Cold Temperature Effects on Geochemical Weathering

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and

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  - SRK – Stephen Day, Kelly Sexsmith, Dylan MacGregor
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Outline

- Project Background
- Availability of Data
- Discussion of Low Temperature Effects.
- Technology Gaps.
- Conclusions and a Request…….

Project Background

- "Update on Cold Temperature Effects on Geochemical Weathering"
  - Previous studies
    - MEND Project 6.1, Geocon 1993. Disposal of tailings in permafrost
    - MEND Project 1.61.2. Dawson and Morin 1996. Thorough review of the state of knowledge of ARD in low temperature environments.
    - MEND Project 1.61.1. CANMET 1996.
    - MEND Project 1.62.2. Norwest 1998.

Project Background

- "Update on Cold Temperature Effects on Geochemical Weathering"
  - Broaden investigation to geochemical effects at low temperatures.

Project Background

- Geo(chemical) Effects
  - Oxidation rates of iron sulphide minerals.
  - Oxidation of other sulphide minerals.
  - Activity of different types of bacteria.
  - Solubility and reactivity of acid buffering minerals including carbonates and silicates.

Project Background

- Geo(chemical) Effects
  - Formation and solubility of secondary minerals (weathering products).
  - Freeze concentration.
  - Physical exposure of minerals due to freeze-thaw processes.
  - Solubility of oxygen in waters used to flood reactive wastes

Methods

- Literature search and review.
- SRK and MEM files.
- Contact with other practitioners.
- Compilation of case studies.
- Evaluation of mechanisms.

Literature Search

- Primary and spinoff papers - 44
- Criteria
  - Sites providing direct comparative information on the effect of temperatures (8 found).
  - Other sites showing geochemical processes operating at low temperature conditions (numerous).

Sites

- Canada
  - Cullaton Lake (NT), Ekati Diamond Mine (NT), Diavik Diamond Mine (NT), Keno Hill (YT), Rankin Inlet Mine (NU), Ulu Project (NU), Windy Craggy (BC).
- US
  - Pogo Mine (AK), Red Dog Mine (AK), Urad Mine (CO).
- Others
  - Citronen Fjord (Norway), Black Angel (Greenland), N Kolyma Lowland (Russia), Stekenjokk (Norway).

Results – Oxidation of Iron Sulphides

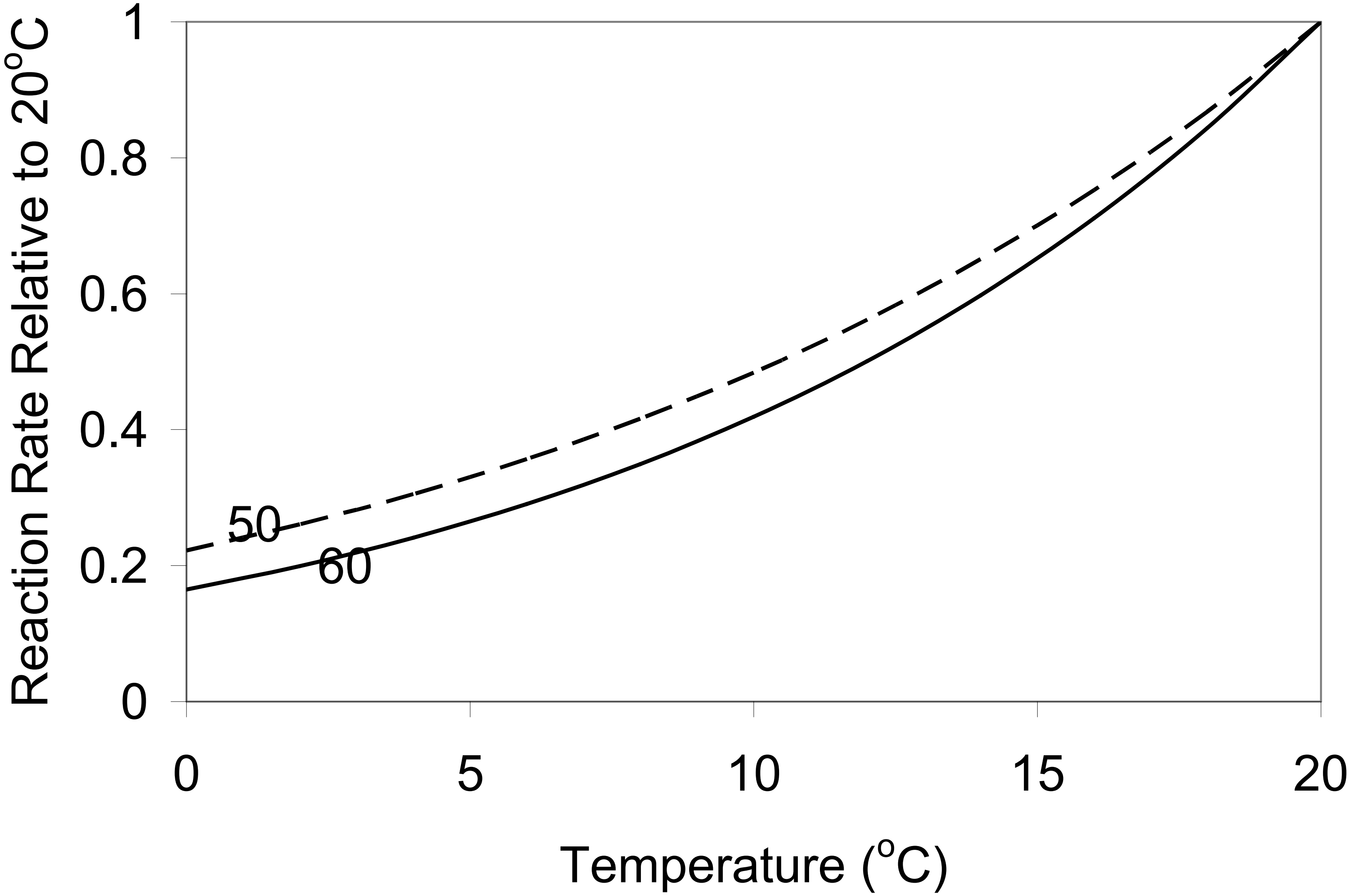
- Effect of temperature described by Arrhenius Equation

$$k=Ae^{(-E_a/RT)}$$

$$\ln(k_1/k_2) = E_a(T_1-T_2)/(RT_1T_2)$$

  - k_1 and k_2 reaction rates at temperatures T_1 and T_2 (in Kelvin)
  - E_a - activation energy
  - R - gas constant.

Results – Oxidation of Iron Sulphides



Results – Oxidation of Sulphides

Site	Tests	Mineral	k_4/k_{20}
Calculated		po, py	0.24 to 0.31
Diavik	4	po	0.3 to 0.4
Ekati	2	py	0.26
Pogo	4	aspy	0.29
		py	0.4 to 0.8
Red Dog Mine	4	py	1
		py	0.37, 0.40
		py	0.11
		py,sl	0.11
Ulu Lake	4	py, aspy	0.23
		py	0.23
Windy Craggy	11	po, py	0.34 to 0.67

Oxidation of Other Sulphides

- Variable E_a's indicate range of temperature effects
  - eg weak effect of T on arsenopyrite
- Laboratory data confusing due to compounding T effects and secondary mineral formation.
- Possible accelerated leaching of zinc under low temperatures.

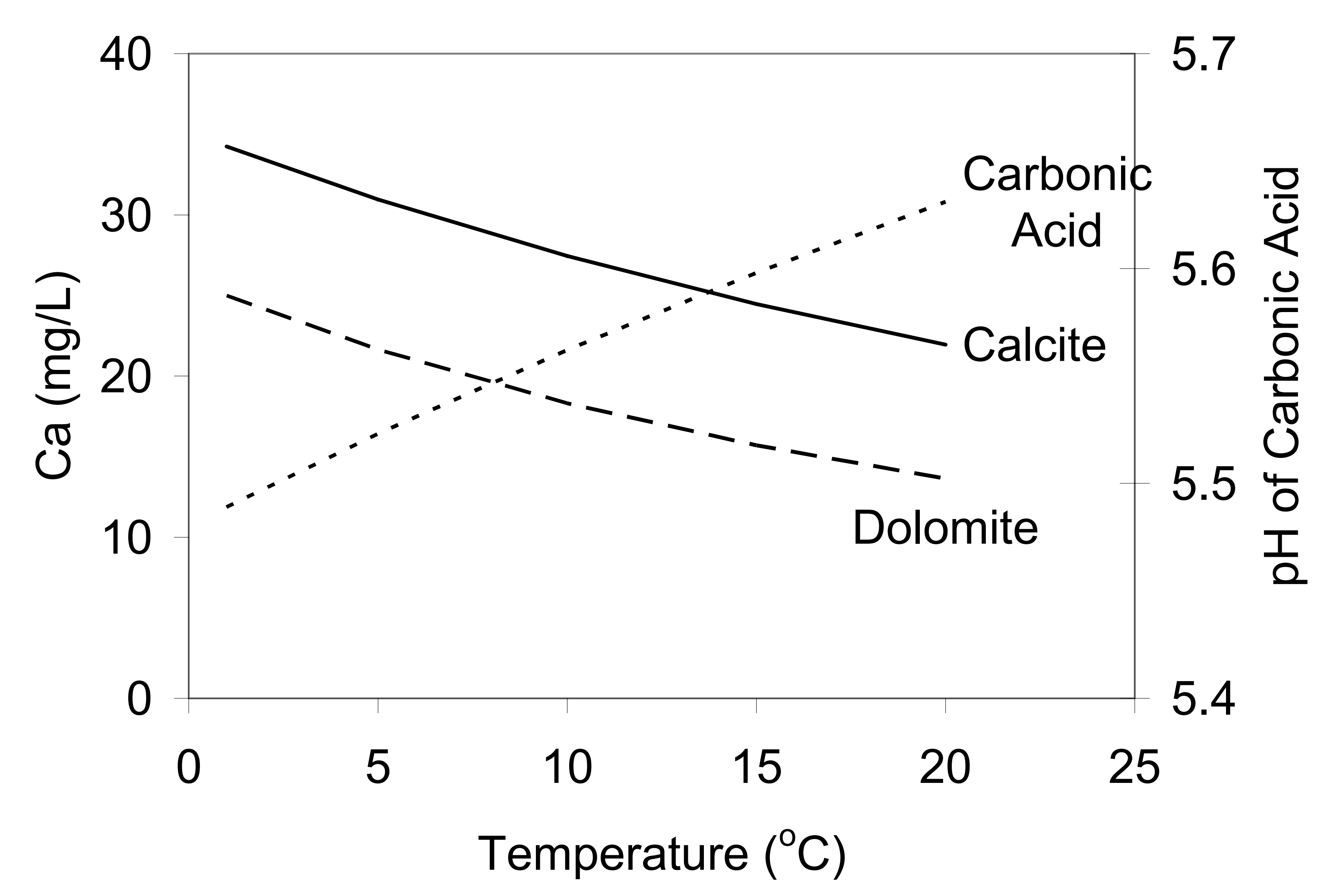
Results - Bacterial Activity

- Demonstrated activity of bacteria at sub-zero conditions.
  - Present at very low temperatures (-30^{o}C) but activity very low.
- Bacteria adapt to conditions.

Results – Acid Buffering Minerals

- Solubility of CO_2 in water increases as temperature decreases
  - Lowers pH and increases solubility of carbonate minerals.
  - May also affect weathering of silicate minerals.

Results – Acid Buffering Minerals



Results – Acid Buffering Minerals

- Implications
  - Increased delivery of dissolved alkalinity at low temperatures in rock mixtures.
  - Accelerated flushing of NP in small experiments.
  - Higher solubility of heavy metal carbonates (eg Zn).

Results – Freeze Concentration

- Increase in concentration
  - Solubility limits operate to limit freeze concentration effects (eg gypsum).
  - High solubility of $MgSO_4$ results in high TDS.
- Freezing Point Depression
  - Build up of solutes particularly in the absence of solubility control allows water to remain liquid.

Results – Solubility of Oxygen in Water Increases

- Limited evaluation
- DO increases by a factor of 1.4 as T decreases from 15^{o}C to 0^{o}C.
- Elberling (2001) notes that oxygen diffusivity decreases by greater factor.
  - Therefore, water covers potentially <u>more effective</u> at low temperatures.

Technology Gaps

- Characterization methods
  - Possible need for specific leach and kinetic (lab and field) tests to address low temperatures.

Technology Gaps

- Predictions
  - Growing and consistent database of kinetic test data for T effects…..
  - …..but limited rigorous data on effects for different sulfide minerals
  - Little specific information on weathering of buffering minerals in short (non-geological) time frame.
  - Solubility of weathering products at low T.

Technology Gaps

- Geochemical design criteria for wastes at low temperatures.
  - Defining “low reactivity” at low temperatures.
  - Effectiveness of covers (parallel MEND project).
  - Effectiveness of water covers.
  - Behaviour of waste rock mixtures.
  - Low T behaviour.

Conclusions

- Compilation of information continues.
- Anyone willing to contribute low T case study data is invited to contact SRK or MEM:
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  - Peri Mehling – pmehling@mehlingenvironmental.com