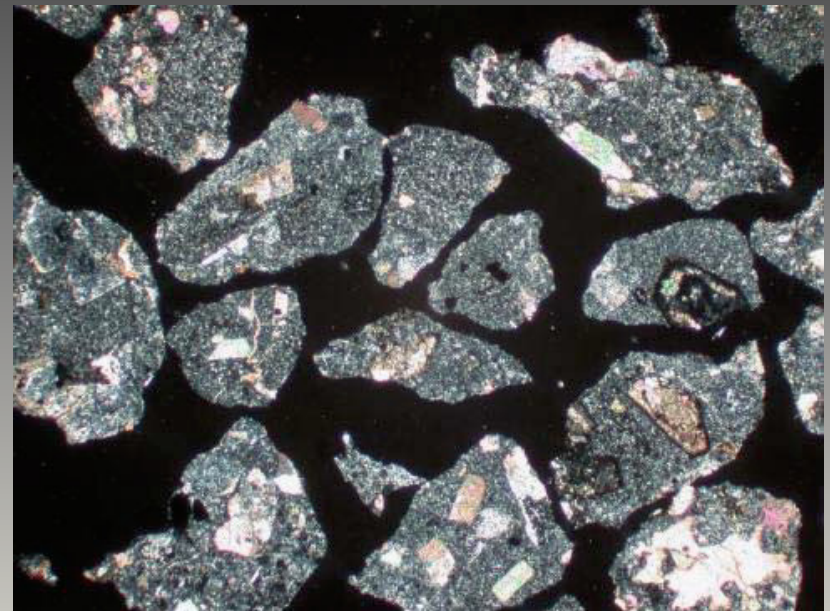
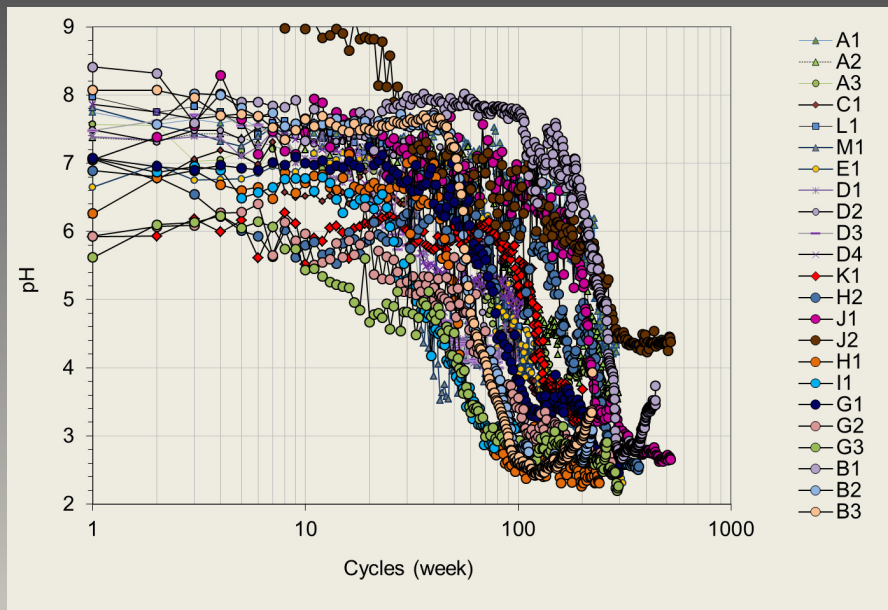


Comparison of actual and calculated lag times in humidity cell tests



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Introduction

- “Lag Time” or “Time to Onset” is the amount of time for acidic conditions to develop
- Needed to assess when management plans should be in place for preventing or mitigating ARD
- Typically defined through kinetic testing
 - Observe lag time (rare)
 - Calculate lag time (subject to uncertainty)

This Study

Evaluated the relationship between actual and calculated lag times

Candidate Tests:

- acidic conditions developed following a distinct lag time
- acidic conditions should have developed but did not develop despite an extensive period of testing

Dataset

- Reviewed inventory of results for 229 tests from 33 sites
- 30 tests from 14 sites met the criteria for this study
- Test durations ranged from 80 to 520 weeks
- 13 of these tests are still operating

Calculating Lag Time

$$\textit{Time to NP depletion} = \frac{NP^*}{(Ca + Mg) \textit{ release rate}} \quad (\text{eqn 1})$$

or

$$\textit{Time to NP depletion} = \frac{NP^*}{SO_4 \textit{ release rate}} \quad (\text{eqn 2})$$

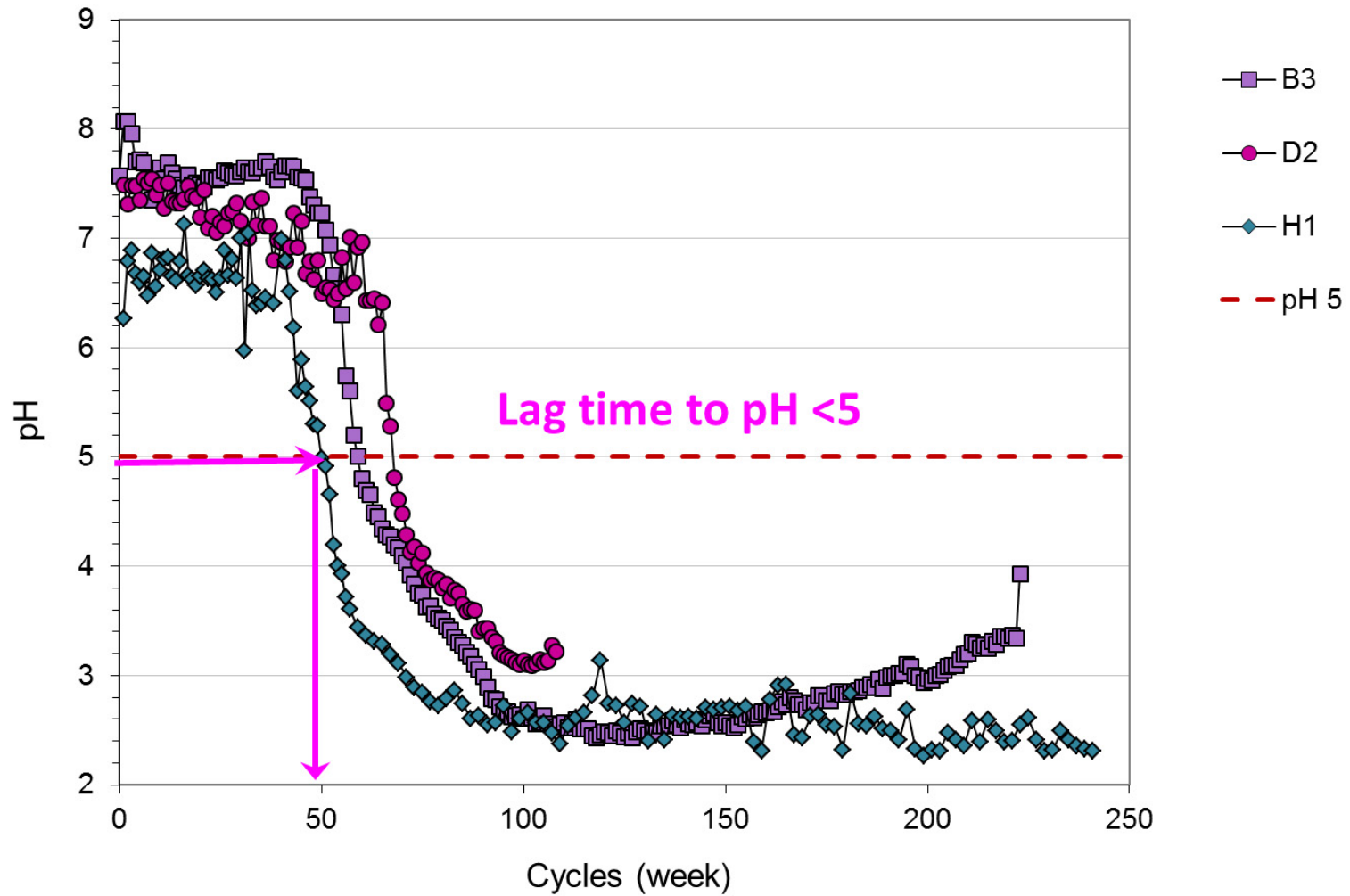
Where: NP* is the available NP in units of kg CaCO₃ eq/t

(Ca+Mg) and SO₄ release rates are the steady state non-acidic rates from the humidity cell test in units of kg CaCO₃ eq/t/year.

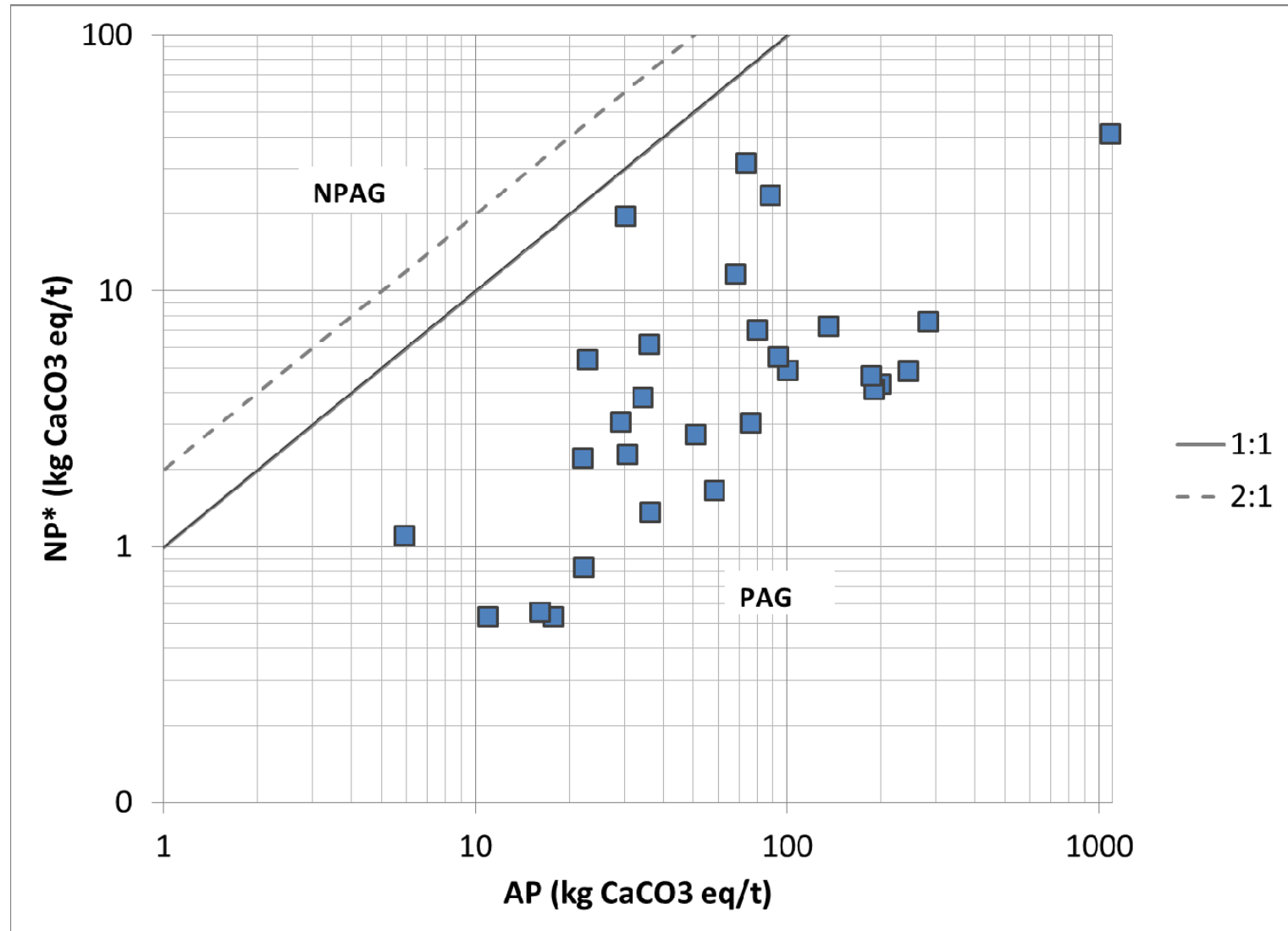
Available NP (NP*)

- TIC or NP by titration (eg. Modified Sobek)
- Correction factors applied to adjust for the limitations on availability and/or reactivity
 - Site specific NP/AP ratios (critical NP/AP)
 - Subtraction of the unavailable NP, or
 - Division by an availability factor (Ca+Mg content of carbonates).

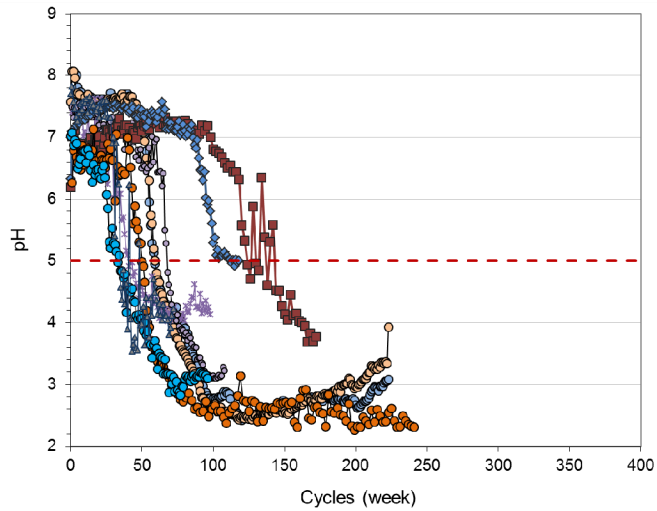
Defining Actual Lag Time



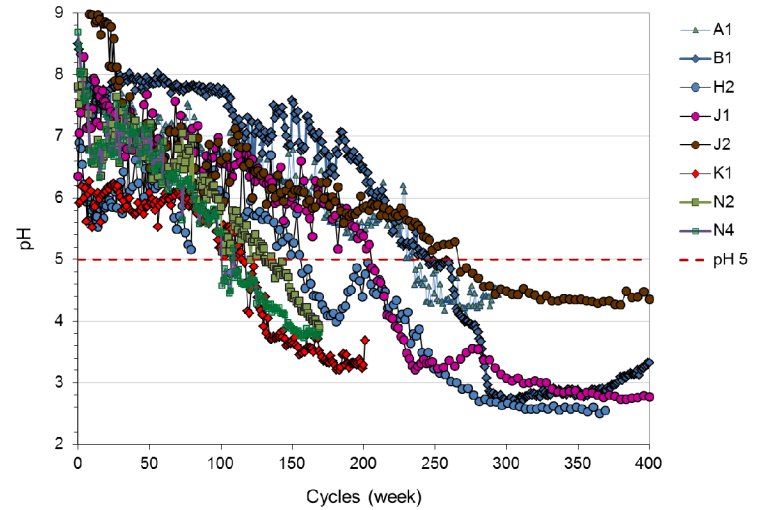
General Characteristics of these Tests



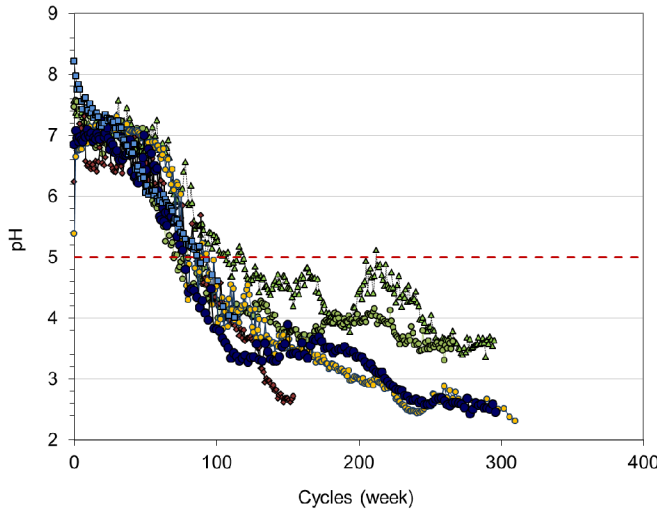
pH Profiles (comparison)



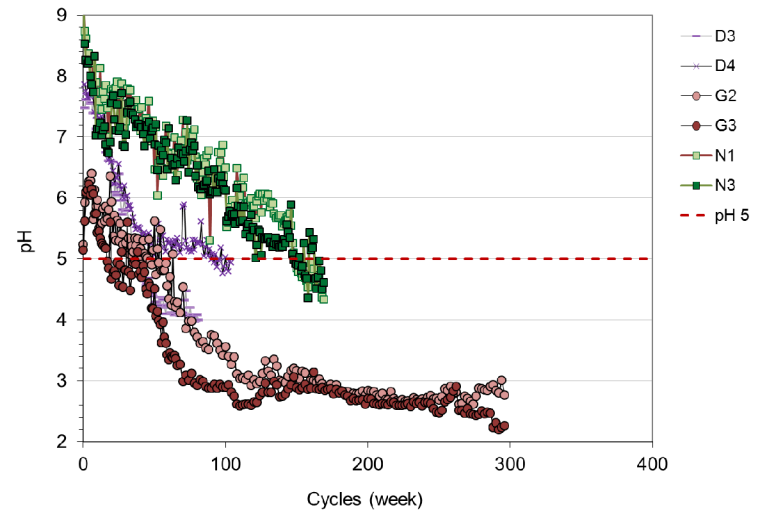
a)



b)

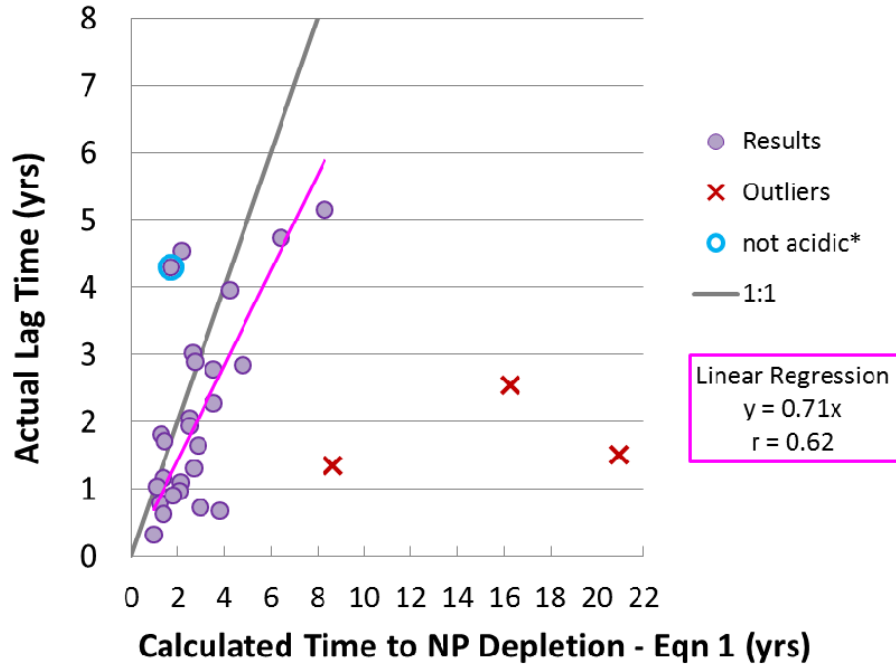


c)



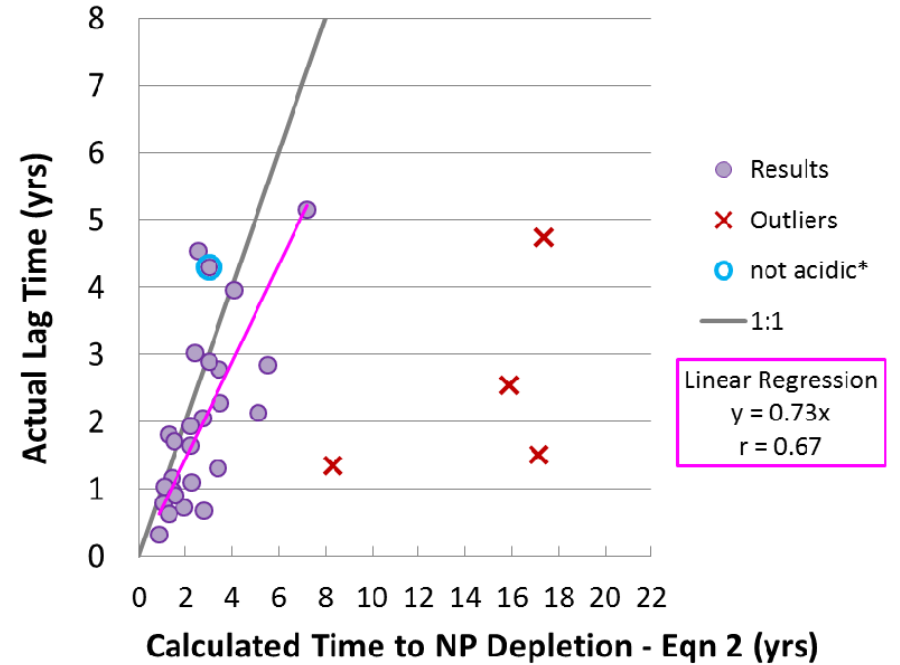
d)

Calculated versus Actual Lag Times



Notes: * test duration is shown on plots - actual time may be longer

a)



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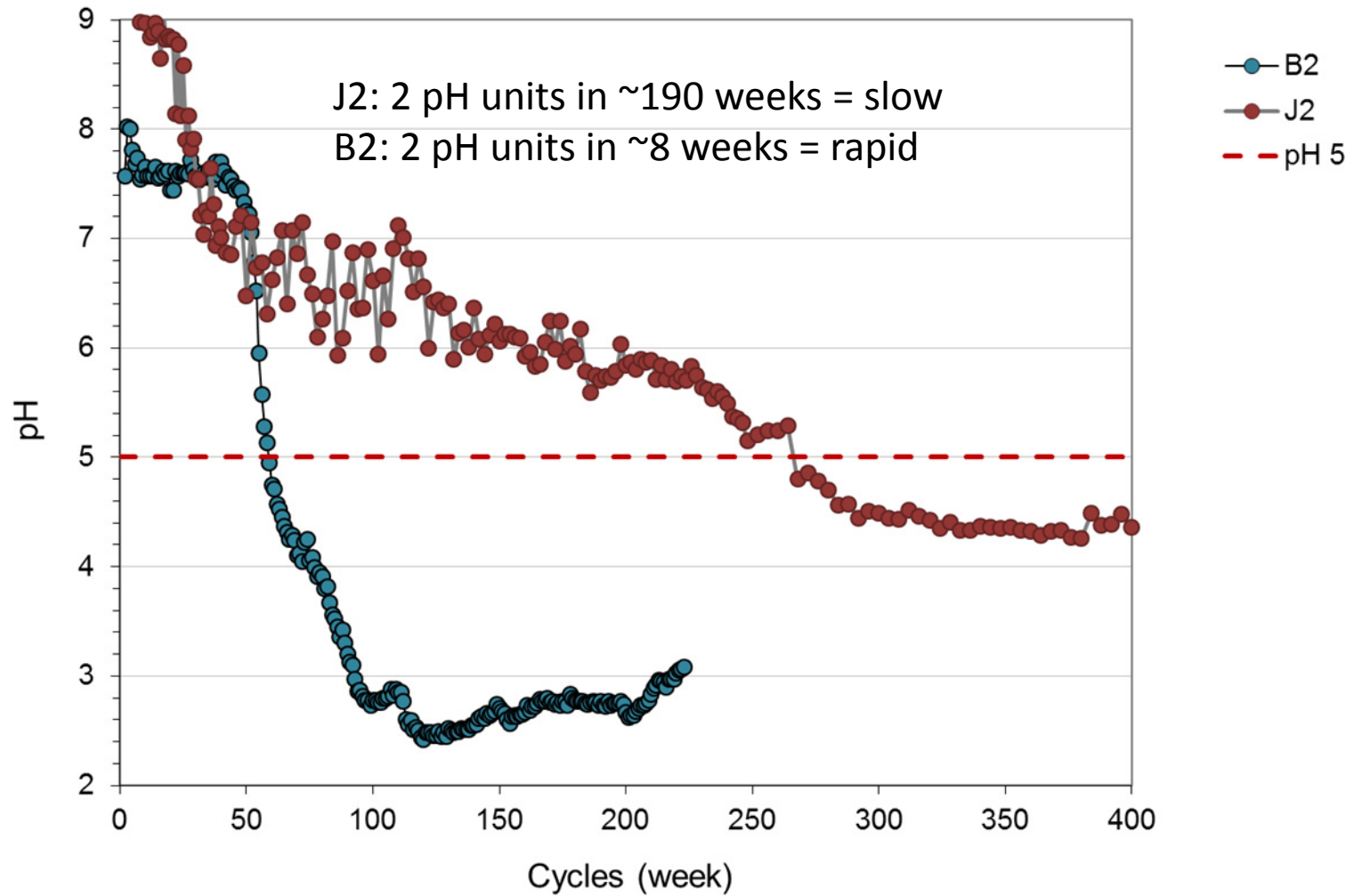
b)

$$\text{predicted lag time} = 0.74 \times \frac{NP^*}{SO_4 \text{ release rate}} \quad (\text{eqn 3})$$

Effects of Other Variables

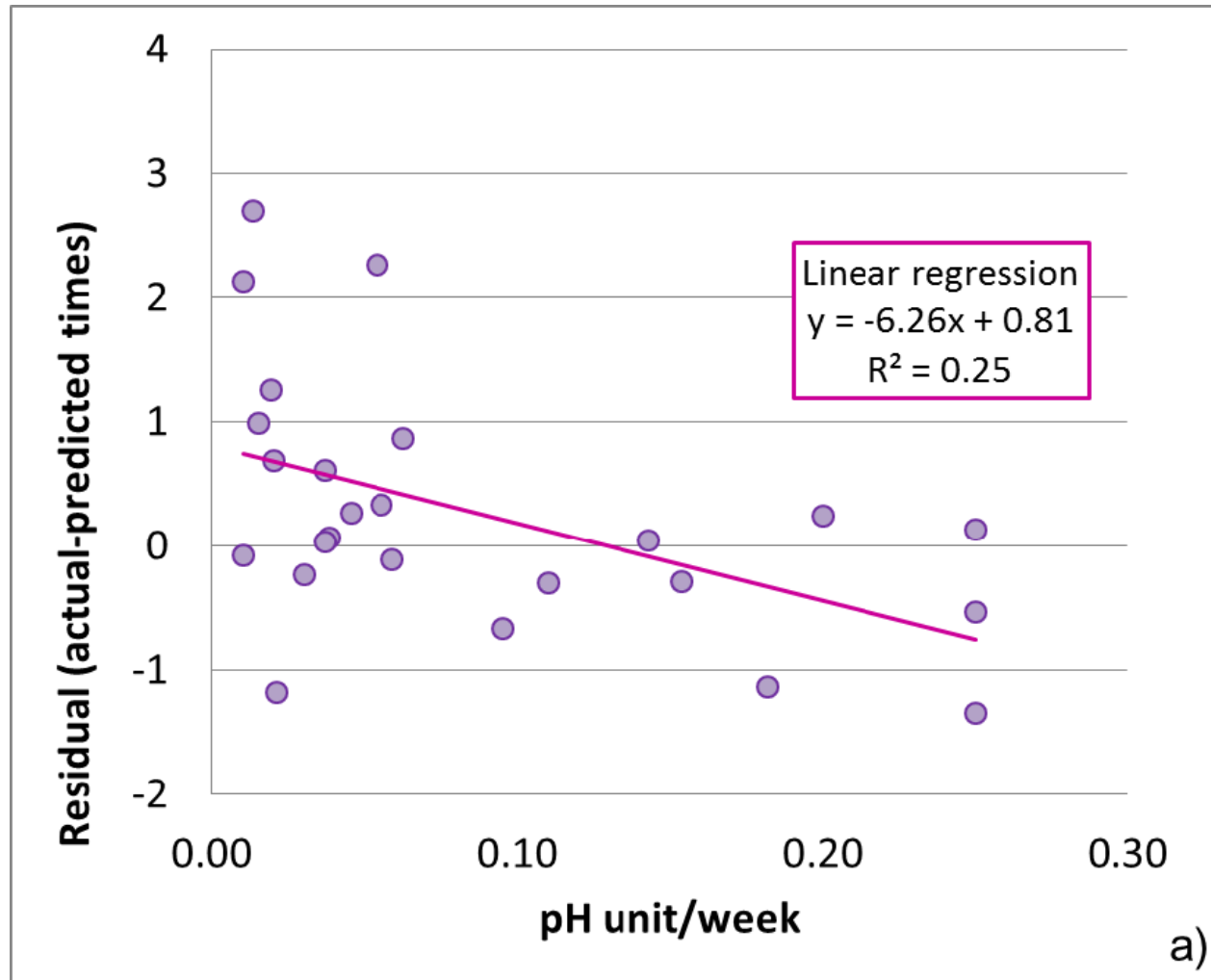
- Secondary relationships examined through residual analysis. Specifically, the difference between actual and predicted lag times (i.e. residuals from eqn 3) plotted against the following other variables:
 - Rate of acidification (pH change)
 - Difference between NP and TIC
 - (Ca+Mg)/SO₄ release rates
 - Sulphur content
 - Sulphate production rates.
- Qualitative approach used for mineralogy

Rate of Acidification

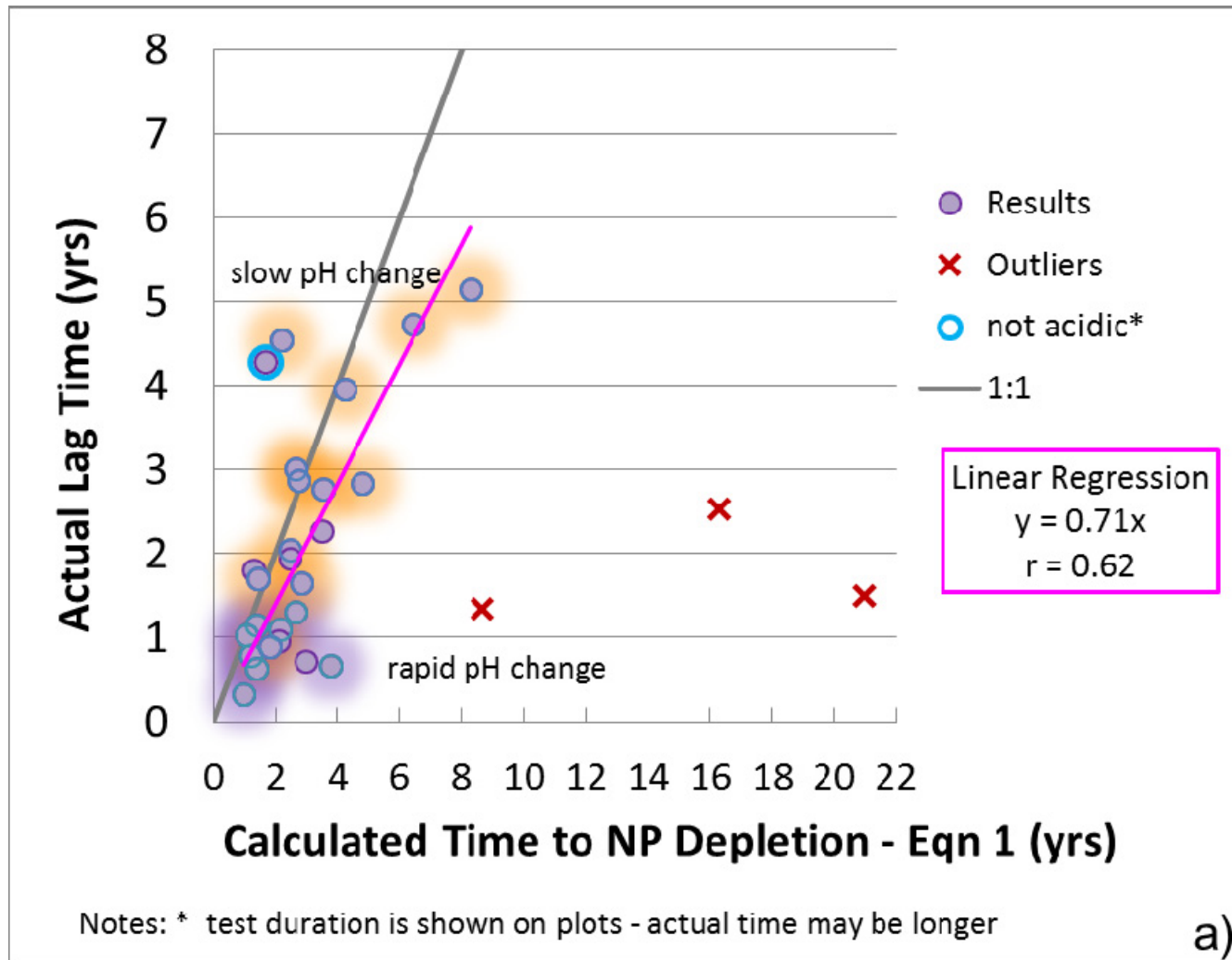


a)

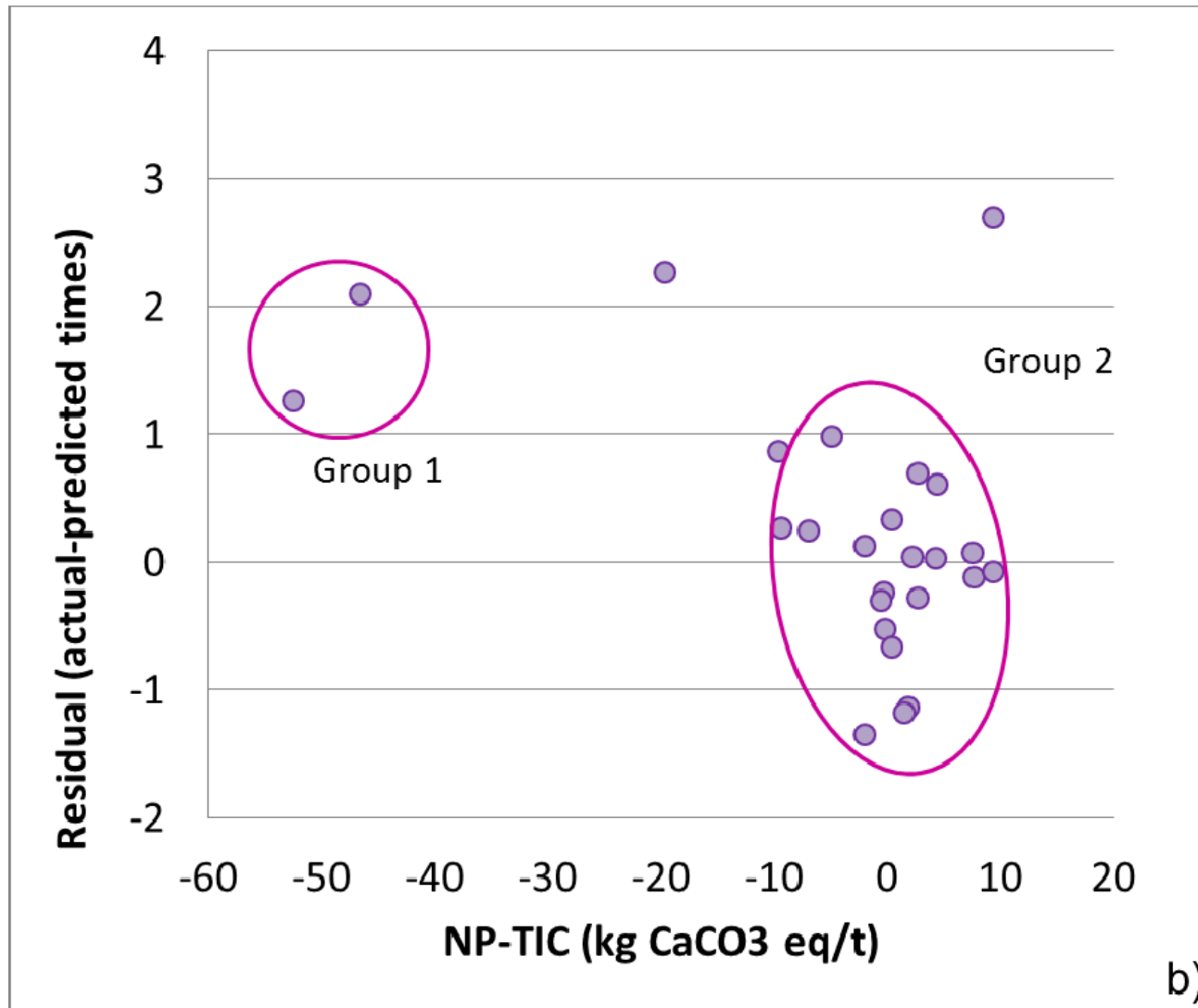
Residual Analysis



Calculated versus Actual Lag Times



Lag Time vs Difference between NP and TIC



Mineralogy

Some indications

- Samples with relatively low carbonate, but with favorable silicate minerals tended to have longer than expected lag times
- Samples with iron carbonates tended to have longer than expected lag times.
- Several exceptions and no clear patterns evident.
- Samples with shorter than expected lag times often had NP measurements that were inconsistent with mineralogy or TIC

Blinding by precipitates did not seem to be a factor

- No relationships of faster than expected lag times in samples with high TIC or high SO_4 production.

Conclusions

- Number of tests where lag time can be measured are relatively rare (30/229 tests)
- All of these tests had low NP and high sulphide content and were clearly PAG
- Calculated lag times were typically longer than actual lag times - but were correlated ($r = 0.67$)
- Estimates of lag time can be improved by selecting the most appropriate NP (usually the lesser of TIC or NP), and by applying correction factors to account for availability/reactivity

Conclusions

- Tests with longer than expected lag times showed a relatively gradual development of acidic conditions and slow rates of acidification
- The results emphasize the value of running certain tests for an extended period of time
 - to determine actual lag times
 - to demonstrate that there is a prolonged period of neutral pH conditions in cases where the lag times are expected to last for an impractically long time.
- Estimation of lag times in the field present further challenges and should be verified through appropriate monitoring.

Acknowledgements

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- Our clients for supporting these long-term testing programs and allowing us to use the data.
- SRK colleagues that helped to prepare the sample inventory and identify candidate tests for this work.

Thank-you

