Uncovered cycloned tailings
- Climatic conditions influence water/gas transport
  - Low *P* and high *PE* produces low drainage, evapoconcentration of mass, and vertical flow (1D model)



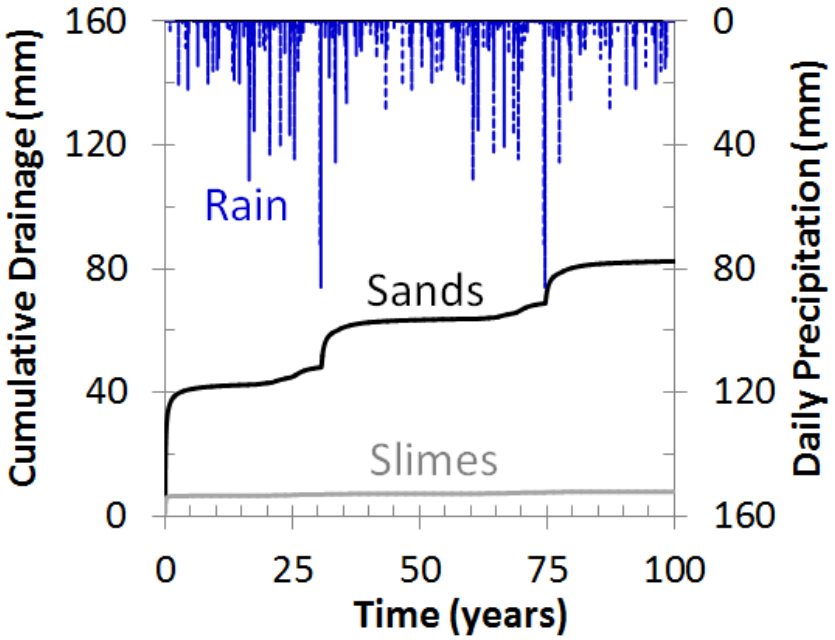
- Geochemical reactions influence changes in porewater chemistry
  - Diffusive gas transport and transient water percolation oxidize sulfides which may be neutralized during carbonate dissolution (if present)

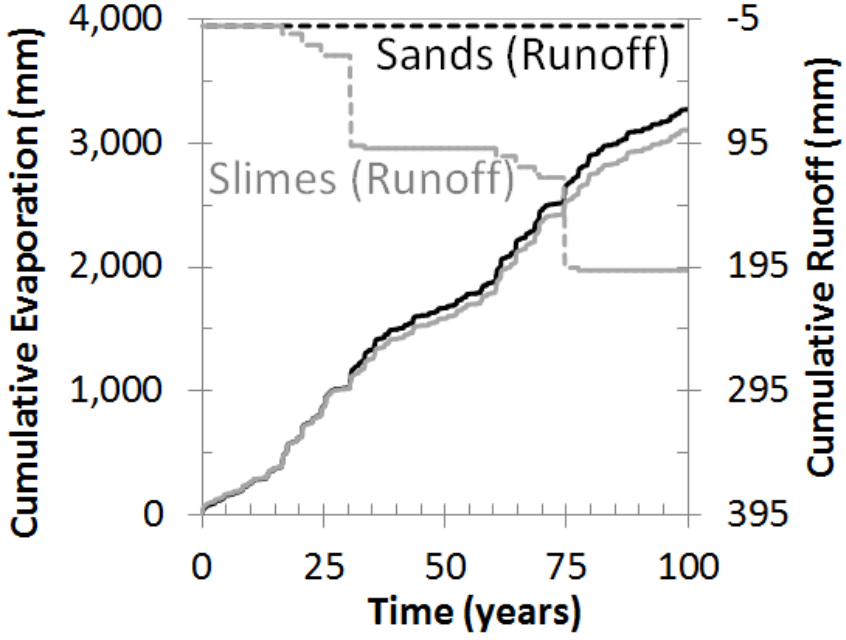
Numerical Model

- Domain: tailing grain size (sands and slimes)
- Sensitivity: calcite concentration (0 and 1 wt.%)



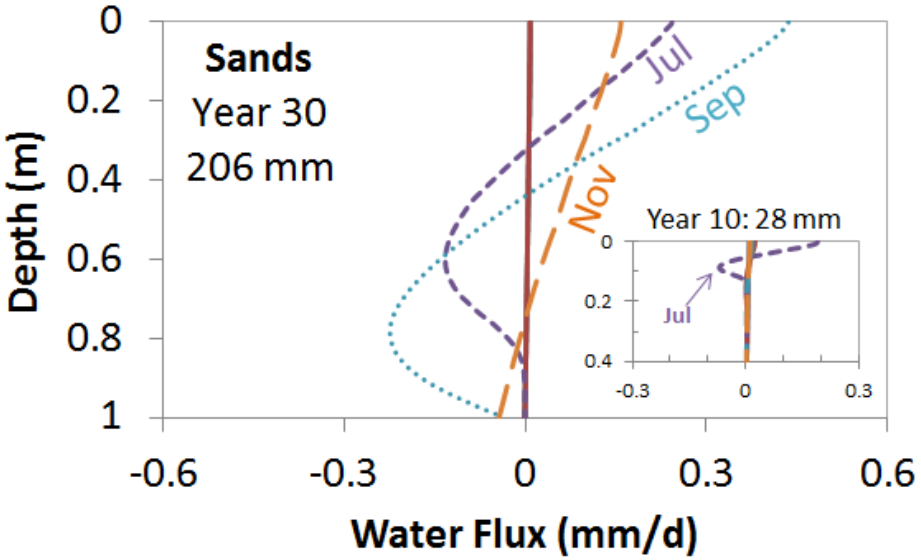
Results – Water Balance

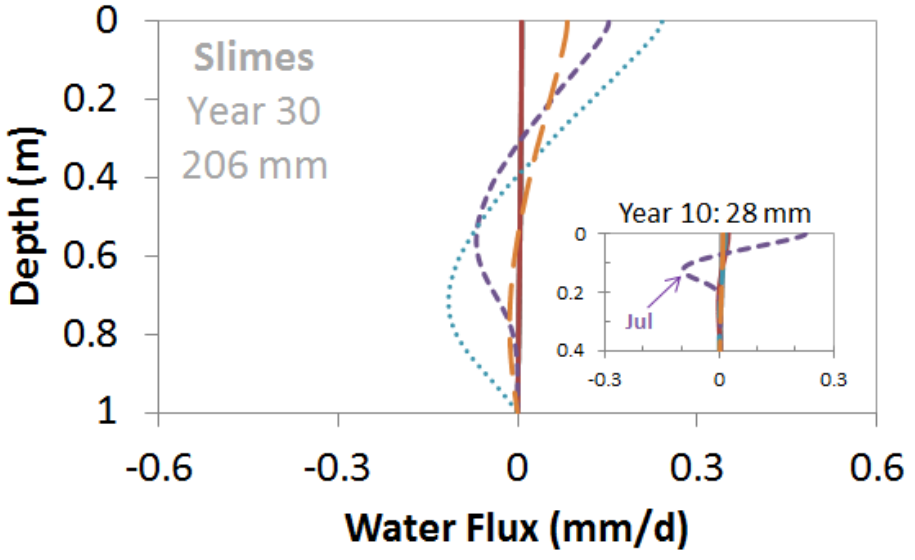




- Drainage rate sensitive to slurry deposition
  - Post draindown flux is 0.4 mm/yr for sands and 0.01 mm/yr for slimes, and likely biased high
- Runoff limited to slimes during winter

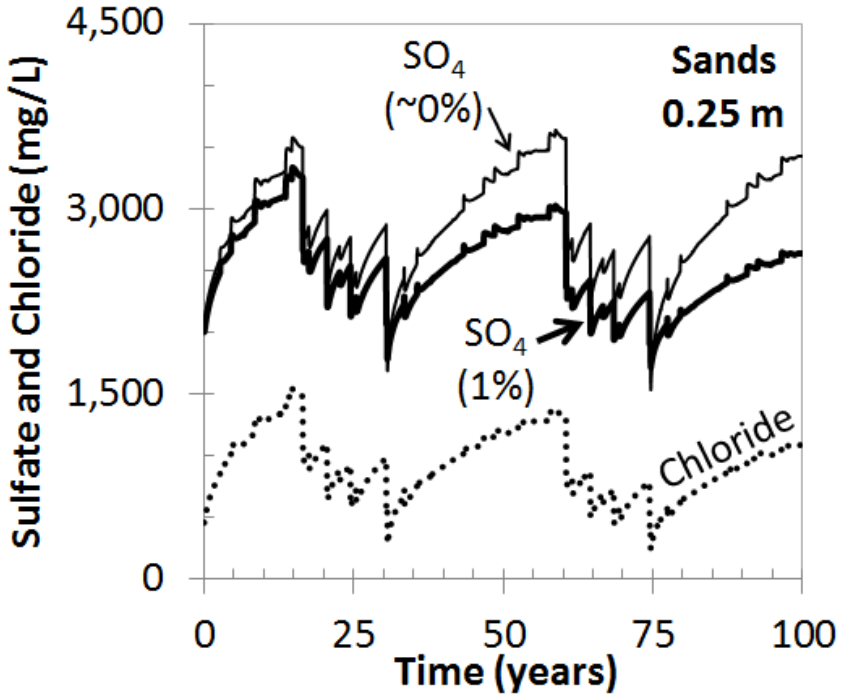
Results – Water Flux

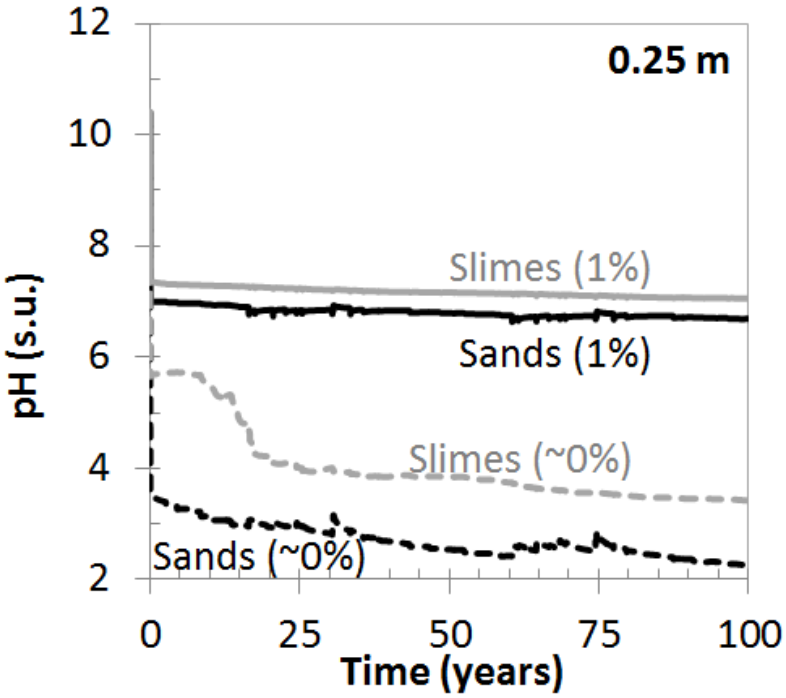




- Transient rain events result in downward flow that is subsequently redirected upward
- Principal flow direction is downward but at a rate that resembles no flow conditions

Results – Porewater Chemistry





- For tailing sands transient drainage events result in dilution followed by evapoconcentration
- Carbonate concentration controls pH

Model Results vs. Field Observations

- Test pits at 3 sites (4 TSFs) in hyperarid climate
  - Porewater pH and mineralogical analyses were noted
  - Tailings of various "ages" and degree of saturation evaluated
- Consistent observations (model and field)
  - pH decreases post deposition during equilibration with solids ~ 11 to 7.5 in near surface and to 9.0 in saturated tailings
  - Buffering at near neutral pH occurs for tailings with carbonate
  - Lack of carbonate results in acidic pH depending on age/depth
- Inconsistent observations (model and field)
  - Field conditions have "less" oxidation for coarse tailings

Conclusions

- Climatic variability controls response at depth
  - Changes in sulfate correlate to changes in water content and chloride (dilution/concentration effects)
  - Changes in calcium correlate to changes in water content and pH (dissolution/exchange effects)
  - Processes are more pronounced for tailing sands and pyrite oxidation influenced by oxygen transport during drainage
- Model simulations generally agree with empirical observations at TSFs in northern Chile
- Presence of calcite around 1 wt.% could delay generation of ARD for millennia (site specific)