MINERALOGIC

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Forecasting opportunities for co-management of Cu-Ni tailings with byproducts of iron ore mining

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NATURE OF THE OPPORTUNITY

Benefits to managing new tailings from Duluth Complex with existing taconite tailings, but geochemistry is uncertain.

Advantages:

- *Reduce footprint*
- *Use existing infrastructure*
- *Upgrade water management at legacy sites*

Key Uncertainty:

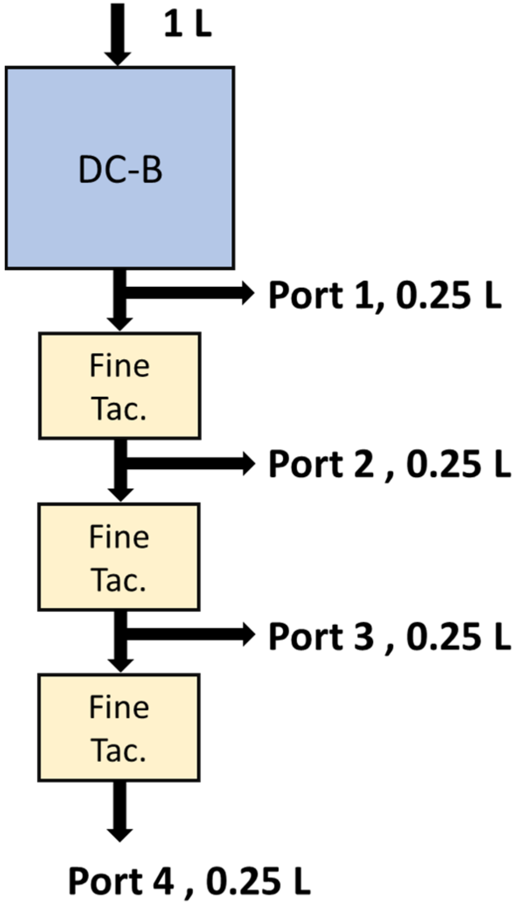
How will the Duluth Complex tailings interreact chemically with the taconite tailings?

Our Finding:

Chemical interactions may be advantageous because taconite tailings appear to generate a sorbent.

TESTS PERFORMED

Humidity Cell style tests operated in series were used to simulate DC/Tac.

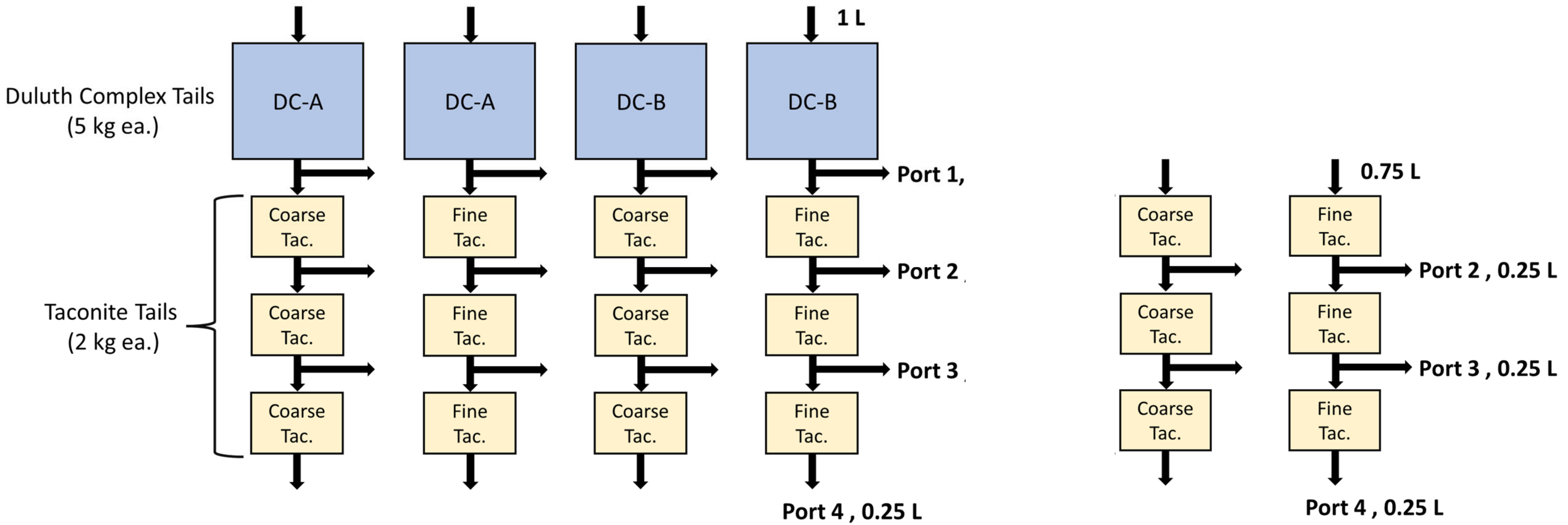


Operational Details

- *Weekly flushing cycle with DI*
- *Open to atmosphere*
- *Minimal materials preparation*
- *Freely draining*
- *Small volume losses to evaporation*
- *Sampled for dissolved ions, pH, alkalinity*
- *Opperated for ~13 years*

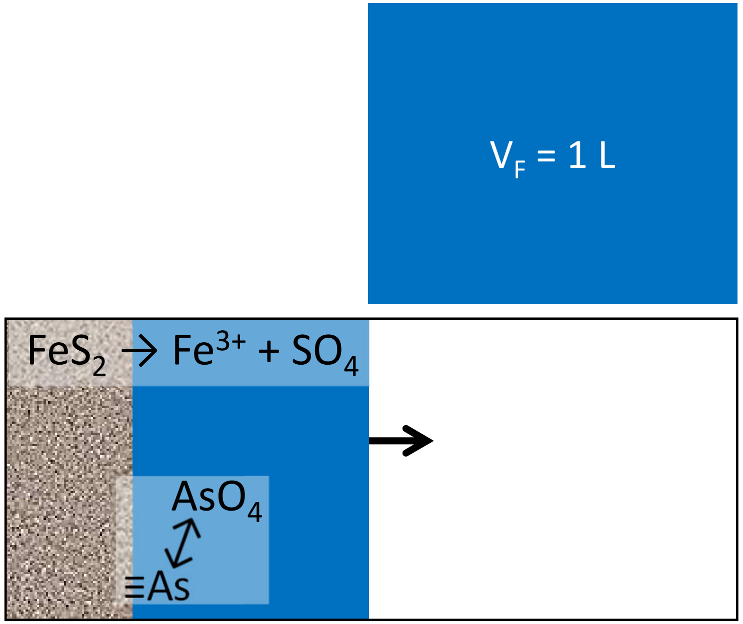
COMBINATIONS OF CELLS

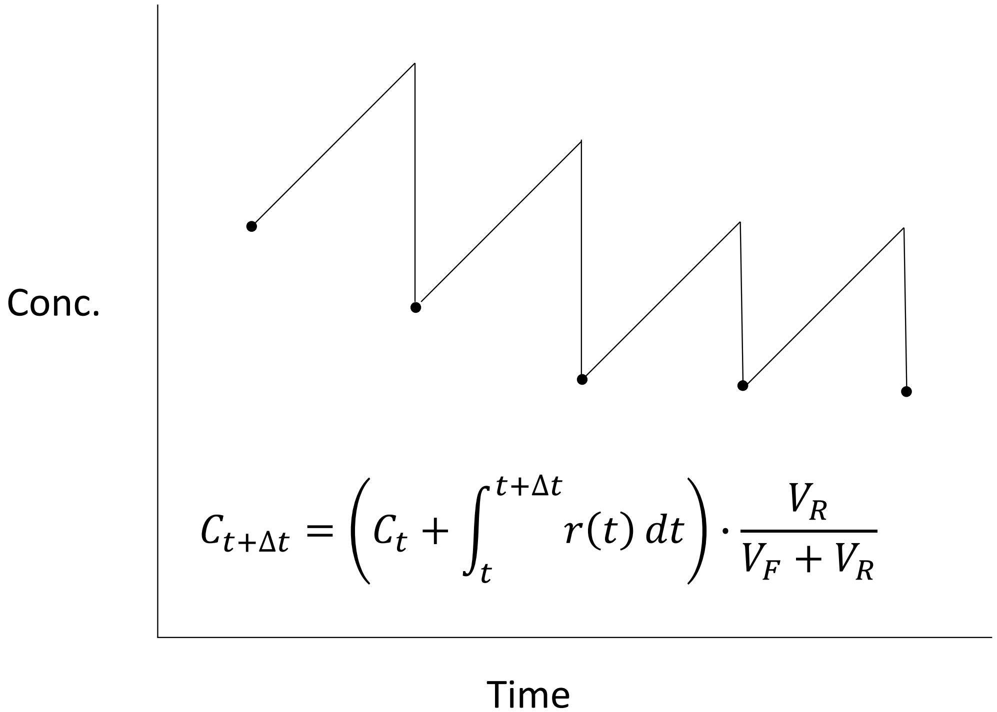
Tested two variants of DC tails, coarse and fine Tac. tails; Controls had no DC cell



MODEL FRAMEWORK

Chemical reactions punctuated by weekly flushing events

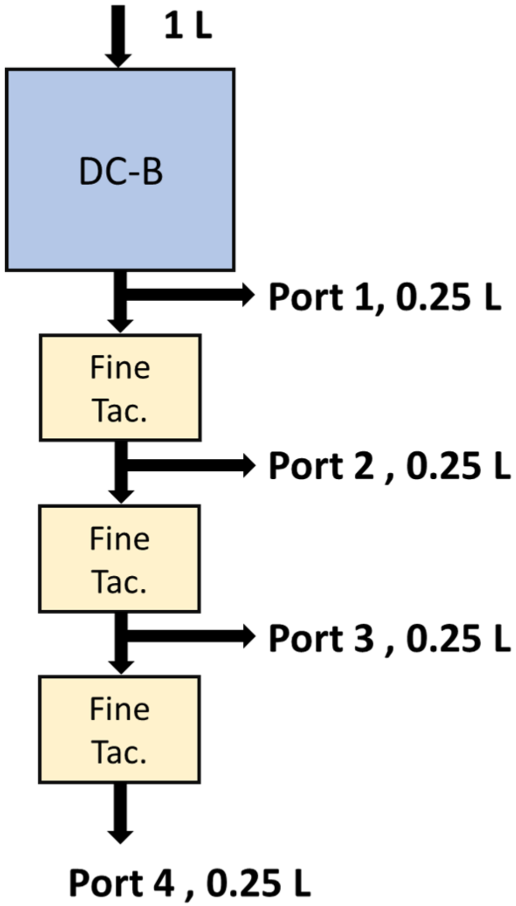




$$C_{t+\Delta t} = \left(C_t + \int_t^{t+\Delta t} r(t)\, dt \right) \cdot \frac{V_R}{V_F + V_R}$$

MATHEMATICAL FORMULATION

Cells in series take in effluent from prior cell



Mass balance assuming rapid and well-mixed rinsing

$$C_f^i(n \cdot \Delta t) = \frac{C_f^{i-1}(n \cdot \Delta t) \cdot V_f^i + C_r^i(n \cdot \Delta t) \cdot \left(V_r^i + K_d^i \cdot M_s^i\right)}{V_f^i + V_r^i + K_d^i \cdot M_s^i}$$

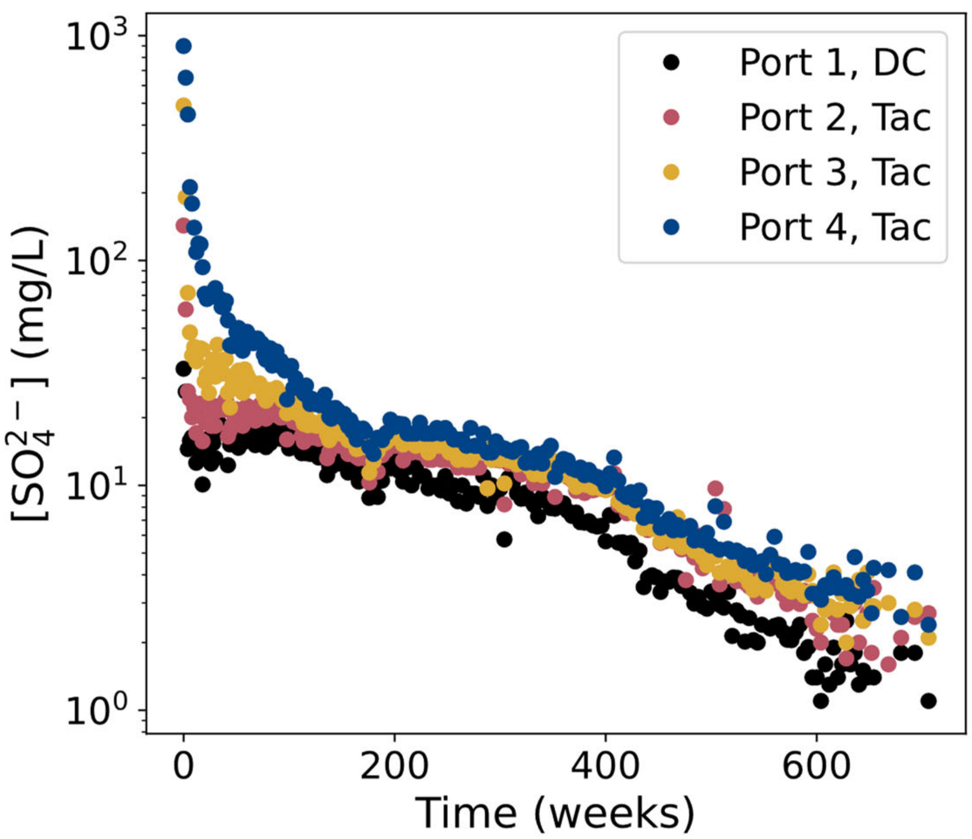
Integration of a rate law during week-long reaction period

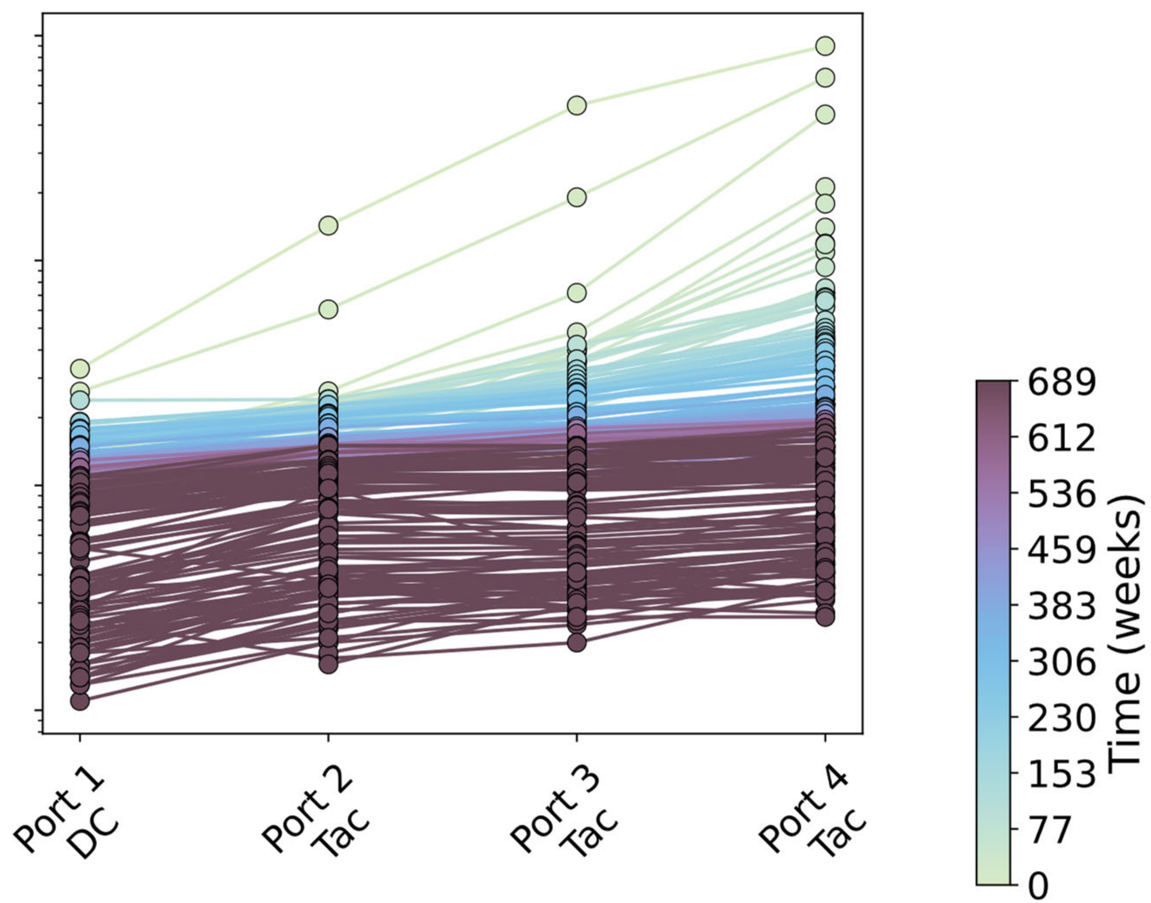
$$C_r^i(n \cdot \Delta t) = C_f^i\left((n-1) \cdot \Delta t\right) + \int_{(n-1)\cdot\Delta t}^{n\cdot\Delta t} r^i(t) \cdot dt \cdot \frac{V_r^i}{V_r^i + K_d^i \cdot M_s^i}$$

Potential for linear sorption assumed throughout

VISUALIZING DATA

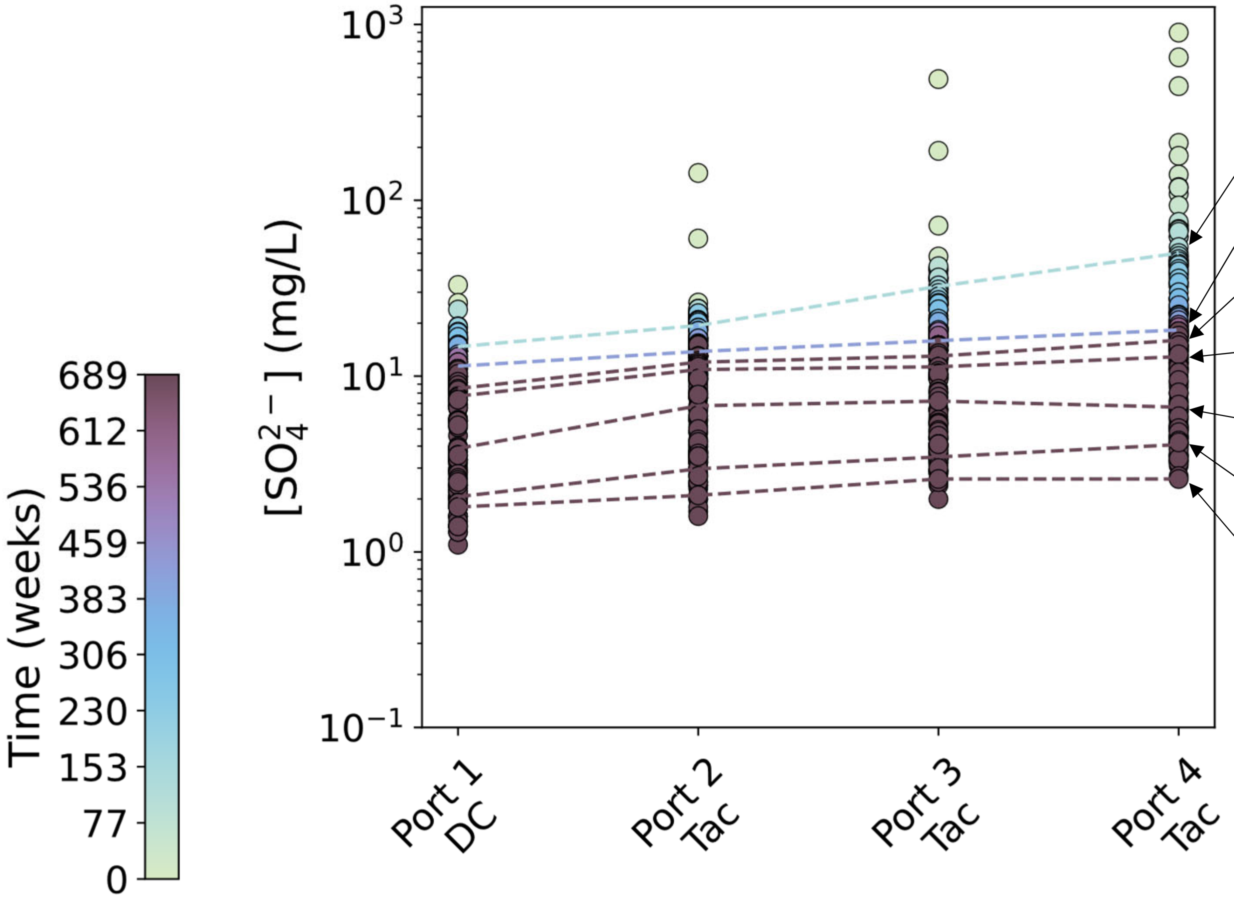
Time-series plot and cross-reactor plot give complementary views





CONSERVATIVE CONSTITUENTS

SO_4 (K, Na) data show conservative transport and declining release rate over time

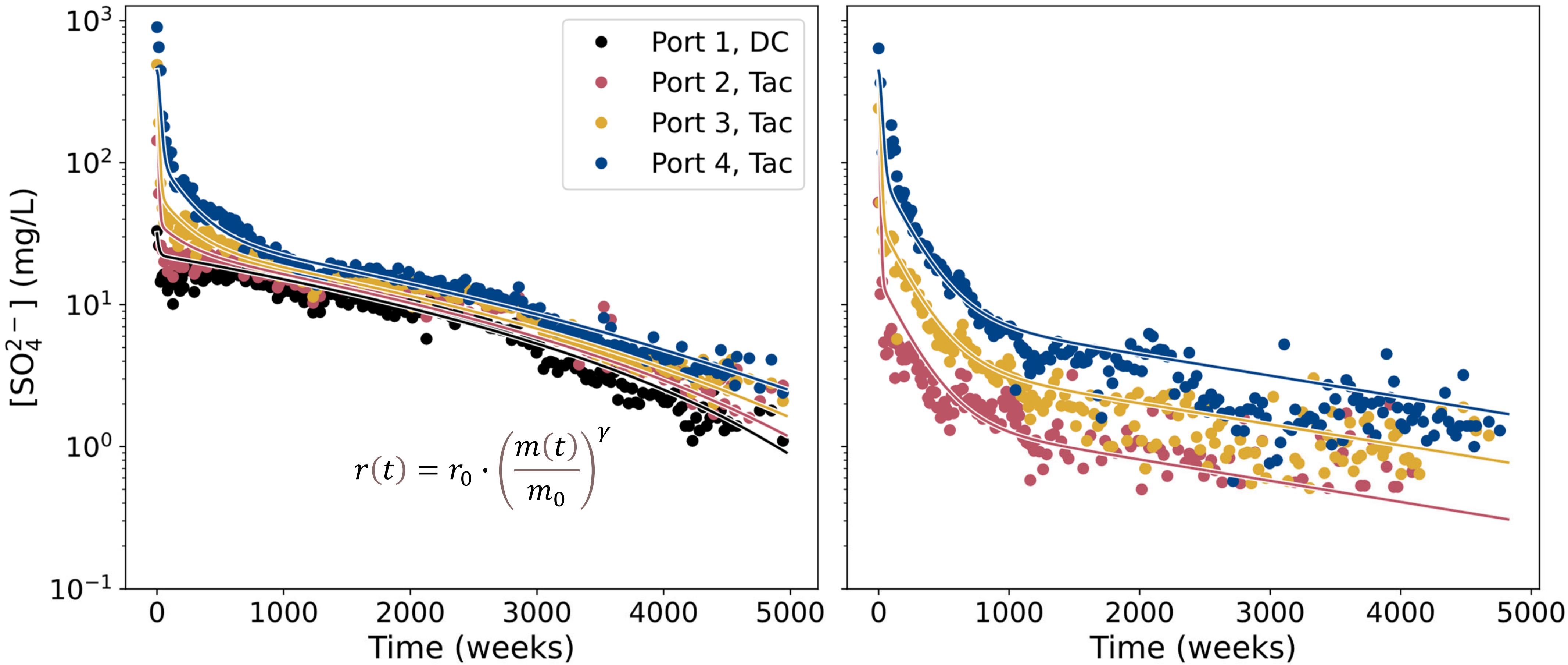


Sulfate:

- *Sulfate added as water passes through DC and Tac cells*
- *Over time, sulfate release decreases*
- *Leachate from Tac control shows similar pattern a w/DC input—only shifted to lower concentration*

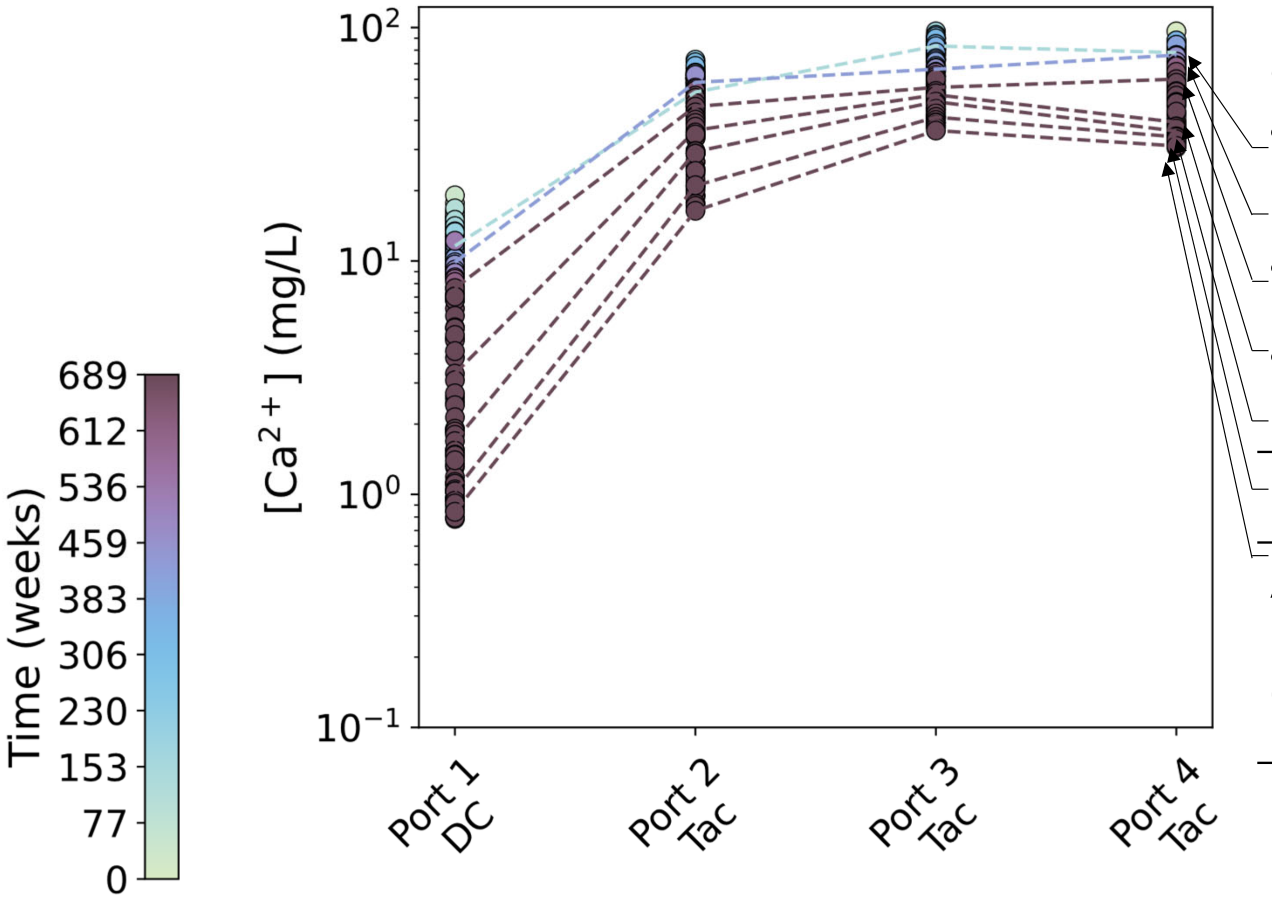
SULFATE FITS

Declining release consistent with shrinking particle; different aging mechanism in Tac



CONSTITUENTS REACHING A LIMIT

Ca (Mg, Sr) appear to approach an asymptote across Tac. cells



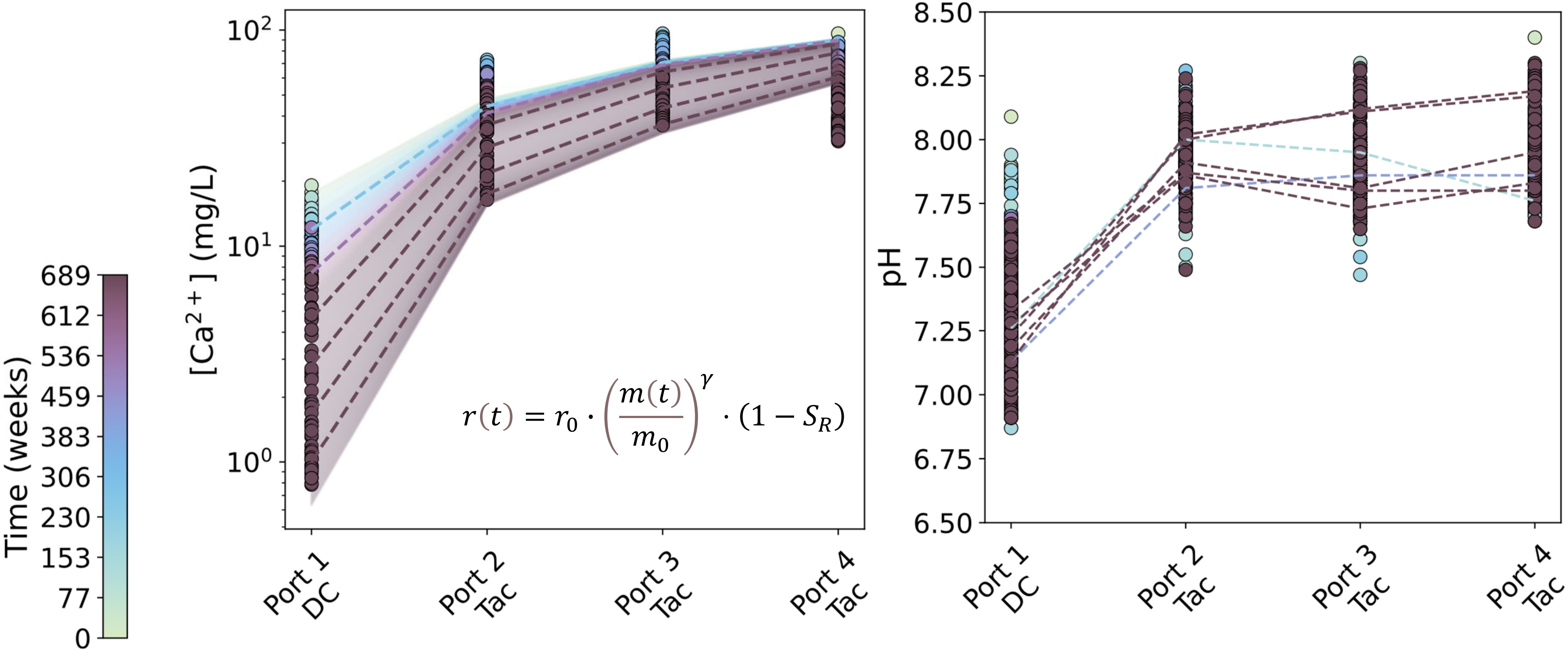
Calcium:

- *Calcium added as water passes through DC and 1st Tac cell*
- *Over time, release decreases*
- *Similar to control*

Mineral	Control	Tac 1	Tac 2	Tac 3
Ankerite (%) $Ca(Fe,Mg,Mn)(CO_3)_2$	4.62	0.32	1.88	3.41
Calcite (%) $CaCO_3$	1.86	0.16	1.34	0.91

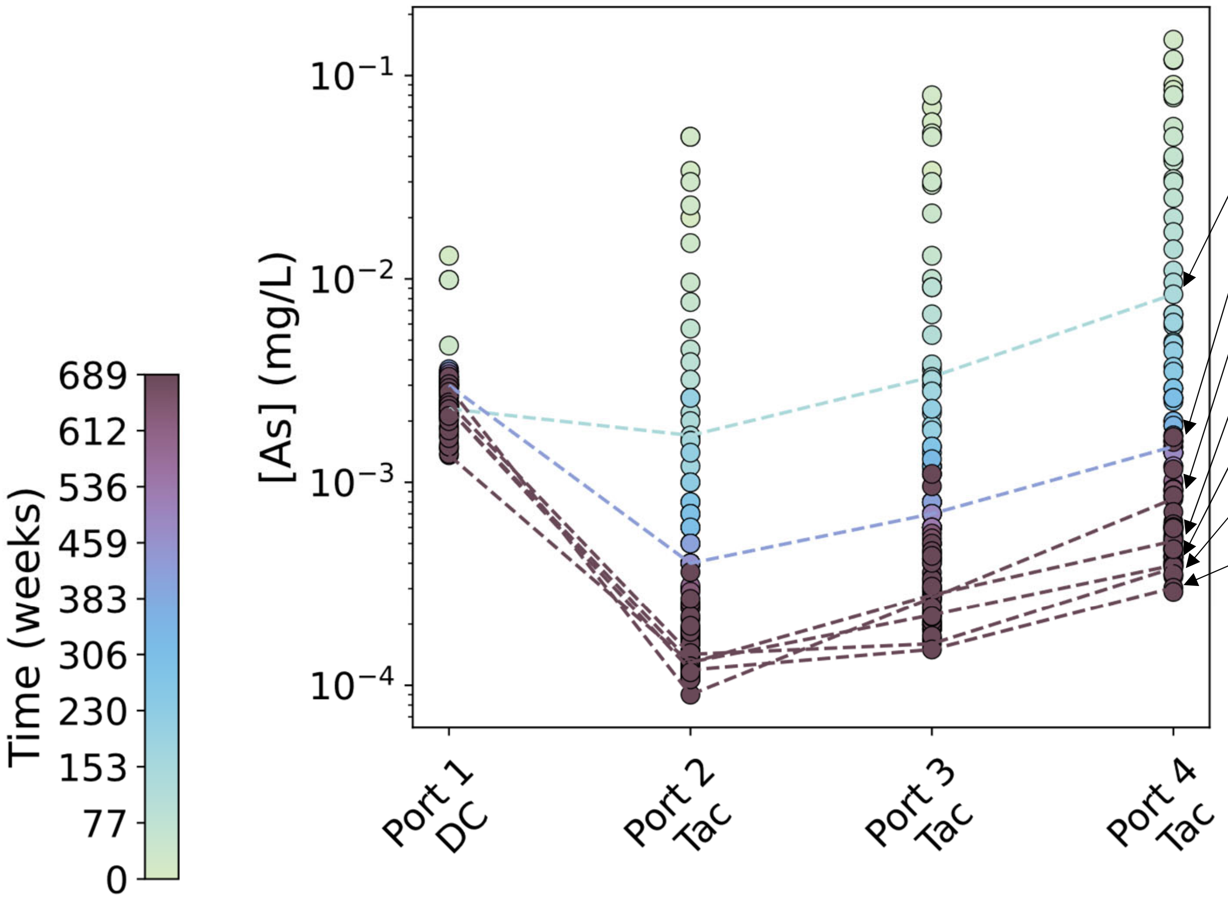
CALCIUM FITS

Kinetic approach to equilibrium suggests evolving saturation level over time



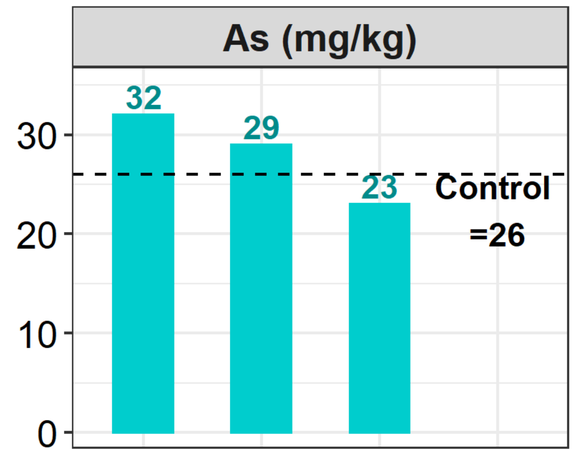
NONCONSERVATIVE CONSTITUENTS

As (Co, Ni, V) are lost across the taconite cells; loss increases with time



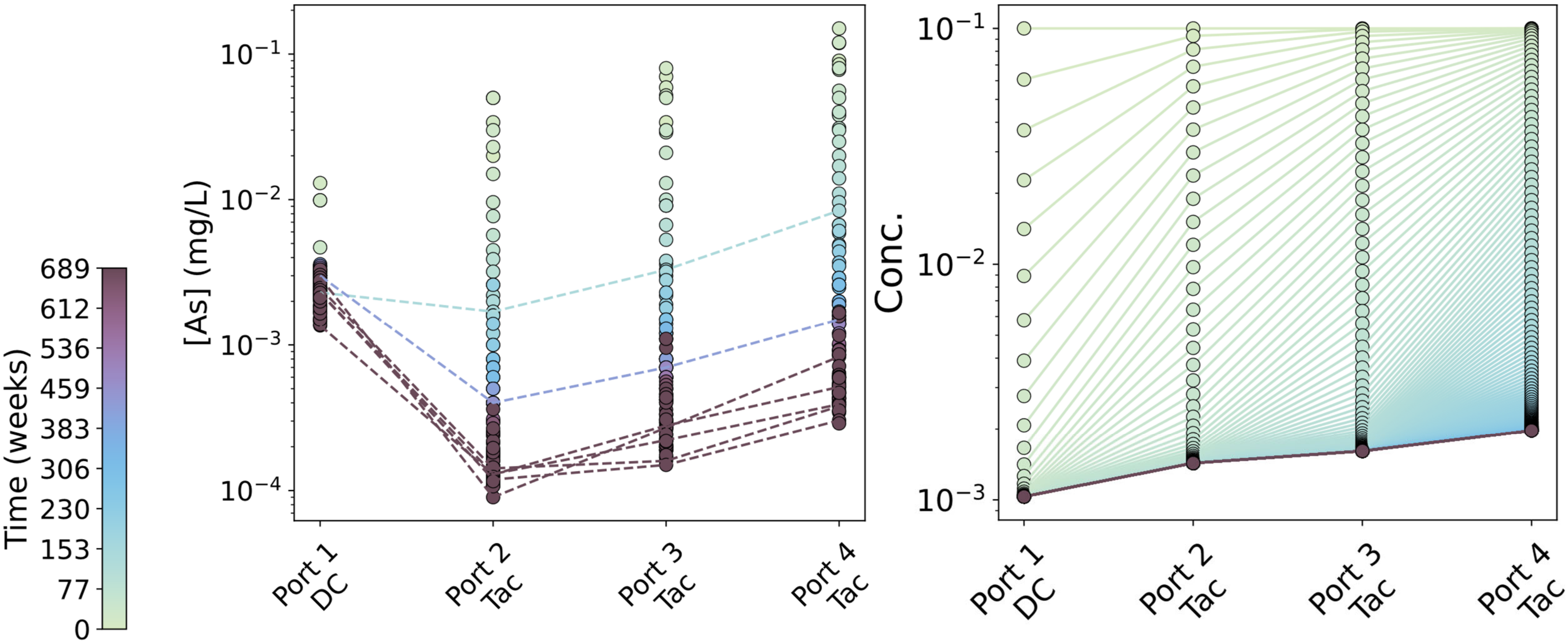
Arsenic:

- *1st year, trace arsenic attributed to all units*
- *Over time, release decreases*
- *Attenuation in first Tac. Cell becoming more pronounced with time*



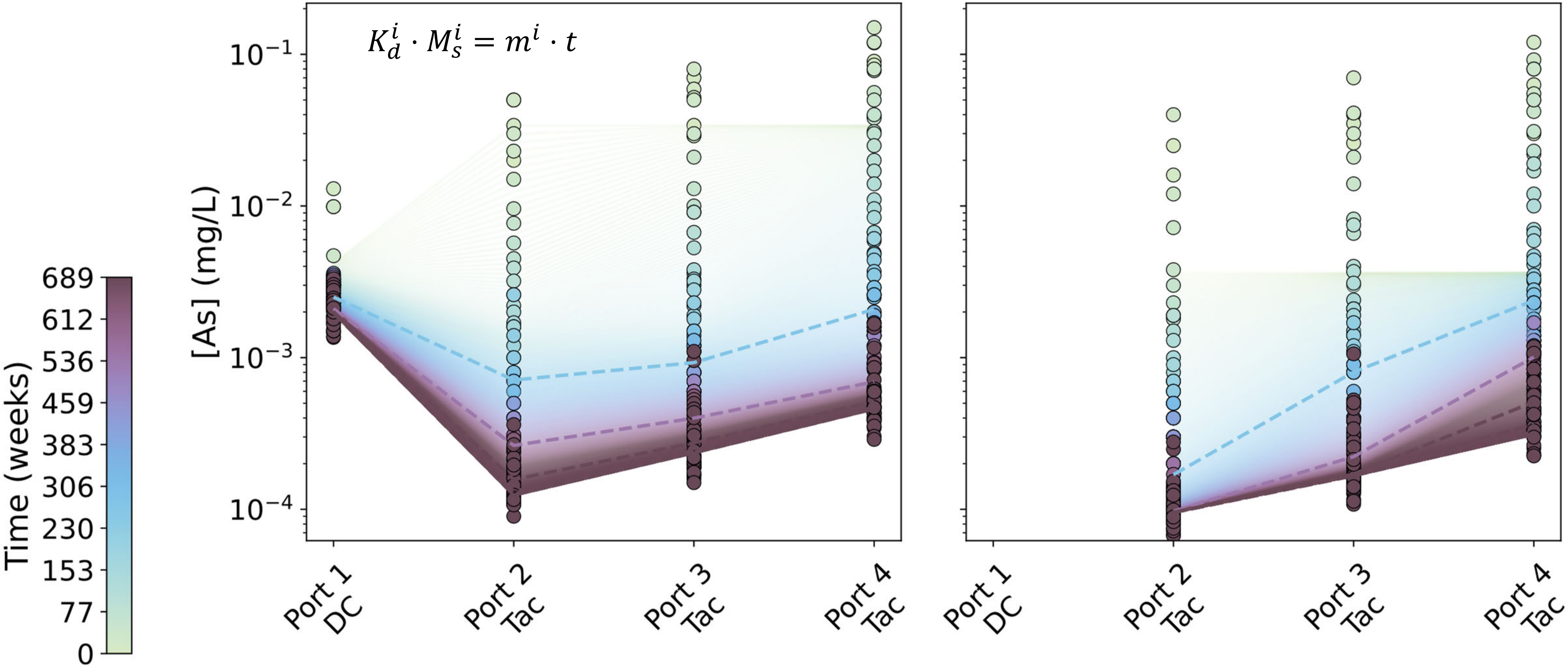
ASERNIC NOT DESCRIBED BY SIMPLE SORPTION

Linear partitioning slows the approach to steady-state but does not produce a sink



ASERNIC FITS

Allowing sorbent concentration to increase over time produces observed pattern



CONCLUSIONS

Geochemical interactions appear to be another advantage of co-managing Duluth Complex and taconite tailings.

Three patterns of interaction between DC and Tac:

- *Conservative, with declining release rate—e.g., Sulfate*
- *Approaching equilibrium, with declining saturation level—e.g., Calcium*
- *Sink in Tac., with increasing strength—e.g., Arsenic*

Open questions:

- *Will the sink outlast the source?*
- *Could pH become too high (oxyanions) or too low (cations) for sorption?*
- *Would a reducing environment still produce a sink?*


Thank you!
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