Evolution of Mine Drainage Chemistry Red Dog Mine, Alaska

Stephen Day, SRK Consulting, Walter Kuit
and Michel Filion, Teck Cominco Ltd

10th ANNUAL BRITISH COLUMBIA
ML/ARD WORKSHOP – December 2003

teckcominco

SRK

Outline

- Mine background
- Geological overview of Red Dog
- Static geochemistry
- Kinetic geochemistry
- Waste rock seepage chemistry
- Mechanisms controlling seepage chemistry

Red Dog Mine

- Located in NW Alaska 55 miles from Chukchi Sea
- Largest zinc deposit in the world.
- Started production in 1989.
- Open pit mine
- Conventional sulphide flotation

teckcominco

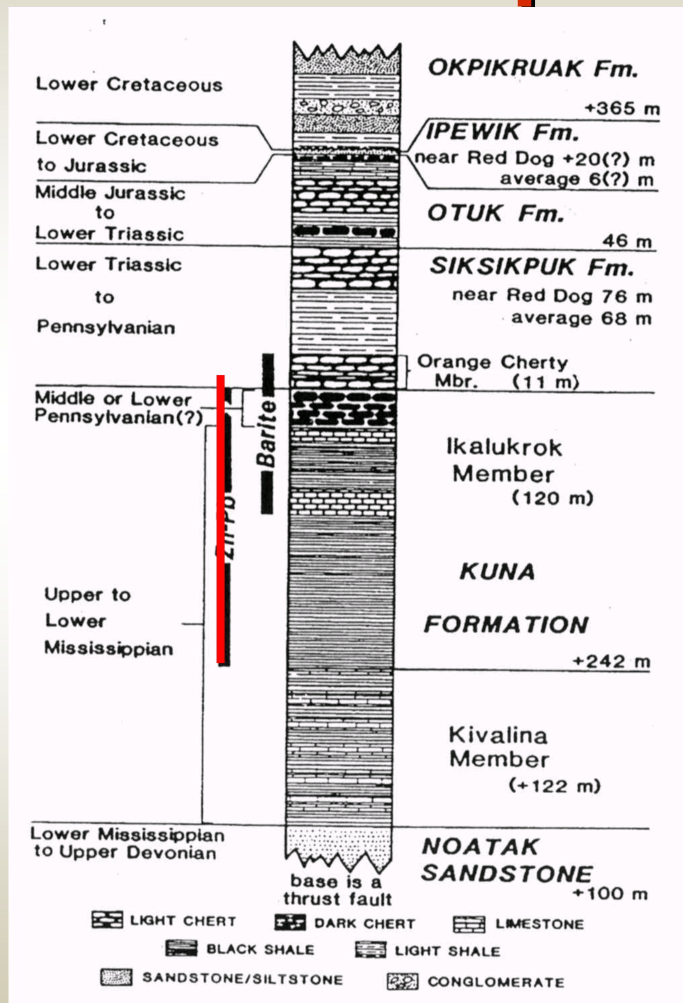
SRK

teckcominco

SRK

Black Shale-Hosted Pb-Zn Deposit

- ➲ **Geology**
  - – Friable rocks
  - – Generally low carbonate content.
  - – Wide range of sulphide mineral occurrences in ore and host rock



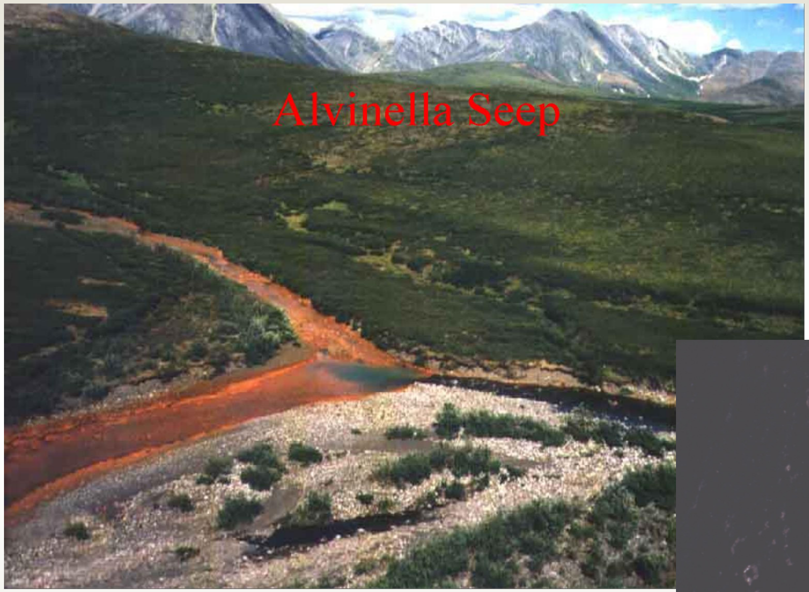
Natural Weathering Effects

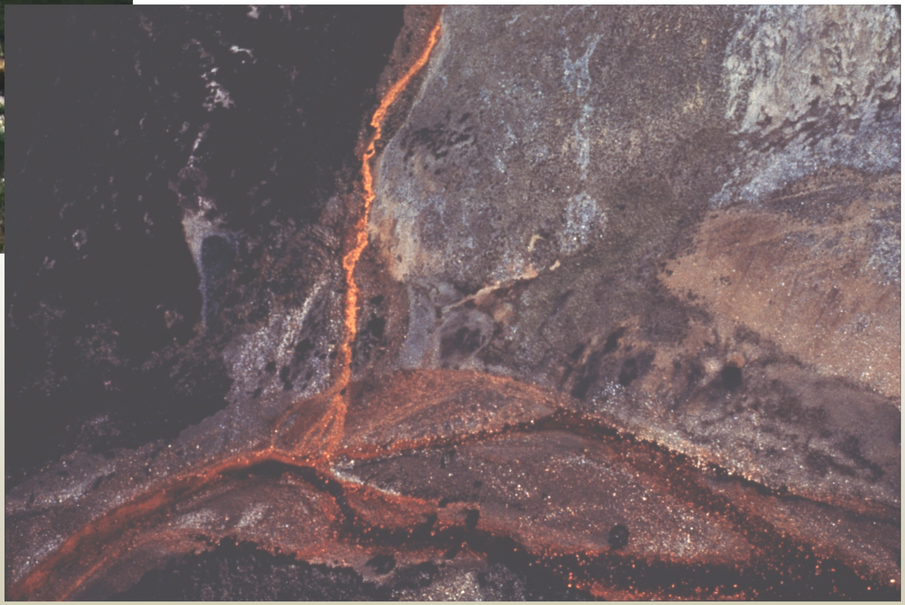
- ➲Deposit discovered by oxidized cap ("gossan")
- ➲Natural oxidation has produced a large number of iron, zinc, lead and copper oxides and sulphates.
- ➲Acidic salts and natural seepage.

teckcominco

SRK

Natural Weathering Effects





Oxidation Salts

Static Geochemistry: Sulphur Speciation

- Complex sulphur speciation
  - Conventional static testing is meaningless.
  - Sulphur speciation calculated from dominant forms:

  S(Fe Sulphide) = Total S – {S(Ba) + S(PbS) + S($PbSO_4$) + S(ZnS) + S($ZnSO_4$)}
  - Acid Potential from S(Fe Sulphide)
- Day et al (2000 – Denver ICARD)

teckcominco

SRK

Static Geochemistry: Neutralization Potential

- Carbonate content of most rock types is very low.
- Mostly calcite.
- Iron and barium carbonates occur.

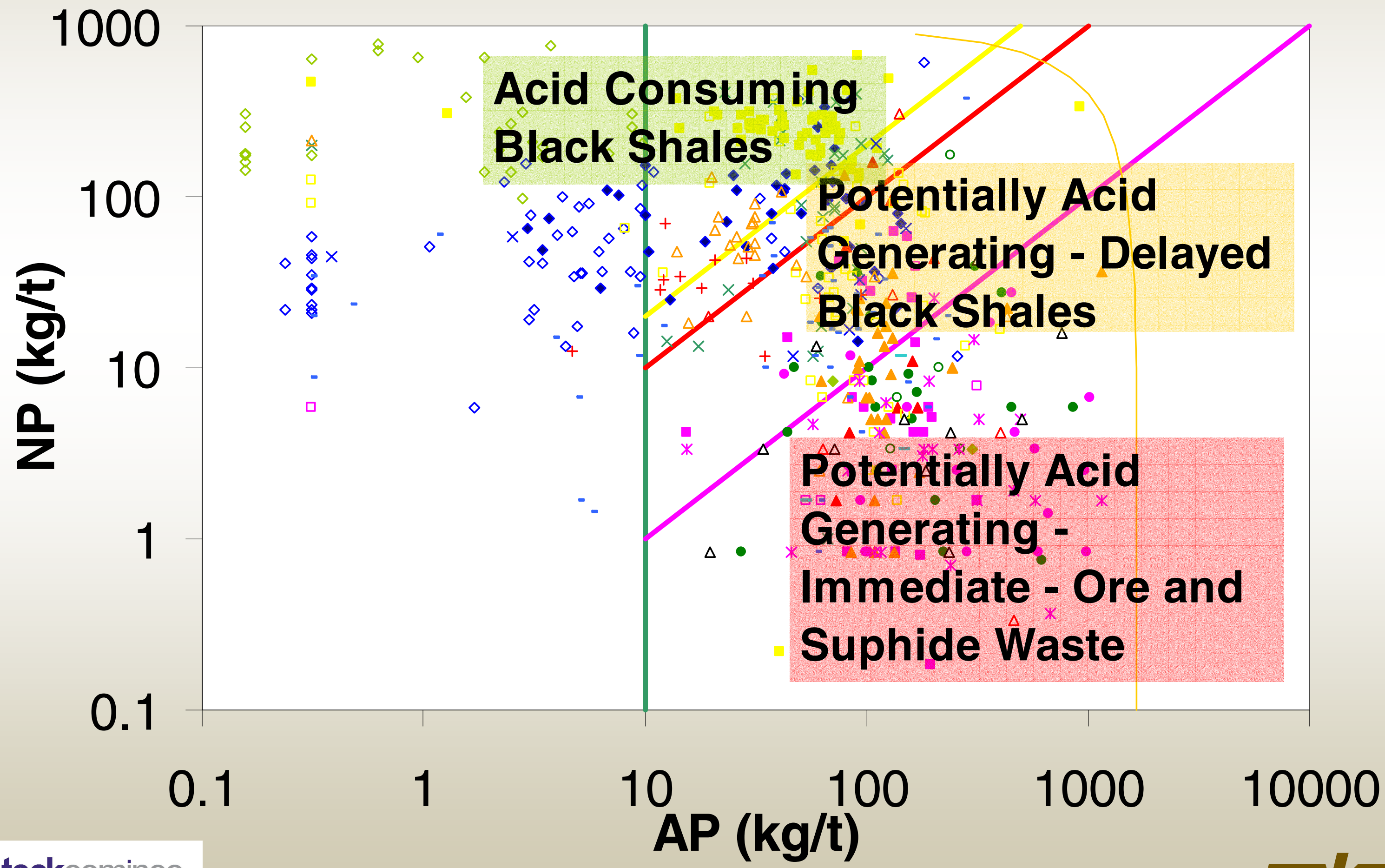
teckcominco

SRK

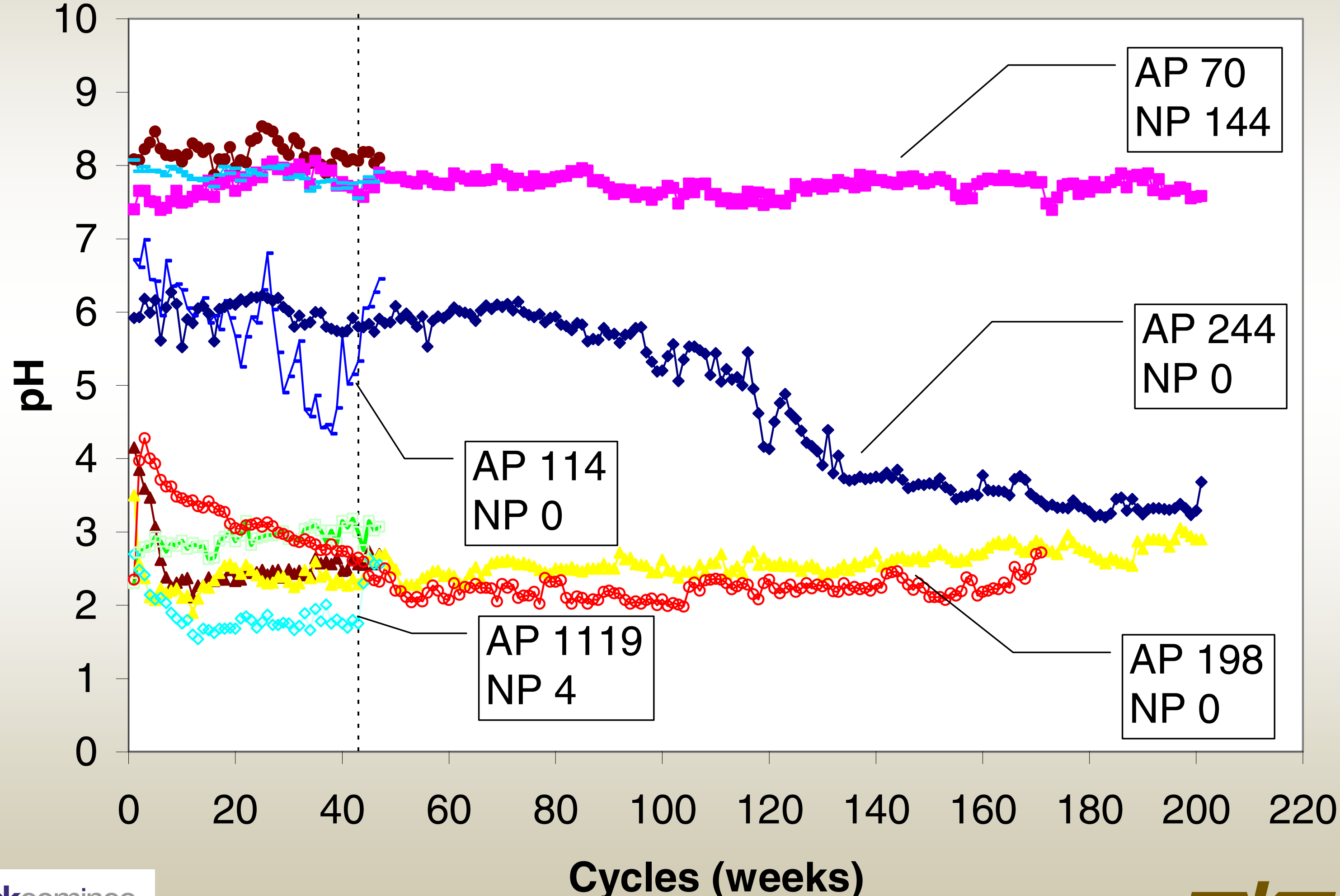
Geochemical Database

- Waste Rock Characterization
  - 600 static tests
  - Eight humidity cells (up to 4 years)
  - Seepage monitoring for waste rock (7 years)
- Tailings
  - Humidity cells and subaqueous columns on one sample (3 years)
  - Seepage monitoring (5 years)

Acid Generation Potential



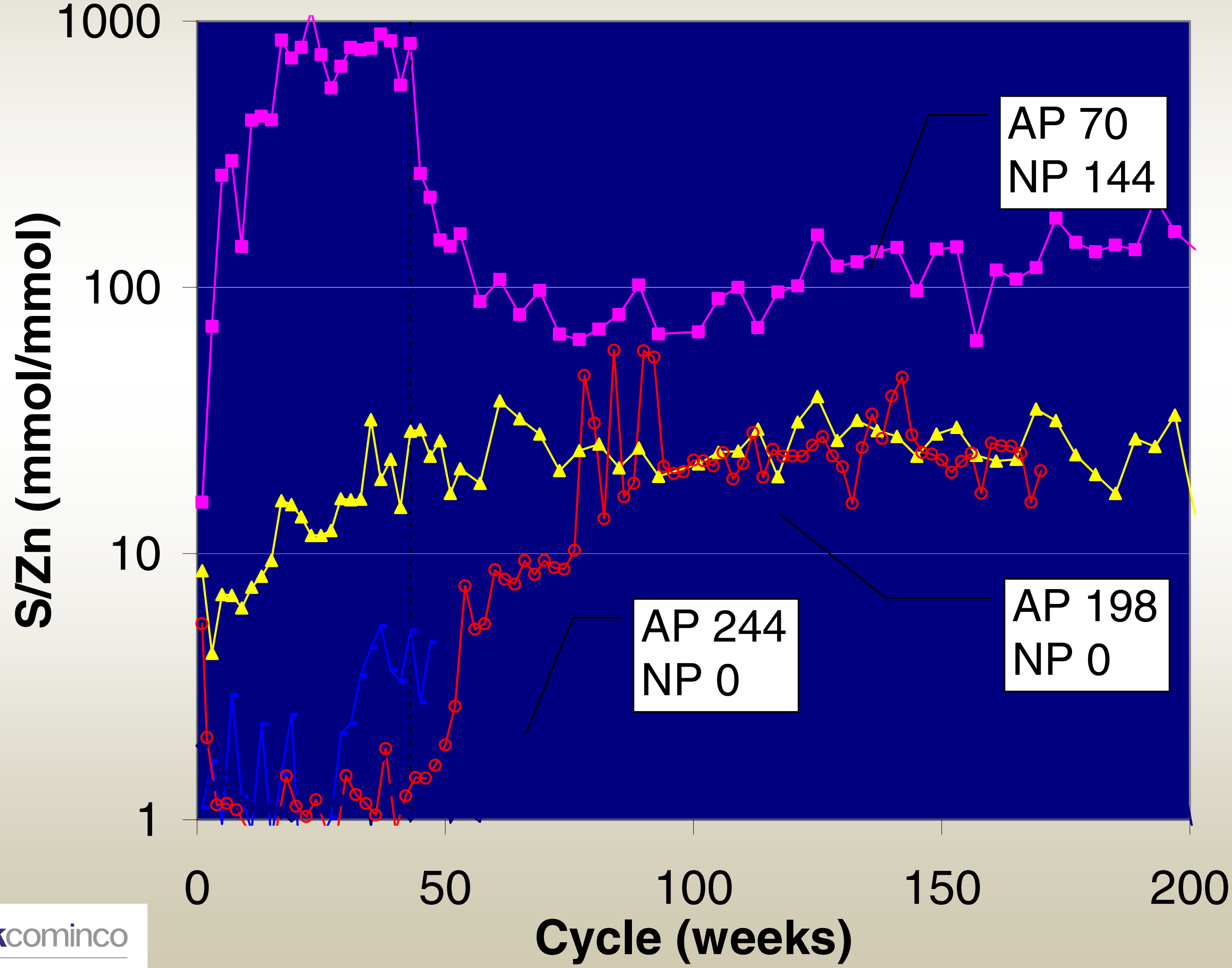
Humidity Cell Results



teckcominco

SRK

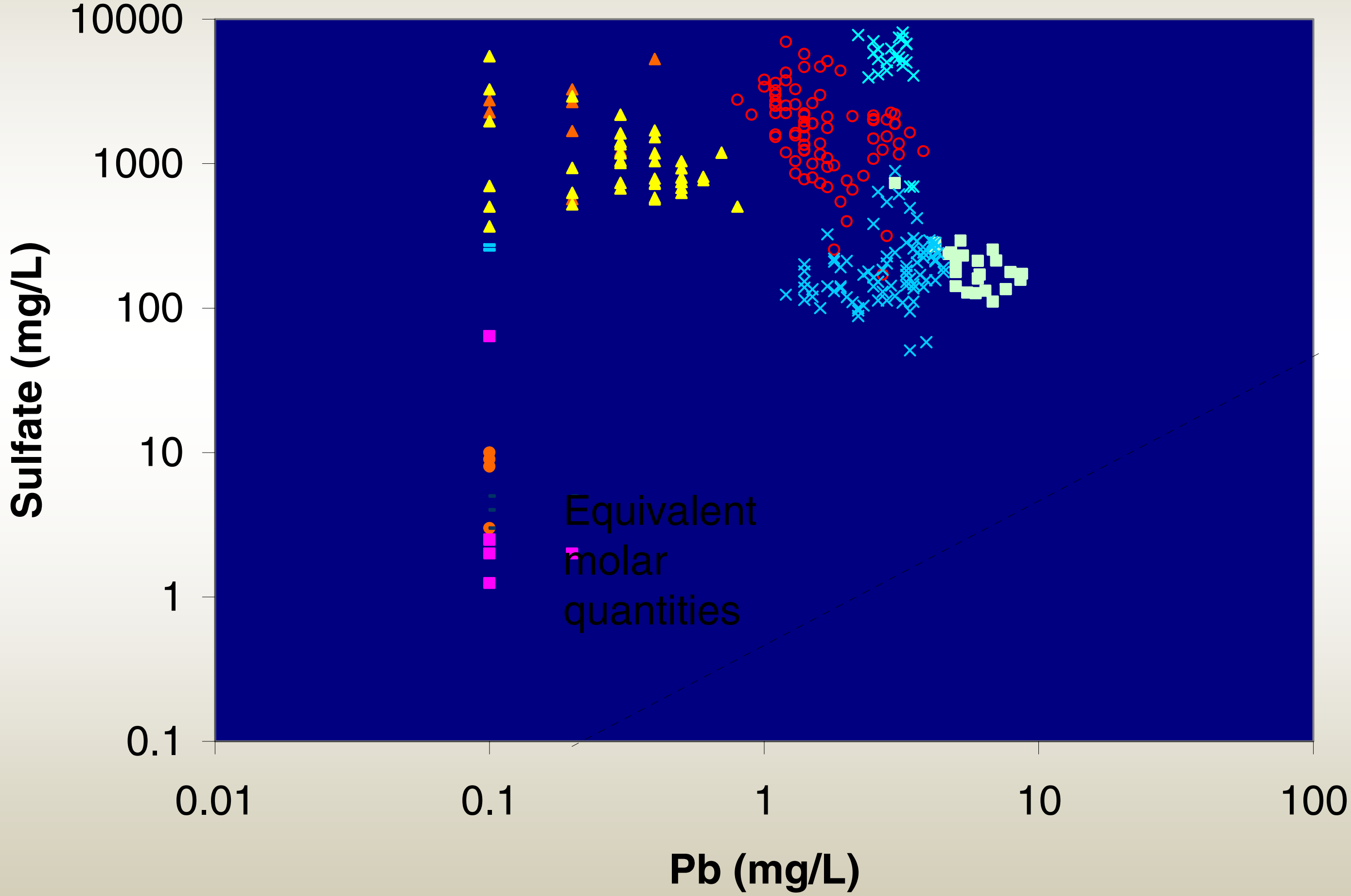
Humidity Cell Results



teckcominco

SRK

Humidity Cell Results



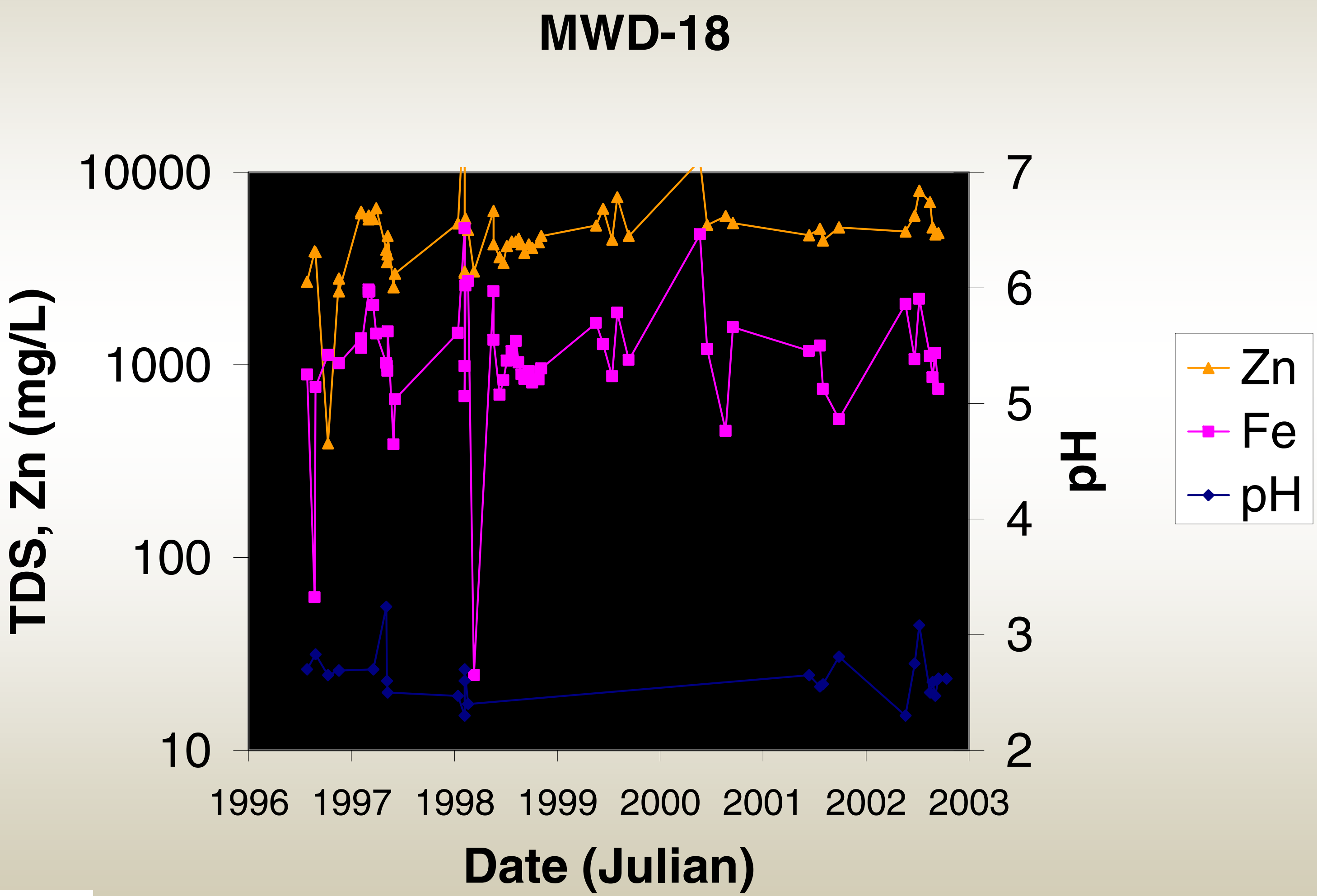
teckcominco

SRK

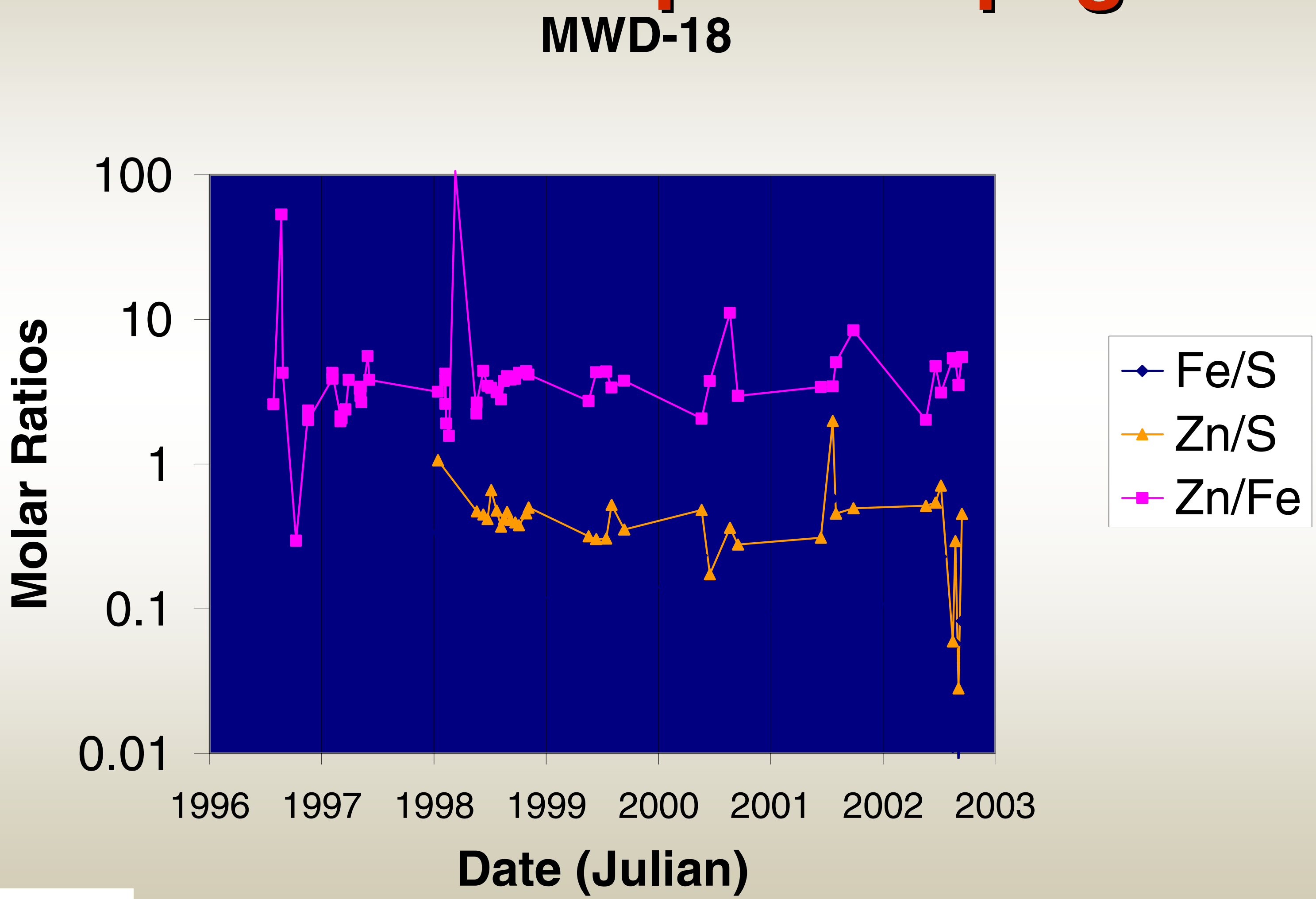
Waste Rock Characteristics

Major Unit	Sub-Unit	Overall Classification	
		Primary	Secondary
Mélange (8%)	Basal and Upper	Non-AG, metals	AG
Kivalina Shale (5%)		Non-AG, metals	
Kogruk Limestone (0%)		Non-AG	
Ikalukrok	Ore host (55%)	Rapid AG	
	Shale (6%)	Rapid AG	Non-AG, metals
Siksikpuk (21%)	Baritic	Delayed AG	
	Chert	Uncertain AG	
	Shale	Rapid AG	Non-AG, metals
Okpikruak (4%)		Non-AG	

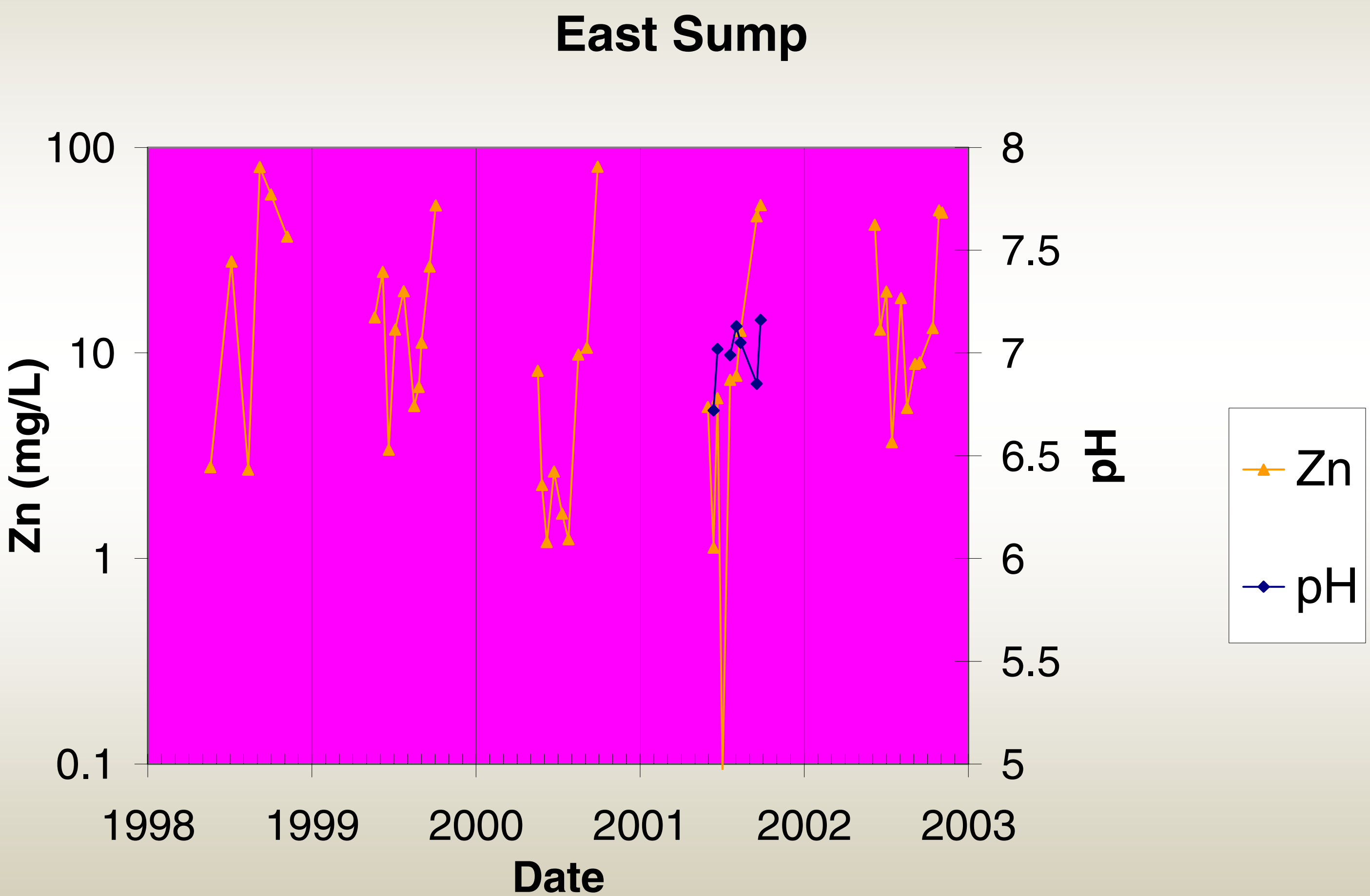
Waste Rock Stockpile Seepage



Waste Rock Stockpile Seepage



Overburden Stockpile Seepage



Observations on Trends

➲Humidity Cells

– Initial flush of (highly acidic) salts.

– Conventional delay of pH depression by carbonates.

– Other delay effect

  • Possible galvanic effect (ZnS oxidizes first)

– Lead release increases late in test as SO_4 decreases.

teckcominco

SRK

Observations on Trends

➲ Waste Rock Seepage

- Main waste seeps are strongly acidic.
- Seeps monitored for several years indicate flat or slightly decreasing trends.
  - Dominance of zinc over iron
- Overburden waste pile has non-acidic seepage
  - No trend.

Conclusion – Evolution of Drainage Chemistry

- Immediate to Short to Medium Term Effects (Zn, Cd, mildly acidic to alkaline)
  - Immediate to Short Term
    - Leaching of natural (original) soluble salts containing mostly zinc, cadmium (± iron).
  - Short to Medium Term
    - Oxidation of zinc sulphides.
    - Galvanic protection of iron sulphides.
    - Carbonate buffering (if carbonates present).
    - Leaching of soluble salts produced by oxidation

Conclusion – Evolution of Drainage Chemistry

- Longer Term Effects (acid rock drainage)
  - Medium to Long Term
    - Zinc sulphide oxidation continues
    - Oxidation of iron sulphides
    - Leaching of soluble salts produced by oxidation
  - Long Term
    - Leaching of lead sulphate (increase in lead)

teckcominco

SRK

Thank you!

teckcominco

SRK