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Setting ARD Management Criteria For Mine Wastes with Low Sulfide and Negligible Carbonate Content

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Outline

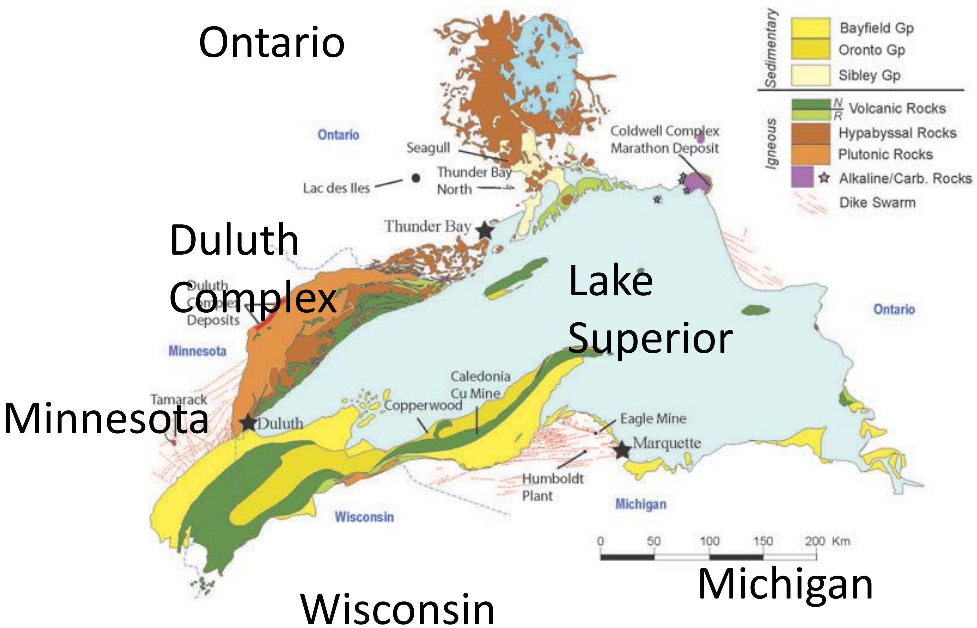
- Project setting
- Observations from long term kinetic testwork
- Hypothesis for trends in leachate pH
- Experimental design
- Results
- Application to setting management criteria

Acknowledgements

POLYMET
MINING

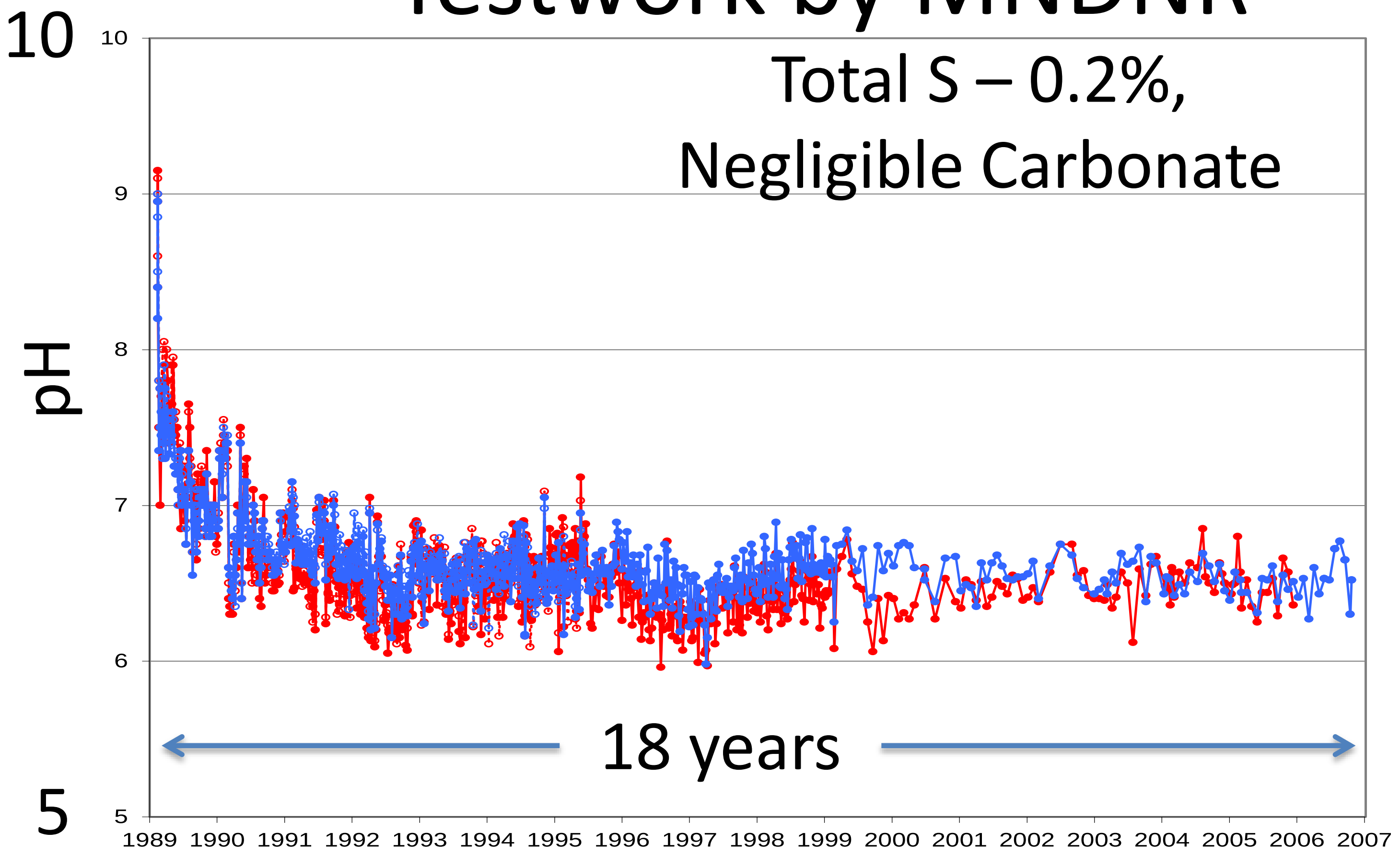
Minnesota Department of Natural Resources – Lands and Minerals (MDNR LAM)

Setting



- Duluth Complex – a gabbroic layered intrusion.
- Containing copper and nickel sulfide deposits.
- PolyMet Mining Corp's NorthMet Project – proposed open pit mine.

Observations from Long Term Kinetic Testwork by MNDNR



Lapakko, KA,.Antonson, DA,(2006) Laboratory dissolution of Duluth Complex Rock from the Babbitt and Dunka Road Prospects, Status Report. MN Dept. Natural Resources, Division of Lands and Minerals, St. Paul, MN. October 2006. 35p.

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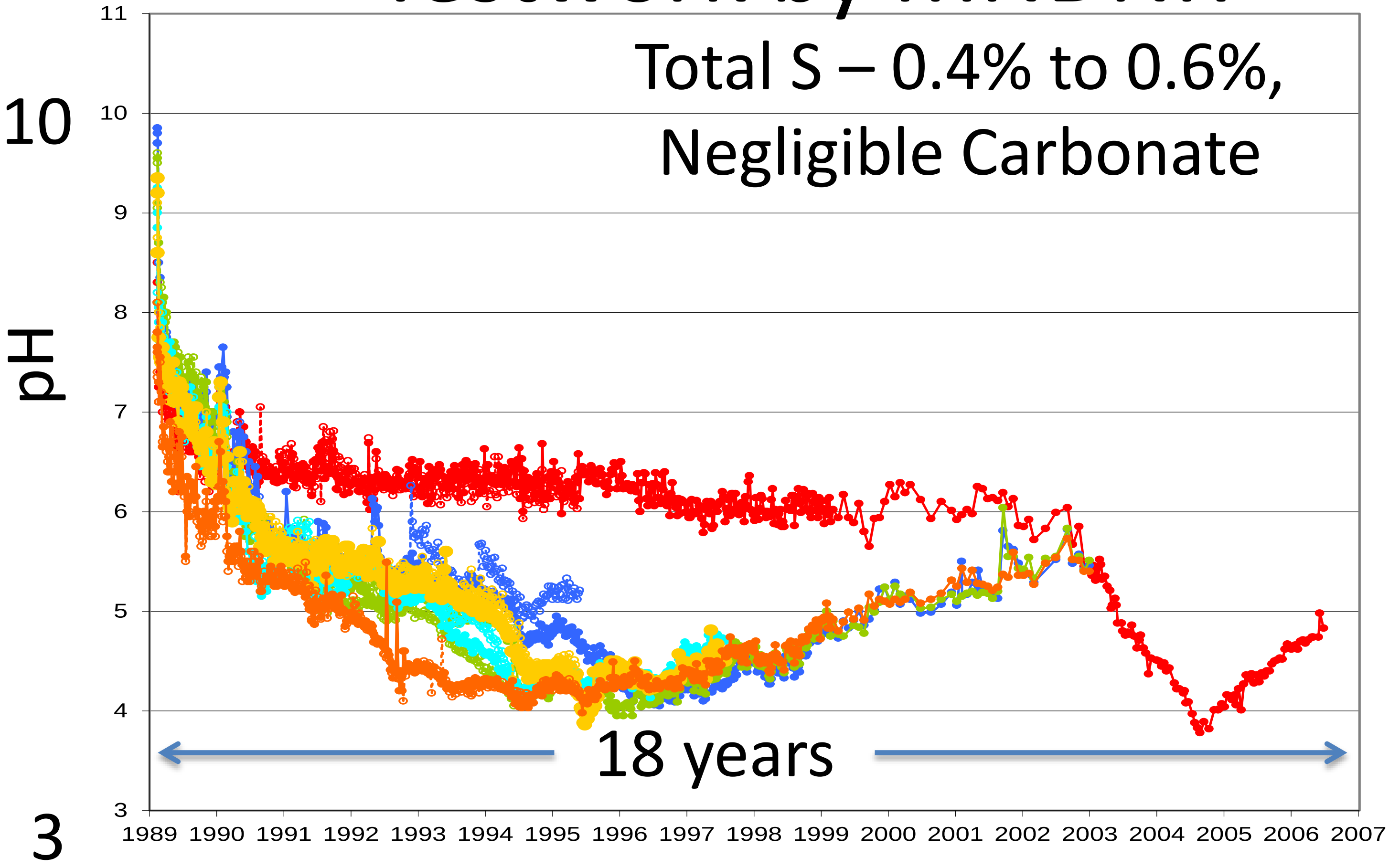

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Hypothesis for Trends in Leachate pH

- Conventional acid neutralization by carbonates (pH buffered in neutral range):
- Acid generation:

$$FeS_2 + {}^{15}\!/\!_4 O_2 + {}^{7}\!/\!_2 H_2O \rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H^+$$

- Acid Neutralization by Carbonates

$$4CaCO_3 + 4H^+ \rightarrow 4Ca^{2+} + 4HCO_3^-$$

Hypothesis for Trends in Leachate pH

- Acid neutralization by alumino-silicates (pH buffered 4 to 5):
- Acid generation:

$$FeS_2 + \tfrac{15}{4} O_2 + \tfrac{7}{2} H_2O \rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H^+$$

- Acid neutralization by alumino-silicates:

$$CaAl_2Si_2O_8 + 8H^+ \rightarrow Ca^{2+} + 2Al^{3+} + 2SiO_2 + 4H_2O$$

$$Al^{3+} + 3H_2O \rightarrow Al(OH)_3 + 3H^+$$

Hypothesis for Trends in Leachate pH

- Acid neutralization by bicarbonate from silicate weathering:

$$CaAl_2Si_2O_8 + 2H_2O + 2H_2CO_3^0 \rightarrow Ca^{2+} + 2Al(OH)_3 + 2SiO_2 + 2HCO_3^-$$

- Resulting bicarbonate is dissolved alkalinity that can participate in acid buffering.

Hypothesis for Trends in Leachate pH

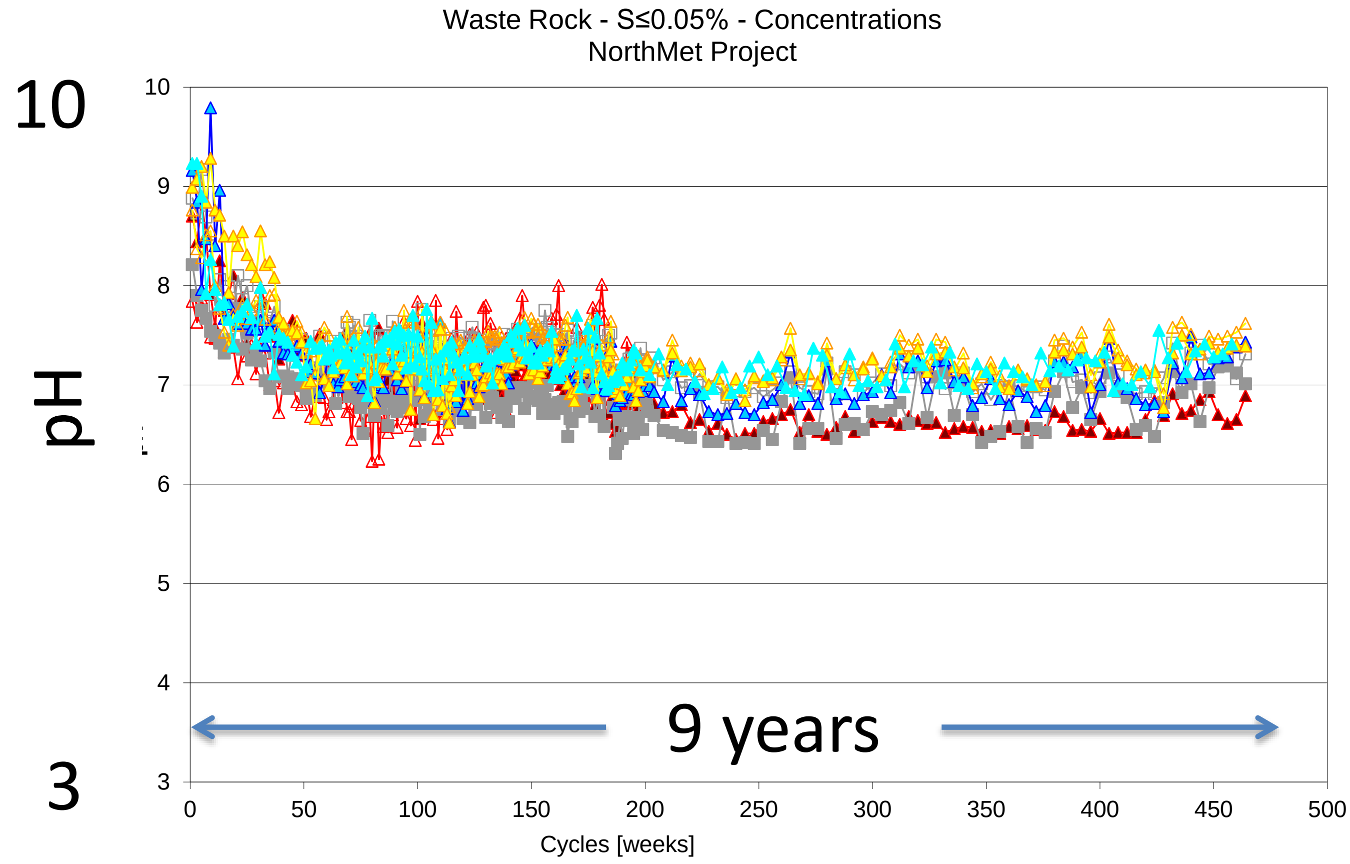
- Long term non-acidic pH can be sustained when alkalinity generation from weathering of silicates exceeds acid generation from sulfide oxidation.

- Acidic leachate occurs when acid generation exceeds alkalinity from silicate weathering.

Experimental Design

- Evaluate silicate weathering
  - Humidity cells on rock samples containing negligible sulfide.
  - Consider variation in silicate mineralogy.
- Correlate acid generation rates with sulfide content
  - Humidity cells representing a range of sulfide contents.
- Supporting mineralogy.

Results



Sulfide S ≤ 0.05%

Results

- For samples with less than 0.05% sulfide:
  - The testing period was sufficient to deplete very low levels of original carbonate minerals.
  - Leachate chemistry (Ca, Na, Mg, Si, pH, HCO_3^-) can be explained by weathering of plagioclase feldspar and olivine at $pCO_2 = 10^{-3.4}$.
  - Base level alkalinity generation rate range of 2.1 to 5.3 $mgCaCO_3$/kg/week

Results

- Sulfate release is strongly correlated with sulfide content.
- Distinctive relationships depending on copper and iron sulfide content:
  - Higher oxidation rates when copper sulfide dominates.

Application to Setting Management Criteria

- Used base level alkalinity generation rate and correlations to define sulfur thresholds for acid generation:
  - >0.12% (higher levels of copper sulfide).
  - >0.31% (lower levels of copper sulfide).
- Consistent with MDNR long term testwork
  - No acid generation for sulfur of about 0.2%.
  - Acid generation if sulfur is 0.4%.

Conclusions

- Weathering of large reservoir of reactive silicates offsets acid generation at low sulfide contents.
- Acid generation criteria can be based on sulfide content rather than conventional acid-base accounting.