Investigation of Alkaline Cover Performance for Abatement of ARD from Waste Rock Dumps at Savage River Mine

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Abstract

The Savage River iron ore mine in north-west Tasmania, Australia, is surrounded by areas of high wilderness value, including the Savage River National Park. Acid rock drainage (ARD) emanating from legacy (sulphide containing) waste rock dumps at the mine site, which flows into both Main Creek and Savage River, has caused environmental harm to the river and its tributaries. The historic B-dump was identified as a significant source of ARD at the site. In 2006, combined water shedding and alkaline (calcite-chlorite schist) covers were constructed over the dump for long-term ARD control.

As part of the AMIRA International funded project "Alternative Treatment Options for Long-term ARD Control" (P933A) a survey of the B-dump calcite-chlorite schist (CCS) side cover was carried out. Combined excavation and drill core sampling of the dump and CCS side cover was undertaken after the cover had been in place for about fiveyears.

This paper focuses on the results from our investigations of water samples taken from B-dump seeps and solid samples, in particular, drill core samples taken from different layers of the cover and original ARD rock within the dump. A mineralogical survey, geochemical characterisation and surface analysis of pyrite in each of the layers were undertaken.

Key words:acid rock drainage, acid mine drainage, dry cover, alkaline cover, cover assessment

Introduction

The Savage River iron ore mine in north-west Tasmania, Australia, is surrounded by areas of high wilderness value, including the Savage River National Park. To date, mining operations have generated in excess of 50 million m^3 of ore and 300 million m^3 of waste rock during the last 40 years. Current mining plans allow for the potential of a further 100 million m^3 waste rock over the next 15 years (Brett, 2007). However, acid rock drainage (ARD), emanating from legacy (sulphide containing) waste rock dumps at the mine site, which flows into both Main Creek and Savage River, has caused environmental harm to the river and its tributaries (Hughes *et al*. 2009). The historic B-dump was identified as a significant source of ARD at the site, and an objective of the Savage River Rehabilitation Project (SRRP), which was initiated in 1996 as a cooperation between the Tasmanian Government and current owners Grange Resources, is to develop and implement a strategy to reduce the acid load from this dump (Rumble, 2005; Hutchison *et al.* 2009).

The waste rock at Savage River iron ore mine has been identified as falling into broad categories as follows (Brett, 2007):

- A Type: Alkaline materials non-acid forming (NAF) or very durable igneous rock;
- B Type: Effectively neutral;
- C Type: Clay or highly weathered rock; and

- D Type: Potentially acid forming (PAF).

Fromearly 1970 to 1996, about 13 Mt of D-type waste rocks from the Centre Pit had been placed into the B-dump. Figure 1 shows that B dump is adjacent to the historic A-dump which is also an ARD source to Main Creek. Both dumps are hydrogeologically related to the Emergency and Main Creek Tailings Dams. It was estimated that approximately 40% of the total Cu load emanates from this overall complex and flows down the Main Creek (Thompson and Brett, 2006).

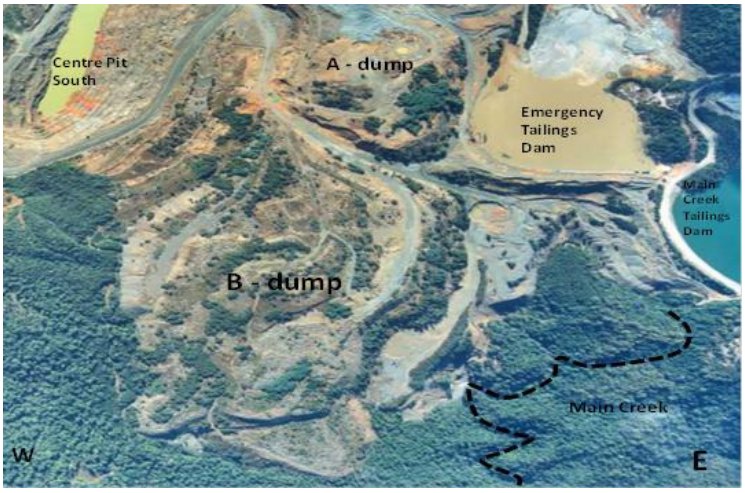


Figure 1.Savage River Mine B-dump (May 1999).

To reduce environmental harm to the river, B-dump was capped in 2006 by the previous owners Australian Bulk Minerals (ABM) under the initiative of the SRRP. The cap comprises (Figure 2) (Hutchison *et al.* 2009):

- a water shedding cover,made by B and C-type materials, sheeted with A-type rocks,over the top of the dump that discharges rain water to an alkaline flow-through on the southern end of the dump;
- an alkaline side cover, made by A-type materials, along the eastern side of the dump; and
- a clay encapsulation cover, made by C-type materials, on the western side of the dump.

A total of 15 Mt A-type rocks were used in the water shedding cover and the alkaline side hill cover.

The climate of the Savage River Mine area is characterised by cool temperatures and a high and consistent average annual rainfall of 1,927 mm. Rainfall exceeds evaporation by a factor of at least 2:1 (Brett, 2007). The water shedding cover, constructed using B and C-type materials and well-graded A-type waste rock, has significantly reduced infiltration from 90% to 3-8% of incident rainfall for50% (111510 m^2) of total B-dump top area, and subsequently reduced the seepage load of acid drainage to Main Creek (Brett, 2009).

The Southern Alkaline Flowthrough comprises about 1,200,000 m^3 of A-type material fill over an area of 86,000 m^2 with an average depth of 13.2 m on the southern end of B-dump. This area was shaped to provide a soakage zone for run-off from the water shedding cover. As such it provides benefit in water dispersion and alkalinity addition.

The Eastern Alkaline Cover comprises about 3,000,000 m^3 of A-type material fill over an area of 120,000m^2 with an average thickness of 25 m. This is a free draining cover and the entire cover overlies historic dump areas. The average rain water inflow rate for the eastern alkaline cover was estimated to be162,000 m^3yr^{-1} and the alkaline water from the cover may produce an estimated 16 t yr^{-}

[1] of alkalinity representing approximately 5% of projected total alkalinity demand from the Main Creek area (Brett, 2005).

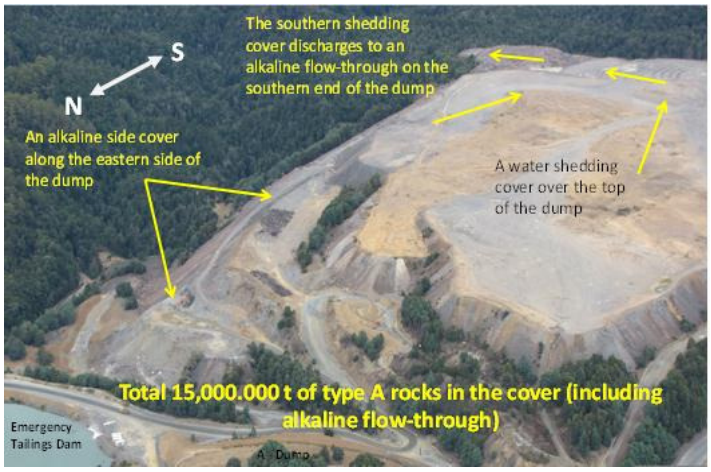


Figure 2.Savage River Mine B-dump after capping (October 2006).

With the overall dump and flow-through being comprised of 15 Mt of A-type alkaline rocks (average NP 225 kg $CaCO_3$/t) then there would be in the order of 3 Mt of alkalinity available for neutralisation (Hutchison *et al.* 2009). It was proposed that the alkaline side cover allows rainwater infiltrating the cover to take up alkalinity from the A-type material. This alkalinity can then react with and neutralise existing acid drainage. Thus, the reaction can result in micro-precipitation of insoluble reaction products, effectively isolating unoxidisedsulfide particles from future oxidation and shutting down the acid forming process(Hutchison *et al.* 2009). Prior to this study, there hadbeen evidence that rainfall waspenetrating the alkaline cover and increasing its alkalinity level. There was,however, no evidence that the micro-precipitation process wastaking place within the dump (Hutchison *et al.* 2009).

The aim of this study was to complete a survey of the B-dump calcite-chlorite schist (CCS) side cover performance after the cover had been in place for about fiveyears. We have completed sampling, including excavation, drill core and water sampling. The results on analysis of three samples, collected in the alkaline cover, at interface of A-type and original D-type materials, and the original D-type materialsduring the excavation at eastern alkaline side cover of the B-dump in April 2010, have been reported previously by Li *et al.*(2011). It was found that alkalinity from the side cover has been migrating down into the potential acid forming (PAF) waste below over the past 5 years, and the formation of passivating layers on pyrite grainsmay have reducedthe acid generation rate within the dump.This paper describes further results from analysis of drill cores and water samples, undertaken as part of the AMIRA International funded project "Alternative Treatment Options for Long-term ARD Control" (P933A) research.

Assessment of B-dump Alkaline Cover Performance

Mineralogy and geochemical characteristics of B-dump drill cores

To complete the B-dump survey, drill core sampling of B-dump was carried out in September 2010. Two drill cores were taken. The southern hole, named as AC1, was drilled through the alkaline side cover (A-type) for 25 m and then through 30 m of the original dump material (D-type). The northern hole, BD1, penetrates 27 m of original dump material (D-type) (Figure 3).

A total of 54 drill core samples were initially selectedandpaste pH was measured for each of the samples. Not surprisingly, the paste pH of all of the samples taken from through the alkaline side cover were neutral to mildly alkaline, while below the cover (>26 m depth) paste pH was lower (4 – 5.5). For the drill core taken from the uncovered section of the dump, paste pH was between 4 and 6, with the exception of the top two meters which gave a neutral paste pH.

Based on the paste pH results and colour of the wastes, eight samples from AC1 and four samples from BD2 were selected for further analysis (Figure 4). The samples were dried and fine materials from each sample were collected for Scanning Electron Microscopy (SEM) and X-ray diffraction (XRD) analysis. The bulk samples were crushed and pulverised to -75 µm for various analyses including bulk assays, XRD, SEM/Energy dispersive X-ray spectroscopy (EDS) analysis and geochemical testing. The total sulphur (S) in a sample was determined by the standard Leco S method and chromium reducible sulphur (CRS) was determined as described in Acid Sulphate Soils Laboratory Methods Guidelines 2004 (Sullivan et al., 2004). The results of these analyses are summarised in Figures 5-7 and Tables 1-2.

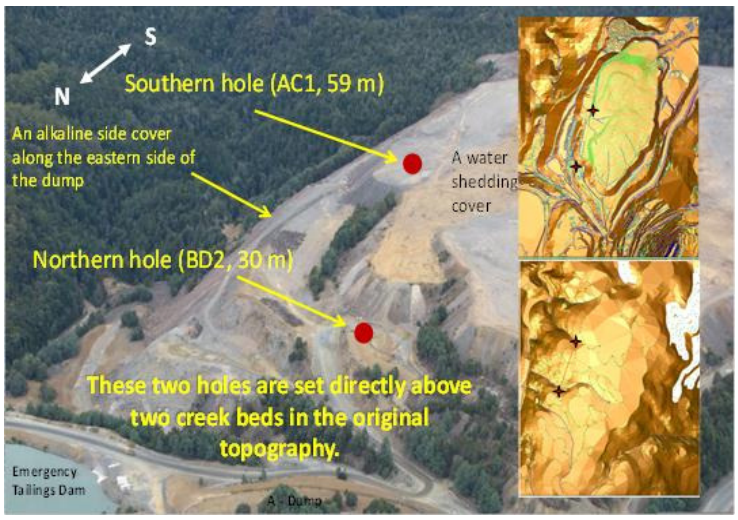


Figure 3.Locations of B-dump drill core sampling. Overlays show current topography (top) and original topography (bottom).

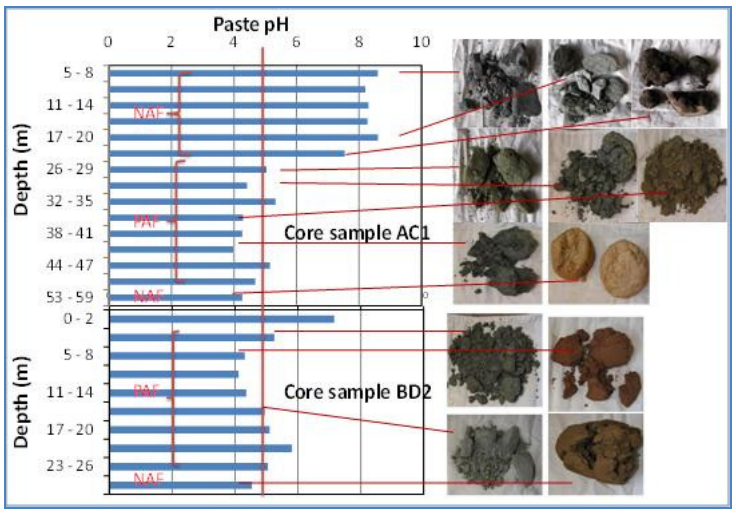


Figure4.Paste pH vs. depth for two drill cores from the southern (AC1) and northern (BD2) drill holes.

The 25 mthick B-dump alkaline cover (AC1) hasbeen naturally weathered for more than five years since it was constructed in 2006. The major carbonate, active silicates and sulphide phases in materials in the alkaline cover are calcite (11-13%), dolomite (3-54%), anorthite (0 - 6%), chlorite (9-12%), albite (0 – 21%) and pyrite (0-0.4%). Calcite and dolomite content decreases with increasing depth from 5m to 20m (Figure 5, left). These carbonate phases predominately contribute to the readily

available short-term acid neutralisation capacity (ANC) of540 kgH_2SO_4/tand 173 kgH_2SO_4/t determined from modified Sobek tests (AMIRA 2002) conducted on samples collected in 5-8m layer and 17-20m layer, respectively (Table 1). Carbon analysis identified 5.62% and 1.32% inorganic C (Table 2) corresponding tocarbonate ANC of 459kgH_2SO_4/t and 108 kgH_2SO_4/t respectively, with the remainder contributed by reactive silicates (Figure 5). At the interface between the type A cover and the type D PAF waste, the inorganic C content was only 0.22% corresponding to a carbonate ANC of 18 kg kgH_2SO_4/t, all of which can be attributed to fine-grained dolomite. The remaining ANC (48 kg kgH_2SO_4/t) is likely to come from anorthite, a relatively reactive silicate mineral contributing to both short and long-term non-carbonate ANC (Ciccarelli *et al*., 2009; Miller *et al.,* 2010). Table 1 shows that the alkaline cover material (5-26m) had low acid potential (MPA), high ANC, strong negative net acid producing potential (NAPP) anda net acid generation (NAG) pH of about 7. It is obvious that this alkaline cover will have both short and long-term available ANC, fully consistent with the results from the previous excavation investigations (Li *et al.* 2011).

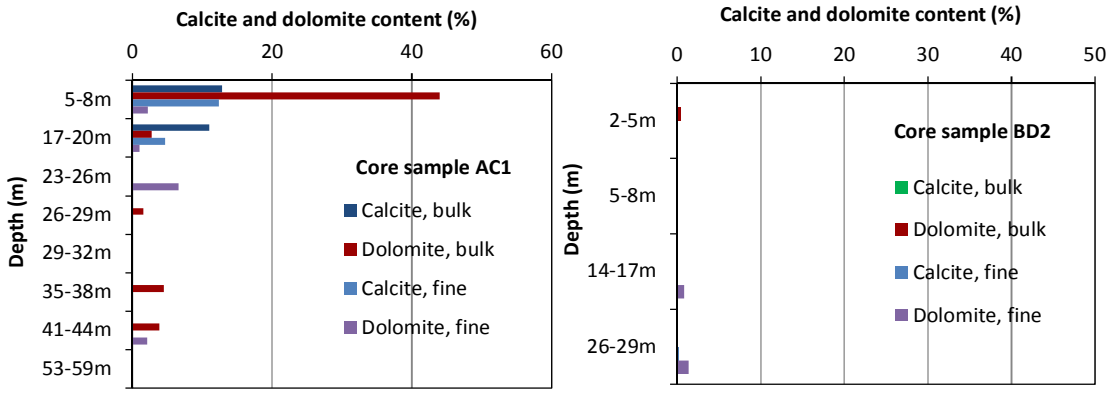


Figure 5.Carbonate distribution within B-dump with (left) and without (right) the alkaline cover.

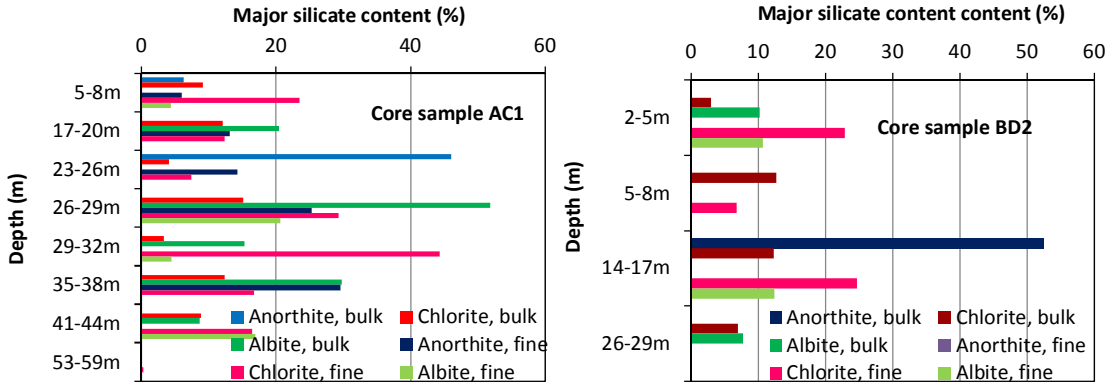


Figure 6.Major silicates distribution within B-dumpwith (left) and without (right) the alkaline cover.

The D-typewaste, below the alkaline cover (26-44m),gave a total S assay of 1.31-2.49 wt% S (Table 1). A significant proportion of this is likely to be in the form of pyritic sulphur(chromium reducible sulphur (CRS) of 0.98-1.06 wt.%). However, at the bottom of the D-type waste(41-44m)a substantial (~50%)amount of the sulphur is in the form of sulphates, possibly as amorphous jarosite, suggesting rapid oxidation of pyrite is occurring at the base of the dump (Table 1). There is, however, still a significant concentration of pyrite throughout the entire depth profile of the D-type waste below the alkaline cover (Figure 7).

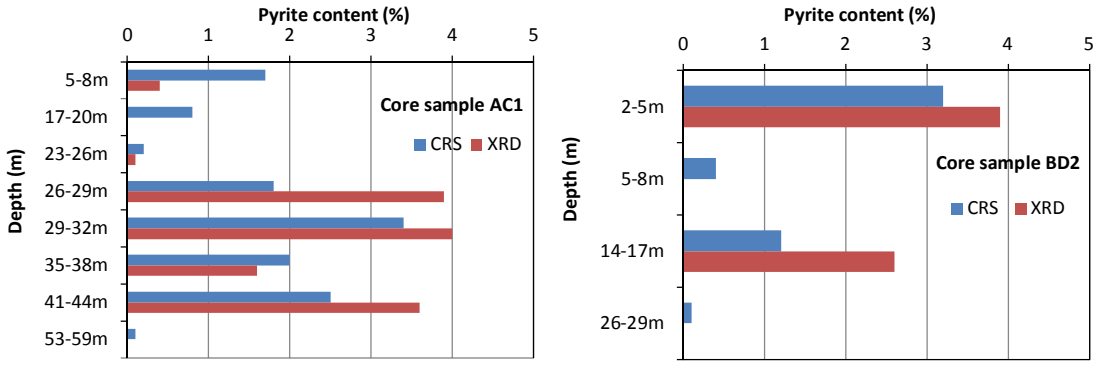


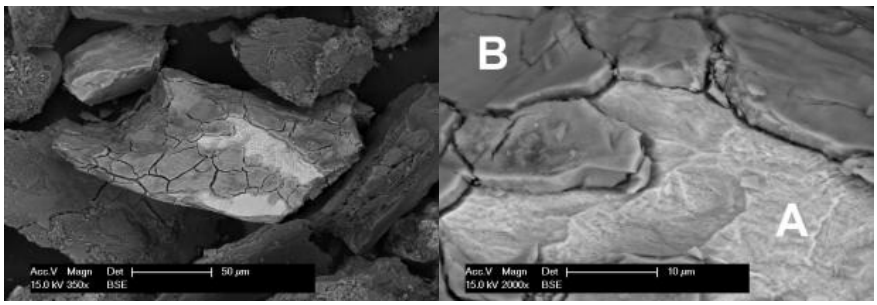
Figure 7. Pyrite distribution within B-dumpwith (left) and without (right) the alkaline cover.

Sulphur assays (total S and CRS) and XRD analysis of the core samples taken form the type-D waste without an alkaline cover, indicate that the pyrite content of this material is variable across the depth profile, but covers a similar range to the core samples taken under the alkaline cover. The lack of any substantial ANC means this material is likely to continue to produc acid for the foreseeable future.

Surface analysis

To investigate whether passivating surface coatings are forming on pyrite grains within the PAF D-type waste under the alkaline cover, surface analyses were carried out on pyrite particles and other sulphides, where any were found, in the AC1 and BD2 drill core samples using SEM with EDS.

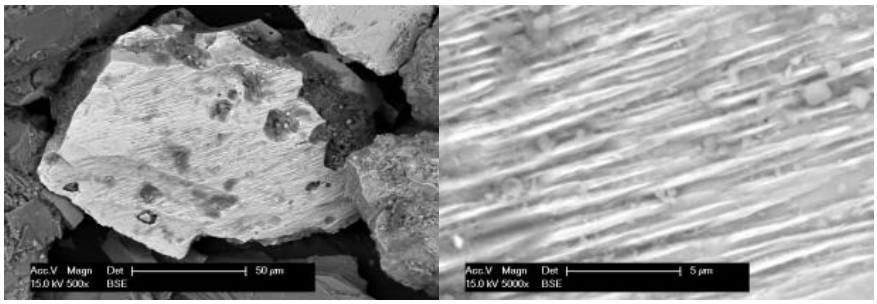
Some pyrite was observed in the A-type alkalinecover (5-8m depth). Figure8 shows that these pyrite particles (A) areheavily coated with iron oxide/hydroxide surface layers (B) which were not removed even after ultra-sonication in ethanol to remove adhering fine particles. The thickness of the surface layer is approximately 1 µm with a number of cracks due to the dehydration under the vacuum conditions used for SEM analysis. This shrinkage under the vacuum confirms the coating had been heavily hydrated when it was sampled at the site. The adheringlayerappears to be stabilised with Si (4.9 wt %) as silicate. This finding is in agreement with our previous work in which silicate-stabilised iron oxyhydroxide layers formed in near neutral pH conditions passivating pyrite in wastes at the PT Freeport Grasberg mine (Miller *et al.* 2009; Smart *et al.*, 2010; Schumann *et al.*, 2008; 2009).



Area	Element (At. %)						
	O	Mg	Al	Si	S	Ca	Fe
A	4.2	-	-	-	63.9	-	31.9
B	51.7	0.9	0.9	4.9	0.8	2.8	38.0

Figure8.Backscatterd electron(BSE) images of pyrite particles found in B-dump A-type cover material in 5-8m layer. Elemental concentrations determined from EDS analysis are given below the image.

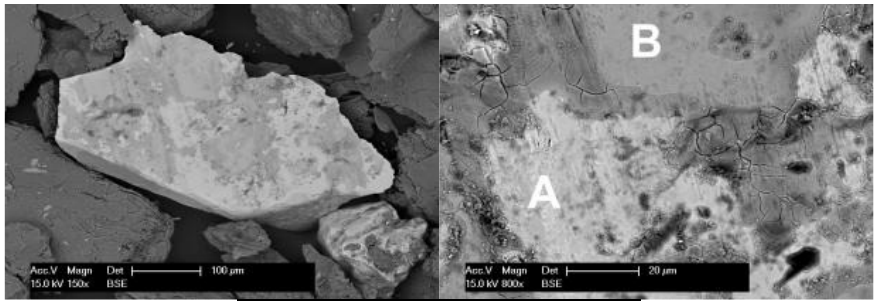
Pyrite particlesin D-type material taken below the alkaline cover (29-44m layer) were severely and continuously reacted as seen in Figure 9. The pyrite was strongly leached with a number of large and small pits all over the surface. Extensive pitting was not observed in the shallow depth samples. The spot EDS analysis showed very low oxygen contents(5.8 At.%) and typical pyrite stoichiometric Fe:S ratio close to 1:2. No surface coating was detected. Similar extensive formation of pits was also observed in pyrite particles in the D-type materials without the alkaline cover.



Element (At. %)			
O	Si	S	Fe
5.8	0.5	60.1	33.6

Figure 9.BSE images of pyrite particles found in B-dump D-type material (35-38m layer) under the alkaline cover.

In the sample taken from the interfacial zone between the D-type PAF waste and the alkaline cover, SEM analysis showed that pyrite particles were typically coated by an iron oxyhydroxide layer, albeit considerably thinner than similar layers found on pyrite grains in the type-A alkaline cover (Figure 10). The lower pH of pore water at the interface in comparison to that in the alkaline cover is not so conducive to the build-up of the oxide layer.



Area	Element (At. %)				
	O	Al	Si	S	Fe
A	5.7	0.4	0.4	61.1	32.5
B	33.7	1.4	0.9	34.5	29.6

Figure 10. BSE images of pyrite particles in D-type waste(26-29m layer) taken from the interfacial zone under the alkaline cover.

Acid generation rates (AGR) and acid neutralising rates (ANR) within B-dump

In addition to analysis of core samples, analysis of drainage from B-dump was also undertaken as part of the assessment of the alkaline cover performance. Water samples were collected from seeps emanating from the toe of the dump well below the alkaline side cover, and from discharge from the alkaline flow-through at the southern end of the dump (Figure 2).

Table 3 shows that water sampled from the B-dump alkaline flow through is characterised by relatively high pH (pH 7.3), low Eh (272 mV) and relatively high alkalinity (215mg $CaCO_3$/L), with moderate levels of sulphate (660 mg/L) and major cations(e.g. 158 mg/L Ca, 92 mg/L Mg, 5 mg/L K, 9 mg/L Na), and low metals (0.2 mg/L Co, 0.1 mg/L Ni, Cu < 5 µg/L). The molar ratio of Ca:Mg of about 1:1 seems to suggest that the alkalinity is predominately derived from dolomite dissolution. In contrast, the B-dump seeps have low pH (3.5) with relatively high acidity (281 mg $CaCO_3$/L) and high Eh. Sulphate concentrationwas high (1636 mg/L) with relatively high levels of Ca (166 mg/L), Mg (261 mg/L), Al (24 mg/L), Si (23 mg/L), Fe (4.4 mg/L), Cu (2.3 mg/L), Co (2.2 mg/L), Ni (1.1 mg/L) and Zn (0.5 mg/L), all characteristic of ongoing pyrite oxidation within the dump.

The sulphate concentration was used to calculate AGR and Ca, Mg, K, Na and Al concentrations were used to calculate ANR based on methods reported by Ciccarelli *et al.* (2009) for both alkaline flow-through and alkaline side cover performance. The results of these calculations shown in Table 4, suggest that the alkalinity derived from dissolution of carbonates (primarily dolomite) in the alkaline cover by rainfall migrating through the cover, is insufficient to meet the acid load generated by oxidation of pyrite in the underlying PAF waste. However, it is also possible that some of the water seeping from below the alkaline side cover has come from flow paths that do not involve flow through the cover and contributing significant acidity. Nevertheless, it appears to effectively neutralise acidity in the B-dump seeps at the current rate of acid generation, it is necessary to collect the water and treat it by contacting it with the alkaline calcite chlorite schist (alkaline flow-through). The results shown in Table 4 do, however, show that the AGR calculated from B-Dump seeps is close to the ANR and that any further reduction in the acid generation rate is likely to result in less acidic drainage.

Table 1.Acid-base account (ABA) and Net acid generation (NAG) test results of solid samples collected from B-dump drill holes.

Sample	Depth	S	CRS	MPA	MPA*	ANC	NAPP	NAPP*	NAGpH	NAG at pH 4.5	NAG at pH 7	NAG7/NAPP	Classification
		%	%	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t		kg H_2SO_4/t	kg H_2SO_4/t		
AC1-1	5-8m	1.14	0.92	34.9	28.0	539.6	-504.7	-511.6	7.2	0.0	0.0	0.0	NAF
AC1-2	17-20m	0.47	0.40	14.4	12.2	173.0	-158.6	-160.8	7.1	0.0	0.0	0.0	NAF
AC1-3	23-26m	0.10	0.08	3.1	2.5	65.7	-62.6	-63.2	7.4	0.0	0.0	0.0	NAF
AC1-4	26-29m	1.31	0.98	40.1	29.9	24.7	15.4	5.2	2.8	26.9	38.8	2.5	PAF
AC1-5	29-32m	2.24	1.79	68.5	54.8	31.6	36.9	23.2	2.8	42.1	52.0	1.4	PAF
AC1-6	35-38m	1.43	1.06	43.8	32.4	24.4	19.4	8.0	2.7	27.1	36.9	1.9	PAF
AC1-7	41-44m	2.49	1.34	76.2	41.0	9.7	66.5	31.3	2.9	37.8	50.1	0.8	PAF
AC1-8	53-59m	0.08	0.03	2.4	1.0	6.0	-3.6	-5.1	4.7	0.0	1.0	-0.3	NAF
BD2-1	2-5m	2.98	1.71	91.2	52.3	21.2	70.0	31.1	2.3	45.5	50.4	0.7	PAF
BD2-2	5-8m	0.82	0.20	25.1	6.0	6.4	18.7	-0.4	3.3	5.7	14.1	0.8	PAF
BD2-3	14-17m	0.96	0.65	29.4	19.9	17.0	12.4	2.9	2.9	15.5	21.6	1.7	PAF
BD2-4	26-29m	0.23	0.05	7.0	1.6	37.6	-30.6	-36.0	4.7	0.0	1.4	0.0	NAF

Key:1. MPA = Total S (%) × 30.6 and MPA* = CRS (%) × 30.6. 2. NAPP = MPA – ANC and NAPP* = MPA* - ANC.

Table 2. Inorganic carbon (C) contentin solid samples collected from B-dump drill holes.

Sample	AC1-1	AC1-2	AC1-3	AC1-4	AC1-5	AC1-6	AC1-7	AC1-8	BD2-1	BD2-2	BD2-3	BD2-4
Depth	5-8m	17-20m	23-26m	26-29m	29-32m	35-38m	41-44m	53-59m	2-5m	5-8m	14-17m	26-29m
Inorganic C (%)	5.62	1.32	0.22	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02

Table 3. Water quality data (mg/L) collected in April 2010 at B-dump.

Location	Flow (L/s)	pH	Eh (mV)	EC (µS/cm)	Acidity (mg $CaCO_3$/L)	Alkalinity (mg $CaCO_3$/L)	SO_4	Ca	Mg	K	Na	Cl	Si	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	
B-dump side cover seeps	48	3.5	627	2838	281	-	1635.6	165.5	260.6	7.5	25.6	39.9	23.2	23.5	<0.01	<0.005	2.2	<0.005	2.344	4.4	18.8	1.1	0.009	0
B-dump alkaline flow-through	6	7.3	272	1262	-	215	660.0	158.0	92.0	4.5	9.1	8.0	3.1	0.045	<0.01	<0.005	0.2	<0.005	<0.005	0.1	1.7	0.1	<0.005	0

Table 4. ANR (mg H_2SO_4/kg/week) and AGR (mg H_2SO_4/kg/week) calculated from water monitoring data for B-dump.

	pH	ANR	AGR	AGR/ANR
B-dump alkaline flow-through	7.3	0.3	0.2	0.9
B-dump seep	3.5	9.4	10.7	1.1

Alkaline side cover performance

To assess the effect of the alkaline side cover on the reactivity of pyrite in the underlying PAF waste, a comparison was made between the total S content of the type D waste both below the alkaline cover and from the area not under the cover, with the total S content of the waste measured before the cover was constructed. Of course this methodology assumes that the sulphur is homogenously distributed throughout the waste dump and that oxidised sulphur is transported out of the waste material through leaching rather than retained as precipitated sulphate salts. The results of this analysis are shown in Table 5. Based on the assumptions outlined above, it appears that the average total S value of the D-type waste from under the alkaline side cover has reduced from 3.2% to 1.9% during the past six years (5 years with the cover in place), a 41% reduction. In comparison, where there is no cover in place, the same time period the average total S content of the D-type waste has been depleted to 0.9%, a reduction of 72%. This suggests that the alkaline side cover has nearly halved the rate of pyrite oxidation in the PAF waste under the cover compared to the same waste in areas without the cover in place.

Table 5. The S oxidised in past 5 years within the B-dump.

	September 2010		**May 2005**
	Under alkaline cover (AC1)	**No cover (BD2)**	**Pre-cover**
	26m - 53m	**5m - 26m**	
Average S%	1.9	0.9	3.2*
MPA (S), kg H_2SO_4/t	57.1	27.2	97.2
Change in total S in 5 yr (%)	**41**	**72**	

*Three of B-dump D-type materials were sampled in May 2005. The average S% is calculated based onthe total S content in the three samples of 3.05%, 3.77% and 2.71%.

Conclusions

B-dump is a legacysulphide containing waste rock dump at the Savage River iron ore mine in Tasmania, and was identified as a significant source of ARD to the Main Creek and Savage River. The dump was capped in 2006 for long-term ARD control. To assess the cap performance a survey of the B-dump calcite-chlorite schist (CCS) side cover was undertaken in 2010 after the cover had been in place for about five years.

Mineralogy and geochemical assessment of the waste rock samples obtained from drill core sampling of the CCS side cover and original D-type PAF wastes has suggested that the D-type PAF waste sampled from below the alkaline side cover still contains average4.9% pyrite (average CRS 1.3%) after more than 35 years weathering (the last 5 years with the cover in place). The fastest oxidation of pyrite is occurring in bottom layer of 41-44m depth with the cover. Although silicates are relatively abundant, in particular, albite (52% in 26-29m layer), chlorite (44% in 39-32m layer) and anorthite(30% in 35-38m layer) in these PAF materials,NAG testing suggests that any ANC from residual calcite and dolomite is minor and the ANRnc from these silicates cannot match the AGR. Consequently, pyrite in these materials is highly oxidised.

Pyrite content inin the interfacial zone between the alkaline cover material and the original PAF material is about 3.7%. Significantly though, pyrite in this material is partially (~ 50% coverage) coated with passivating layers of silicate-stabilised iron oxyhydroxide which may result in a reduced AGR, but as yetthere isinsufficient neutralising capacity to produce the neutral conditions required to fully passivate the system. However, the CCS alkaline side cover continues to contain sufficient neutralising minerals (calcite and dolomite) to deliver alkalinity required for passivation of the PAF waste below the cover well into the future, but migration of this alkalinity and subsequent passivation down through the dump will likely occur over decades.

The water monitoring results from B-dump alkaline flow-through show that drainage emanating from the flow through has neutral pH and that alkalinity derived from this material is available at a faster rate than acidity is generated in the PAF waste. This result indicates good performance of the alkaline flow-through cover.

Seeps from below the alkaline side cover have lower pH (3.5) and a calculated AGR/ANR ratio of 1.1, suggesting that currently acid generation in the PAF material occurs at a faster rate than alkalinity is supplied from the CCS cover. However, the results of this study show that alkalinity from the side cover has been migrating down into the PAF waste below over the past 5 years, and forming passivating layers on pyrite grains that has reduced the pyrite oxidation rate by 43%.However, it may be some time before the remaining PAF waste in the dump is fully passivated and the side cover may be more effective if the whole of the dump were covered.

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