Geochemistry for mine drainage predictions at the Te Kuha coal deposit.

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Abstract

Mine drainage geochemistry at the Te Kuha deposit has been predicted using traditional acid base accounting, column leach testing and a theoretical approach based on geochemical processes that will operate in the waste rock dumps.

The Te Kuha deposit is unusual because it contains both Paparoa and Brunner Coal measures and because Brunner Coal Measures in the deposit have the lowest acid formation potential (average MPA) of deposit where acid base accounting analysis has been completed. The Paparoa Coal Measures have excess neutralising capacity (average ANC) and the overall balance for the site is net acid neutralising.

Column leach data indicates that Brunner Coal measures will produce slightly acidic mine drainage and that Paparoa Coal Measures will produce neutral mine drainage with excess dissolved alkalinity. In addition these tests indicate that Al, Zn & Ni could occur at elevated concentrations in mine drainages and that Co, Cu, Pb, & Mn could be elevated in mine seeps.

A theoretical approach to prediction of mine drainage chemistry has also been used which provides a worst case scenario for mine drainage chemistry based on oxygen availability, net percolation and assumed geochemical reactions that occur in the waste rock dump.

In combination these approaches lead to a set of geochemical predictions that can be used to plan waste rock management, site monitoring, compliance conditions, management of aquatic eco-systems and adaptive management for mine drainage treatment.

Keywords: geochemistry, acid base accounting, column leach testing, mine drainage.

Introduction

The proposed Te Kuha Mine site is on the coastal foothills east of Westport and is operated by Stevenson Mining Ltd. The Te Kuha coal resource includes coal from within both Brunner and Paparoa Coal Measures (roughly 50:50), has desirable coal quality properties, and can be mined by opencast methods. During 2011 – 2012, Stevenson Mining completed a resource development drilling programme and resource modelling, (Dutton et al., 2013) to enable JORC code compliant resource estimates to be completed.

Subsequently to the geological investigation Stevenson Mining Ltd has been collecting environmental baseline data to develop environmental management plans for the Te Kuha mine site and has been in discussion with landholders related to access arrangements as well as regulators for resource consents. Resource consent hearings are arranged for mid to late September 2017.

Geochemical evaluation of the rocks that will be disturbed by mining to enable prediction of mine drainage chemistry has been completed as one of the baseline environmental studies and the results from this study feeds into several aspects of environmental management at the mine site including:

- Overburden management and engineered landform construction
- Management of aquatic ecosystems
- Vegetation management and rehabilitation planning
- Water management and treatment
- Setting consent compliance conditions

The main geochemical studies completed at Te Kuha include industry standard acid base accounting analysis, and column leach testing (Smart et al., 2002) as well as theoretical mine drainage predictions. Acid base accounting tests are used to determine if the rocks that will be disturbed by mining are likely to release acid or neutralise acid after they become exposed to water and oxygen. Prior to development of mines a complete suite of acid base accounting tests are completed, however, as operations proceed the test regimes can be refined and reduced so that efficient classification schemes are developed (Olds et al., 2015). Column leach testing is used to predict the release of trace elements from rocks disturbed by mining and indicate the chemistry of seeps from waste rock or tailings that might be stored on the mine site. At Te Kuha column leach tests were operated in the field rather than in the laboratory because, these larger volume tests produce more stable and interpretable results at similar oxidation rates to laboratory scale tests (Pope et al., 2011).

Methods

Sampling

Just over 100 samples for acid base accounting analyses were collected from HQ drill core that was wrapped in plastic and stored in a shipping container. Samples were selected to be representative of the variability of rocks that will be disturbed by mining including factors such as rock type, proximity to coal seams, presence of diagenetic minerals (particularly sulphide or carbonate) and geological formation (Brunner or Paparoa). Sampling occurred twice, the first time about 6 months drilling and the second time about 5 ½ years after drilling. Sample preservation was assessed as good during sample collection on both occasions. Few secondary minerals, oxidation or weathering products were observed on the core and analysis results do not indicate that the samples were substantially oxidised. Sample collection from old (~ >1 year) drill core for acid base accounting analyses is usually avoided because of the potential for spurious results caused by secondary minerals. However, in the case of Te Kuha core, preserved in plastic and kept in a sheltered environment, sample preservation issues were not detected.

Static testing - Acid base accounting analysis

Acid base accounting analyses are often referred to as static tests and include several commonly applied procedures (Smart et al. 2002).

- Maximum Potential Acidity (MPA). This test typically uses a total sulphur analyses to determine the maximum possible acid released assuming all S is bound in pyrite. This assumption usually valid, however, it is possible that sulphate minerals or organically bound S could provide false positive data. Pyrite specific S analyses can be used for calculation of MPA if necessary (Sullivan et al., 2000; Sullivan et al., 1999).

- Acid Neutralising Capacity (ANC). This analysis determines the acid consumption of a crushed rock sample by reaction with a fixed quantity of acid.

- Net Acid Production Potential (NAPP). This analysis is the difference between MPA and ANC

$$NAPP = MPA – ANC$$

- Net Acid Generation (NAG). This analysis oxidises all reactive sulphide forming acid and allows the acid to react with any ANC in the rock. Acidity titrations and pH measurements of the reaction liquor are used to quantify the acid producing potential. False positive analyses can occur in NAG data if samples contain abundant organic material because organic acids can be released (Smart et al. 2002).

- Paste pH measures the water soluble acidity within a sample and includes adsorbed protons, soluble acidic salts and adsorbed metals that hydrolyse (Lin et al., 2000). The paste pH does not measure the potential of a sample to produce acid with continued weathering because that process requires oxidation to release acid but paste pH can be correlated with other data to indicate acid producing samples (Weber et al., 2006).

- Soluble acidity leach tests can also be completed to determine the amounts of acidity stored in exchangeable sorption sites or as sparingly soluble secondary minerals (Ahern et al., 2004). These leach tests measure acidity that has been released through oxidation of sulphide minerals but has not been flushed out of rock.

Kinetic testing – Field column leach testing

Kinetic testing was conducted in the field using large columns (50 L) to expose rock to natural rainfall, temperature and the atmosphere. The objective of the leach columns is to rapidly react the rocks from the proposed Te Kuha mine site to determine the total amount of leachable acid, alkalinity and trace elements.

Field column kinetic tests are conducted on drill core of five different rock types including 3 columns from Brunner Coal Measures and two columns from Paparoa Coal Measures.

- Column 1 contains sandstone from Brunner Coal Measures, likely low PAF to NAF.
- Column 2 contains mudstone from Brunner Coal measures, likely low PAF
- Column 3 contains mudstone from Brunner Coal Measures, likely PAF.
- Column 4 contains fine grained Paparoa Coal Measures - mixed mudstone and fine sandstone, likely NAF
- Column 5 contains coarse grained Paparoa Coal Measures – mixed fine to coarse sandstone, likely NAF

Each field column was constructed with about ~23kg of rock in a 50L plastic bucket that drains into a 210L drum. All leachate is retained in the drum between sampling rounds and the volume is measured at sample collection and then the drum is drained prior to collection of the next sample. A coarse quartz gravel layer was placed in the bottom of each 50L drum and was covered by the rock sample. Geotexile cloth was used to prevent any material being lost through the outlet. Head space of 25cm above is left above the top of the sample to allow for slow drainage through the system (Figure 1).

Figure 1: Field column set up.

After sampling, chemical analyses on the leachate are completed. Analytes include; pH, EC, acidity, alkalinity, major cations and anions and trace elements.

Theoretical leachate chemistry calculations

It is possible to predict worst case leachate scenario by using field data from analogous sites and assumptions related to the geochemical reactions that will take place in the dump. Key assumptions are:

- Waste rock dumps will be constructed in short lifts to minimise ingress of oxygen by advection (Pope et al., 2016).
- The oxygen available in the dump can be calculated from Ficks Law for diffusion and oxygen carried in with surface water (Wels et al., 2003). Convection or air is minimised by construction of the dump in layers.
- The water flow through the dumps can be approximated by analogy with other dumps constructed in a similar manner.
- Pyrite oxidation is limited by the available oxygen and there is sufficient acid neutralising capacity in the dumps from rocks with high ANC to neutralise all available acid.

Results

Acid Base Accounting

Acid base accounting analyses have been completed for 104 samples at the proposed Te Kuha opencast mine site (Table 1), 57 from each of the Brunner and Paparoa Coal Measures sequences. Brunner Coal Measures rocks at Te Kuha are weakly PAF average MPA 4.3 kg H_2SO_4/t, average NAPP 2.3 kg H_2SO_4/t). Paparoa Coal Measures rocks at Te Kuha are strongly NAF, average ANC 19 kg H_2SO_4/t, and average NAPP -17 kg H_2SO_4/t.

Paparoa / Brunner	NAG (kgH_2SO_4/t)	Total S (%)	Paste pH	NAG pH	ANC (kgH_2SO_4/t)	MPA (kgH_2SO_4/t)	NAPP (kgH_2SO_4/t)
PCM	4	0.11	6.44	4.8	5	3	-2
PCM	0	0.01	7.86	7.5	13	0	-13
PCM	0	0.01	8.40	8.0	92	0	-92
PCM	0	<0.01	8.10	7.3	12	0	-12
PCM	3	<0.01	7.32	6.1	6	0	-6
PCM	4	<0.01	6.80	5.8	6	0	-6
PCM	4	0.05	7.30	5.3	13	2	-11
PCM	4	0.02	7.16	5.7	9	1	-8
PCM	37	0.23	7.26	2.9	11	7	-4
PCM	36	0.12	7.62	3.0	0	4	4
PCM	60	0.45	6.58	2.6	2	14	12
PCM	5	0.02	7.64	6.3	14	1	-13
PCM	16	0.40	6.94	3.2	4	12	8
PCM	2	0.04	7.22	6.5	8	1	-7
PCM	7	0.02	7.79	6.0	12	1	-11
BCM	1	0.01	7.34	6.0	0	0	0
BCM	2	0.01	7.00	5.9	0	0	0
BCM	10	0.01	7.36	5.9	0	0	2
BCM	9	0.01	7.38	5.9	0	0	0
BCM	0	0.03	8.02	7.4	22	1	-21
BCM	2	<0.01	7.13	5.9	0	0	0
BCM	5	0.01	6.43	5.0	0	0	3
BCM	5	0.01	7.49	5.8	0	0	2
BCM	6	0.19	6.48	3.7	0	6	6
BCM	10	0.02	6.66	3.9	0	1	1
BCM	14	0.02	6.29	3.4	0	1	7
BCM	64	0.09	6.07	2.6	0	3	3
BCM	83	0.23	6.07	2.6	0	7	7
BCM	34	0.05	6.32	2.7	0	2	5
BCM	27	0.02	6.28	3.0	0	1	1
BCM	8	0.01	6.42	5.2	0	0	0
BCM	4	0.02	7.50	4.9	11	1	-10
PCM	34	0.22	7.40	3.2	14	7	-7
PCM	0	0.02	8.00	7.5	46	1	-45
BCM	48	1.90	6.51	2.5	0	58	58
PCM	20	0.36	7.02	3.0	14	11	-3
PCM	20	0.40	7.35	3.1	7	12	5
BCM	17	0.01	6.24	4.0	0	0	0
BCM	23	0.03	6.02	3.6	0	1	1
BCM	6	<0.01	6.52	5.4	0	0	0
BCM	7	<0.01	6.44	5.4	0	0	0
BCM	6	<0.01	6.44	5.0	0	<1	0
BCM	6	<0.01	6.61	5.6	1	<1	-1
BCM	2	0.07	5.14	5.4	1	2	1
BCM	7	<0.01	6.58	5.0	2	<1	-2
BCM	8	<0.01	6.27	5.0	2	<1	-2
PCM	6	<0.01	6.17	4.9	1	<1	-1
PCM	7	<0.01	6.11	5.0	1	<1	-1
BCM	0	0.10	5.51	7.3	2	3	1
PCM	0	0.02	7.41	8.3	20	1	-19
BCM	7	<0.01	6.76	6.4	5	<1	-5
BCM	6	0.02	5.99	6.1	3	<1	-3
PCM	8	<0.01	6.39	5.0	1	<1	-1
PCM	2	<0.01	9.04	6.5	20	<1	-20
PCM	0	<0.01	9.13	7.0	28	<1	-28
BCM	13	<0.01	7.00	5.4	0	<1	0
BCM	32	<0.01	6.63	5.8	0	<1	0
BCM	34	1.20	4.14	2.8	0	37	37
BCM	26	0.04	5.71	3.8	0	1	1
BCM	36	0.01	5.71	5.0	0	0	0
BCM	25	0.09	5.41	4.0	0	3	3
BCM	15	<0.01	5.88	4.9	0	<1	0
BCM	25	0.02	5.71	4.8	0	<1	0
BCM	45	0.06	5.28	3.4	0	2	2
BCM	21	0.02	5.64	4.6	0	1	1
BCM	14	<0.01	6.26	5.3	0	<1	0

Paparoa / Brunner	NAG (kgH_2SO_4/t)	Total S (%)	Paste pH	NAG pH	ANC (kgH_2SO_4/t)	MPA (kgH_2SO_4/t)	NAPP (kgH_2SO_4/t)
BCM	7	0.01	6.71	5.5	0	<1	0
BCM	67	<0.01	6.67	5.1	0	<1	0
PCM	0	0.01	8.19	7.5	45	<1	-45
PCM	3	0.02	8.12	6.0	10	1	-9
PCM	0	0.02	8.48	7.5	56	1	-55
PCM	5	<0.01	8.25	5.8	6	<1	-6
BCM	98	0.09	5.44	2.9	0	3	3
BCM	107	0.28	4.82	2.2	0	9	9
BCM	8	0.10	4.35	4.7	0	3	3
BCM	8	<0.01	6.07	5.1	2	<1	-2
BCM	9	<0.01	5.88	4.8	2	<1	-2
BCM	22	0.03	5.36	4.0	1	1	0
BCM	54	0.21	4.90	2.5	0	7	7
BCM	20	0.03	6.09	4.1	1	1	0
BCM	8	<0.01	6.84	6.2	1	<1	-1
PCM	0	0.09	6.64	6.9	12	3	-9
PCM	0	0.10	7.68	7.1	12	3	-9
PCM	0	0.11	7.86	7.2	18	3	-15
PCM	6	0.15	7.38	4.9	6	5	-1
PCM	0	0.02	8.38	8.1	89	1	-88
PCM	0	0.03	7.78	8.5	53	1	-52
PCM	2	0.12	6.48	6.5	11	4	-7
BCM	6	0.02	4.72	6.1	1	1	0
BCM	304	0.37	3.84	2.1	0	11	11
PCM	0	0.10	7.76	8.5	76	3	-73
PCM	0	0.06	7.53	7.5	9	2	-7
PCM	0	0.04	7.48	7.4	15	1	-14
PCM	0	0.02	7.44	8.1	12	1	-11
PCM	0	0.01	7.75	8.2	24	<1	-24
PCM	3	0.01	7.68	6.3	12	<1	-12
PCM	0	0.01	7.93	7.6	13	<1	-13
PCM	0	0.01	7.87	8.1	33	<1	-33
BCM	11	0.02	5.25	5.2	0	1	1
BCM (col)	12		7.10	4.8	0	<1	0
BCM (col)	6		5.60	5.5	0	2	2
BCM (col)	47		5.10	2.9	0	5	5
PCM (col)	0		6.40	7.1	18	6	-12
PCMCol)	0		7.40	8.0	16	4	-12

Table 1. Acid Base Accounting Data at Te Kuha

Column leach tests

Column leach testing has been completed over a 3 year period and the data from these columns can be mass balanced as volumes of leachate have also been measured. The acidity, alkalinity and trace elements released during these tests are assessed (Table 2) and also the trends in concentration with time. Brunner coal measures column samples produce weakly acidic leachate, pH – 4.1 - 6, Al 0.009 – 4.0 mg/L and Fe <0.02 – 0.53 mg/L. Paparoa coal measures column samples produce circum-neutral leachate, pH 7.0-8.4, with excess alkalinity, HCO_3^- 1 – 95 mg/L. Similar trace elements are enriched in both Brunner and Paparoa coal measures, Zn and Ni are most consistently enriched at concentrations above baseline water quality monitoring at Te Kuha, but Co, Cu, Pb, & Mn are also enriched in some leachate samples. In general, the concentrations of trace elements decreases rapidly with progressive leaching over the first 6 leach cycles.

	Column 1			Column 2			Column 3			Column 4			Column 5		
	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min
pH		6.0	4.1		6.0	4.3		4.8	4.0		7.9	7.0		8.4	7.7
HCO_3	2.3	3.2	1.0	1.9	3.2	1.0	1.0	1.5	1.0	32.2	54.0	1.0	68.8	95.0	1.0
Cl	5.3	11	2	4.61	11.2	2	4.6	9.5	1.9	4.83	7.2	1.8	6.8	56	2
NO_3 NO	0.06	0.41	0.00	0.16	1.03	0.00	0.14	0.38	0.00	0.06	0.55	0.00	0.03	0.30	0.00
PO_4	0.012	0.240	0.004	0.005	0.017	0.004	0.004	0.013	0.004	0.004	0.004	0.004	0.004	0.004	0.004
SO_4	3.2	7.0	2.0	3.9	8.0	2.0	11.8	54.0	3.0	23.1	96.0	5.0	14.9	54.0	3.0
Al	0.059	0.198	0.008	0.068	0.480	0.009	0.972	4.0	0.071	0.033	0.430	0.006	0.013	0.021	0.004
Sb	<	<	<0.0002	<	<	<0.0002	<	<	<0.0002	<	<	<0.0002	-	0.0006	<0.0002
As	<	<	<0.001	<	<	<0.001	<	<	<0.001	-	0.002	<0.001	0.001	0.001	0.001
Ba	0.006	0.015	0.001	0.007	0.016	0.001	0.017	0.055	0.002	0.011	0.034	0.002	0.018	0.040	0.003
Bi	<	<	<0.0001	<	<	<0.0001	<	<	<0.0001	<	<	<0.0001	<	<	<0.0001
B	0.0078	0.0480	0.0050	0.0065	0.0260	0.0050	0.0063	0.0150	0.0050	-	0.0070	<0.005	-	0.0050	<0.005
Cd	<	0.00010	<0.00005	<	0.00007	<0.00005	0.0011	0.0037	0.0002	-	0.00022	<0.00005	-	0.00026	<0.00005
Cs	<	0.0002	<0.0001	<	0.0007	<0.0001	0.0019	0.0034	0.0007	0.0003	0.0007	0.0001	-	0.001	<0.0001
Ca	0.737	1.610	0.280	0.797	2.000	0.250	0.785	2.70	0.260	6.723	15.400	3.600	16.3	27.0	10.8
Cr	-	0.0009	<0.0005	-	0.0018	<0.0005	-	0.0012	<0.0005	<	<	<0.0005	-	0.0029	<0.0005
Co	-	0.0079	<0.0002	-	0.011	<0.0002	0.0101	0.0450	0.0009	-	0.075	<0.0002	-	0.0169	<0.0002
Cu	-	0.011	<0.0005	-	0.014	<0.0005	0.0436	0.1290	0.0079	-	0.023	<0.0005	-	0.0047	<0.0005
Fe	-	0.160	<0.02	-	0.520	<0.02	-	0.530	<0.02	-	1.010	<0.02	<	<	<0.02
La	-	0.0003	<0.0001	-	0.00026	<0.0001	-	0.0032	<0.0001	-	0.0010	<0.0001	<	<	<0.0001
Pb	-	0.0029	<0.0001	-	0.0024	<0.0001	0.0055	0.0410	0.00051	-	0.0031	<0.0001	-	0.023	<0.0001
Li	0.000	0.002	<0.0002	0.0013	0.0028	0.0004	0.0028	0.0135	0.0005	0.0019	0.0109	0.0011	0.0007	0.0044	0.0002
Mg	0.443	0.890	0.140	0.557	1.020	0.140	0.571	3.20	0.180	7.73	15.6	3.60	7.95	13.9	4.9
Mn	0.056	0.177	0.002	-	0.046	<0.0005	0.025	0.2200	0.0021	-	0.400	<0.0005	-	0.114	<0.0005
Mo	<	<	<0.0002	<	<	<0.0002	<	<	<0.0002	-	0.0008	<0.0002	-	0.005	<0.0002
Ni	-	0.0052	<0.0005	-	0.0045	<0.0005	0.063	0.560	0.0068	-	0.102	<0.0005	-	0.139	<0.0005
K	0.496	2.700	0.180	0.491	0.810	0.140	0.676	2.90	0.190	1.04	2.40	0.380	0.863	2.200	0.310
Rb	0.0013	0.0041	0.0004	0.0037	0.0083	0.0009	0.0074	0.0197	0.0019	0.0031	0.0073	0.0013	0.0022	0.0052	0.0008
Se	<	<	<0.001	<	<	<0.001	<	0.0027	<0.001	-	0.014	<0.001	-	0.0016	<0.001
Ag	<	<	<0.0001	<	<	<0.0001	<	<	<0.0001	<	<	<0.0001	<	<	<0.0001
Na	3.178	6.300	1.310	3.074	6.100	1.720	3.01	5.80	1.63	3.029	5.300	1.710	3.07	6.20	1.32
Sr	0.0051	0.0124	0.0007	0.0051	0.0130	0.0011	0.0066	0.0370	0.0013	0.017	0.035	0.009	0.025	0.044	0.016
Tl	<	<	<0.00005	<	<	<0.00005	0.00024	0.00048	0.00005	-	0.00006	<0.00005	<	<	<0.00005
Sn	<	<	<0.0005	<	0.017	<0.0005	-	0.0011	<0.0005	<	<	<0.0005	-	0.020	<0.0005
U	-	0.00007	<0.00002	-	0.00015	<0.00002	-	0.00009	<0.00002	-	0.00017	<0.00002	0.00020	0.00057	0.00003
V	<	<	<0.001	<	<	<0.001	<	<	<0.001	-	0.0018	<0.001	-	0.003	<0.001
Zn	0.088	0.560	0.006	0.042	0.370	0.004	0.274	1.330	0.070	-	0.250	<0.001	0.026	0.550	0.001

Table 2. Summary data for column leach studies.

Theoretical Leachate Chemistry Calculations

A worst case scenario chemistry can be calculated by assuming complete reaction of all available oxygen with pyrite to produce acid that is neutralized by the excess ANC in the rocks. Available oxygen is calculated from Ficks law (Wels et al., 2003) and assumptions relating to saturation within the waste rock. This is diluted into available water based net percolation. The value for net percolation is based on analogy to other sites with similar waste rock dump construction.

This approach indicates a seeps with neutral pH, elevated concentrations of Fe(II) up to 158mg/L, Al 4mg/L and concentrations of Zn, Ni, Cu, Pb, Co & Mn that occur at maximum values from the leach columns. Modelling of this chemistry with PhreeqC indicates that the Fe concentration will be limited to ~20mg/L by mineral solubility and that there will be excess alkalinity of about 10mg/L. Should seeps occur with this chemistry, active treatment will be completed at the seep collection points.

Discussion

Acid base accounting data for the waste rock at Te Kuha are unique compared to other opencast coal mining operations in New Zealand for two reasons.

1. Both Paparoa and Brunner Coal measures will be mined simultaneously.
2. Brunner Coal Measures at this site have the lowest MPA results for any mine site that operates in these rocks (Figure 1).

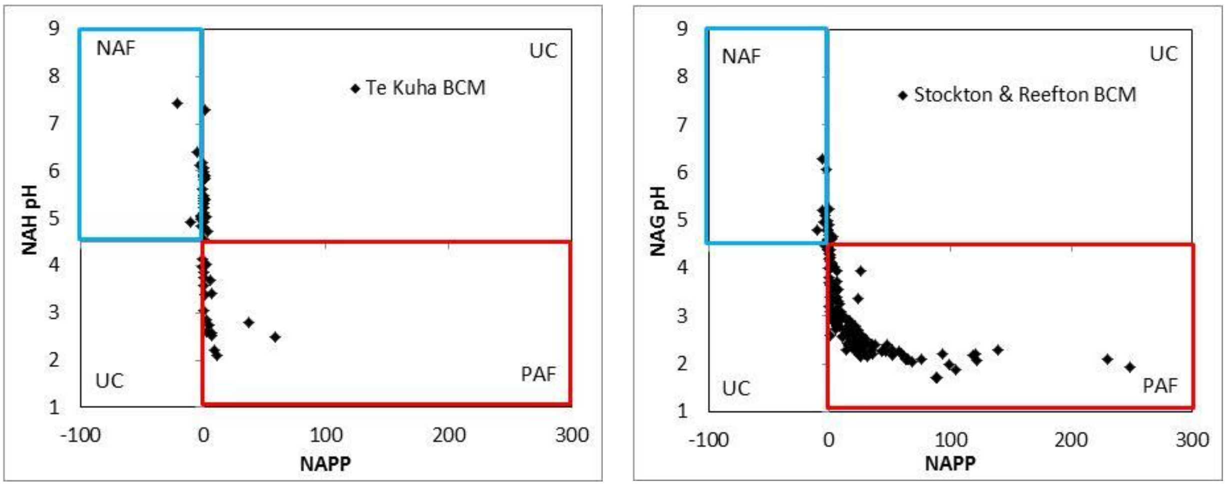

Figure 1. Brunner Coal Measures Acid Base Accounting at Te Kuha compared to other published data (Pope, 2010)

The average MPA for Brunner Coal Measures Rocks collected from Stockton and Reefton Coal mines have is 24.7 kg/t H_2SO_4 (Pope et al., 2010). The Average MPA of Brunner Coal Measures at Te Kuha is 4.2 kg/t H_2SO_4. In addition to the low acid production potential for the Brunner Rocks, Paparoa Coal Measures at Te Kuha have negative NAPP values and the average ANC is 19.3 kg/t H_2SO_4.

Column leach testing of the low MPA Brunner Coal Measures rocks from this site indicate that pH in the leachate will be relatively high and acidity relatively low compared to other leachate data for these rocks (Pope and Weber, 2013). Column leach testing for the Paparoa Coal Measures indicate neutral mine drainage with excess alkalinity (Table 2).

These datasets combined with the total tonnages of Paparoa and Brunner Coal Measures rocks that will be disturbed by mining indicate that net drainage from the waste rock dumps will be neutral. The mine drainage drainage could contain elevated concentrations of trace elements particularly Al, Zn & Ni but Co, Cu, Pb, & Mn might also have elevated concentrations at some seeps.

If the worst case scenario chemistry is used it is possible that Fe will also be released, however, the concentrations predicted for Fe are high using this approach and additional modelling is required.

Conclusion

Waste rock geochemistry at the Te Kuha deposit is unusual because it includes both Paparoa Coal Measures and Brunner Coal Measures. In addition the Brunner Coal Measures have low acid forming potential compared to Brunner Coal Measures at other deposits including, Stockton Plateau, Denniston, and the Reefton Area. The Paparoa Coal Measures provide a source of acid neutralising capacity and this can be used to develop a waste rock management plan to avoid acid formation in waste rock dumps at the deposit.

Column leach data from samples of Brunner Coal Measures at Te Kuha indicate that mine drainage chemistry will be mildly acidic pH 4.1-6. This is substantially less acid than Brunner Coal Measures column leach test data collected from other deposits where the pH in column leach tests is commonly less than 3 and sometimes less than 2. Column leach tests from the Paparoa Coal Measures have circum neutral pH and alkalinity concentrations between 1 and 95 mg/L HCO_3^-.

Column leach tests also indicate that several elements will be enriched in the mine drainage chemistry including Al, Zn & Ni in most mine drainages and Co, Cu, Pb, & Mn at some seeps. However, direct application of column leach testing to determining mine drainage chemistry is difficult because waste rock dumps have variable grainsize, variable oxygen content and because the chemistry at seeps evolves with time.

A theoretical approach to establishing seep chemistry based on net percolation, oxygen ingress using Ficks law and assumptions on geochemical reactions in the waste rock dumps has been applied to the Te Kuha deposit. This approach produces worst case scenario chemistry for mine drainage seeps at the deposit. The chemistry of this leachate from waste rock dumps is neutral because of excess ANC from Paparoa Coal Measures, and this geochemistry is modelled, then used to inform a contingency plan for treatment of mine drainage chemistry at seeps should it be necessary. In addition, it is possible that parts of the deposit will produce more typical highly acidic Brunner Coal Measures AMD, and a contingency plan has also been developed for this occurrence.

The approaches for mine drainage chemistry prediction outlined provide defensible method for identification of the likely range of mine drainage chemistry that will occur at the Te Kuha mine site. These predictions combined with appropriate adaptive management plans provide confidence that mine drainage chemistry can be managed at the site with minimal impact on the downstream environment.

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