3.7. DETERMINATION OF NP IN ARD PREDICTION

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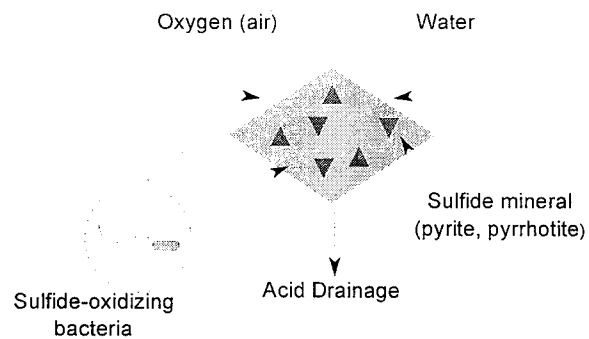
Determination of NP
in ARD Prediction

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ARD predictions - the key questions

- Is there a potential for ARD?
- Will ARD be generated?
- When will ARD be generated?
- How much ARD will be generated?
- For how long will ARD be generated?
- What will be the water quality?

Ingredients of acid rock drainage

Oxygen (air)   Water

Sulfide mineral
(pyrite, pyrrhotite)

Acid Drainage

Sulfide-oxidizing
bacteria

Factors affecting drainage water quality...

- method of waste deposition / control
- waste characteristics
    - mineralogy and mineralogical factors, particle size, ...
- rate and extent of oxidation reactions
- rate and extent of neutralization reactions
- rate and extent of metal leaching
- reactions along flow path
    - physical, physico-chemico, chemical, biological controls

Neutralizing minerals

Typical Rock Minerals
calcite, aragonite, dolomite, magnesite, bructite
anorthite, nepheline, forsterite, olivine, garnet, jadeite, leucite, spodumene, diopside, wollastonite
sorosilicates (epidote, zoisite), pyroxenes (enstatite, hypersthene, augite, hedenbergite), amphiboles (hornblende, glaucophane, tremolite, actinolite, antophyllite), phyllosicates (serpentine, chrysotile, talc, chlorite, biotite)
plagioclase feldspars (albite, oligoclase, labradorite), clays (vermiculite, montmorillonite)
K-feldspars, muscovite
quartz, rutile, zircon

Decreasing Reactivity ↓

Mineral reactivity [after Sverdrup 90 and Kwong 93]

MINERAL GROUP	TYPICAL MINERALS	REACTIVITY AT pH 5
Dissolving	calcite, aragonite, dolomite, magnesite, bructite	1.00
Fast weathering	anorthite, nepheline, forsterite, olivine, garnet, jadeite, leucite, spodumene, diopside, wollastonite	0.40
Intermediate weathering	sorosilicates (epidote, zoisite), pyroxenes (enstatite, hypersthene, augite, hedenbergite), amphiboles (hornblende, glaucophane, tremolite, actinolite, antophyllite), phyllosicates (serpentine, chrysotile, talc, chlorite, biotite)	0.02
Slow weathering	plagioclase feldspars (albite, oligoclase, labradorite), clays (vermiculite, montmorillonite)	0.01
Very slow weathering	K-feldspars, muscovite	0.01
Inert	quartz, rutile, zircon	0.004

Determination of NP

- Overview of principals
- Methods of NP determination
- The fizz test
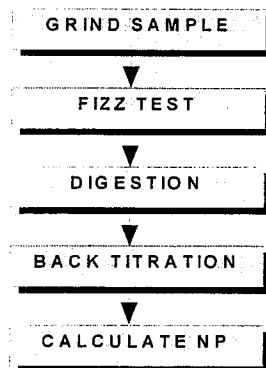- Comparison of empirical methods
- Method to calculate NP
- Add-ons

Methods of NP determination

- Sobek ABA (Sobek 78)
- Modified ABA (Lawrence 90; Lawrence and Wang 96)
- B.C Research Initial Test (Duncan and Bruynesteyn 79)
- Lapakko (Lapakko 94)
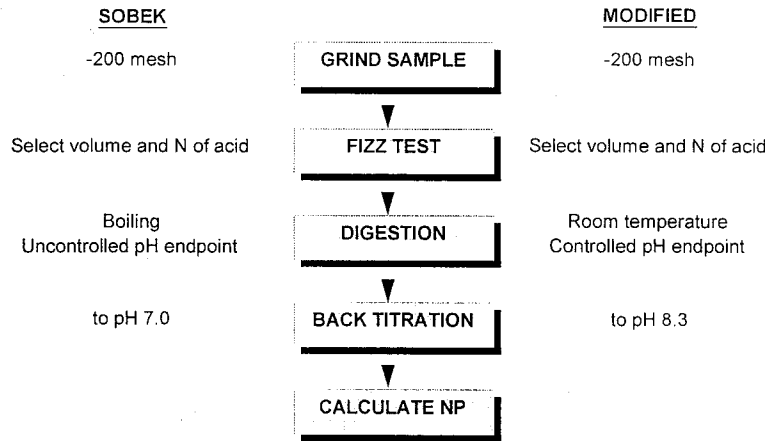- Carbonate NP (Lawrence et al 89)

Objective of static tests

NP methodology

Comparison of NP methodology

SOBEK		MODIFIED
-200 mesh	**GRIND SAMPLE**	-200 mesh
	▼	
Select volume and N of acid	**FIZZ TEST**	Select volume and N of acid
	▼	
Boiling Uncontrolled pH endpoint	**DIGESTION**	Room temperature Controlled pH endpoint
	▼	
to pH 7.0	**BACK TITRATION**	to pH 8.3
	▼	
	CALCULATE NP	

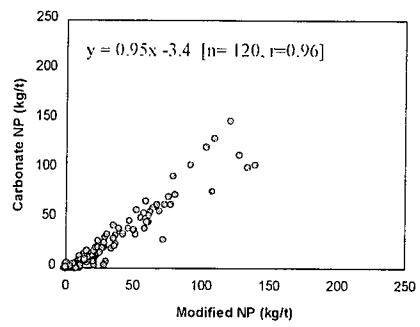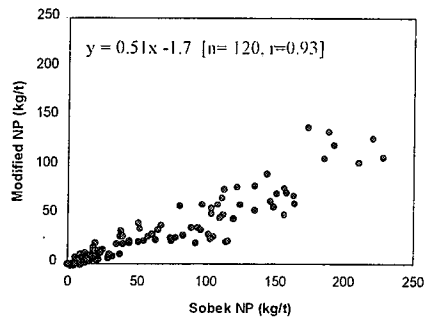# Effect of test conditions on mineral dissolution

MINERAL GROUP	TYPICAL MINERALS
Dissolving	calcite, aragonite, dolomite, magnesite, bructite
Fast weathering	anorthite, nepheline, forsterite, olivine, garnet, jadeite, leucite, spodumene, diopside, wollastonite
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Very slow weathering	K-feldspars, muscovite
Inert	quartz, rutile, zircon

Lapakko ⇕   ↑   ↑
  Modified ▼

  Sobek ↓
      ▼

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Comparison of NP results

Left plot: $y = 0.51x - 1.7$ [n= 120, r=0.93], Modified NP (kg/t) vs Sobek NP (kg/t)

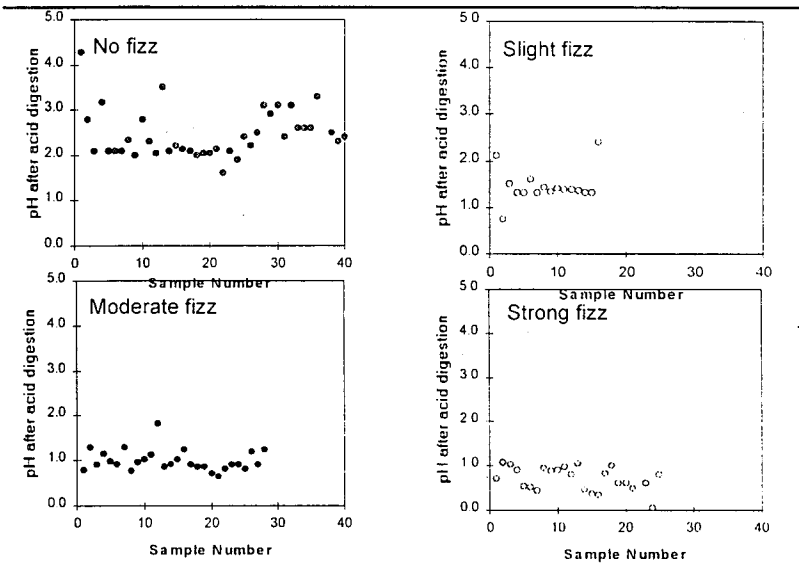Right plot: $y = 0.95x - 3.4$ [n= 120, r=0.96], Carbonate NP (kg/t) vs Modified NP (kg/t)
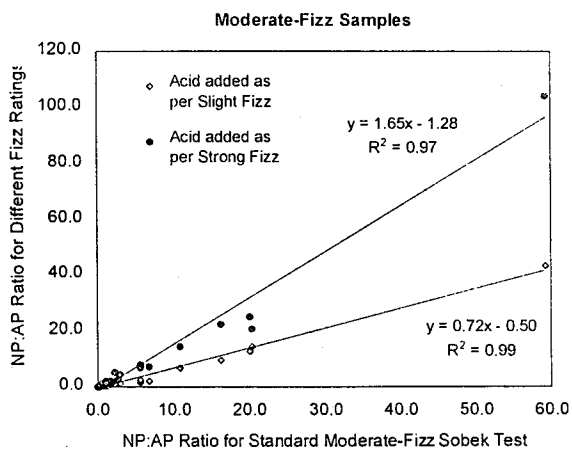
The fizz test

- How much did it fizz?
- Very subjective
- Some labs don't use it
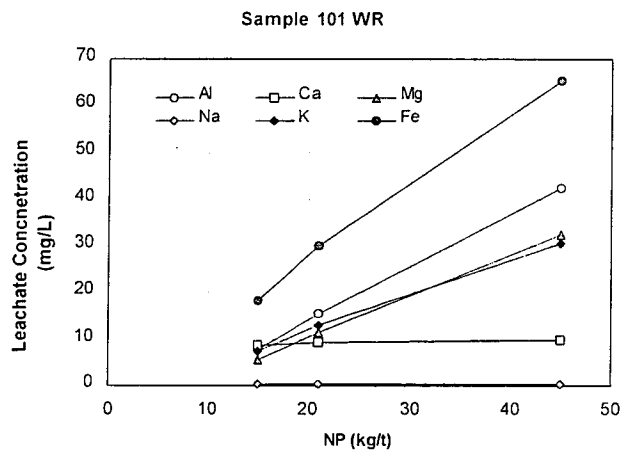- Leads to overestimation or underestimation of acid addition

pH after digestion in Sobek tests

Comparison of NP/AP results

Moderate-Fizz Samples

○ Acid added as per Slight Fizz

● Acid added as per Strong Fizz

$y = 1.65x - 1.28$
$R^2 = 0.97$

$y = 0.72x - 0.50$
$R^2 = 0.99$

NP:AP Ratio for Different Fizz Ratings

NP:AP Ratio for Standard Moderate-Fizz Sobek Test

Analysis of digestion leachates *vs* NP

Sample 101 WR

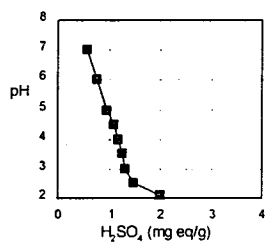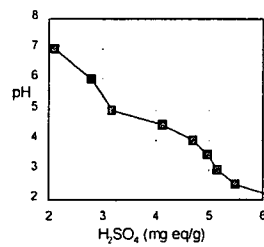# Back titration curves
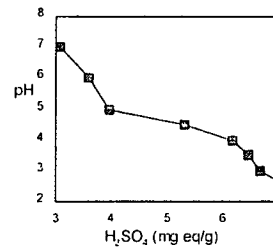
Sample: Waste rock |Modified NP = 28 Carbonate NP = 21|
Fizz rating: moderate

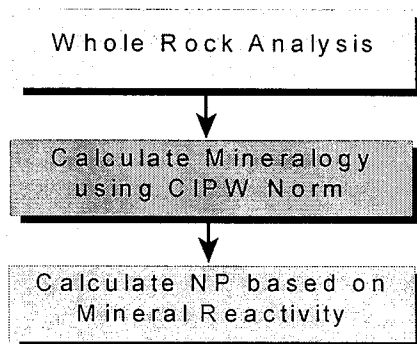Fizz classification: slight   Fizz classification: moderate   Fizz classification: strong
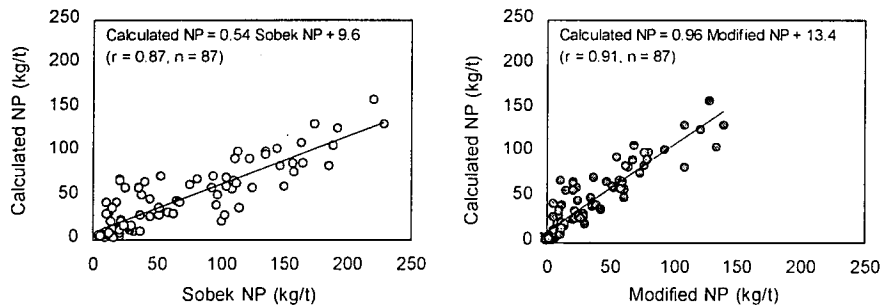Sobek NP = 29   Sobek NP = 105   Sobek NP = 153

NP of Sample NBM-1

Test Method	NP (kg CaCO$_3$/t)	Net NP (kg CaCO$_3$/t)	NP:AP
Sobek (high fizz)	95.2	85.9	10.2
Sobek (standard fizz)	61.1	51.8	6.6
Inter-laboratory Study	42 ± 9	32.7	4.5
Sobek (low fizz)	41.4	32.1	4.5
Calculated NP	36.6	27.3	3.9
Modified (digestion end pH 1.8)	34.7	25.4	3.7
Inorganic Carbon Analysis	33.9	24.6	3.6
Modified (digestion end pH 2.5)	30.2	20.9	3.2
Modified (digestion end pH 3.0)	27.1	17.8	2.9
Modified (digestion end pH 6.6)	24.0	14.7	2.6
Lapakko	15.8	6.5	1.7

Method to calculate NP

Whole Rock Analysis

↓

Calculate Mineralogy using CIPW Norm

↓

Calculate NP based on Mineral Reactivity

Comparison of calculated NP and empirical NP

Calculated NP = 0.54 Sobek NP + 9.6
(r = 0.87, n = 87)

Calculated NP = 0.96 Modified NP + 13.4
(r = 0.91, n = 87)

Conclusions from recent study

- NP value depends on sample mineralogy and test conditions
- Acid quantity added is critical... importance of fizz test
- Sobek method overestimates NP in most cases... and NP/AP ratio
- Modifed ABA procedure is preferred
- Lapakko method is very time consuming
- Back titration curves can give useful information
- NP can be calculated from elemental analytical data

Recommendations for NP determination

- Use Modified ABA method or.....
- Follow procedure exactly and document fully in report
- Determine NP due to carbonate
- Record pH at end of digestion
- Plot back titration curve
- Determine mineralogy and its implications