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Geochemical behaviour of adit drainage under saturated and unsaturated conditions at two underground mines in Northern British Columbia

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1. **Two geologically distinct mine sites with similar mining histories**
2. **Similarities in geochemical trends**
 - Sulphate concentrations increase when mine workings are unsaturated
 - Metal cation (Zn and Cd) concentrations decrease when mine workings are unsaturated
3. **Identify mechanisms that could result in decline in metal cation solubility between saturated and unsaturated time periods**
4. **Results show that metal cation behaviour is controlled by pH related solubility constraints in neutral mine drainage.**



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Site Naming Conventions

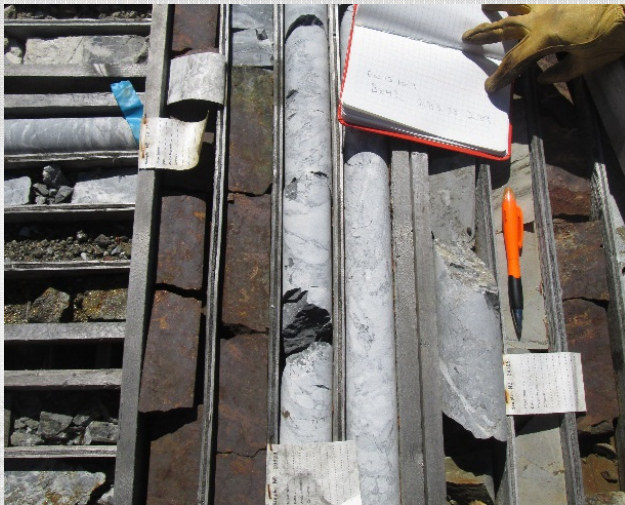


Site Background: Geology



Site A

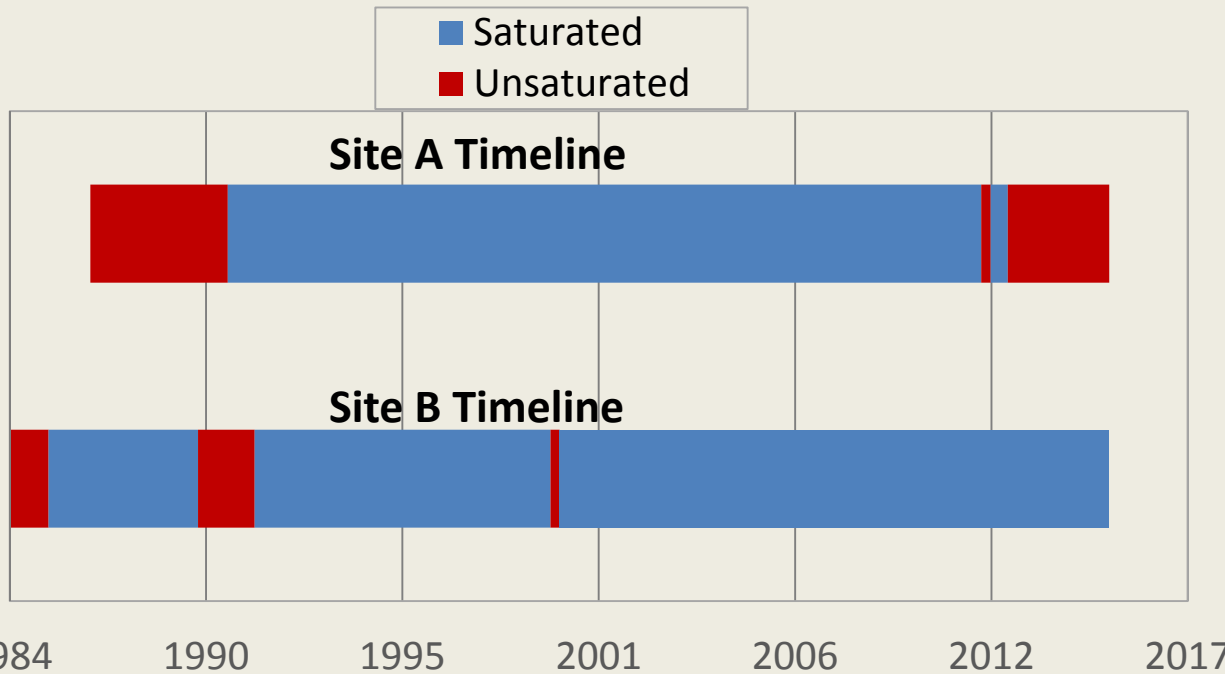
- Epithermal Au-Ag deposit hosted in stockwork veining intruding a primarily volcanic host rock.
- Existing excavations are primarily in hydrothermally-altered PAG rock consisting of volcanic and volcaniclastic sedimentary rock units



Site B: aka the tunnel of love

- Ag-Pb-Zn carbonate replacement deposit hosted in a limestone formation
- Existing excavations are primarily in non-PAG limestone with minor amounts of mudstone and ore excavated as part of bulk sampling program.

Site Background: Mining History



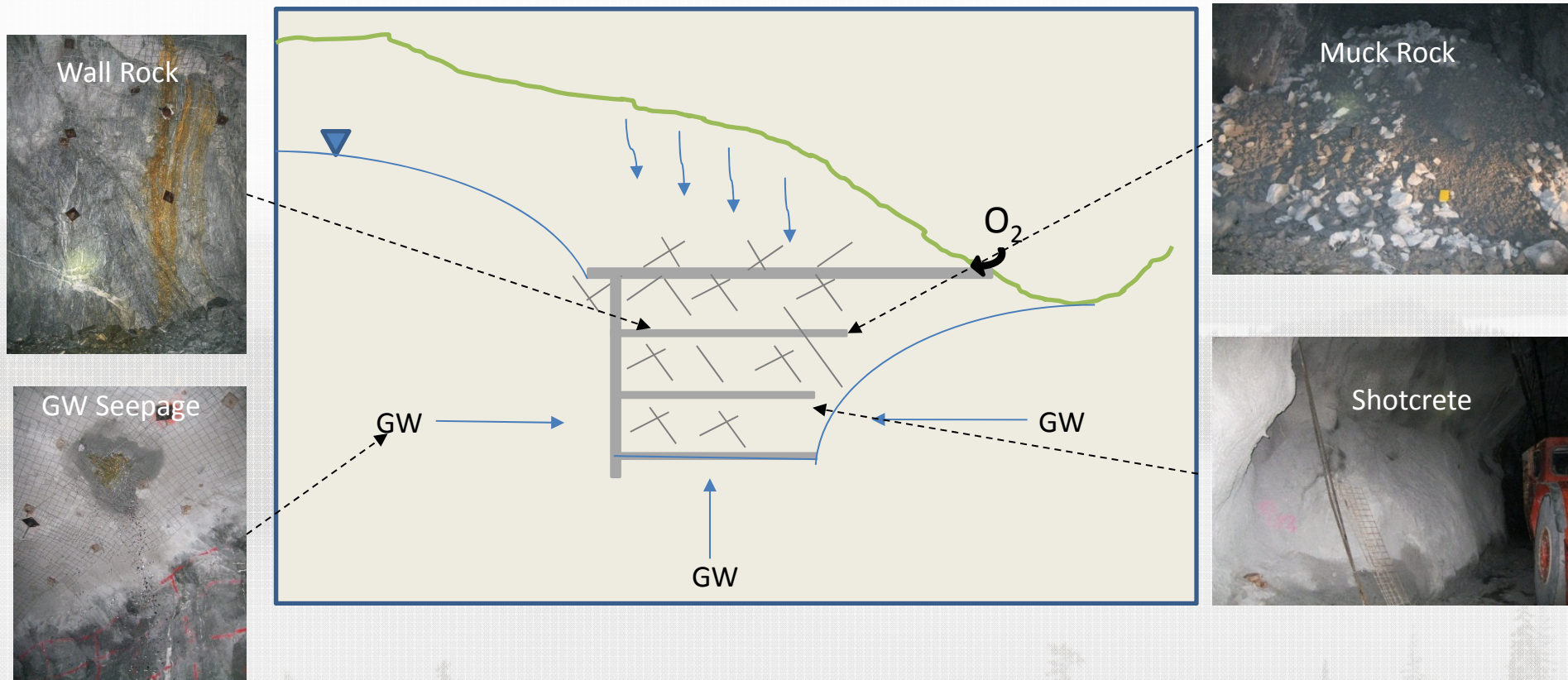
Site A:
Total Excavations: 7200 m

Site B:
Total Excavations: 2400 m

- Nearly all mine workings are below adit elevation in both sites
- No backfilled waste rock or tailings are present at either site



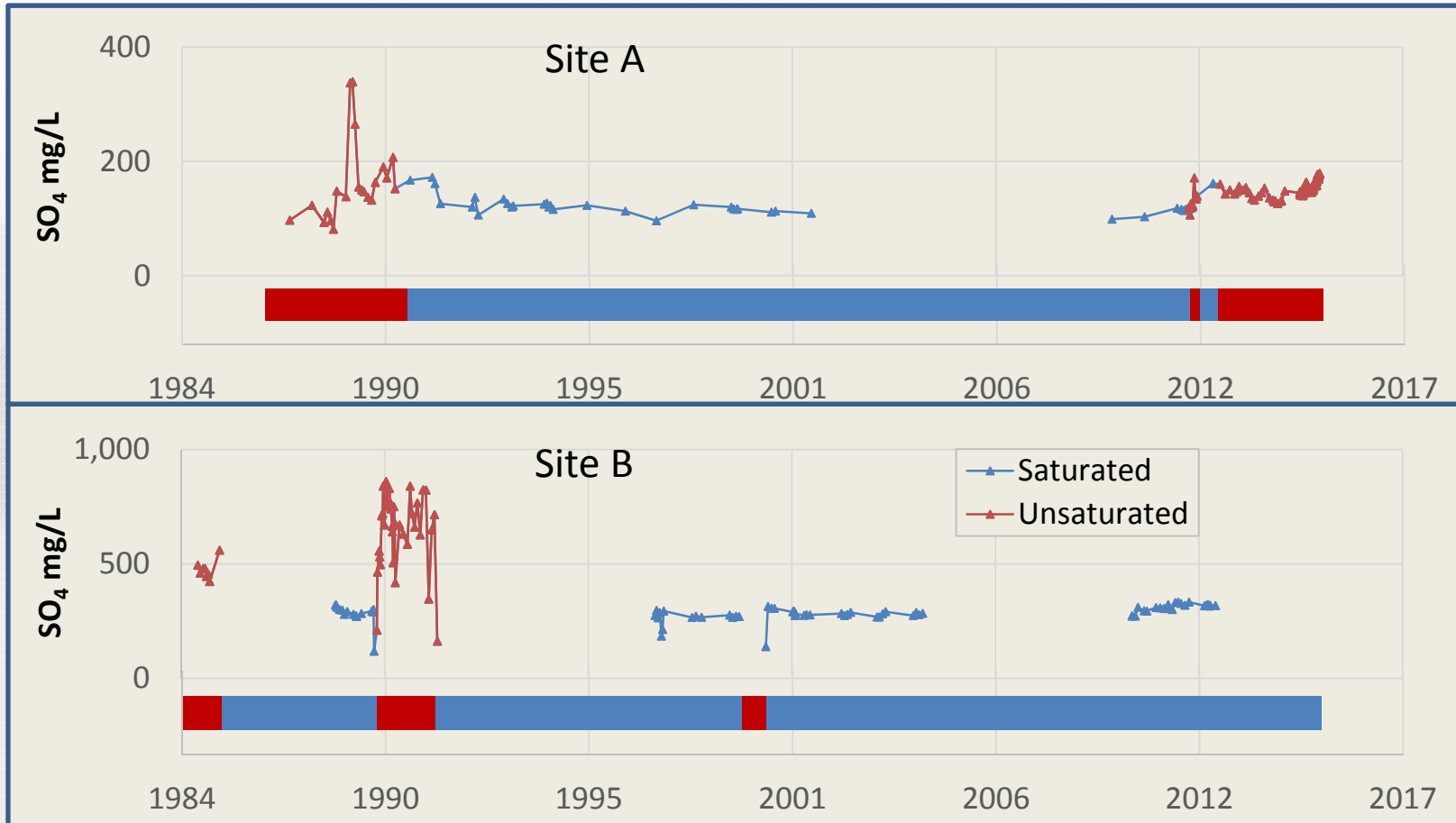
Conceptual Model of Geochemical Loading: Unsaturated



Unsaturated Geochemical Load = Wall Rock Oxidation + Rinsing of Freshly Exposed Surfaces + Additives + Groundwater



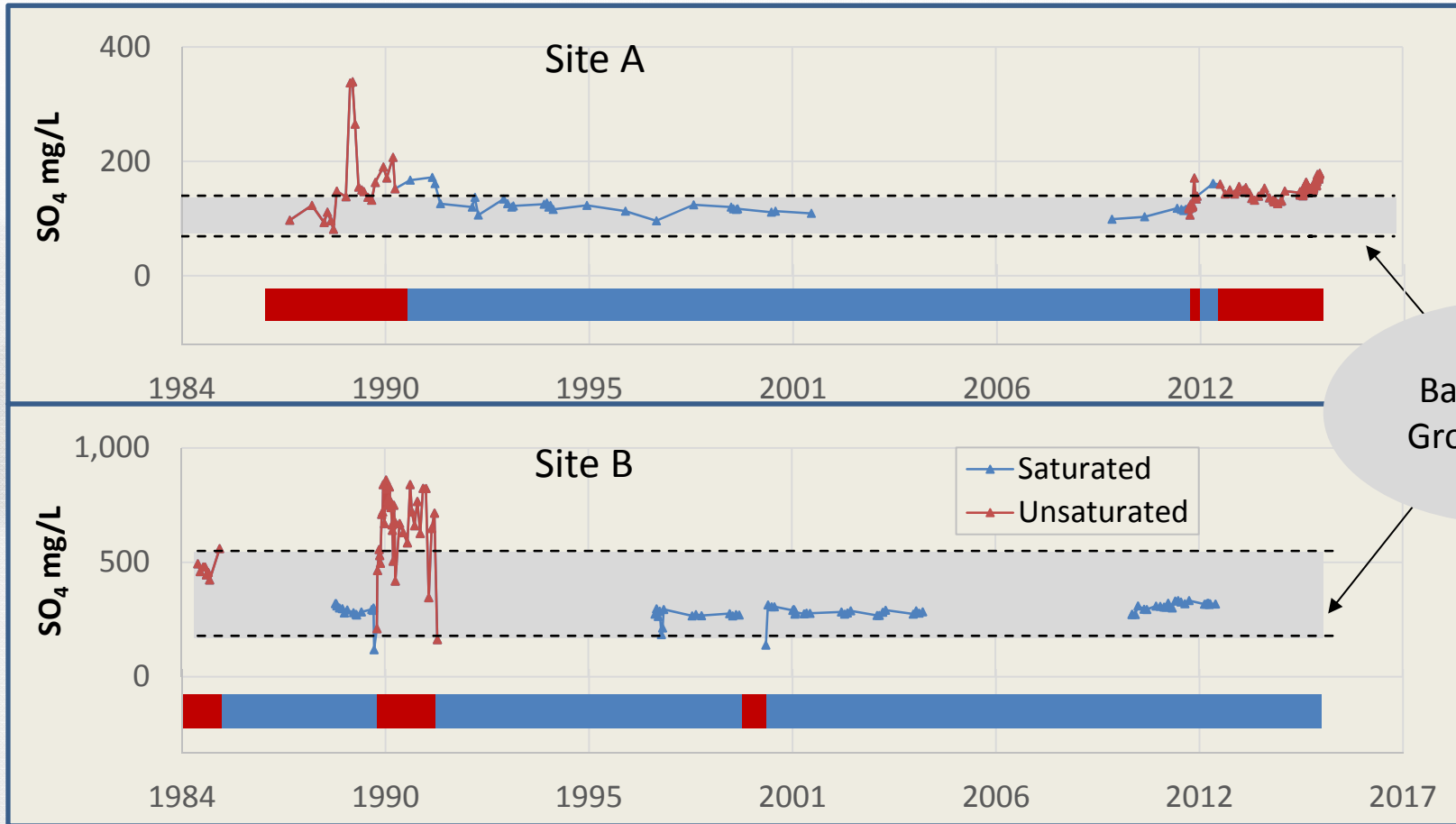
Sulphate Results



- Sulphate concentrations reflect impact of oxygen ingress and sulphide mineral oxidation during unsaturated time periods at both minesites.



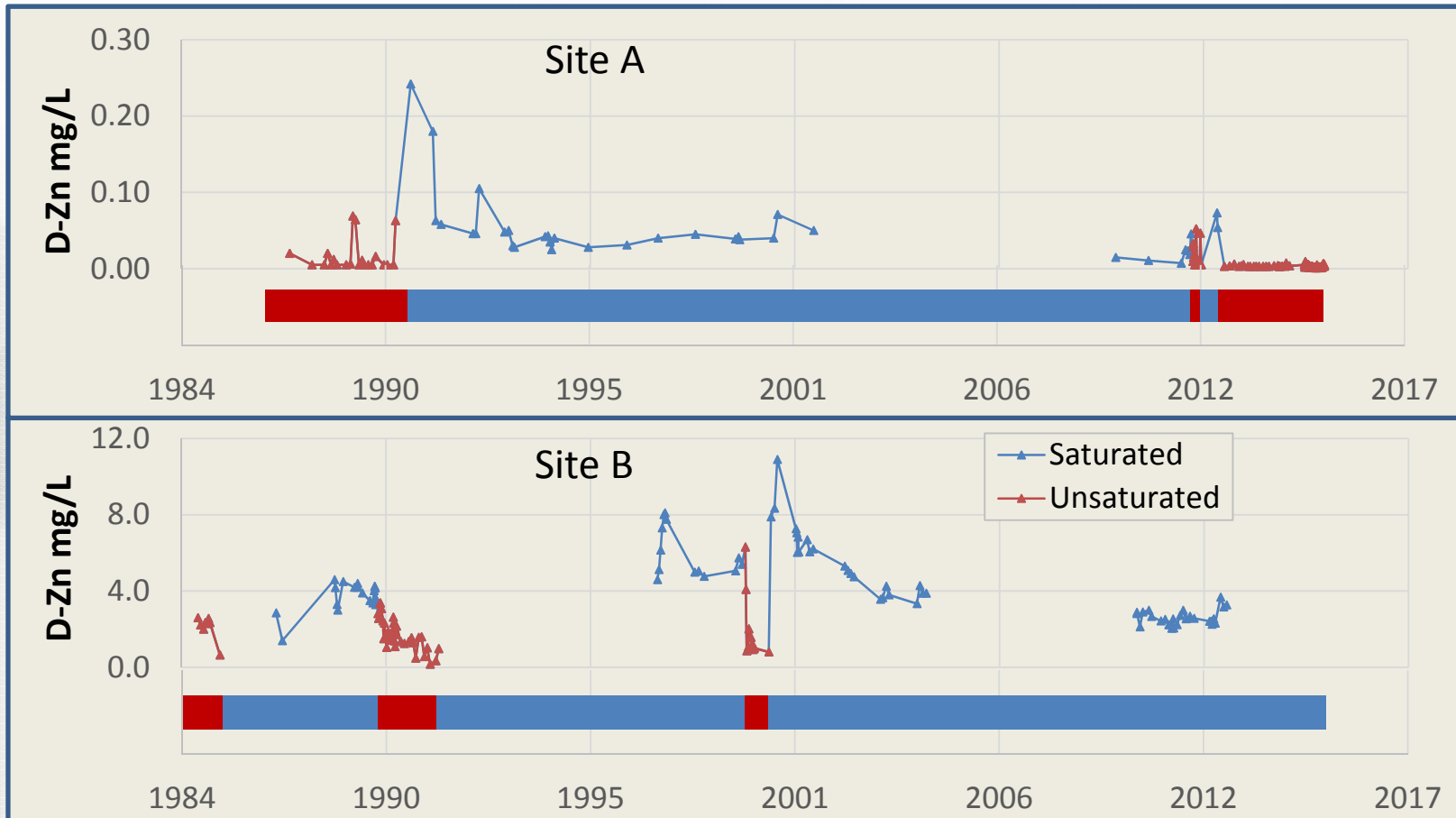
Sulphate Results



- Sulphate concentrations return to the range observed in background groundwater when mine workings are saturated.



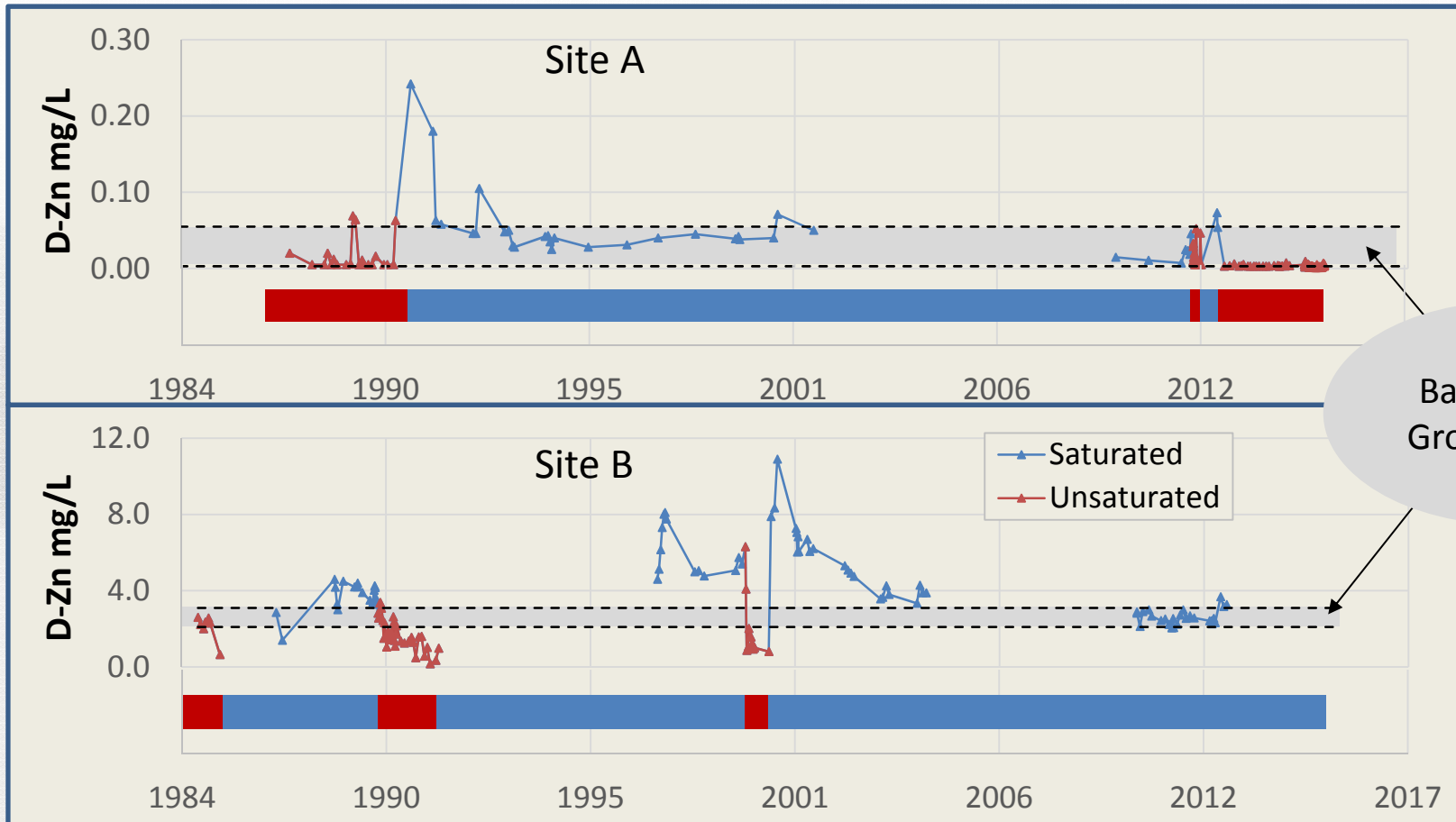
Zinc Results



- Zinc concentrations tend to be lower when mine workings are unsaturated.



Zinc Results



Background Groundwater

- Zinc concentrations decline to below background groundwater when mine workings are drained, indicating that zinc is being attenuated

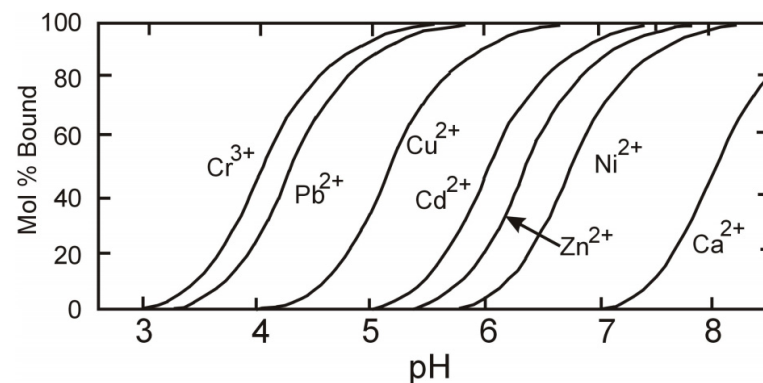
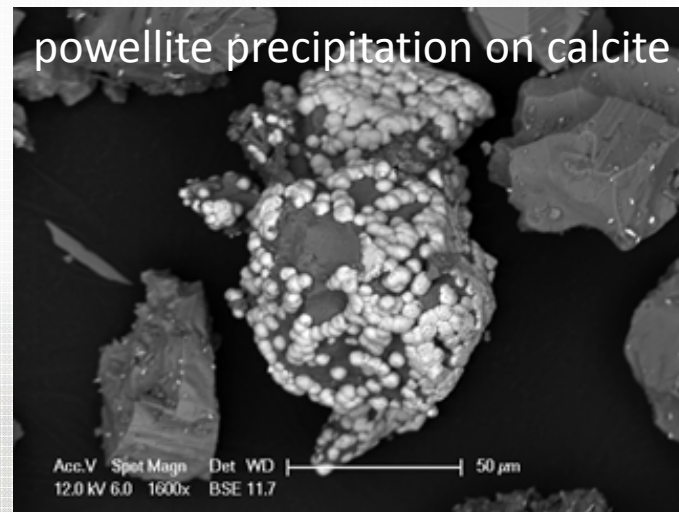
Potential Attenuation Mechanisms

1. Secondary Mineral Precipitation

- solution chemistry
- equilibrium concentrations can be calculated
- thermodynamic data only available for end-members
- potential rate limitations

2. Sorption to Particle Surfaces

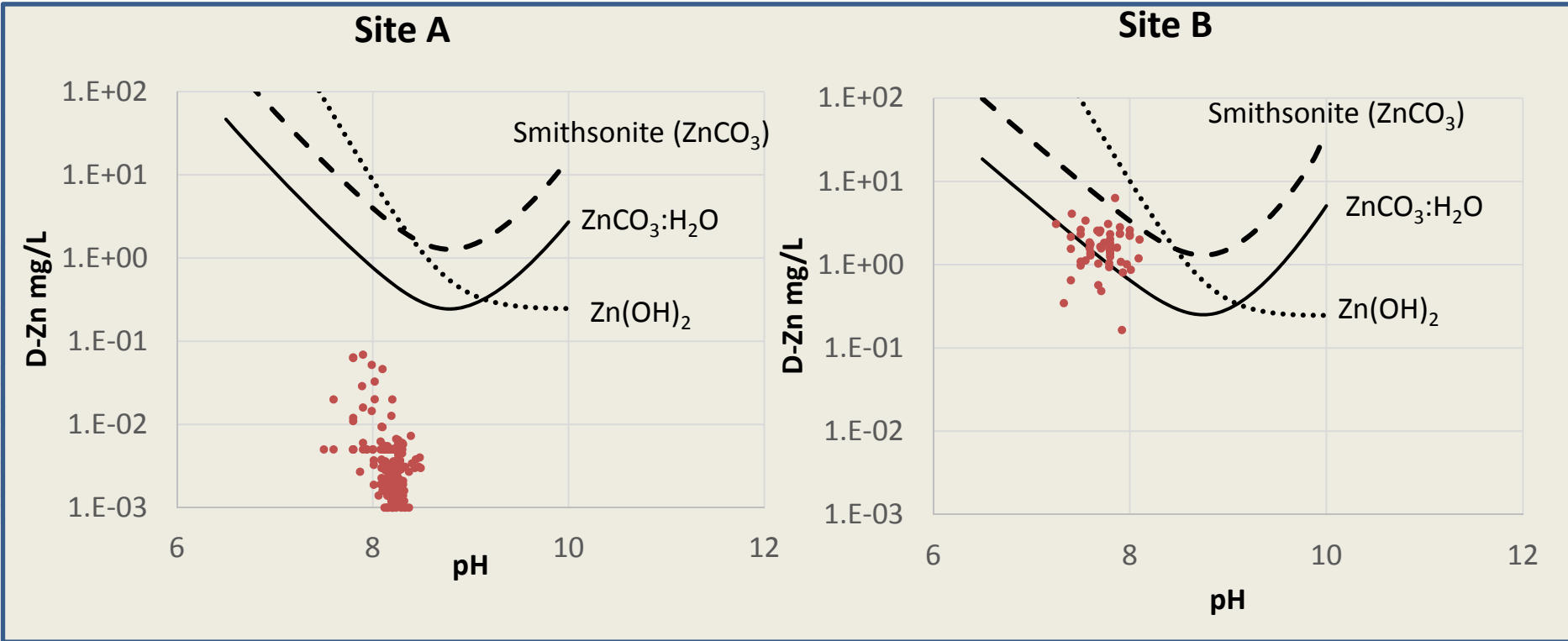
- solution chemistry
- availability of surfaces
- mineralogy of surfaces
- must be empirically determined



The pH Dependence of Metal Sorption on Fe-oxide (After Stumm, 1992)



Potential Attenuation Mechanisms



- **Site A: sorption controlled**
- **Site B: secondary mineral control**



Factors influencing sorption and solubility during active mining

- 1. Elevated TSS: increased particle surfaces available for sorption**
- 2. Cement in additives: dissolution of CaO**
- 3. Cation exchange: increase in carbonate mineral equilibrium pH**
- 4. Aeration of mine water: leading to degassing of carbon dioxide**

Elevated TSS

- During active mining TSS is observed to increase at both minesites
- Blasting and ground disturbance releases and suspends silt and clay particles

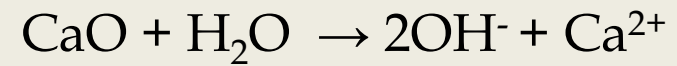




Cement in Additives



Cement Dissolution:

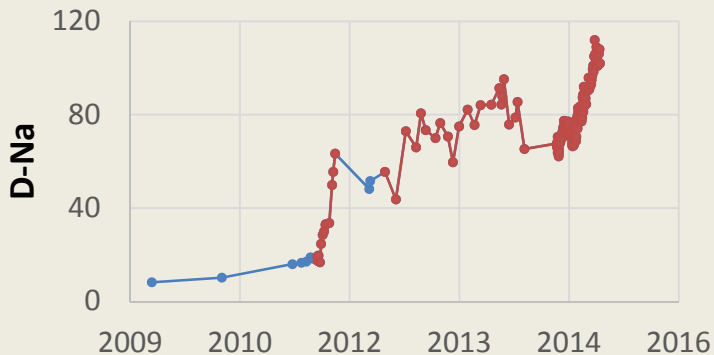
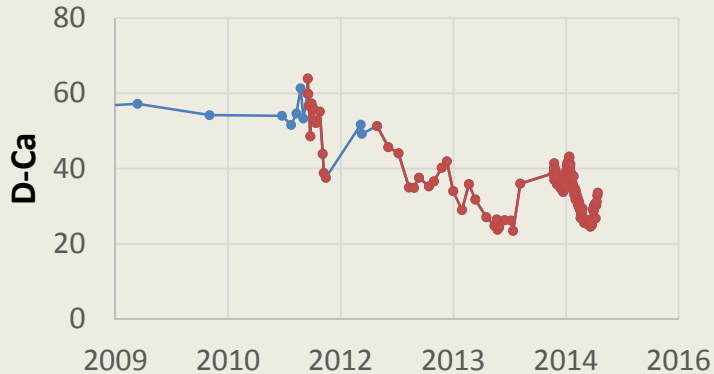


- Dissolution of cement in grout or shotcrete can drive up pH

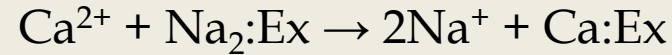


Cation Exchange

Site A



Cation Exchange:



- Water quality trends provide evidence that Na:Ca exchange reactions are occurring and potentially driving up pH at site A.
- Similar trend observed in early humidity cell data from freshly crushed drill core samples

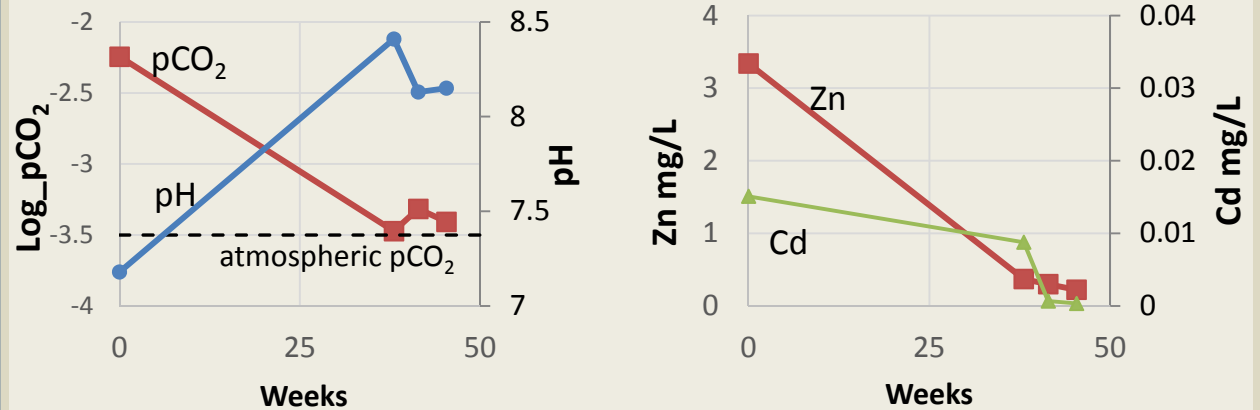
Aeration of Mine Drainage



Portal Drainage
Stored in 20L
Jug at 2°C



Ageing Experiment of Saturated Portal Drainage (Site B)



- Aeration of saturated drainage and degassing of carbon dioxide leading to an increase in pH and attenuation of Cd and Zn.

Conclusions

- **Geology is not the dominant control of metal cation behaviour.**
- **Solubility controls dictate metal cation behaviour in neutral pH settings. Solubility decreases when mine workings are drained due to:**
 - **Elevated TSS**
 - **Dissolution of cement**
 - **Cation exchange reactions**
 - **Aeration**
- **Interpreting neutral mine drainage datasets and predicting future water quality must take into account geochemical reactions which are highly sensitive to pH in addition to the intrinsic metal leaching potential of mine rock.**



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Questions?

