ANSTO/C1647

Leach Studies on the Bigrlyi Deposit – Improved V Recovery

Client: Energy Metals Ltd

Date: 12th September 2019

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Revision	Date	Description	Approved
Version 1	12/09/2019	Issued to client for comment	Bob Ring
Version 2	30/9/2019	Approved and Published	Bob Ring

Executive Summary

ANSTO Minerals (AM) completed a scoping study on Bigrlyi drill cores in 2008 by examining the preferred parameters for uranium extraction under both acidic and alkaline conditions. At the conclusion of the studies, sulfuric acid was determined to be the preferred lixiviant as long as the $CaCO_3$ content of the ore could be controlled to a concentration which yields an acceptable acid requirement.

Further leach studies (2010-2011) completed on a bulk composite ore sample under "base case" and "severe" acid conditions showed the uranium minerals were readily soluble under mild acid conditions (base case, pH 1.8, 50 °C, 500 mV: U 99%, V 47.6% extraction) but more intense conditions (pH 1.2, 60 °C, 600 mV) were required to achieve high vanadium extraction (U 99.4%, V 80%). Conventional leach tests also showed that grind size was critical, with optimum uranium extraction achieved at P_{80} 150 µm. Increasing the ORP (>500 mV) was favourable for improved uranium extraction.

Energy Metals is currently looking to improve the extraction of vanadium from its Bigrlyi deposit. Wayne Taylor of Energy Metals requested ANSTO carry out a work program for the ongoing assessment of leach conditions, with the main objective being to optimise, with respect to acid addition, the extraction of vanadium from a composite sample.

Sample

With vanadium extraction being the focus of the program, a new composite Bigrlyi sample with a higher vanadium content was required, compared to the composite used in earlier studies which focused on uranium. The composite was prepared by blending a 50:50 mix of the AN4 C/D and AN15 C/D samples (-2 mm size each). The uranium and vanadium concentrations in the composite were 2007 ppm U_3O_8 and 0.27%, respectively.

Size by grade analysis of the composite sample (P_{80} 150 µm) showed that almost half of the uranium (44.3%) and more than half of the vanadium (57.7%) were distributed in the finest size fraction (-38 µm). The head composition calculated using the size by grade assays matched closely with the original head assay.

Diagnostic Leach Tests

Five diagnostic leach tests were conducted at 2 wt% slurry density on pulverised ore to determine the maximum extractions of uranium and vanadium obtainable under ideal leach conditions. In order to allow comparison with earlier studies (2011), the first two tests were carried out under the previous "base case" and "severe" conditions. In the remaining three tests, temperature and pH were varied, with the ORP kept constant.

The results show similarly high uranium extractions, at ≥ 99% in all tests, irrespective of pH and ORP. However, the vanadium extractions varied with the test conditions, with the maximum extraction of 80.4% obtained at 60 °C, pH 1.2 and 600 mV (Test 2B). The results

were almost identical to those produced in the previous 2011 study under the same test conditions.

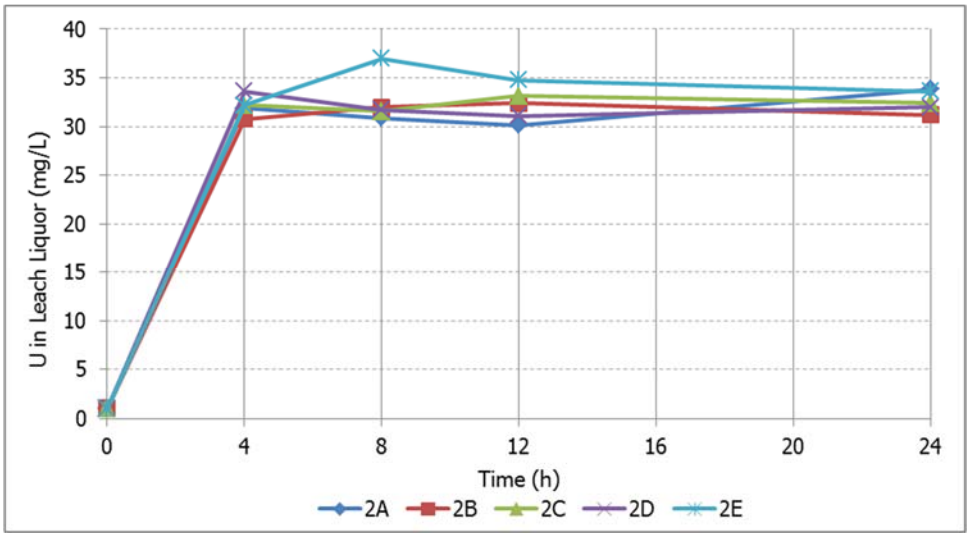
These results indicate that the pH (acidity) has a greater impact on the extraction of vanadium than temperature. However, the effect of ORP on V extraction was not conclusive under the conditions tested.

Diagnostic Test Results

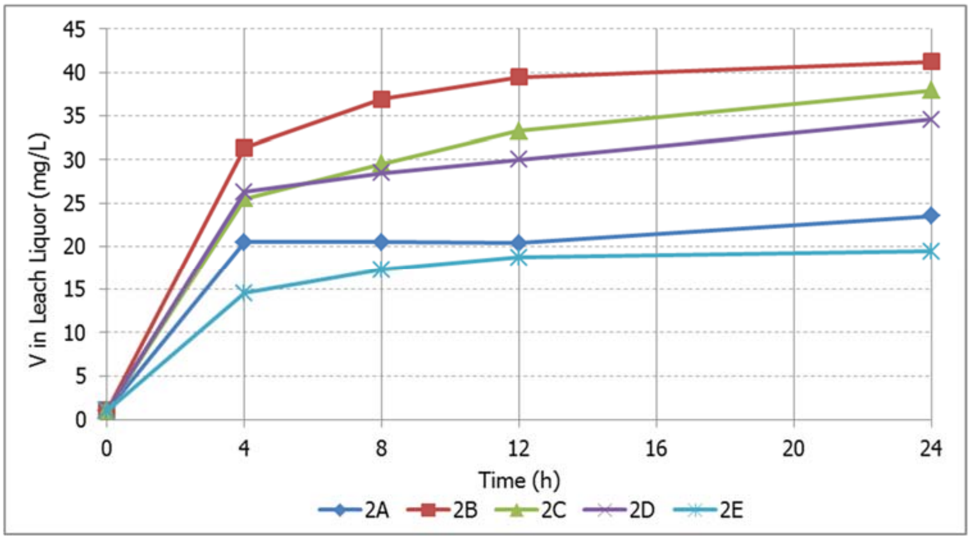
Test	Temp (°C)	pH	Target ORP (mV)	Test ORP* (mV)	Extraction (%)#	
					U	V
2A	50	1.8	500	555	98.9	47.5
2B	60	1.2	600	600	99.5	80.4
2C	50	1.2	550	568	99.3	73.0
2D	60	1.5	550	566	99.2	67.8
2E	80	1.7	550	556	99.2	41.4
2011 Study						
A	50	1.8	600		99.0	47.6
B	60	1.2	600		99.4	80.0

* Average; # Calculated based on solid assay and includes mass loss.

Uranium and vanadium tenors of the leach liquors plotted against time for each of the five diagnostic tests indicate that dissolution of uranium was complete within 12 h, whereas vanadium dissolution was continuing at the conclusion of the 24 h test period, indicating that an extended leach time may favour increased vanadium extraction (see Figures below).



Uranium Concentration vs. Time



Vanadium Concentration vs. Time

Conventional Leach Tests

Three conventional acid leach tests (50 wt %) were conducted under varying conditions. On the basis of the diagnostic test results, and with the client target of 70% V extraction, the selected conditions for the first conventional leach were 50 °C, pH 1.2, and 60 °C for 24 h. With a desire to minimise free acidity in the leach liquor, and with it the acid consumption, subsequent tests examined increasing the pH and temperature but with an extended 48 h residence time. As the effect of ORP was not conclusive in previous tests, a 550 mV target was maintained.

The uranium extraction was similarly high under all conditions, at ~99%, whereas the extraction of vanadium varied with pH and temperature, and in all cases was lower than achieved in the diagnostic tests.

Comparison of Diagnostic and Conventional Test Results

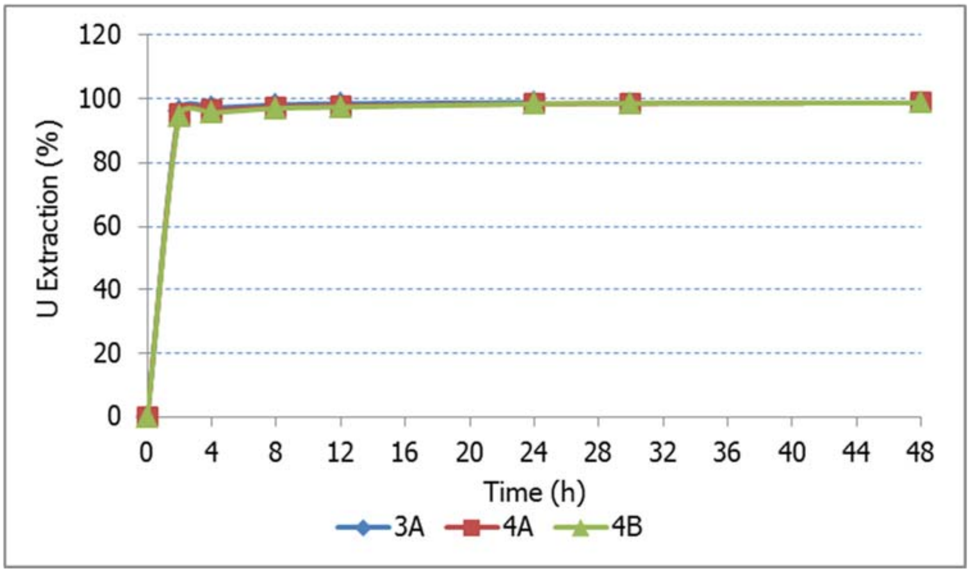
Test ID	Slurry (wt %)	Duration (h)	Temp (°C)	pH	ORP (mV)	Reagent Utilisation (kg/t)			Extraction (%)*	
						Acid Addition	Acid Consumption	Oxidant[#] Addition	U	V
2B	2	24	60	1.2	600	N/A	N/A	N/A	99.5	80.4
3A	50	24	60	1.2	550	140.2	123.4	2.9	98.9	72.7
4A	50	48	60	1.4	550	134.1	123.8	4.2	98.8	68.1
4B	50	48	70	1.5	550	133.2	123.2	4.8	98.7	64.0

* Calculated based on solid assay and includes mass loss. # $NaMnO_4$.

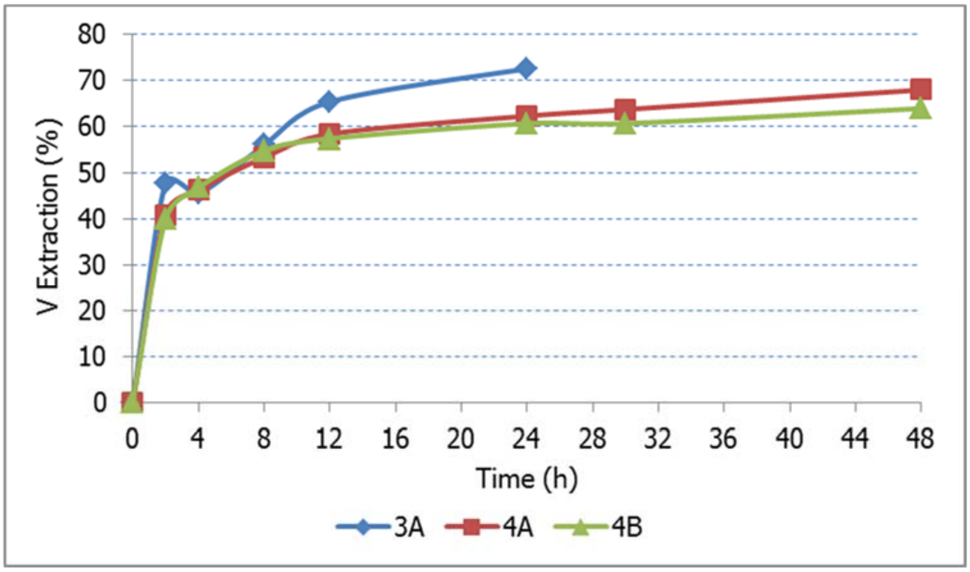
Under the same leach conditions of pH 1.2 and 60 °C, the vanadium extraction from the conventional test decreased to 72.7% from 80.4% in the diagnostic test. This may be partially attributed to particle size (P_{80} 150 µm in the conventional leach compared to -38 µm in the diagnostic leach), but also to possible solution effects in the higher slurry density (50 wt% vs. 2 wt%).

Increasing the pH to 1.4 (test 4A), but with an extended residence time of 48 h, failed to achieve the same vanadium extraction as achieved at pH 1.2 and 24 h (V 68.1 vs. 72.7%). An increase in temperature, and higher pH again (pH 1.5) resulted in only 64% V extraction.

Uranium and vanadium extractions plotted versus time show that the uranium extraction was complete in all cases within 12 hours, but the vanadium extraction continued beyond 24 hours, although at a considerably slower rate.



Uranium Extraction vs. Time



Vanadium Extraction vs. Time

The final leach liquor compositions for the three conventional leaches show that along with uranium and vanadium, considerable concentrations of aluminium, iron and magnesium were also leached. The high final iron concentration (~6 g/L Fe) shows that the addition of 2 g/L Fe^{3+} at the start of the leach was not required. The manganese present in solution is a result of the oxidant (40% $NaMnO_4$), and therefore the higher manganese concentration in the 48 h tests reflects the higher oxidant additions in these tests.

Final Composition of Conventional Test Liquors (mg/L)

Leach ID	Al	Ca	Fe	Fe^{3+}	K	Mg	Mn	Na	P	S	Si	U	V	Cl
3A	3872	793	6264	4061	582	2939	1467	564	198	23118	487	1541	1828	157
4A	3330	775	5172	4818	391	3024	1806	733	150	19993	395	1751	1835	268
4B	3607	809	3096	2480	30	3264	1912	780	124	22011	352	1717	1803	256

Conclusions and Recommendations

The conclusions from the test work are as follows:

- The composition of the current composite prepared from a 50:50 mixture of AN4 C/D and AN15 C/D was similar to the composition of the composite prepared from three Bigrlyi composites (AN4 B/C, AN4 C/D and AN15 C/D) in 2010-2011;
- Size by grade analysis of the head sample showed that almost 44.3% of uranium and 57.7% vanadium was contained in the finest size fraction (-38 μm) of the new composite sample (ground to P_{80} 150 μm);
- Diagnostic leach tests yielded uranium extractions ≥ 99%, irrespective of test conditions;
- Vanadium extractions varied with the diagnostic test conditions, with the maximum vanadium extraction of 80.4% obtained at 60 °C, pH 1.2 and 600 mV for 24 h;
- Conventional leach tests produced similarly high uranium extractions (99%) as found in the diagnostic tests, but the vanadium extraction was less (maximum 72.7% at 60 °C, pH 1.2 and 550 mV for 24 h);
- Extended residence time (48 h) at reduced acidity (higher pH) failed to improve the vanadium extraction, despite a similar acid consumption; and
- Vanadium extraction was most responsive to leach acidity, and extraction improved as the acidity increased.

The following recommendations are made for future test work:

- With acidity being identified as the key driver for vanadium extraction, improved vanadium extraction will only be achieved by leaching at lower pH. Leach testing at lower pH and shorter residence time should be examined, with the goal of increasing vanadium extraction and reducing overall acid consumption by limiting excess gangue dissolution;

- There was a reasonable difference between the vanadium extractions achieved in the diagnostic leaches and the conventional leaches, under similar conditions. The potential impact of solution composition effects on vanadium extraction should be examined; and
- The impact of ORP on the extraction of vanadium was not tested in this study and should be confirmed in future work.

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1 Introduction

The Bigrlyi uranium and vanadium deposit in the Northern Territory is sandstone-hosted. The mineralogy is considered to be similar to the well-known Colorado Plateau U-V sandstone ores where uranium is present as readily leachable coffinite, uraninite and carnotite, with vanadium reporting to both readily leachable oxyhydroxide minerals (e.g. montroseite) and refractory aluminosilicate minerals (e.g. degraded biotite, chlorite-smectite interlayer minerals and clays such as vanadian illite).

ANSTO Minerals (AM) completed a scoping study on Bigrlyi drill cores in 2008 by examining the preferred parameters for uranium extraction under both acidic and alkaline test conditions. At the conclusion of the studies, sulfuric acid was determined to be the preferred lixiviant as long as the $CaCO_3$ content of the ore could be controlled to a concentration which yields an acceptable acid requirement.

Further leach studies (2010-2011) completed on a bulk composite ore sample under "base case" and "severe" acid conditions showed the uranium minerals were readily soluble under mild acid conditions (base case, pH 1.8, 50 °C, 500 mV: U 99%, V 47.6% extraction), but more intense conditions (pH 1.2, 60 °C, 600 mV) were required to achieve high vanadium extraction (U 99.4%, V 80%). Conventional leach tests also showed that grind size was critical, with optimum uranium extraction achieved at P_{80} 150 µm. Increasing the ORP (>500 mV) was favourable for improved uranium extraction. The impact of higher ORP and ferric concentration on vanadium extraction from the Bigrlyi ore was not clear, but was expected to improve extraction.

Energy Metals is currently looking to improve the extraction of vanadium from its Bigrlyi deposit. Wayne Taylor of Energy Metals[1], requested ANSTO carry out a work program for the ongoing assessment of leach conditions, with the main objective being to optimise, with respect to acid addition, the extraction of vanadium from a composite sample. The results of this program are presented in this report.

2 Scope and Objectives

The primary objective of the work program was to improve the extraction of vanadium from Bigrlyi ore. The specific tasks in the scope were:

- Preparation of a new composite sample using the AN4 C/D and AN15 C/D core composites;
- Carrying out grind establishments;
- Completion of size by grade analysis on the composite head and one leach residue;
- Carrying out five diagnostic leach tests under varying conditions;
- Carrying out three conventional leach tests under preferred conditions.

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[1] Email from Wayne Taylor 28th May 2019 to Bob Ring.

3 Work Program

3.1 Sample Preparation

With vanadium extraction being the focus of the program, a new composite Bigrlyi sample with a higher vanadium content was required, compared to the composite used in earlier Bigrlyi studies which focused on uranium.

Sufficient quantities of the following Bigrlyi core composite samples were in storage at AM and were used to prepare the new composite for this test program:

AN4 C/D	-2 mm
AN15 C/D	-2 mm

The composite sample (9 kg) was prepared from a 50:50 mix of the AN4 C/D and AN15 C/D samples (-2 mm). The composite was riffled to 9 x 1 kg lots after crushing to -1 mm. From a single 1 kg lot, a sub-sample of 300 g was pulverised and split into 100 g for head assay and 5 portions of 40 g for diagnostic leaches. The head sample was analysed for Al, As, Ba, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Si, Sr, Th, Ti, V, Zn, Zr by XRF and for U by Delayed Neutron Activation Analysis (DNA).

The composition of two core composites (AN4 C/D and AN15 C/D), the target blended composition and the final assay result of the current composite are presented in **Table 1**. The target and the actual assay results of the composite matched very well. The new composite also matched the 2011 composite (prepared from three Bigrlyi composites AN4 B/C, AN4 C/D and AN15 C/D), also shown in **Table 1**, although it would appear that the concentrations of Zr and Sr were in error in the earlier XRF analyses[2].

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[2] AM XRF calibrations have been refined for low concentrations in the intervening period, which only impacted results for some elements.

Table 1
Composition of Drill Core Composites and Blended Composite (wt%)

Elements	AN4 C/D	AN15 C/D	Blended Target	Blended Actual	2011 Composite
Al	3.09	3.56	3.33	3.30	3.17
As	0.001	0.001	0.001	<0.001	<0.001
Ba	0.087	0.091	0.089	0.094	0.073
Ca	4.48	1.73	3.10	3.08	3.24
Co	<0.001	0.001	0.001	0.001	<0.005
Cr	0.010	0.025	0.018	0.021	0.042
Cu	<0.001	0.010	0.010	0.010	<0.001
Fe	0.88	0.87	0.88	0.89	0.81
K	2.28	2.48	2.38	2.37	2.19
Mg	0.47	0.56	0.51	0.51	0.55
Mn	0.046	0.022	0.034	0.033	0.027
Na	0.039	0.048	0.044	0.040	< 0.01
Ni	0.002	0.004	0.003	0.008	0.005
P	0.029	0.027	0.028	0.029	0.027
Pb	0.014	0.004	0.009	0.011	0.010
S	0.066	0.093	0.080	0.076	0.076
Si	35.1	37.9	36.5	36.4	35.2
Sr	0.019	0.015	0.017	0.013	0.14
Th	0.001	0.002	0.002	0.002	0.006
Ti	0.091	0.114	0.103	0.107	0.10
U	0.274	0.076	0.180	0.183	0.197
$U_3O_8^*$	3230	897		2007	2320
V	0.45	0.10	0.27	0.27	0.225
Zn	0.001	0.003	0.002	<0.001	<0.005
Zr	0.014	0.016	0.015	0.014	0.12

* ppm

3.2 Grind Establishment and Size by Grade Analysis

Grinding tests were carried out on the bulk composite to produce grind response curves to determine the time required to produce the nominated grind distribution of P_{80} 150 µm for feeding to conventional leach tests.

Two grinding tests of 7.5 and 6 minute duration were carried out on 1 kg of composite using 667 mL Sydney tap water in a batch rod mill (20 rods, 66 rpm). Grinding was followed by dry screening at 1000, 850, 600, 425, 300, 212, 150, 106, 75, 53, and 38 µm (wet screen). A further 1 kg sample was screened similarly, without grinding. The grind response curves in **Figure 1** show that a grinding time of 6 minutes was suitable to produce the nominated size distribution.

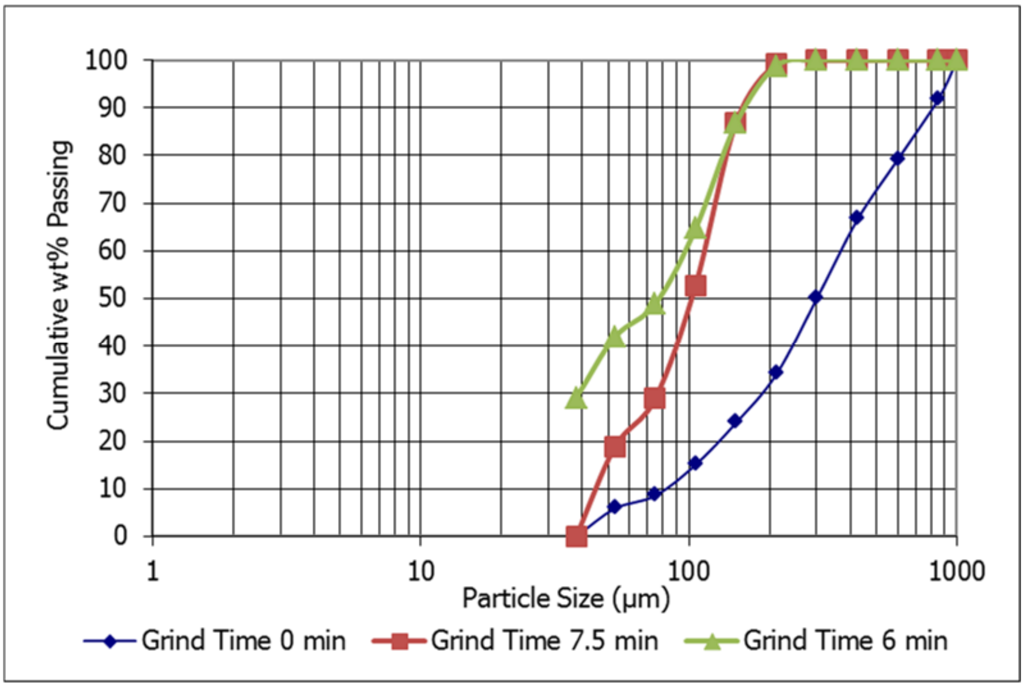

Figure 1 **Grind Response Curves**

The separated fractions from the 6 minute grind were assayed by XRF for size by grade assessment. No oversize fraction was obtained at the 1000, 850, 600, 425 and 300 µm mesh sizes and therefore, only seven size fractions (+212, 150, 106, 75, 53, 38 and -38 µm) were analysed. The size by grade analysis of the composite in **Table 2**, and the elemental distribution in **Table 3**, show that almost half of the uranium (44.3%) and more than half of the vanadium (57.7%) were distributed in the finest size fraction (-38 µm), along with most of the other gangue elements, except for silica. The head composition calculated using the size by grade assays matched closely with the original head assay.

Table 2
Elemental Composition (wt%) of 6 Minute Grind Sample

Size (µm)	Weight %	Al	As	Ba	Ca	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Pb	S	Si	Sr	Th	Ti	U	V	Zn	Zr
+212	1.2	1.63	0.001	0.05	1.13	0.01	0.001	0.45	1.44	0.17	0.02	0.02	0.002	0.013	0.006	0.03	42.2	0.009	0.001	0.05	0.12	0.10	0.001	0.005
-212+150	12.1	1.82	0.001	0.06	1.48	0.02	0.001	0.47	1.62	0.21	0.02	0.03	0.003	0.017	0.006	0.04	41.4	0.012	0.001	0.05	0.13	0.12	0.002	0.007
-150+106	22.1	2.19	0.001	0.06	1.86	0.01	0.001	0.49	1.93	0.26	0.02	0.03	0.003	0.020	0.006	0.05	40.3	0.014	0.001	0.06	0.13	0.14	0.001	0.008
-106+75	15.8	2.57	0.001	0.08	2.33	0.01	0.001	0.62	2.26	0.33	0.03	0.04	0.004	0.024	0.008	0.05	38.9	0.014	0.001	0.08	0.14	0.16	0.001	0.014
-75+53	7.0	2.87	0.001	0.08	2.64	0.02	0.001	0.75	2.46	0.40	0.03	0.05	0.004	0.025	0.007	0.06	38.0	0.015	0.001	0.09	0.14	0.19	0.002	0.019
-53+38	12.9	3.26	0.001	0.10	3.30	0.02	0.001	0.87	2.70	0.49	0.04	0.05	0.006	0.034	0.008	0.08	36.6	0.011	0.001	0.11	0.16	0.23	0.001	0.024
<38	29.1	5.41	0.002	0.13	5.22	0.07	0.002	1.72	2.95	0.95	0.06	0.06	0.025	0.044	0.017	0.14	30.1	0.016	0.002	0.18	0.27	0.53	0.002	0.023
Head	Assay	3.30	<0.001	0.09	3.08	0.02	0.010	0.89	2.37	0.51	0.03	0.04	0.008	0.029	0.011	0.08	36.4	0.01	0.002	0.11	0.18	0.27	<0.001	0.014
	Calculated	3.32	0.001	0.09	3.10	0.03	0.001	0.93	2.37	0.50	0.04	0.04	0.010	0.029	0.010	0.08	36.6	0.01	0.001	0.10	0.18	0.27	0.001	0.016

Table 3
Elemental Distribution (%) of 6 Minute Grind Sample

Size (µm)	Weight %	Al	As	Ba	Ca	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Pb	S	Si	Sr	Th	Ti	U	V	Zn	Zr
+212	1.2	0.6	0.9	0.7	0.4	0.5	0.9	0.6	0.7	0.4	0.6	0.5	0.2	0.5	0.7	0.5	1.4	0.8	0.9	0.6	0.8	0.5	0.8	0.4
-212+150	12.1	6.6	9.3	7.4	5.8	6.1	9.3	6.1	8.2	5.1	5.8	7.2	3.6	7.0	7.4	6.6	13.6	10.4	9.3	6.0	8.9	5.3	16.3	5.3
-150+106	22.1	14.6	17.1	14.7	13.2	7.0	17.1	11.7	18.0	11.3	11.9	16.8	6.6	15.0	13.4	13.7	24.3	22.1	17.1	12.5	16.3	11.2	14.9	11.0
-106+75	15.8	12.2	12.2	13.3	11.9	7.0	12.2	10.4	15.0	10.4	11.2	14.6	6.3	12.9	12.8	10.6	16.7	15.8	12.2	11.5	12.4	9.5	10.6	13.8
-75+53	7.0	6.0	5.4	6.3	6.0	4.2	5.4	5.6	7.2	5.5	6.0	7.6	2.8	6.0	5.0	5.4	7.2	7.5	5.4	5.9	5.6	4.8	9.4	8.3
-53+38	12.9	12.6	10.0	14.2	13.7	8.6	10.0	11.9	14.6	12.5	13.2	15.3	7.7	14.9	10.5	13.0	12.8	10.1	10.0	13.2	11.7	11.1	8.7	19.3
<38	29.1	47.4	45.1	43.4	49.0	66.6	45.1	53.7	36.2	54.7	51.3	38.0	72.7	43.7	50.2	50.2	23.9	33.3	45.1	50.3	44.3	57.7	39.3	41.9

3.3 Diagnostic Leach Tests

Diagnostic leach tests were conducted at low slurry density on pulverised ore to determine the maximum extractions of uranium and vanadium obtainable under ideal conditions. Because of the low slurry density used, dissolution of gangue does not impact on the leach liquor composition, and adsorption or precipitation reactions are avoided. Five diagnostic leach tests (2 wt%, 2 L scale) were conducted for 24 h to determine the extractions under varying conditions (**Table 4**). In order to allow comparison with earlier studies (2011), the first two tests were carried out under the previous "base case" and "severe" conditions. In the remaining three tests, temperature and pH were varied, with the ORP[3] kept constant.

Table 4
Conditions of Diagnostic Leaches

Parameters	Test ID				
	2A	2B	2C	2D	2E
Temperature (°C)	50	60	50	60	80
Time (h)	24	24	24	24	24
Slurry Density (wt %)	2	2	2	2	2
pH	1.8	1.2	1.2	1.5	1.7
ORP (mV)	500	600	550	550	550
Fe^{3+} (g/L)	2	2	2	2	2

At the start of the leach, 1.96 L of Sydney tap water in a 2 L titanium tank was heated to the test temperature using an automatically controlled hot plate. Once at temperature, the pH was reduced to ~2, and $Fe_2(SO_4)_3.7H_2O$ was added to obtain a Fe^{3+} tenor of 2 g/L. The liquor pH was then adjusted to the target value prior to addition of 40 g of the pulverised ore to start the leach. Concentrated sulfuric acid and 30 wt% hydrogen peroxide were used to maintain pH and ORP, respectively. ORP control by oxidant addition was required only for Test 2B. For the remaining tests, the ORP was above the target from the start.

Thief samples were withdrawn after 0, 4, 8, 12 and 24 h for liquor analysis by ICP-OES for Al, Ca, Fe, Mg, Mn, Na, P, S, Si, U, V. Ferrous ion and free acidity were determined in all leach liquor samples by titration. It should be noted that interference of tetravalent V on the oxidimetric determination of Fe^{2+}(by oxidizing Fe^{2+} to Fe^{3+} using Ce^{4+} in 0.5 M H_2SO_4) was overcome in this work by conducting the titration in 5 M H_2SO_4 (**Ref. b**).

After 24 h all solids were recovered, washed, dried and assayed for U by DNA and for Al, As, Ba, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Si, Sr, Th, Ti, V, Zn, and Zr by XRF. The test results are summarised in **Table 5** and the full leach results are presented in **Appendix A**.

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[3] ORP measured relative to a Ag/AgCl reference electrode (3 M KCl)

Table 5
Diagnostic Leach Results

Test	Temp (°C)	pH	Target ORP (mV)	Test ORP* (mV)	Extraction (%)#	
					U	V
2A	50	1.8	500	555	98.9	47.5
2B	60	1.2	600	600	99.5	80.4
2C	50	1.2	550	568	99.3	73.0
2D	60	1.5	550	566	99.2	67.8
2E	80	1.7	550	556	99.2	41.4
2011 Study						
A	50	1.8	600		99.0	47.6
B	60	1.2	600		99.4	80.0

* Average; # Calculated based on solid assay and includes mass loss.

The results in **Table 5** show similarly high uranium extractions, at ≥ 99% in all tests, irrespective of test pH and ORP. However, vanadium extractions varied with the test conditions, with the maximum extraction of 80.4% obtained from the leach conducted at 60 °C, pH 1.2 and 600 mV (Test 2B). At the same pH, but at a lower temperature and ORP, the extraction decreased to 73% (Test 2C), whereas at the same temperature as Test 2B, but at a higher pH and lower ORP, the extraction decreased even further to 67.8% (Test 2D). At a temperature 80 °C and pH 1.7, vanadium extraction was only 41.4% (Test 2E).

These results indicate that the pH has a greater impact on the extraction of vanadium than temperature. However, the effect of ORP on V extraction was not conclusive under the conditions tested.

Also shown in **Table 5** are the results obtained in 2011 from diagnostic leaching of a similar Bigrlyi composite (see **Section 3.1**), with head grades of 2320 ppm U_3O_8 and 0.225% V. As mentioned before, the conditions used in the two tests were the same as for tests 2A and 2B in the current study. Both uranium and vanadium extractions from the previous and the current composites were virtually identical.

The compositions of the final test liquors are summarised in **Table 6**. The initial Fe concentration was approximately 2 g/L in all tests due to the ferric sulfate addition at the start of leaching. However, in the case of test 2E, the total Fe, Fe^{3+} and K concentrations decreased throughout the test, suggesting jarosite formation at pH 1.7 and 80 °C.

Calcium was another key ion in solution, from the dissolution of calcium carbonate, the concentration of which was not impacted by leach conditions. Magnesium concentrations were similar for each test apart from a reduction under the milder conditions in test 2A. Low pH and high temperature (Tests 2B and 2E) resulted in increased dissolution of aluminium and silica.

Table 6
Composition of 24 h Diagnostic Test Liquors (mg/L)

Tests	Al	Ca	Fe	Fe^{3+}	K	Mg	Mn	Na	P	S	Si	U	V
2A	27	629	1950	1800	13	104	10	16	1	2750	29	34	24
2B	97	649	2050	1990	26	145	10	16	5	5300	102	31	41
2C	75	645	2040	1880	22	133	10	16	4	5010	76	32	38
2D	68	645	2030	1860	18	130	10	16	3	4030	73	32	35
2E	84	641	1470	1220	<1	142	11	13	1	4000	105	34	19
	2011 Study												
A	37	587			21	42	14	35	3		100		26
B	108	590			47	82	15	32	5		175		42

The leach liquor compositions for tests A and B from the 2011 study are also presented in **Table 6**. The compositions are generally comparable, with the main differences being the greater Si, Na, Mn, K and Al dissolutions in the 2011 study, which are somewhat off-set by the increased Mg and Ca dissolutions in the current study. On balance, the acid consumptions for both composites are likely to be very similar, and dominated by calcium carbonate dissolution.

Uranium and vanadium tenors of the leach liquors plotted against time for each of the five diagnostic tests (**Figures 2** and **3**) indicate that dissolution of uranium was complete within 12 h whereas vanadium dissolution was continuing at the conclusion of the 24 h leach period, indicating that extended leaching time may favour increased vanadium extraction.

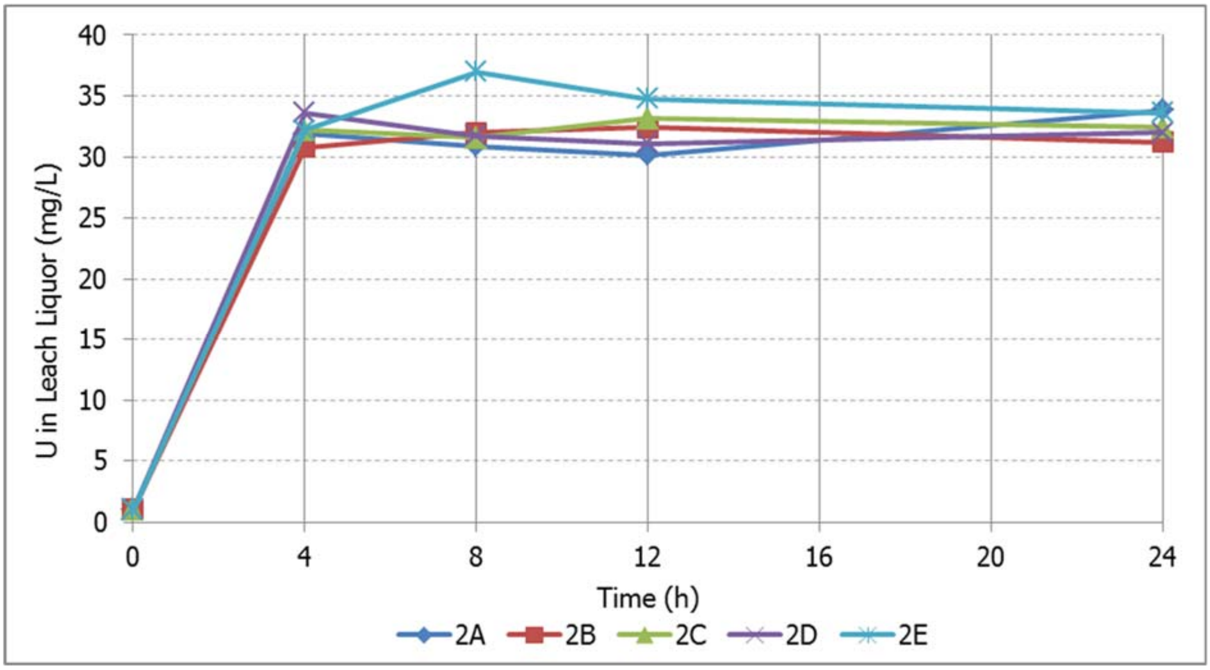

Figure 2 Uranium Concentration vs. Time

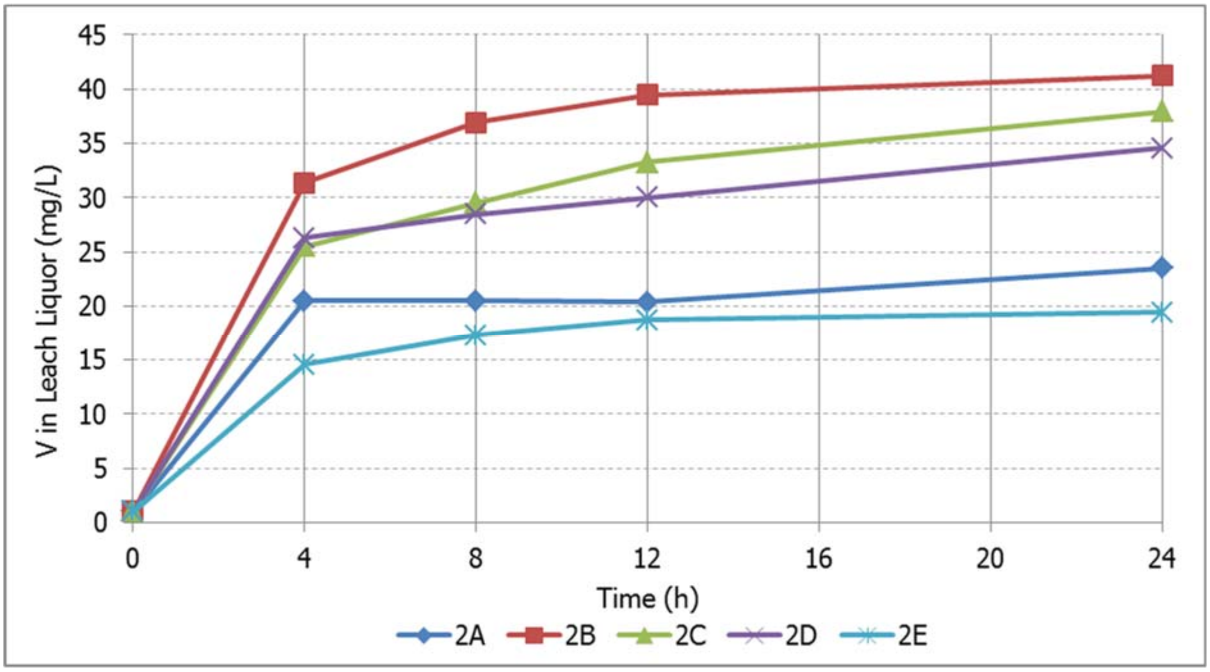

Figure 3 Vanadium Concentration vs. Time

3.4 Conventional Leach Tests

The elemental distribution of the composite head sample (P_{80} 150 µm) showed 94% of the vanadium was present at -150 µm, with ~58% of the vanadium in the -38 µm fraction (see **Section 3.2**). Therefore, P_{80} 150 µm was selected as a suitable particle size for conventional leach tests, with finer grinding unlikely to result in significantly improved vanadium extraction.

Three conventional acid leach tests (50 wt %) were conducted on 1 kg of composite (P_{80} 150 µm) under varying test conditions (**Table 7**). On the basis of the diagnostic test results (see **Section 3.3**), and with the client target of 70% V extraction, the preferred conditions for the first conventional leach were 50 °C, pH 1.2, and 550 mV for 24 h. With an aim of minimising free acidity in the leach liquor, and with it the acid consumption, subsequent tests examined increasing the pH and temperature, but with an extended 48 h leach residence time. As the effect of ORP was not conclusive in the diagnostic tests a 550 mV target was maintained in these tests.

Table 7
Conventional Leach Test Conditions

Test ID	P_{80} (µm)	Slurry (wt%)	Duration (h)	Temp (°C)	pH	ORP (mV)	Fe^{3+} (g/L)
3A	150	50	24	60	1.2	550	2
4A	150	50	48	60	1.4	550	2
4B	150	50	48	70	1.5	550	2

Leach slurries were prepared by grinding 1 kg portions of the composite sample for 6 minutes in Sydney tap water. The slurry was allowed to settle after grinding and adjusted to a slurry density of 50 wt%.

At the start of the leach, the 50 wt% slurry was heated to the test temperature in a 2 L titanium tank using an automatically controlled hot plate. Once at temperature, the pH was reduced to ~2 to start the leach and $Fe_2(SO_4)_3.7H_2O$ was added. The pH was then adjusted to the test target and the ORP was maintained at 550 mV by auto-dosing of concentrated sulfuric acid and 40% sodium permanganate,[4] respectively. Thief samples withdrawn at designated times from each of the tests were centrifuged and the residues were washed with pH water (at leach pH) followed by DI water, and dried at 105 °C. The dried solids were pulverised and assayed by XRF and DNA. The filtrates from the thief slurry filtration were re-filtered through a 0.45 µm filter, immediately diluted 1:10 in 3% nitric acid and subsequently analysed by ICP-OES for the suite of elements as before. Ferrous ion and free acidity were determined in all leach liquor samples by titration. The final leach liquors were also analysed for U by ICP-MS and Cl by ISE. The bulk residues from the three tests were washed and bagged wet.

The results of the three conventional leach results are summarised in **Table 8**, and are compared to the best diagnostic leach test result (2B). Detailed results of the three conventional leach tests are presented in **Appendix B**.

Table 8
Comparison of Diagnostic and Conventional Leach Results

Test ID	Slurry (wt %)	Duration (h)	Temp (°C)	pH	ORP (mV)	Reagent Utilisation (kg/t)			Extraction (%)*	
						Acid Addition	Acid Consumption	Oxidant Addition	U	V
2B	2	24	60	1.2	600	N/A	N/A	N/A	99.5	80.4
3A	50	24	60	1.2	550	140.2	123.4	2.9	98.9	72.7
4A	50	48	60	1.4	550	134.1	123.8	4.2	98.8	68.1
4B	50	48	70	1.5	550	133.2	123.2	4.8	98.7	64.0

* Calculated based on solid assay and includes mass loss.

As was expected, the uranium extraction was high under all the test conditions, at ~99%, whereas the extraction of vanadium varied with the different pH and temperature targets, and in all cases was lower than achieved in the diagnostic tests.

Under the same leach conditions of pH 1.2 and 60 °C, the vanadium extraction from the conventional test decreased to 72.7% from 80.4% in the diagnostic test. This may be partially attributed to particle size (P_{80} 150 µm in the conventional leach compared to <38 µm in the diagnostic leach) but also to possible solution effects at the higher slurry density (50 wt% vs. 2 wt%).

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[4] This oxidant would not be used in practice, but is used in laboratory tests for convenience and ease of control. Other work by ANSTO Minerals has shown that this oxidant will yield the same extraction of uranium as commonly used commercial oxidants, e.g. pyrolusite, sodium chlorate under equivalent conditions.

Increasing the pH to 1.4 (test 4A), but with an extended residence time of 48 h, failed to achieve the same vanadium extraction as achieved at pH 1.2 and 24 h (V 68.1 vs. 72.7%). An increase in temperature, and higher pH again (pH 1.5) resulted in only 64% V extraction.

The final leach liquor compositions for the three conventional leaches are presented in **Table 9**. The liquors show that along with uranium and vanadium, considerable concentrations of aluminium, iron and magnesium were also leached. The high final iron concentration (~6 g/L Fe) shows that the addition of 2 g/L Fe^{3+} at the start of the leach was not required. The manganese in solution is a result of the oxidant (40% $NaMnO_4$), and therefore the higher manganese concentration in the 48 h tests reflects the higher oxidant additions in these tests.

Table 9
Final Composition of Conventional Test Liquors (mg/L)

Leach ID	Al	Ca	Fe	Fe^{3+}	K	Mg	Mn	Na	P	S	Si	U	V	Cl
3A	3872	793	6264	4061	582	2939	1467	564	198	23118	487	1541	1828	157
4A	3330	775	5172	4818	391	3024	1806	733	150	19993	395	1751	1835	268
4B	3607	809	3096	2480	30	3264	1912	780	124	22011	352	1717	1803	256

The leach liquor composition plotted against time for test 3A (**Figure 4**) confirms the dissolution of uranium was complete in <12 h, whereas vanadium, and other gangue elements, continued to leach for the full 24 hours. Dissolution of the other gangue elements may have a negative impact on vanadium dissolution, thus reducing the extraction compared to the corresponding dilute leach.

Similar plots for tests 4A and 4B (**Figure 5** and **Figure** 6) showed only minor improvement in vanadium extraction between 24 and 48 hours, indicating that acidity remains the key driver for improved vanadium extraction. The decreasing potassium and ferric concentrations, particularly evident after 12 h for test 4B at 70 °C and pH 1.5, show that jarosite was forming under these conditions.

Plots of acid consumption versus uranium and vanadium extractions confirm the correlation between acid consumption and vanadium extraction (**Figures 7**, **8** and **9**), with the extended residence time in tests 4A and 4B producing similar acid consumptions to that at 24 h despite the lower acid addition. The higher oxidant consumption in the 48 h tests will have contributed to the higher acid consumption.

It is important to note that the majority of the acid consumption occurs immediately due to dissolution of the carbonate (calcite and dolomite) in the ore.

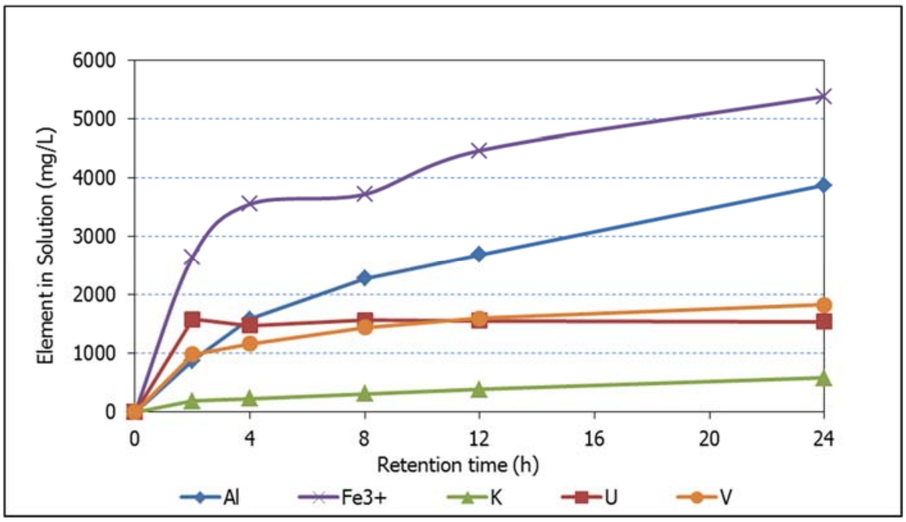

Figure 4 Leach Liquor Composition vs. Time (3A: pH 1.2, 60 °C, 550 mV, 24 h)

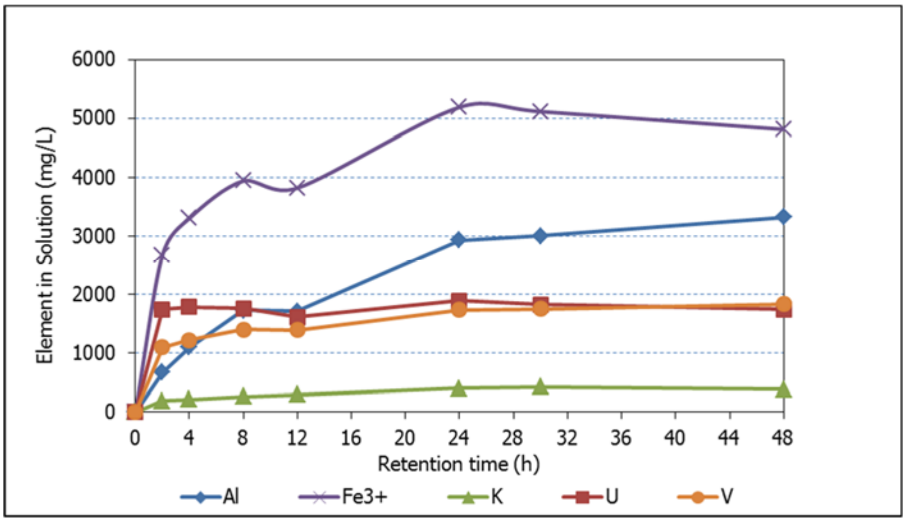

Figure 5 Leach Liquor Composition vs. Time (4A: pH 1.4, 60 °C, 550 mV, 48 h)

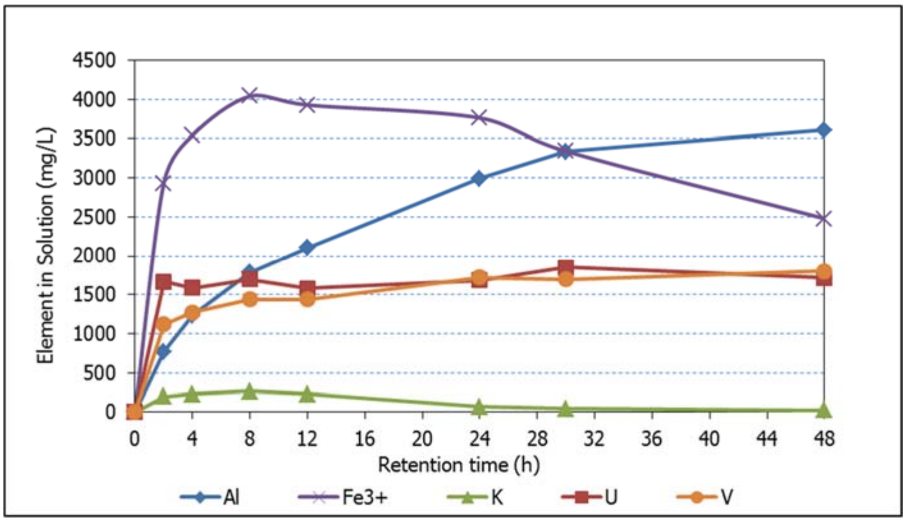

Figure 6 Leach Liquor Composition vs. Time (4B: pH 1.5, 70 °C, 550 mV, 48 h)

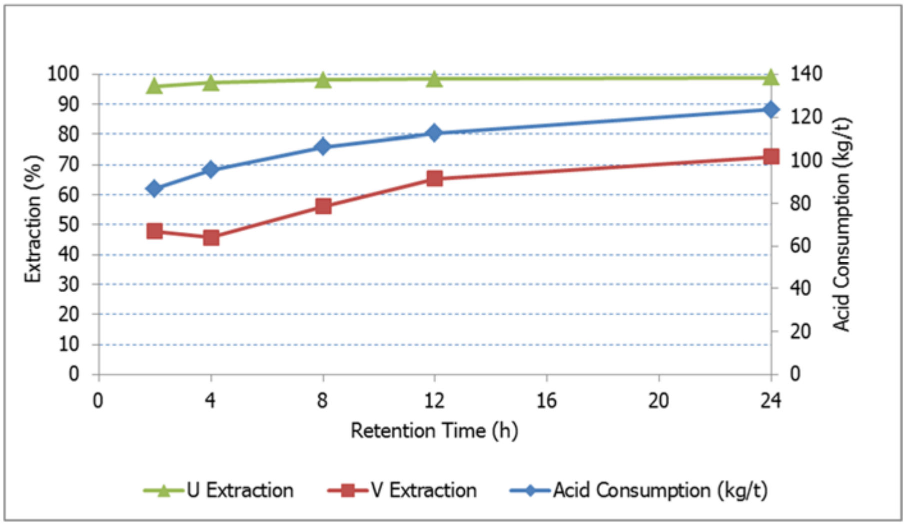

Figure 7 Extractions, Acid Consumption vs. Time (3A: pH 1.2, 60 °C, 24 h)

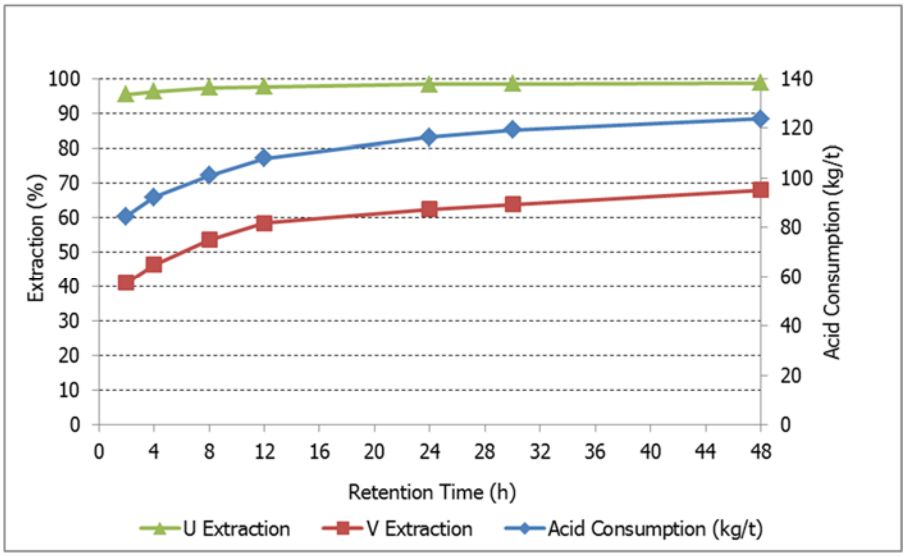

Figure 8 Extractions, Acid Consumption vs. Time (4A: pH 1.4, 60 °C, 48 h)

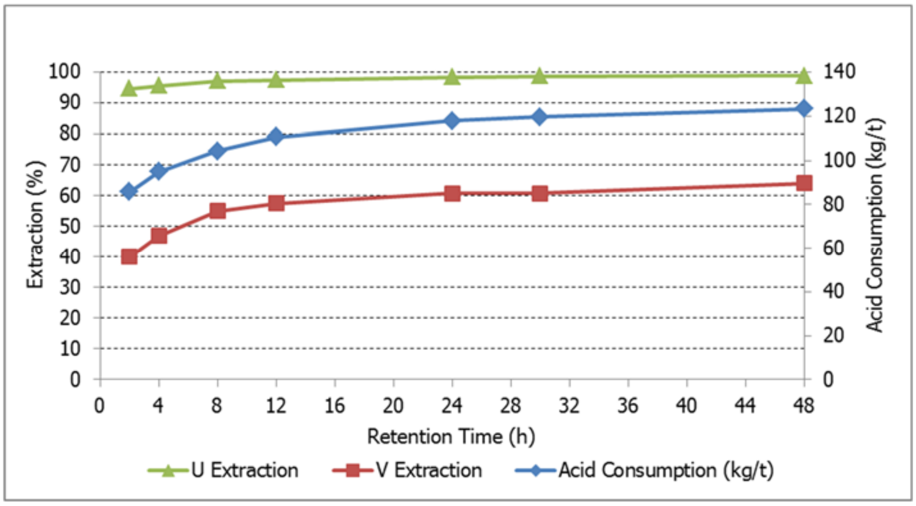

Figure 9 Extractions, Acid Consumption vs. Time (4B: pH 1.5, 70 °C, 48 h)

3.5 Size by Grade Analysis of Leach Residue

Size by grade analysis was completed on the bulk leach residue from Test 3A, which had produced the highest vanadium extraction of 72.7%. Dry screening of the residue was completed using 1000, 850, 600, 425, 300, 212, 150, 106, 75, 53, and 38 µm (wet screen) meshes. The particle size distribution of the leach residue is compared to the P_{80} 150 µm head sample in **Figure 10** and shows a very slight increase in the amount of fines in the leach residue.

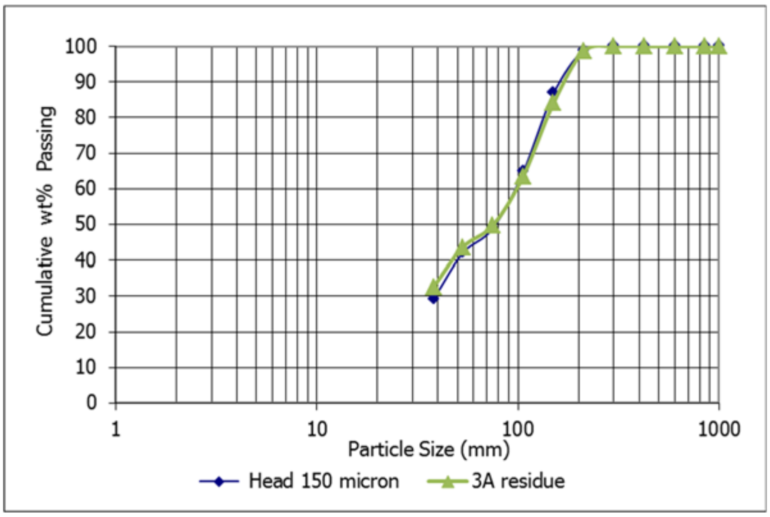

Figure 10 Particle Size Distribution Before and After 24 h Leaching

The size fractions obtained from the 3A leach test residue were analysed by XRF and the results are presented in **Table 10**, with the elemental distributions shown in **Table 11**. The results confirm a small increase in the amount of the finest fraction following leaching, and a slight increase in the proportion of vanadium reporting to the -38 µm fraction. The high calcium and sulfur content in the fines is a result of gypsum precipitation due to calcite dissolution from the ore.

The uranium and vanadium extractions were also calculated for each size fraction (**Table 12**). Uranium recovery was high in all fractions whereas the vanadium extraction was reduced in the -38 µm fraction.

Table 12
U and V Extractions by Fraction

Size (µm)	Extraction (%)	
	U	V
+212	98.0	77.2
-212+150	99.1	69.1
-150+106	98.6	73.7
-106+75	98.8	75.0
-75+53	98.8	74.7
-53+38	98.9	77.6
<38	98.4	67.8

Table 10
Elemental Composition (wt%) of 3A Leach Residue

Size (µm)	Weight %	Al	As	Ba	Ca	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Pb	S	Si	Sr	Th	Ti	U	V	Zn	Zr
+212	1.4	1.25	0.001	0.04	0.06	0.02	0.001	0.26	1.30	0.03	0.001	0.01	0.002	0.004	0.001	0.06	44.1	0.014	0.001	0.04	0.002	0.020	0.007	0.010
-212+150	14.5	1.52	0.001	0.05	0.07	0.01	0.001	0.23	1.60	0.05	0.001	0.02	0.002	0.004	0.003	0.08	43.5	0.014	0.002	0.04	0.001	0.030	0.001	0.010
-150+106	20.6	1.92	0.001	0.05	0.12	0.01	0.002	0.26	2.00	0.07	0.001	0.02	0.003	0.016	0.003	0.12	42.8	0.016	0.002	0.06	0.002	0.038	0.001	0.010
-106+75	13.7	2.35	0.001	0.08	0.16	0.01	0.001	0.34	2.40	0.09	0.002	0.03	0.002	0.007	0.002	0.15	41.9	0.018	0.002	0.08	0.002	0.046	0.003	0.018
-75+53	6.2	2.65	0.001	0.08	0.18	0.02	0.001	0.44	2.67	0.12	0.003	0.04	0.004	0.007	0.005	0.18	41.2	0.014	0.001	0.09	0.002	0.053	0.001	0.024
-53+38	11.1	2.98	0.001	0.10	0.14	0.02	0.004	0.48	2.98	0.14	0.005	0.05	0.004	0.009	0.005	0.16	40.6	0.016	0.002	0.11	0.002	0.060	0.001	0.028
<38	32.5	4.54	0.002	0.12	7.44	0.05	0.002	0.86	2.63	0.36	0.004	0.04	0.017	0.009	0.019	5.83	26.0	0.013	0.003	0.20	0.004	0.152	0.001	0.021
3A Residue	Assay	2.98	0.001	0.09	1.42	0.02	<0.001	0.45	2.46	0.19	0.002	0.05	0.007	0.009	0.007	1.13	39.0	0.015	0.002	0.11	0.003	0.076	<0.001	0.018
	Calculated	2.93	0.001	0.08	2.51	0.02	0.002	0.51	2.34	0.17	0.003	0.03	0.007	0.007	0.008	1.98	37.0	0.015	0.002	0.11	0.003	0.078	0.001	0.018

Table 11
Elemental Distribution (%) of 3A Leach Residue

Size (µm)	Weight %	Al	As	Ba	Ca	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Pb	S	Si	Sr	Th	Ti	U	V	Zn	Zr
+212	1.4	0.6	1.1	0.6	0.0	1.2	0.8	0.7	0.8	0.3	0.5	0.6	0.4	0.8	0.2	0.0	1.7	1.3	0.6	0.5	1.1	0.4	7.3	0.8
-212+150	14.5	7.6	11.0	8.1	0.4	7.6	7.8	6.8	9.9	4.0	5.4	7.3	3.9	8.1	5.2	0.6	17.1	13.7	12.9	5.3	5.8	5.6	10.7	8.3
-150+106	20.6	13.5	15.6	13.3	1.0	8.3	22.1	10.9	17.6	8.2	7.7	15.6	8.3	17.2	7.4	1.3	23.9	22.2	18.3	11.4	16.5	10.0	15.2	11.8
-106+75	13.7	11.0	10.3	12.4	0.9	6.6	7.3	9.3	14.0	7.3	10.2	14.2	3.7	13.3	3.3	1.0	15.5	16.6	12.2	9.7	10.9	8.0	30.2	14.0
-75+53	6.2	5.6	4.6	6.0	0.4	5.2	3.3	5.5	7.1	4.2	6.9	8.1	3.3	6.0	3.7	0.5	6.9	5.8	2.7	4.9	4.9	4.2	4.5	8.4
-53+38	11.1	11.3	8.3	12.7	0.6	7.1	23.7	10.6	14.1	8.8	20.6	17.4	6.0	13.8	6.6	0.9	12.2	11.9	9.8	10.6	8.8	8.5	8.1	17.7
<38	32.5	50.5	49.1	46.9	96.6	64.0	34.9	56.2	36.5	67.2	48.6	36.8	74.4	40.8	73.7	95.6	22.9	28.5	43.4	57.8	52.0	63.3	24.0	39.0

4 Conclusions and Recommendations

The conclusions from the test work are as follows:

- The composition of the current composite prepared from a 50:50 mixture of AN4 C/D and AN15 C/D was similar to the composition of the composite prepared from three Bigrlyi composites (AN4 B/C, AN4 C/D and AN15 C/D) in 2010-2011;
- Size by grade analysis of the head sample showed that almost 44.3% of uranium and 57.7% vanadium was contained in the finest size fraction (-38 µm) of the new composite sample (ground to P_{80} 150 µm);
- Diagnostic leach tests yielded uranium extractions ≥ 99%, irrespective of test conditions;
- Vanadium extractions varied with the diagnostic test conditions, with the maximum vanadium extraction of 80.4% obtained at 60 °C, pH 1.2 and 600 mV for 24 h;
- Conventional leach tests produced similarly high uranium extractions (99%) as found in the diagnostic tests, but the vanadium extraction was less (maximum 72.7% at 60 °C, pH 1.2 and 550 mV for 24 h);
- Extended residence time (48 h) at reduced acidity (higher pH) failed to improve the vanadium extraction, despite a similar acid consumption; and
- Vanadium extraction was most responsive to leach acidity, and extraction improved as the acidity increased.

The following recommendations are made for future test work:

- With acidity being identified as the key driver for vanadium extraction, improved vanadium extraction will only be achieved by leaching at lower pH. Leach testing at lower pH and shorter residence time should be examined, with the goal of increasing vanadium extraction and reducing overall acid consumption by limiting excess gangue dissolution;
- There was a reasonable difference between the vanadium extractions achieved in the diagnostic leaches and the conventional leaches, under similar conditions. The potential impact of solution composition effects on vanadium extraction should be examined; and
- The impact of ORP on the extraction of vanadium was not tested in this study and should be confirmed in future work.

5 References

a. M. Baker, D. Collier, R. Ring, "Bigrlyi Uranium/Vanadium Project - Assessment of Acid/Alkaline Leaching", ANSTO/C1159, report to Energy Metals, issued 2011.

b. GH. Walden, LP. Hammett, SM. Edmonds, "Direct Determination of Iron in Presence of Vanadium", J. Amer. chem. Soc. 56, 350 (1934), p350-p353.

Appendix A

Diagnostic Leach Results

BV-2A		**Leach Studies on Bigrlyi deposit-V recovery**			**Oxidant:**	30% Hydrogen Peroxide	**OES:**	1901288
Diagnostic Leach		**Solids:**	40 g	AN4+AN15 composite(latest)	**Leach Duration:**	24 h		
P80 Pulverized microns		**Leach Liquor Matrix:**	1960 g	Sydney Tap Water	**Temperature:**	50 °C	**XRF:**	1901300
pH	1.8				**ORP:**	500 mV	**DNA:**	1901300
		Slurry:	2%		**pH:**	1.8	**Date:**	9/07/2019
Fe in feed:	2 g/L	**SG**	1.01	Initial				

Sample ID	Leach Conditions																	
	Time (h)	Temp. (°C)	pH	ORP (mV)	Acid Addition (kg/t)	Free Acidity (g/L H_2SO_4)	Acid Cons. (kg/t)	Oxidant Addition (kg/t)	U_3O_8 (ppm)	U Extraction (%)	V (wt%)	V Extraction (%)	Uranium Mass Balance			Vanadium Mass Balance		
													Solid (g)	Liquor (g)	Total (g)	Solid (g)	Liquor (g)	Total (g)
Feed									2007		0.27		0.068	0.00	0.070	0.106	0.00	0.108
BV-2A-4 h	4	50.0	1.81	564		1.4												
BV-2A-8 h	8	50.0	1.82	556		1.5												
BV-2A-12 h	12	50.0	1.80	553		1.7												
BV-2A-24 h	24	50.0	1.82	545		2.0			26	98.9	0.16	47.5	0.001	0.07	0.067	0.056	0.05	0.102
													Accountability:		**95.2%**	**Accountability:**		**93.9%**

Sample ID	**Solution Concentration (mg/L)**																								
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe^{3+}**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U**	**V**	**Zn**	**Zr**
BV-2A- 0 h	1			15				1931	1931	3	74	4		15		1		2090	7				1	1		
BV-2A-4 h	16			609				1941	1872	12	100	10		16		1		2730	16				32	20		
BV-2A-8 h	18			602				1892	1792	12	96	10		16		1		2726	17				31	20		
BV-2A-12 h	20			627				1950	1836	12	94	9		16		1		2730	19				30	20		
BV-2A-24 h	27			629				1949	1804	13	104	10		16		1		2745	29				34	24		

Sample ID	**Solid Concentrations (% except for U_3O_8 - ppm)**																								
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe3+**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U3O8**	**V**	**Zn**	**Zr**
AN4+AN15 composite	3.30	0.001	0.09	3.08	0.001	0.02	0.01	0.89		2.37	0.51	0.03	0.00	0.04	0.01	0.03	0.01	0.08	36.39	0.01	0.002	0.11	2007	0.27	0.001	0.01
BV-2A-4 h																										
BV-2A-8 h																										
BV-2A-12 h																										
BV-2A-24 h	3.34	0.001	0.09	0.001	0.002	0.018	0.001	0.78		2.49	0.35	0.003	0.001	0.04	0.002	0.02	0.01	0.06	40.36	0.01	0.002	0.15	26	0.16	0.001	0.02

BV-2B			**Leach Studies on Bigrlyi deposit-V recovery**		**Oxidant:**	30% Hydrogen Peroxide	**OES:**	1901288
Diagnostic Leach		**Solids:**	40 g	AN4+AN15 composite(latest)	**Leach Duration:**	24 h		
P80 Pulverized microns		**Leach Liquor Matrix:**	1960 g	Sydney Tap Water	**Temperature:**	60 ºC	**XRF:**	1901300
pH	1.2				**ORP:**	600 mV	**DNA:**	1901300
		Slurry:	2%		**pH:**	1.2	**Date:**	9/07/2019
Fe in feed:	2 g/L	**SG**	1.01	Initial				

Sample ID	Leach Conditions																	
	Time	Temp.	pH	ORP	Acid Addition	Free Acidity	Acid Cons.	Oxidant Addition	U_3O_8	U Extraction	V	V Extraction	Uranium Mass Balance			Vanadium Mass Balance		
	(h)	(°C)		(mV)	(kg/t)	(g/L H_2SO_4)	(kg/t)	(kg/t)	(ppm)	(%)	(wt%)	(%)	Solid (g)	Liquor (g)	Total (g)	Solid (g)	Liquor (g)	Total (g)
Feed									2007		0.27		0.068	0.00	0.070	0.106	0.00	0.108
BV-2B-4 h	4	60.1	1.21	599		8.3												
BV-2B-8 h	8	60.0	1.22	603		8.4												
BV-2B-12 h	12	60.0	1.20	604		8.9												
BV-2B-24 h	24	60.0	1.22	599		9.1			12	99.5	0.06	80.4	0.000	0.06	0.061	0.021	0.08	0.101
														Accountability:	**86.9%**		**Accountability:**	**93.6%**

Sample ID	**Solution Concentration (mg/L)**																							
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe^{3+}**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U**	**V**	**Zn**	**Zr**
BV-2B- 0 h	1			15				1868	1868	2	79	4		15		1		3783	5				1	1		
BV-2B-4 h	50			627				1986	1926	16	122	10		16		4		4981	43				31	31		
BV-2B-8 h	70			639				2029	1958	21	135	10		16		4		5044	65				32	37		
BV-2B-12 h	81			617				1958	1893	27	145	10		16		4		5172	80				32	39		
BV-2B-24 h	97			649				2052	1986	26	145	10		16		5		5297	102				31	41		

Sample ID	**Solid Concentrations (% except for U_3O_8 - ppm)**																								
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe3+**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U3O8**	**V**	**Zn**	**Zr**
AN4+AN15 composite	3.30	0.001	0.09	3.08	0.001	0.02	0.01	0.89		2.37	0.51	0.03	0.00	0.04	0.01	0.03	0.01	0.08	36.39	0.01	0.002	0.11	2007	0.27	0.001	0.01
BV-2B-4 h																										
BV-2B-8 h																										
BV-2B-12 h																										
BV-2B-24 h	3.13	0.001	0.09	0.001	0.002	0.018	0.001	0.38		2.56	0.16	0.002	0.001	0.04	0.007	0.01	0.01	0.04	41.19	0.01	0.002	0.13	12	0.06	0.001	0.02

BV-2C			**Leach Studies on Bigrlyi deposit-V recovery**		**Oxidant:**	30% Hydrogen Peroxide	**OES:**	1901288
Diagnostic Leach		**Solids:**	40 g	AN4+AN15 composite(latest)	**Leach Duration:**	24 h		
P80 Pulverized microns		**Leach Liquor Matrix:**	1960 g	Sydney Tap Water	**Temperature:**	50 ºC	**XRF:**	1901300
pH	1.2				**ORP:**	550 mV	**DNA:**	1901300
		Slurry:	2%		**pH:**	1.2	**Date:**	9/07/2019
Fe in feed:	2 g/L	**SG**	1.01	Initial				

Sample ID	Leach Conditions																	
	Time (h)	Temp. (°C)	pH	ORP (mV)	Acid Addition (kg/t)	Free Acidity (g/L H_2SO_4)	Acid Cons. (kg/t)	Oxidant Addition (kg/t)	U_3O_8 (ppm)	U Extraction (%)	V (wt%)	V Extraction (%)	Uranium Mass Balance			Vanadium Mass Balance		
													Solid (g)	Liquor (g)	Total (g)	Solid (g)	Liquor (g)	Total (g)
Feed									2007		0.27		0.068	0.00	0.070	0.106	0.00	0.108
BV-2C-4 h	4	50.0	1.21	578		7.7												
BV-2C-8 h	8	50.0	1.22	570		7.3												
BV-2C-12 h	12	49.9	1.20	566		8.5												
BV-2C-24 h	24	49.9	1.20	559		8.3			15	99.3	0.08	73.0	0.000	0.06	0.063	0.029	0.07	0.103
														Accountability:	**90.4%**		**Accountability:**	**94.7%**

Sample ID	**Solution Concentration (mg/L)**																									
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe^{3+}**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U**	**V**	**Zn**	**Zr**
BV-2C- 0 h	1			15				1893	1890	2	72	4		15		1		3849	5				1	1		
BV-2C-4 h	32			628				1977	1899	15	104	10		16		4		4813	26				32	26		
BV-2C-8 h	46			635				1975	1866	17	113	10		16		4		4853	39				32	30		
BV-2C-12 h	56			635				1979	1848	17	123	10		16		4		5101	52				33	33		
BV-2C-24 h	75			645				2038	1877	22	133	10		16		4		5014	76				32	38		

Sample ID	**Solid Concentrations (% except for U_3O_8 - ppm)**																									
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe3+**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U3O8**	**V**	**Zn**	**Zr**
AN4+AN15 composite	3.30	0.001	0.09	3.08	0.001	0.02	0.01	0.89		2.37	0.51	0.03	0.00	0.04	0.01	0.03	0.01	0.08	36.39	0.01	0.002	0.11	2007	0.27	0.001	0.01
BV-2C-4 h																										
BV-2C-8 h																										
BV-2C-12 h																										
BV-2C-24 h	3.15	0.001	0.10	0.001	0.002	0.018	0.001	0.46		2.48	0.21	0.003	0.001	0.04	0.002	0.01	0.01	0.05	41.10	0.01	0.002	0.13	15	0.08	0.001	0.03

BV-2D			**Leach Studies on Bigrlyi deposit-V recovery**		**Oxidant:**	30% Hydrogen Peroxide	**OES:**	1901288
Diagnostic Leach		**Solids:**	40 g	AN4+AN15 composite(latest)	**Leach Duration:**	24 h		
P80 Pulverized microns		**Leach Liquor Matrix:**	1960 g	Sydney Tap Water	**Temperature:**	60 ºC	**XRF:**	1901300
pH	1.5				**ORP:**	550 mV	**DNA:**	1901300
		Slurry:	2%		**pH:**	1.5	**Date:**	9/07/2019
Fe in feed:	2 g/L	**SG**	1.01	Initial				

Sample ID	Leach Conditions																
	Time (h)	Temp. (°C)	pH	ORP (mV)	Acid Addition (kg/t)	Free Acidity (g/L H_2SO_4)	Acid Cons. (kg/t)	Oxidant Addition (kg/t)	U_3O_8 (ppm)	U Extraction (%)	V (wt%)	V Extraction (%)	Uranium Mass Balance			Vanadium Mass Balance		
													Solid (g)	Liquor (g)	Total (g)	Solid (g)	Liquor (g)	Total (g)
Feed									2007		0.27		0.068	0.00	0.070	0.106	0.00	0.108
BV-2D-4 h	4	59.9	1.51	575		4.1												
BV-2D-8 h	8	60.0	1.52	567		4.2												
BV-2D-12 h	12	60.0	1.50	564		4.5												
BV-2D-24 h	24	60.0	1.51	559		4.6			17	99.2	0.10	67.8	0.001	0.06	0.063	0.034	0.07	0.102
														Accountability:	**89.5%**		**Accountability:**	**93.9%**

Sample ID	**Solution Concentration (mg/L)**																									
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe^{3+}**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U**	**V**	**Zn**	**Zr**
BV-2D- 0 h	1			16				1887	1885	2	80	4		15		1		2595	5				1	1		
BV-2D-4 h	31			594				1931	1852	13	116	10		16		2		3592	28				34	26		
BV-2D-8 h	42			630				1994	1864	15	116	10		15		2		3630	40				32	28		
BV-2D-12 h	51			630				1997	1844	15	118	10		15		2		3877	50				31	30		
BV-2D-24 h	68			645				2027	1861	18	130	10		16		3		4026	73				32	35		

Sample ID	**Solid Concentrations (% except for U_3O_8 - ppm)**																									
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe3+**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U3O8**	**V**	**Zn**	**Zr**
AN4+AN15 composite	3.30	0.001	0.09	3.08	0.001	0.02	0.01	0.89		2.37	0.51	0.03	0.00	0.04	0.01	0.03	0.01	0.08	36.39	0.01	0.002	0.11	2007	0.27	0.001	0.01
BV-2D-4 h																										
BV-2D-8 h																										
BV-2D-12 h																										
BV-2D-24 h	3.22	0.001	0.10	0.001	0.002	0.014	0.01	0.52		2.55	0.23	0.002	0.001	0.04	0.002	0.01	0.01	0.04	40.83	0.01	0.002	0.14	17	0.10	0.001	0.02

BV-2E			**Leach Studies on Bigrlyi deposit-V recovery**	**Oxidant:**	30% Hydrogen Peroxide	**OES:**	1901288
Diagnostic Leach		**Solids:**	40 g AN4+AN15 composite(latest)	**Leach Duration:**	24 h		
P80 Pulverized microns		**Leach Liquor Matrix:**	1960 g Sydney Tap Water	**Temperature:**	80 ºC	**XRF:**	1901300
pH	1.7			**ORP:**	550 mV	**DNA:**	1901300
		Slurry:	2%	**pH:**	1.7	**Date:**	9/07/2019
Fe in feed:	2 g/L	**SG**	1.01 Initial				

Sample ID	Leach Conditions																	
	Time (h)	Temp. (°C)	pH	ORP (mV)	Acid Addition (kg/t)	Free Acidity (g/L H_2SO_4)	Acid Cons. (kg/t)	Oxidant Addition (kg/t)	U_3O_8 (ppm)	U Extraction (%)	V (wt%)	V Extraction (%)	Uranium Mass Balance Solid (g)	Liquor (g)	Total (g)	Vanadium Mass Balance Solid (g)	Liquor (g)	Total (g)
Feed									2007		0.27		0.068	0.00	0.070	0.106	0.00	0.108
BV-2E-4 h	4	80.0	1.72	565		2.9												
BV-2E-8 h	8	80.0	1.73	557		2.6												
BV-2E-12 h	12	80.0	1.72	554		3.1												
BV-2E-24 h	24	79.8	1.71	549		3.4			17	99.2	0.17	41.4	0.001	0.07	0.066	0.062	0.04	0.100
														Accountability:	**94.1%**		**Accountability:**	**92.5%**

Sample ID	**Solution Concentration (mg/L)**																								
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe^{3+}**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U**	**V**	**Zn**	**Zr**
BV-2E- 0 h	1			15				1928	1923	1	79	4		15		1		2395	5				1	1		
BV-2E-4 h	42			660				1647	1477	9	122	10		16		1		3064	45				32	15		
BV-2E-8 h	59			648				1576	1388	1	139	11		15		1		2961	72				37	17		
BV-2E-12 h	68			650				1555	1344	1	140	11		14		1		3034	83				35	19		
BV-2E-24 h	84			641				1468	1224	1	142	11		13		1		3099	105				34	19		

Sample ID	**Solid Concentrations (% except for U_3O_8 - ppm)**																								
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe3+**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U3O8**	**V**	**Zn**	**Zr**
AN4+AN15 composite	3.30	0.001	0.09	3.08	0.001	0.02	0.01	0.89		2.37	0.51	0.03	0.00	0.04	0.01	0.03	0.01	0.08	36.39	0.01	0.002	0.11	2007	0.27	0.001	0.01
BV-2E-4 h																										
BV-2E-8 h																										
BV-2E-12 h																										
BV-2E-24 h	2.94	0.001	0.09	0.001	0.001	0.014	0.001	3.02		2.48	0.19	0.002	0.003	0.06	0.002	0.02	0.01	0.60	38.51	0.01	0.001	0.17	17	0.17	0.001	0.02

Appendix B

Conventional Leach Results

BV-3A			**Leach Studies on Bigrlyi deposit-V recovery**		**Oxidant:**	40% Sodium Permanganate	**OES:**	1901421
Conventional Leach		**Solids:**	1000 g	AN4+AN15 composite(latest)	**Leach Duration:**	24 h		
P80 150 mm microns		**Leach Liquor Matrix:**	1000 g	Sydney Tap Water	**Temperature:**	60 ºC	**XRF:**	1901426
pH	1.2				**ORP:**	550 mV	**DNA:**	1901426
		Slurry:	50%		**pH:**	1.2	**Date:**	25/07/2019
Fe in feed:	2 g/L	**SG**	1.00	Initial				

Sample ID	Leach Conditions																	
	Time (h)	Temp. (°C)	pH	ORP (mV)	Acid Addition (kg/t)	Free Acidity (g/L H_2SO_4)	Acid Cons. (kg/t)	Oxidant Addition (kg/t)	U_3O_8 (ppm)	U Extraction (%)	V (wt%)	V Extraction (%)	Uranium Mass Balance Solid (g)	Uranium Mass Balance Liquor (g)	Uranium Mass Balance Total (g)	Vanadium Mass Balance Solid (g)	Vanadium Mass Balance Liquor (g)	Vanadium Mass Balance Total (g)
Feed									2007		0.27		1.702	0.001	1.703	2.660	0.00	2.661
BV-3A-2 h	2	60.0	1.20	552	99.1	12.3	86.7	0.74	82	95.9	0.15	45.5						
BV-3A-4 h	4	59.9	1.21	553	108.5	12.9	95.6	1.26	60	97.0	0.15	43.2						
BV-3A-8 h	8	59.9	1.21	552	119.8	13.5	106.3	1.81	40	98.0	0.12	54.1						
BV-3A-12 h	12	60.0	1.20	553	128.0	15.4	112.5	2.05	31	98.4	0.10	63.9						
BV-3A-24 h	24	60.0	1.18	567	140.2	16.8	123.4	2.88	24	98.8	0.08	71.4	0.019	1.67	1.690	0.727	1.98	2.708
														Accountability:	**99.2%**		**Accountability:**	**101.8%**

Sample ID	**Solution Concentration (mg/L)**																							
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe^{3+}**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U**	**V**	**Zn**	**Zr**	**Cl**
Sydney Tap Water	1			13				1	0	1	2	1		13		1		3	5				1	1			
BV-3A-2 h	883			800				3288	2640	194	1241	543		157		103		10442	431				1587	989			
BV-3A-4 h	1582			774				4080	3553	237	1607	759		231		128		13485	533				1479	1169			
BV-3A-8 h	2276			766				4715	3722	314	2063	961		324		144		16468	523				1564	1444			
BV-3A-12 h	2686			782				5188	4468	390	2442	1103		399		168		19149	518				1559	1598			
BV-3A-24 h	3872			793				6264	5383	582	2939	1467		564		198		23118	487				1541	1828			157

Sample ID	**Solid Concentrations (% except for U_3O_8 - ppm)**																							
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe3+**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U3O8**	**V**	**Zn**	**Zr**
AN4+AN15 composite(	3.30	<0.001	0.094	3.08	0.001	0.02	0.010	0.89		2.37	0.51	0.033	<0.001	0.039	0.008	0.029	0.011	0.08	36.39	0.01	0.002	0.11	2007	0.27	<0.001	0.0140
BV-3A-2 h	3.13	0.001	0.089	0.73	0.001	0.02	<0.001	0.68		2.47	0.33	0.005	0.01	0.041	0.009	0.014	0.006	0.48	39.92	0.01	0.001	0.10	82	0.15	<0.001	0.0140
BV-3A-4 h	3.57	0.001	0.098	0.41	<0.001	0.03	0.001	0.78		2.64	0.37	0.006	<0.001	0.042	0.010	0.013	0.007	0.30	39.67	0.01	0.002	0.12	60	0.15	0.0010	0.0170
BV-3A-8 h	3.37	0.001	0.091	0.16	0.002	0.03	<0.001	0.64		2.59	0.30	0.005	<0.001	0.041	0.009	0.012	0.008	0.13	40.35	0.01	0.001	0.12	40	0.12	<0.001	0.0200
BV-3A-12 h	3.12	<0.001	0.093	0.07	0.002	0.02	<0.001	0.53		2.54	0.24	0.004	<0.001	0.045	0.009	0.010	0.008	0.08	41.07	0.01	0.002	0.11	31	0.10	<0.001	0.0180
BV-3A-24 h	2.98	0.001	0.091	1.42	0.001	0.02	<0.001	0.45		2.46	0.19	0.002	0.01	0.048	0.007	0.009	0.007	1.13	39.03	0.02	0.002	0.11	24	0.08	<0.001	0.0180

BV-4A		**Leach Studies on Bigrlyi deposit-V recovery**		**Oxidant:** 40% Sodium Permanganate	**OES:** 1901546
Conventional Leach		**Solids:** 1000 g	AN4+AN15 composite(latest)	**Leach Duration:** 48 h	
P80 150 mm microns		**Leach Liquor Matrix:** 1000 g	Sydney Tap Water	**Temperature:** 60 ºC	**XRF:** 1901565
pH	1.4			**ORP:** 550 mV	**DNA:** 1901565
		Slurry: 50%		**pH:** 1.4	**Date:** 14/08/2019
Fe in feed:	2 g/L	**SG** 1.00	Initial		

Sample ID	Leach Conditions																	
	Time (h)	Temp. (°C)	pH	ORP (mV)	Acid Addition (kg/t)	Free Acidity (g/L H_2SO_4)	Acid Cons. (kg/t)	Oxidant Addition (kg/t)	U_3O_8 (ppm)	U Extraction (%)	V (wt%)	V Extraction (%)	Uranium Mass Balance			Vanadium Mass Balance		
													Solid (g)	Liquor (g)	Total (g)	Solid (g)	Liquor (g)	Total (g)
Feed									2007		0.27		1.702	0.001	1.703	2.660	0.00	2.661
BV-4A-2 h	2	59.9	1.41	549	92.4	7.9	84.5	1.07	97	95.4	0.17	41.1						
BV-4A-4 h	4	60.0	1.40	559	101.3	9.0	92.2	1.60	78	96.3	0.15	46.4						
BV-4A-8 h	8	60.0	1.42	553	110.7	9.7	101.0	2.22	54	97.4	0.13	53.5						
BV-4A-12 h	12	60.0	1.42	556	116.4	8.4	108.0	2.72	47	97.8	0.12	58.5						
BV-4A-24 h	24	59.9	1.39	561	126.8	10.4	116.4	3.44	34	98.4	0.11	62.4						
BV-4A-30 h	30	60.0	1.40	548	129.8	10.5	119.3	3.70	31	98.6	0.10	63.8						
BV-4A-48 h	48	60.0	1.40	554	134.1	10.3	123.8	4.15	26	98.8	0.09	68.1	0.021	1.90	1.916	0.850	1.99	2.836
													Accountability:		**112.6%**	**Accountability:**		**106.6%**

Sample ID	**Solution Concentration (mg/L)**																									
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe^{3+}**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U**	**V**	**Zn**	**Zr**	**Cl**
Sydney Tap Water	1			13				1	0	1	2	1		13		1		3	5				1	1			
BV-4A-2 h	674			779				2927	2675	189	1282	626		205		87		9948	423				1751	1103			
BV-4A-4 h	1100			737				3511	3310	221	1564	841		279		102		11950	500				1789	1224			
BV-4A-8 h	1728			788				4248	3947	266	1976	1102		368		113		14326	484				1763	1406			
BV-4A-12 h	1715			773				4090	3826	297	1893	1093		440		117		16521	454				1619	1392			
BV-4A-24 h	2932			701				5468	5194	406	2758	1697		600		141		19448	415				1899	1742			
BV-4A-30 h	3004			692				5497	5119	430	2779	1690		624		143		20724	391				1829	1758			
BV-4A-48 h	3330			775				5172	4818	391	3024	1806		733		150		19993	395				1751	1835			268

Sample ID	**Solid Concentrations (% except for U_3O_8 - ppm)**																								
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe3+**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U3O8**	**V**	**Zn**	**Zr**
AN4+AN15 composite	3.30	<0.001	0.094	3.08	0.001	0.02	0.010	0.89		2.37	0.51	0.033	<0.001	0.039	0.008	0.029	0.011	0.08	36.39	0.01	0.002	0.11	2007	0.27	<0.001	0.0140
BV-4A-2 h	3.45	0.001	0.088	0.57	0.001	0.03	<0.001	0.85		2.55	0.40	0.009	0.00	0.042	0.009	0.017	0.006	0.29	39.46	0.01	0.002	0.11	97	0.17	0.0020	0.0160
BV-4A-4 h	3.38	<0.001	0.092	0.78	0.001	0.03	<0.001	0.79		2.52	0.37	0.006	0.00	0.047	0.008	0.017	0.009	0.49	39.19	0.01	0.002	0.11	78	0.15	<0.001	0.0170
BV-4A-24 h	3.30	0.001	0.092	0.48	0.001	0.02	<0.001	0.59		2.58	0.26	0.003	0.00	0.042	0.002	0.017	0.006	0.38	40.11	0.02	0.002	0.11	34	0.11	0.0030	0.0160
BV-4A-30 h	3.24	<0.001	0.096	0.65	0.002	0.02	<0.001	0.58		2.55	0.25	0.003	0.00	0.040	0.003	0.014	0.009	0.52	39.72	0.01	0.001	0.12	31	0.10	<0.001	0.0190
BV-4A-30 h	3.24	<0.001	0.096	0.65	0.002	0.02	<0.001	0.58		2.55	0.25	0.003	0.00	0.040	0.003	0.014	0.009	0.52	39.72	0.01	0.001	0.12	31	0.10	<0.001	0.0190
BV-4A-30 h	3.24	<0.001	0.096	0.65	0.002	0.02	<0.001	0.58		2.55	0.25	0.003	0.00	0.040	0.003	0.014	0.009	0.52	39.72	0.01	0.001	0.12	31	0.10	<0.001	0.0190
BV-4A-48 h	3.04	<0.001	0.083	1.66	0.001	0.01	<0.001	0.55		2.46	0.20	0.002	0.02	0.039	0.003	0.014	0.008	1.34	38.32	0.01	0.001	0.11	26	0.09	<0.001	0.0180

BV-4B			**Leach Studies on Bigrlyi deposit-V recovery**		**Oxidant:**	40% Sodium Permanganate	**OES:**	1901546
Conventional Leach		**Solids:**	1000 g	AN4+AN15 composite(latest)	**Leach Duration:**	48 h		
P80 150 mm microns		**Leach Liquor Matrix:**	1000 g	Sydney Tap Water	**Temperature:**	70 ºC	**XRF:**	1901565
pH	1.5				**ORP:**	550 mV	**DNA:**	1901565
		Slurry:	50%		**pH:**	1.5	**Date:**	14/08/2019
Fe in feed:	2 g/L	**SG**	1.00	Initial				

Sample ID	Leach Conditions												Uranium Mass Balance			Vanadium Mass Balance		
	Time (h)	Temp. (°C)	pH	ORP (mV)	Acid Addition (kg/t)	Free Acidity (g/L H_2SO_4)	Acid Cons. (kg/t)	Oxidant Addition (kg/t)	U_3O_8 (ppm)	U Extraction (%)	V (wt%)	V Extraction (%)	Solid (g)	Liquor (g)	Total (g)	Solid (g)	Liquor (g)	Total (g)
Feed									2007		0.27		1.702	0.001	1.703	2.660	0.00	2.661
BV-4B-2 h	2	70.1	1.51	547	93.1	7.5	85.7	1.53	111	94.6	0.17	40.0						
BV-4B-4 h	4	70.0	1.50	554	103.0	8.2	94.9	2.30	92	95.6	0.15	46.9						
BV-4B-8 h	8	70.0	1.52	550	113.1	9.0	104.2	3.08	62	97.0	0.12	54.9						
BV-4B-12 h	12	70.0	1.51	554	119.1	8.5	110.7	3.53	54	97.4	0.12	57.5						
BV-4B-24 h	24	69.8	1.51	552	128.1	10.4	117.7	4.21	33	98.4	0.11	60.8						
BV-4B-30 h	30	69.8	1.52	548	130.0	10.5	119.5	4.38	30	98.6	0.11	60.8						
BV-4B-48 h	48	70.1	1.52	543	133.2	10.0	123.2	4.79	26	98.7	0.10	64.0	0.021	1.86	1.881	0.957	1.95	2.911
														Accountability:	**110.5%**		**Accountability:**	**109.4%**

Sample ID	**Solution Concentration (mg/L)**																							
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe^{3+}**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U**	**V**	**Zn**	**Zr**	**Cl**
Sydney Tap Water	1			13				1	0	1	2	1		13		1		3	5				1	1			
BV-4B-2 h	769			866				3247	2931	200	1431	818		275		77		10669	468				1666	1123			
BV-4B-4 h	1240			823				3822	3541	228	1727	1088		387		92		12707	519				1589	1273			
BV-4B-8 h	1786			839				4320	4040	267	2118	1329		520		107		15446	466				1698	1440			
BV-4B-12 h	2103			799				4220	3927	230	2215	1440		545		101		15044	388				1582	1438			
BV-4B-24 h	2991			776				4024	3762	73	2940	1915		739		116		18992	391				1685	1724			
BV-4B-30 h	3339			729				3671	3341	46	3058	1955		802		119		19096	378				1851	1697			
BV-4B-48 h	3607			809				3096	2480	30	3264	1912		780		124		22011	352				1717	1803			256

Sample ID	**Solid Concentrations (% except for U_3O_8 - ppm)**																								
	Al	**As**	**Ba**	**Ca**	**Co**	**Cr**	**Cu**	**Fe**	**Fe3+**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sr**	**Th**	**Ti**	**U3O8**	**V**	**Zn**	**Zr**
AN4+AN15 composite	3.30	<0.001	0.094	3.08	0.001	0.02	0.010	0.89		2.37	0.51	0.033	<0.001	0.039	0.008	0.029	0.011	0.08	36.39	0.01	0.002	0.11	2007	0.27	<0.001	0.0140
BV-4B-2 h	3.46	<0.001	0.092	0.52	0.003	0.03	0.006	0.90		2.54	0.39	0.009	<0.001	0.047	0.010	0.020	0.008	0.21	39.53	0.01	0.001	0.11	111	0.17	<0.001	0.0180
BV-4B-4 h	3.37	0.001	0.095	0.85	0.002	0.03	<0.001	0.77		2.53	0.36	0.007	0.00	0.042	0.009	0.019	0.008	0.52	39.19	0.01	0.002	0.11	92	0.15	0.0020	0.0190
BV-4B-24 h	3.20	<0.001	0.092	0.66	0.002	0.02	<0.001	0.72		2.56	0.23	0.003	0.00	0.044	0.005	0.018	0.009	0.60	39.58	0.01	0.001	0.11	33	0.11	0.0020	0.0160
BV-4B-30 h	3.20	<0.001	0.092	0.64	0.002	0.02	<0.001	0.78		2.59	0.22	0.002	0.00	0.045	0.006	0.017	0.010	0.61	39.58	0.01	0.001	0.12	30	0.11	<0.001	0.0160
BV-4B-30 h	3.20	<0.001	0.092	0.64	0.002	0.02	<0.001	0.78		2.59	0.22	0.002	0.00	0.045	0.006	0.017	0.010	0.61	39.58	0.01	0.001	0.12	30	0.11	<0.001	0.0160
BV-4B-30 h	3.20	<0.001	0.092	0.64	0.002	0.02	<0.001	0.78		2.59	0.22	0.002	0.00	0.045	0.006	0.017	0.010	0.61	39.58	0.01	0.001	0.12	30	0.11	<0.001	0.0160
BV-4B-48 h	3.05	0.001	0.090	1.81	0.001	0.02	<0.001	0.79		2.49	0.18	0.002	0.02	0.050	0.005	0.017	0.009	1.56	37.88	0.02	0.001	0.11	26	0.10	<0.001	0.0160