Acid base accounting and modelling the acid generating potential of waste rock at Canterbury Coal Mine, Malvern Hills

17 September 2018
AUSIMM NZ Branch Conference

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Canterbury Coal Mine

• Underground Mines 1872 – 1980s
• Open pit opened 2002
• BRL Purchased 2013
Canterbury Coal Mine Location
Introduction to Acid and Metalliferous Drainage

Acid mine drainage, acid and metalliferous drainage (AMD) refers to the outflow of acidic water from metal mines or coal mines.

When rocks containing sulfide minerals such as pyrite are exposed to oxygen and water as a result of mining the rocks undergo weathering processes and oxidise releasing acidity and metals.

Pyrite is the main form of sulfide mineral present at the Canterbury Coal Mine. The oxidation of pyrite is explained by Equations 1-3 where the Fe$^{3+}$ precipitates in a goethite or ferrihydrite type form (Fe oxyhydroxide).

\[
\text{FeS}_2 + \frac{7}{2} \text{O}_2 + \text{H}_2\text{O} = \text{Fe}^{2+} + 2\text{SO}_4^{2-} + 2\text{H}^+ \quad (1)
\]

\[
\text{Fe}^{2+} + \frac{1}{4} \text{O}_2 + \text{H}^+ = \text{Fe}^{3+} + \frac{1}{2} \text{H}_2\text{O} \quad (2)
\]

\[
\text{Fe}^{3+} + 3\text{H}_2\text{O} = \text{Fe(OH)}_3(s) + 3\text{H}^+ \quad (3)
\]
Acid Base Accounting

What is Acid base accounting?

ABA is a screening procedure for waste rock

- acid-neutralizing potential (assets)
- acid-generating potential (liabilities)
- net neutralizing potential (equity)

ABA data is used to categorize waste rock to manage acid generation by identifying and adequately treating higher risk waste rock

\[
\text{NAPP} = \text{MPA} - \text{ANC}
\]
Acid Base Accounting

The acid-forming and acid-neutralising minerals within a rock unit can be determined by acid base accounting (ABA) methodologies, which means mineralogical analysis is often not required.

ABA is the balance between the acid production and acid consumption properties of a mine waste material

Common ABA analysis:
- Total Sulfur
- ANC
- Paste pH
- Rinse pH
- NAG pH
- NAG acidity
- NAPP
- Stored Acidity
- Sulfide sulfur
- Others
Acid Base Accounting Analysis

**Total S** Total sulfur, usually presented in wt% (weight percent) and determined by LECO furnace methodologies or similar

**MPA** Maximum Potential Acidity, where MPA = wt% Sulfur (S) multiplied by 30.6 (stoichiometric conversion factor for wt% S to kg H2SO4/tonne, where all S is assumed to be pyrite)

**ANC** Acid Neutralisation Capacity, where ANC is determined by acid digest of the sample followed by back titration to pH 7.0 to determine the amount of acidity consumed

**Paste pH** pH measurement of a 1:2 solid to liquid solution; pH values < 5.0 generally indicates stored acidic oxidation products (**Stored Acidity**)
Acid Base Accounting Analysis

**NAG** Net acid generation (NAG) test, where 2.5 g of waste rock and 250 mL of 15% H$_2$O$_2$ are mixed leading to rapid oxidation of any sulfides present thereby releasing acidity and metals. Any acid released reacts with any reactive acid neutralising minerals to produce a final NAG pH value at the completion of the test. Back titration of this solution to pH 7.0 provides an indication of the NAG acidity in kg H$_2$SO$_4$/tonne equivalent

**NAPP** Net Acid Production Potential, where NAPP = MPA − ANC
AMD Management

• Prediction
• Prevention
• Minimization
• Control
• Treatment
• Planning for closure
AMD at Canterbury
The effects of Acid Mine Drainage (AMD) was first observed at the site following open casting during the summer of 2003/2004 (student project studies by Alipate, 2005; de Boer, 2005).

de Boer, 2005 undertook first waste rock characterization for propensity to generate acid:
- Assessed 34 rock samples from the site
- 4 sampled in detail, NAPP ranged from 3 – 280 kg H2SO4/Tonne
- Some samples showed significant Acid neutralizing capacity

It was suggested that the main seam footwall was the most likely contributor to the observed AMD.
Sampling undertaken by de Boer (2005)
AMD observed by BRL

• noted a number of seeps emanating from the old waste rock dump immediately behind the ROM pad
• The pH of these seeps ranged from 2.5 – 2.6 (Feb 2015) with very high acidity loads
• Primary source to the contaminant load being observed at water quality monitoring site CC02.
• Have since been managed using passive mussel shell reactors
• Indicated that old waste dump was not well constructed – PAF rock not well managed
AMD observed by BRL
Initial ABA waste rock characterisation by BRL

BRL recognized requirement to understand waste rock propensity to produce AMD
- 18 waste rock samples taken from open pit in 2014-2015
- Cross section of exposed waste rock plus quaternary cover gravels
- Results: Predominately low risk or weakly acid forming. One sample 15% CaCO₃
- Sample representation?
Analysed:
Total Sulfur
ANC
NAG pH
Paste pH
Quantitative Data – Diamond Drilling

4 Drill holes through stratigraphic sequence
Coal sampled – normal resource definition drilling
Full core ABA sampling completed
Quantitative Data – Diamond Drilling
Quantitative Data – Diamond Drilling

Analysed for:
- Total Sulfur
- Sulfide sulfur
- Paste pH
- NAG pH
- ANC
- MPA

- Sampled by lithology
- 2m – 4m sample interval
- Unweathered rock
Data

Total Sulfur vs NAPP

Total sulfur vs sulphide sulfur

\[ y = 0.7004x + 0.0006 \]

\[ R^2 = 0.9771 \]
Data

![Total sulphur vs NAG pH](image1)

![Sulphur vs paste pH](image2)
ABA Classification Scheme

Sampling for ABA characterisation provided a good understanding of waste rock through the stratigraphic sequence

Process Flow Classification Scheme Developed

- Reduced uncertain category samples
- Minimised testing requirements
- Reduced Analysis Costs – less samples required
- Simplifies modelling

See Olds et al, Ausimm 2015
Continue to sample

Utilise coal resource definition drilling programs
Sample waste rock from holes drilled for coal resource confidence
• Kill two birds with one stone
• Ensure that a subset of drill holes from each campaign is sampled for ABA classification
Current Dataset

563 drill core samples from 28 drill holes

Covers full section through stratigraphic sequence
2.5km along strike of deposit
Now What?

Time to model!

- Utilise geology structure model used for coal resources
- Sub block interburdens and waste blocks – 5m x 5m x 2.5m
- Grade estimate ABA parameters used for ABA classification
- Classify waste blocks
Grade estimating ABA

- Treat like ore grade variables
  - Total Sulphur
  - ANC

- Composite data into even length samples
  - 2.5m

- Geostatistics?
  - Not at CCM – not normal distribution

- Grade estimate using Vulcan Tetra Projection
  - Utilised coal roof/floor structures to constrain grade estimation
Resultant ABA Block Model

Section through current pit
Canterbury waste schedule

<table>
<thead>
<tr>
<th>ABA Class</th>
<th>Total Volume (BCM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN</td>
<td>337,000</td>
</tr>
<tr>
<td>NAF</td>
<td>5,482,000</td>
</tr>
<tr>
<td>Lowrisk</td>
<td>2,879,000</td>
</tr>
<tr>
<td>PAF</td>
<td>2,106,000</td>
</tr>
</tbody>
</table>

Total volume weighted ANC
13.4 kg $\text{H}_2\text{SO}_4$/t

Total volume weighted MPA
10.4 kg $\text{H}_2\text{SO}_4$/t

Total volume weighted NAPP
3.0 kg $\text{H}_2\text{SO}_4$/t

Thank You
Questions?