

**SECTION B.7**

***UNCERTAINTY IN NEUTRALIZATION POTENTIAL  
DETERMINATION***

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Uncertainty in Neutralization Potential Determination  
Presentation Outline for  
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1. Static test rationale

- 1.1. Static tests assess the potential for producing acid drainage by comparing the potential of a sample to produce acid (AP) and to neutralize acid (NP).
- 1.2. The NP assessment is subject to error due to the simplifications in determination.
- 1.3. The prediction of drainage quality based on solid-phase characteristics is subject to error.
- 1.4. Understanding these potential errors, NP data must be applied with caution and consideration of other data.

2. Chemical and mineralogic considerations.

- 2.1. Acid is produced as a result of iron sulfide (e.g. pyrite, pyrrhotite) oxidation and dissolution of sulfate minerals such as jarosite and alunite.
- 2.2. Acid neutralization.
  - 2.2.1. Calcium and magnesium carbonates are the most effective acid neutralizing mineral.
  - 2.2.2. Dissolution of many silicate minerals will neutralize acid but this dissolution is generally very slow, except at low pH.
  - 2.2.3. Dissolution of iron and manganese carbonates does not neutralize acid in an oxidizing environment.
- 2.3. The amount of acid which will be neutralized while maintaining drainage pH  $\geq 6$  is a critical consideration for compliance with water quality regulations.
- 2.4. Drainage will remain neutral as long as the rate of acid neutralization equals or exceeds that of acid production.
  - 2.4.1. The rate of calcium and magnesium carbonate dissolution is dependent on Reactivity is dependent on mineralogy.
    - Dependent on mineral present (calcite > dolomite > ankerite) and
    - Extent of coating formation on mineral surfaceThe mineral surface area available for reaction dependent on mineralogy.
    - Calcium and magnesium carbonate content,
    - Degree of mineral grain liberation from rock matrix,
    - Mineral grain size,
    - Surface roughness, and
    - Extent of agglomeration as dissolution continues.

- 2.4.2. The amount of acid neutralized per mole Ca/Mg carbonate mineral dissolved is dependent on pH.  
Below ~pH 6.4: 2 moles H<sup>+</sup> neutralized per mole Ca/Mg carbonate.  
Above ~pH 6.4: 1 mole H<sup>+</sup> neutralized per mole Ca/Mg carbonate.  
Reaction rate increases as pH decreases.
- 2.4.3. Silicate minerals generally dissolve  
Slowly in the circumneutral range,  
More rapidly at low pH and small particle size.  
Consequently, these minerals generally do not contribute greatly to maintaining pH > 6 unless rates of acid production are very slow.

### 3. Static test methods

- 3.1. Commonly used methods (see table 1)
  - 3.1.1. Standard ABA (Sobek et al. 1978)
  - 3.1.2. Modified ABA (Lawrence 1990)
  - 3.1.3. B.C. Research Initial Test (Duncan and Walden 1975; Bruynesteyn and Duncan 1979).
- 3.2. The potential to produce acid (AP) is based on analysis of sulfur present in the sample. This measurement of total sulfur will provide a conservative value for AP. More accurately, the measurement should determine sulfur present as iron sulfide and sulfate present with acid producing sulfate minerals such as jarosite and alunite. AP determination will not be discussed further.
- 3.3. The potential to neutralize acid is generally determined as follows.
  - 3.3.1. For waste rock, reduce size to prescribed range
  - 3.3.2. React sample (partial digestion) with acidic solution (~0.5 < pH < 3.5).  
For Standard ABA and Modified ABA, the amount of acid added is dependent on subjective interpretation of the fizz test. Modified ABA requires digestion pH in range of 1.5-2.0.
  - 3.3.3. Determine the amount of acid neutralized by direct measurement of acid added (BCRI) or by titration to determine the acidity remaining after reaction of solid and acid.

### 4. Effects of protocol variables on NP values determined.

- 4.1. NP determined increases as the particle size decreases. (Excess contributions from silicate mineral dissolution, as mentioned in 2.4.3. Figure 1.)
- 4.2. NP determined increases as digestion pH decreases. (Excess contributions from silicate mineral dissolution, as mentioned in 2.4.3. Figures 2-4.)
- 4.3. NP determined using pH 7 titration endpoint is higher than that with pH 8.3 endpoint. (Underestimation of mineral acidity present in digestate. Figure 5)

5. Comparison of static test NP values with neutralization potential present as calcium and magnesium carbonate (NP[(Ca/Mg)CO<sub>3</sub>]).
  - 5.1. Static tests tend to overestimate the NP[(Ca/Mg)CO<sub>3</sub>] (Figures 6, 7).
  - 5.2. The low digestion pH, underestimation of residual acidity and, for waste rock samples, excessive particle size reduction lead to overestimation.
  - 5.3. The extent of overestimation is dependent upon sample mineralogy.
  
6. Comparison of static test NP with empirical data (Figure 8).
  - 6.1. Static test NP values tend to overestimate the ability of samples to neutralize acid in laboratory dissolution tests.
    - 6.1.1. The laboratory value is referred to as empirical laboratory NP or ENP<sub>lab</sub>.
    - 6.1.2. The extent of overestimation is dependent on sample mineralogy (Figures 9-13).
  - 6.2. NP values in laboratory tests tend to overestimate the empirical field NP or ENP<sub>field</sub> (Figure 14).
  
7. Suggestions to reduce NP uncertainty
  - 7.1. Use in conjunction with other tests (e.g. kinetic tests).
  - 7.2. Employ safety factors.
  - 7.3. Know mineralogy of rock type
    - 7.3.1. Mineral content
    - 7.3.2. Grain size
    - 7.3.3. Mode of occurrence
  - 7.4. Protocol considerations
    - 7.4.1. Do not reduce particle size excessively.
    - 7.4.2. Limit acid addition.
    - 7.4.3. Accurately determine acidity after digestion.
  - 7.5. Verify results by rock type
    - 7.5.1. Compare results to calcium and magnesium carbonate content.
    - 7.5.2. Compare to empirical NP in laboratory dissolution tests.
    - 7.5.3. Compare to empirical NP in field dissolution tests.

Table 1. Standard and Modified ABA, BCRI, and NP (pH6) methods.

ABA Method	Particle Size (mesh) <sup>1</sup>	AP sulfur form	NP-Determination Acid Leach				Back Titration Endpoint pH
			Acid & N	pH (range)	Duration (h)	Temp (°C)	
ABA, standard	-60	total	HCl, 0.1-0.5	0.5-7.0 <sup>2</sup>	1	85	7.0
ABA, modified	-200	sulfide	HCl, 0.1-0.5	1.5-2.0 <sup>3</sup>	24	RT	8.3
BCRI	-100 to -400	total	H <sub>2</sub> SO <sub>4</sub> , 1.0	≥3.5	4+	RT	NA
NP(pH6)	-150 to -325	sulfide	H <sub>2</sub> SO <sub>4</sub> , 0.1-1.0	≥6.0	4+	RT	NA

<sup>1</sup> Particle size for the Modified ABA was reported as -200 by Lawrence (1990). Particle size for the BCRI test was reported as -100 mesh by Bruynesteyn and Duncan (1979) and -400 mesh by Bruynesteyn and Hackl (1982). 75% passing 325 mesh has been used by industry laboratories (Lapakko, 1994).

<sup>2</sup> pH is not controlled with this method.

<sup>3</sup> This range was used by Lawrence Consulting Ltd (1991); a range of 1.0 to 1.6 was reported in an earlier publication (Lawrence 1990).

From White et al. 1997.

Figure 1. Standard ABA NP decreased as particle size increased.

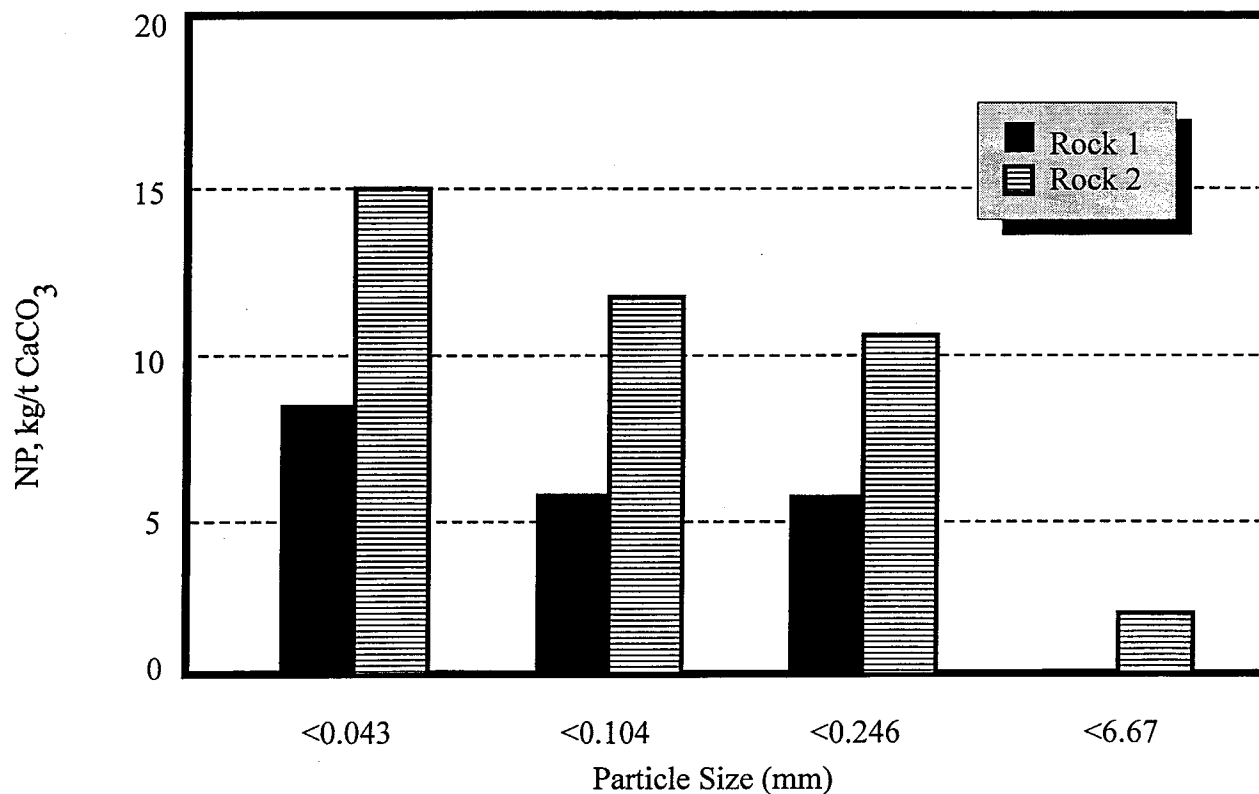


Figure 2. NP decreased as digestion pH increased.

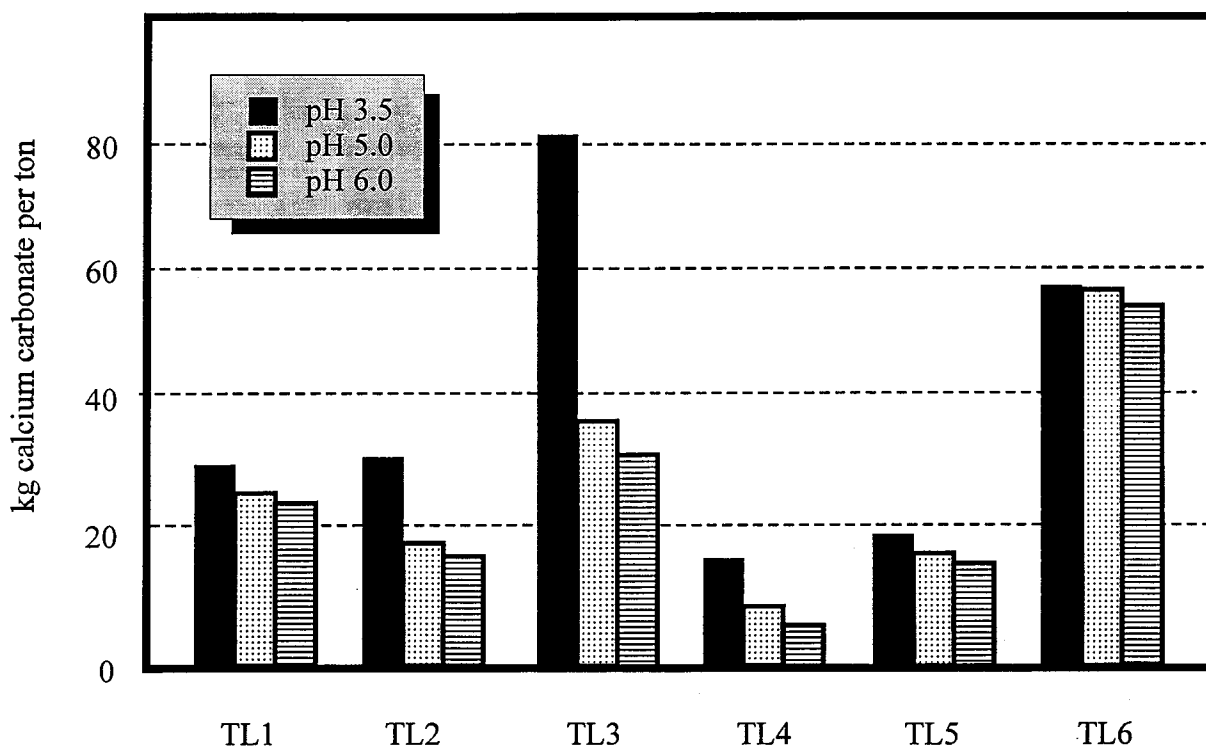


Figure 3. NP decreased as drainage pH increased.

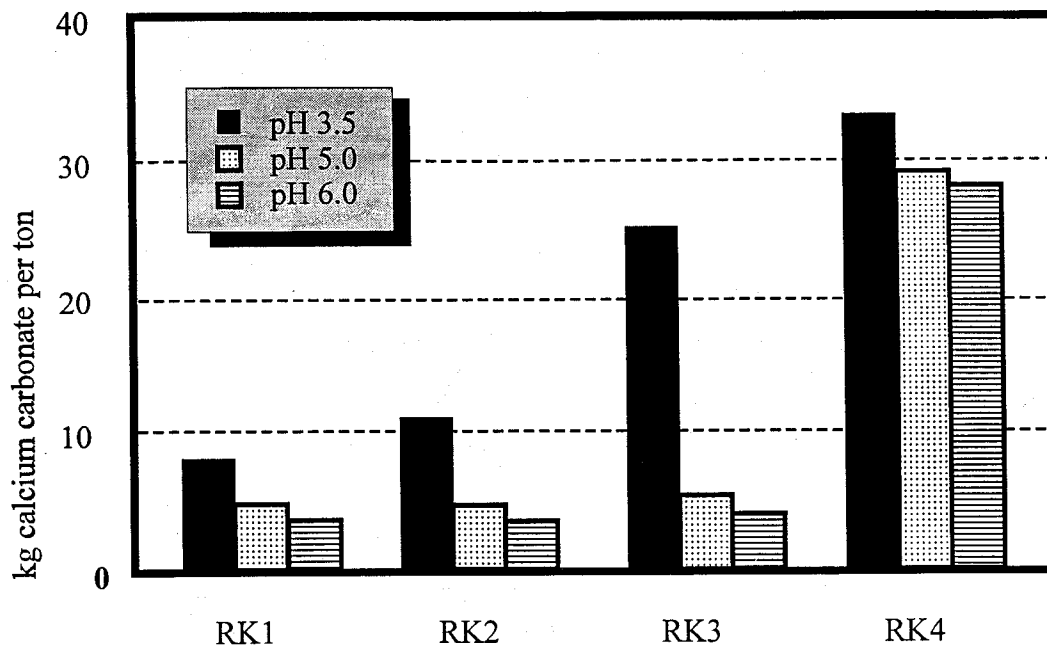


Figure 4. Variation of quartz-carbonate tailings' NP with digestion pH (Modified ABA Digestion).

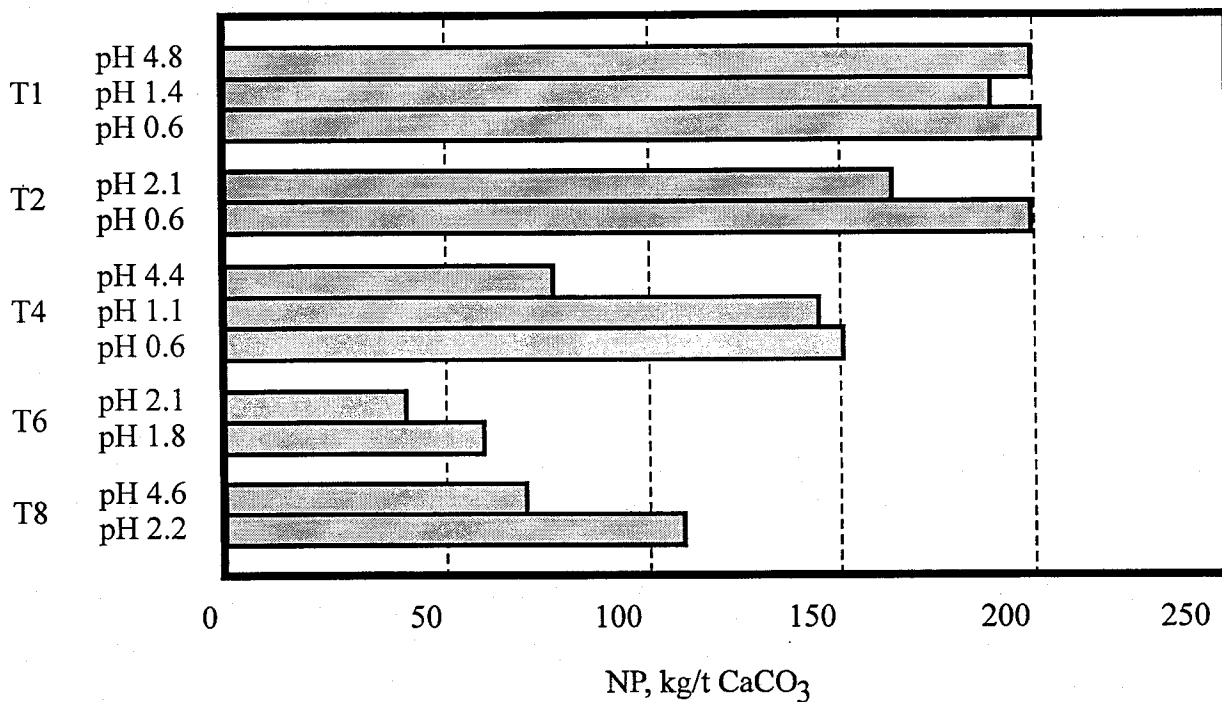




Figure 5. Variation of Quartz-Carbonate Tailings' NP with Backtitration Endpoint: Modified ABA Digestion.

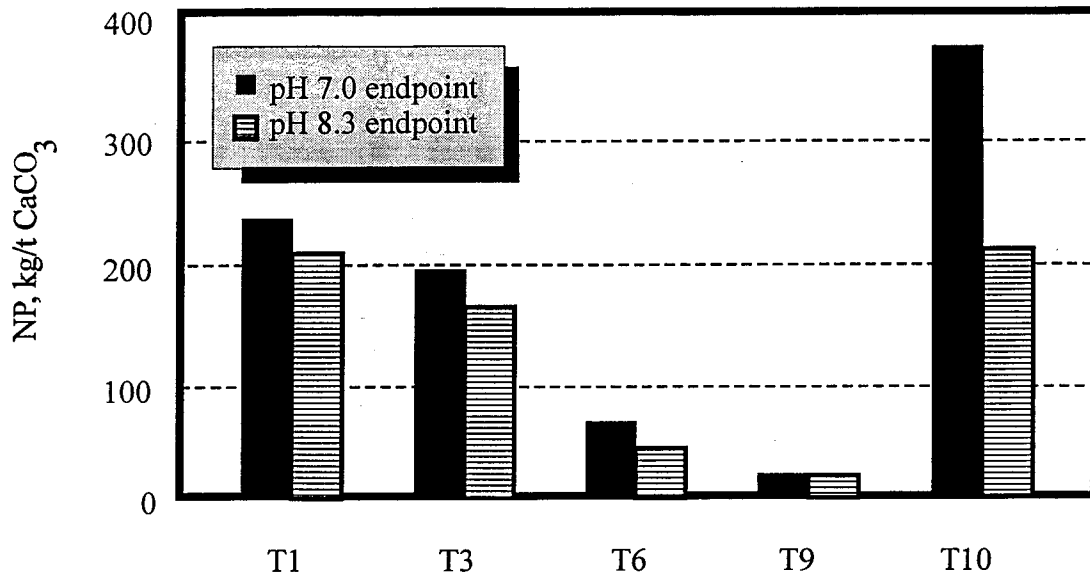


Figure 6. Traditional NP > mineralogic NP.

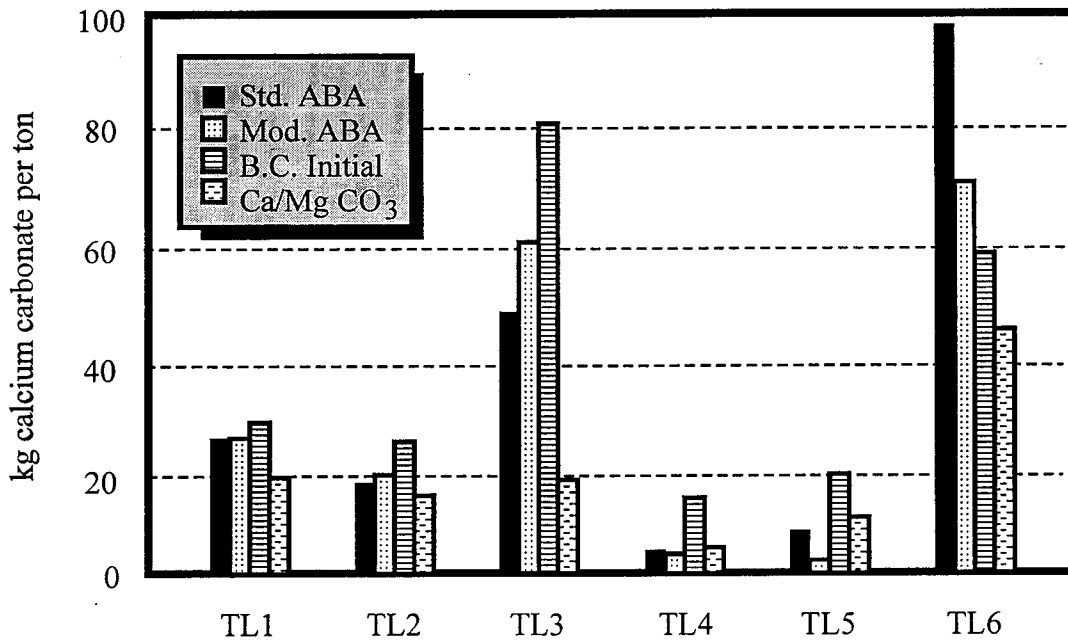


Figure 7. Traditional NP > Mineralogic NP.

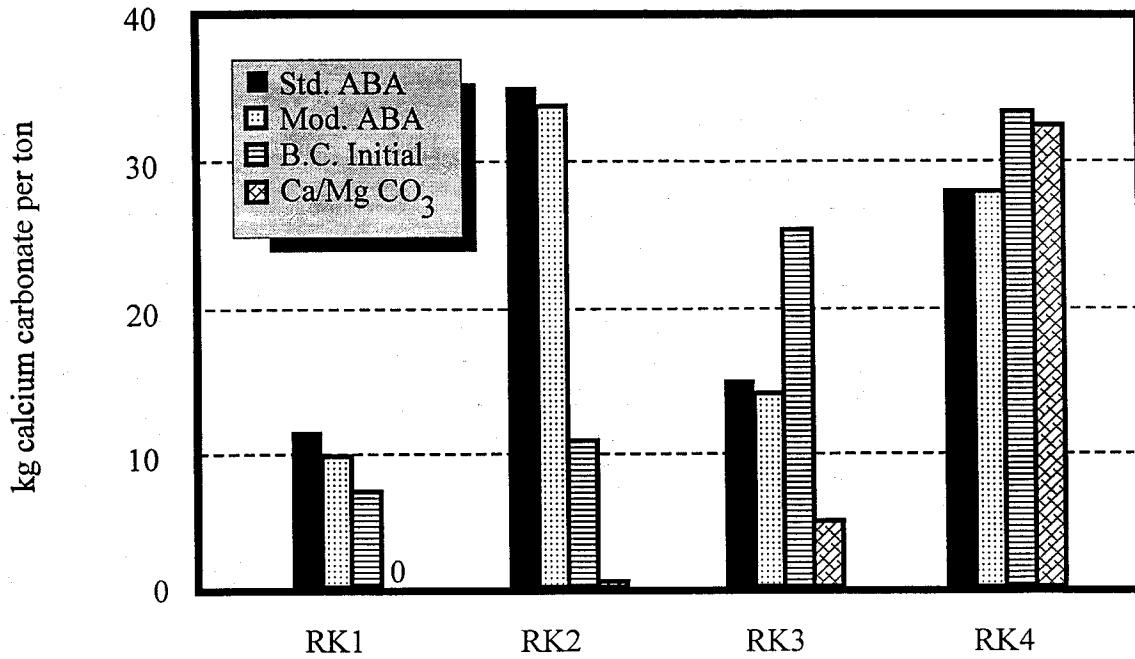


Figure 8. The mass of calcium and magnesium released while pH remains above 6.0 can be used to determine the amount of neutralizing mineral dissolution.

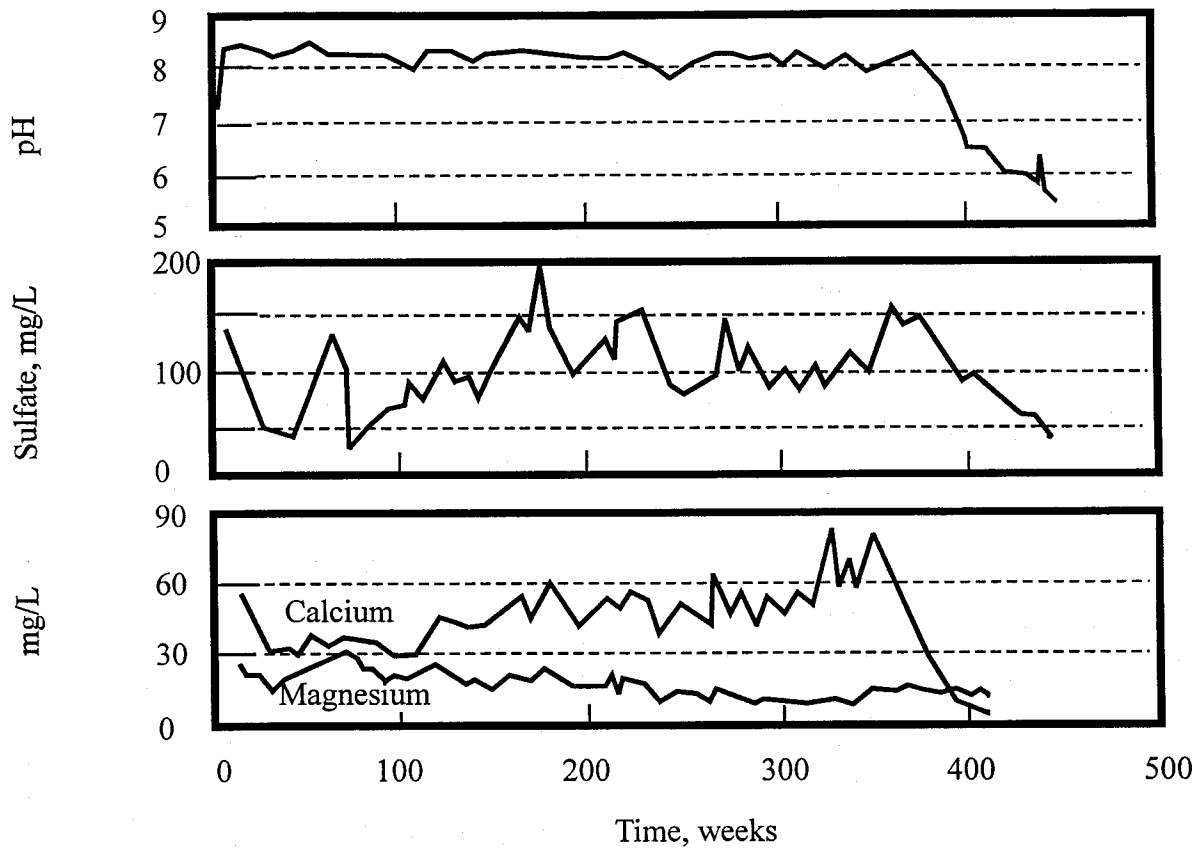


Figure 9. For some mineralogies there is fairly good agreement among static test NP, NP[(Ca/Mg)CO<sub>3</sub>], and the empirical NP determined in laboratory dissolution tests.

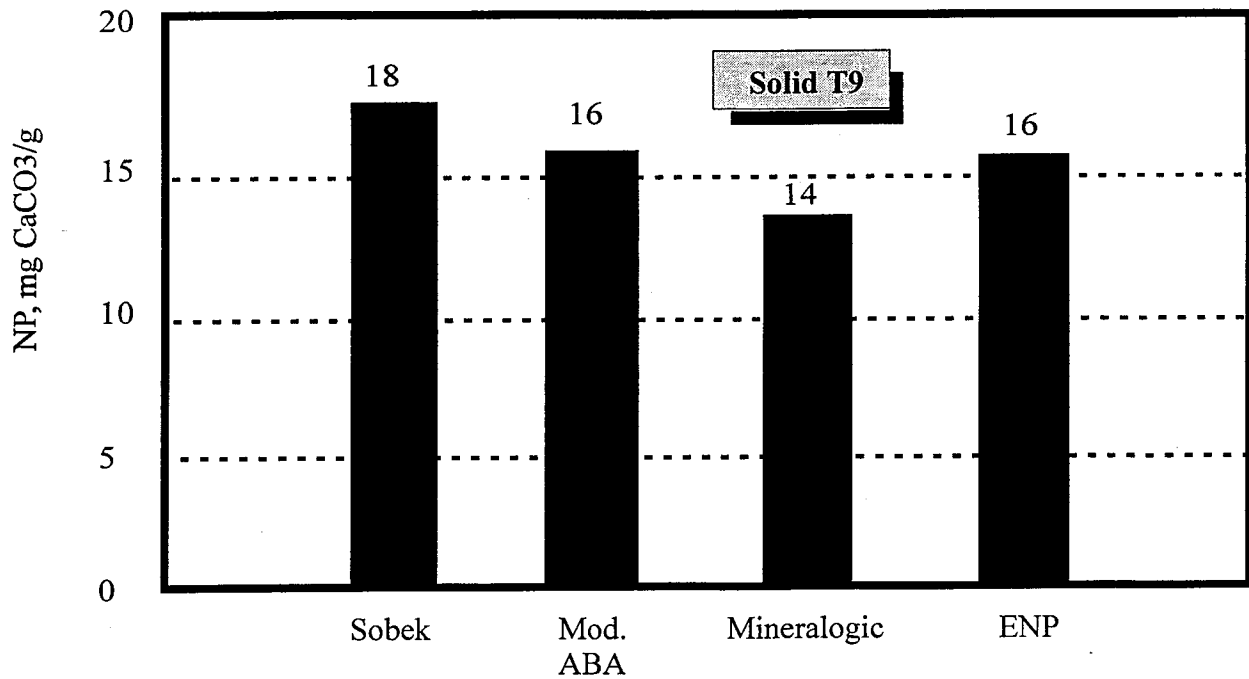


Figure 10. For some mineralogies there are fairly large discrepancies between static test NP values and verification values of NP[(Ca/Mg)CO<sub>3</sub>], and the empirical laboratory NP.

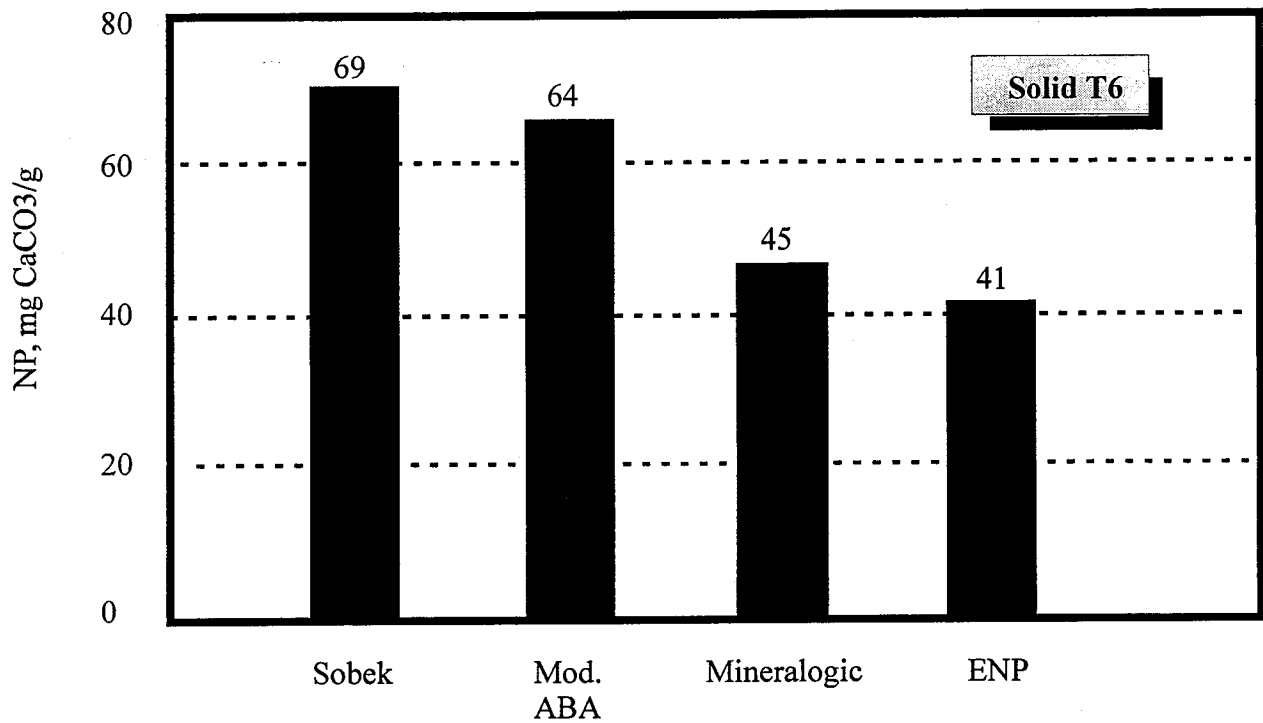


Figure 11. The discrepancy between static test NP values and mineralogic NP[(Ca/Mg)CO<sub>3</sub>] and empirical laboratory dissolution test NP can be large..

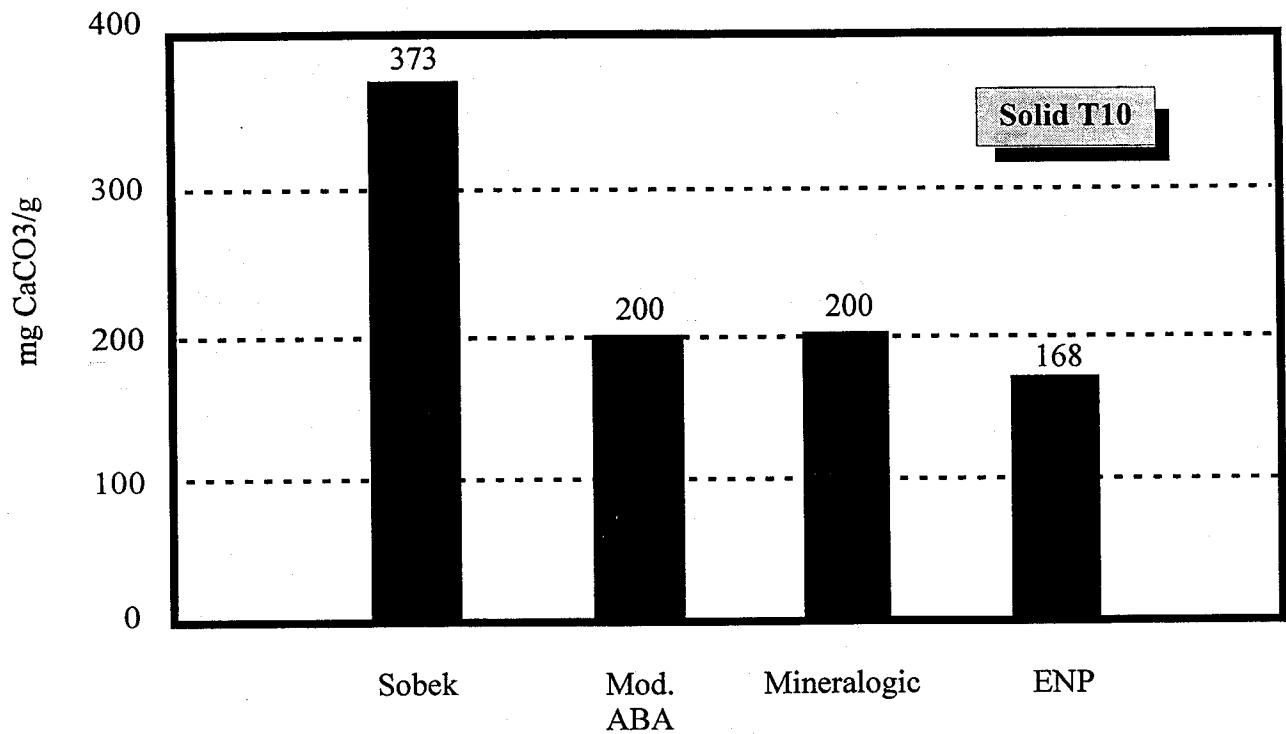


Figure 12. Standard ABA NP values for Duluth Complex rock samples were 5 to 20 kg/t CaCO<sub>3</sub> higher than the empirical NP observed in laboratory tests.

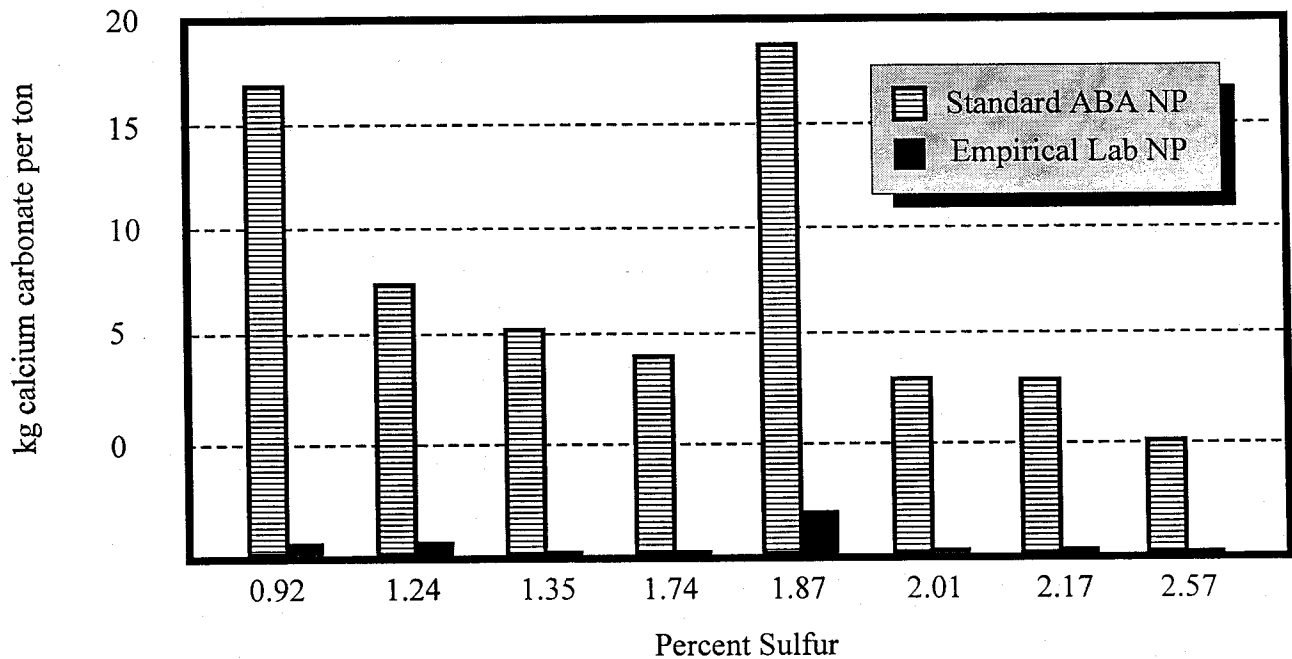


Figure 13. The NP of leached Duluth Complex rock samples, after producing acidic drainages in laboratory tests, ranged from 3 to 35 kg/t CaCO<sub>3</sub>. Since the samples had produced acidic drainage, they had no capacity to maintain drainage in the neutral pH range.

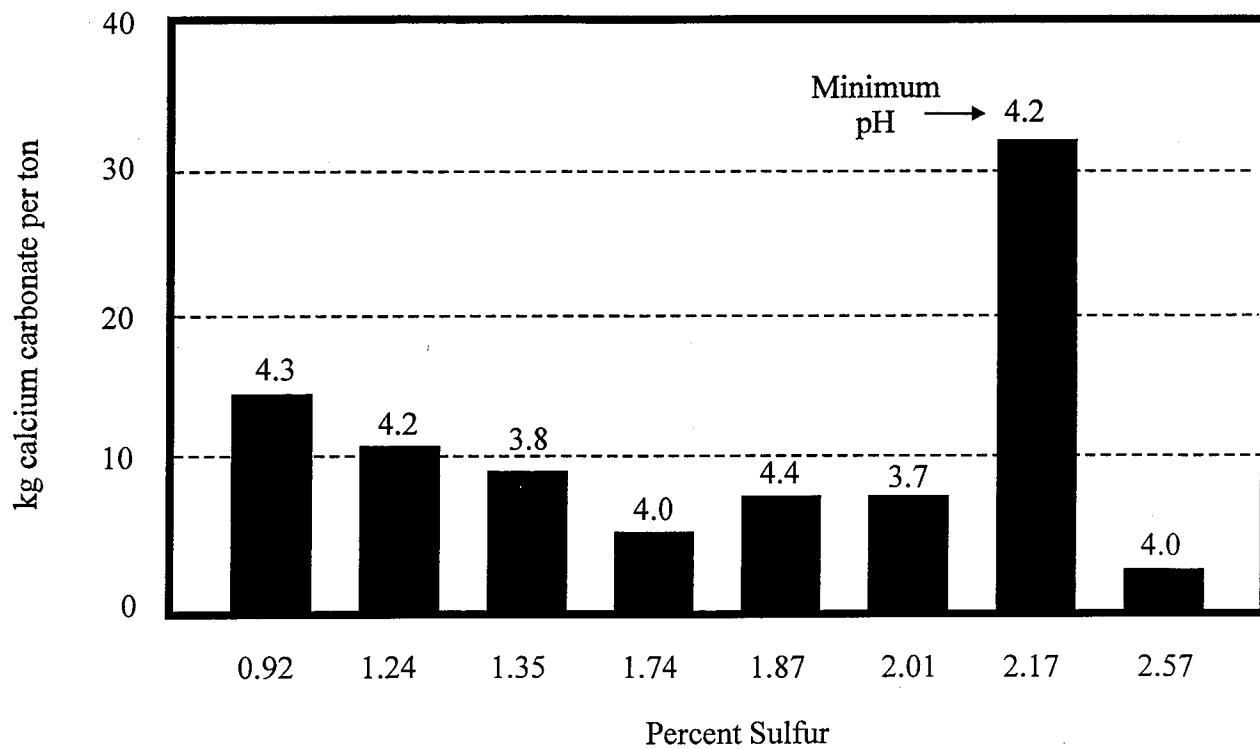
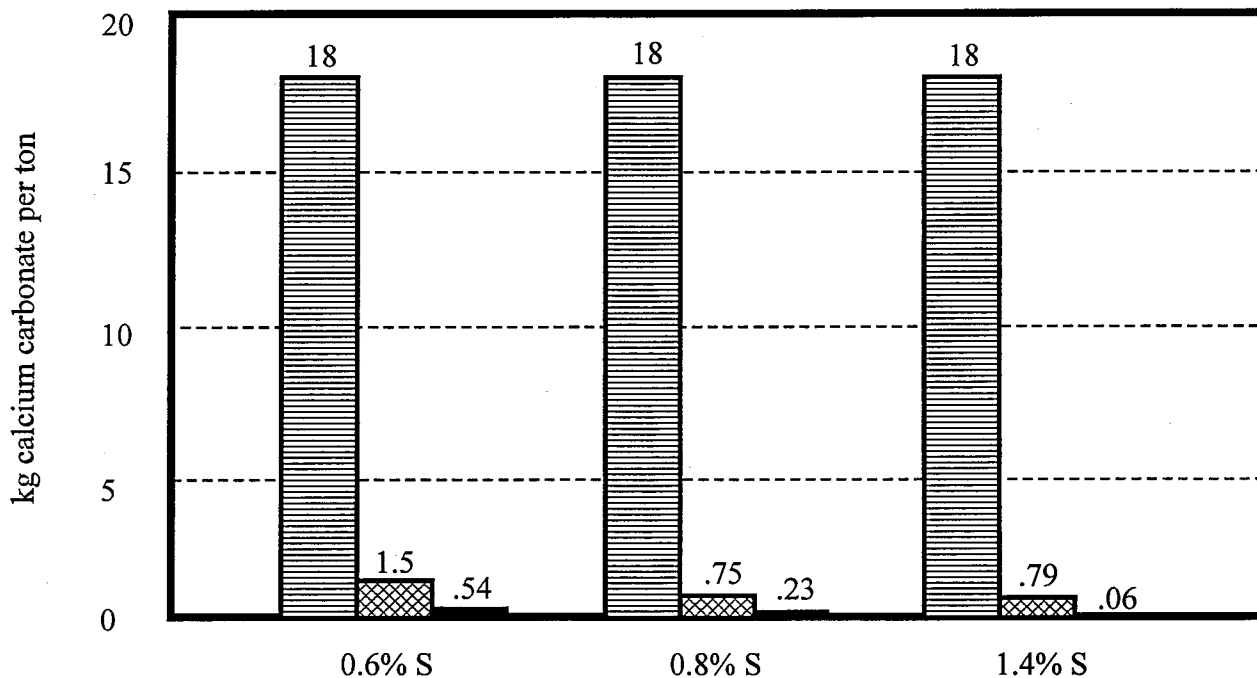


Figure 14. For Duluth Complex rock, Standard ABA NP > empirical laboratory NP > empirical field NP.



## Additional Information

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