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V Leach Research

Mineralogy of Bigrlyi Composite and Leach Residue

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1. Introduction

A composite head and leach residue sample from the Bigrlyi vanadium leach research study were received for characterisation. Of particular interest was identification of the vanadium and uranium bearing minerals, and their respective mineral associations, especially for those retained in the leach residue.

This report presents the results of the characterisation of the Bigrlyi samples. Major and minor constituents were assessed using QEMSCAN. Manual SEM with EDS was undertaken to examine the phases present in the samples in greater detail.

2. Samples

Two samples were submitted for characterisation using QEMSCAN and manual SEM.

A portion of each sample was mixed with similarly sized particles of graphite to ensure good separation of the particles for examination using QEMSCAN. The sample/graphite blends were impregnated with epoxy resin to form resin blocks with a polished surface for examination by SEM/QEMSCAN. The polished surfaces of the resin blocks were coated with a thin layer of carbon (a few nanometres thick), prior to analysis, to maintain electrical conductivity during examination.

Chemical analyses by ICP/XRF were carried out on pulverised portions of the samples. These results have been reported in detail elsewhere. The uranium and vanadium elemental concentrations in the composite are reported as 0.183 wt% and 0.266 wt% respectively, contrasting with 0.004 wt% and 0.152 wt% in the leach residue.

3. Analysis

3.1 QEMSCAN

QEMSCAN particle mineralogical analysis (PMA) was carried out using a Quanta 650 electron microscope with dual Bruker XFlash 5030 energy dispersive detectors, controlled by iDiscover and iMeasure image analysis hardware/software. The SEM was operated at an accelerating voltage of 15 keV with a working distance of 13 mm and using a beam current of approximately 10 nA.

The phases identified in the samples by QEMSCAN and their indicative modal abundances are presented in **Table 1.**

The QEMSCAN technique is unable to differentiate conclusively between some minerals with similar chemistry. For this reason minerals with similar chemistry have been grouped, e.g. amphibole/pyroxene. In addition, the residue had been pulverized so the particles are relatively small and often these small phases are present as composite clusters (closely intermixed with one another). Unfortunately the QEMSCAN technique does not have the resolution necessary to separate some of these closely intergrown particles and hence some the data captured reflects mixed phase compositions for example, gypsum and quartz/clays.

Some of the uranium and vanadium bearing minerals are very small, and/or intimately intergrown with other phases which often resulted in mixed phase compositions which could not be resolved adequately by QEMSCAN. These unidentified phases have been captured as "Uranium Phase" and "Vanadium Phase" in the QEMSCAN data.

Table 1
QEMSCAN Modal Mineralogy of the Bigrlyi Composite and Leach Residue

Mineral	Formulae	AN4/15 Composite	BV-3A Final <38 µm
		wt%	
Uraninite	UO_2	0.06	0.00
Coffinite	$U(SiO_4)_{1-x}(OH)_{4x}$	0.16	0.00
Uranium Phase	U,Si,O,H,Ca	0.10	0.00
Carbonates	$CaCO_3$, $CaMg(CO_3)_2$	5.00	0.09
Barytes	$(Ba,Sr,Ca)SO_4$	0.01	0.09
Quartz	SiO_2	71.45	43.82
Plagioclase Feldspar	$(Na,Ca)(Si,Al)_4O_8$	0.05	0.04
Alkali Feldspar	$KAlSi_3O_8$	14.28	15.97
Pyrite	FeS_2	0.13	0.26
Gypsum/Sulfate*	$CaSO_4/CaSO_4.2H_20$	0.01	22.41
Ilmenite	$FeTiO_3/(Fe,Mn)TiO_3$	0.21	0.19
Rutile	TiO_2	0.03	0.21
Biotite	$K(Mg,Fe)_3[AlSi_3O_{10}(OH,F)_2]$	0.96	0.97
Muscovite/Sericite	$KAl_2(Si_3Al)O_{10}(OH,F)_2$	3.30	9.05
Roscoelite	$K(V,Al,Mg)_2AlSi_3O_{10}(OH)_2$	0.37	0.21
Kaolinite Group	$Al_2Si_2O_5(OH)_4$	0.86	2.91
Smectite Group	$(K,Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2.nH_2O$	1.15	1.41
Chlorite Group	$(Fe,Al,Mg)_6(Si,Al)_4O_{10}(OH)_8$	0.63	0.39
Amphibole/Pyroxene	$Ca,Mg,FeSi_xO_y,O,H$	0.32	0.16
Bokite	$(Al,Fe)_{1.3}(V,Fe)_8O_{20}.7.4H_2O$	0.02	0.00
Montroseite	$(V,Fe)O(OH)$	0.04	0.00
Vandiferous Rutile	$(V,Ti)O_2$	0.03	0.02
Vanadium Phase	V,Al,Fe,Si,Mg,Ca	0.07	0.00
Unclassified	-	0.63	1.20
Other	various	0.13	0.62

* Likely to contain some composite assemblages

The composite sample is dominated by quartz and alkali feldspar (71 wt% and 14 wt%, respectively), see **Table 1**. Other constituents include carbonates (5 wt%), muscovite (3 wt%) and smectite clays (1 wt%). Trace constituents include pyrite, ilmenite/rutile, biotite, chlorite clays, amphibole/pyroxene, and notably, vanadium bearing roscoelite (0.37 wt%). Also present are sparse quantities of the vanadium bearing minerals montroseite (0.04 wt%) and bokite (0.02 wt%) and vandiferous rutile (0.03 wt%). 0.07 wt% vanadium bearing minerals were too fine grained or inter-grown with other phases to enable successful classification and these are reported as "vanadium phase" in **Table 1**. Uraninite (0.06 wt%) and coffinite (0.16 wt%) are the predominant uranium bearing phases identified, with 0.1 wt% of additional unclassified uranium phases captured as "uranium phase".

The <38 µm leach residue is dominated by quartz (44 wt%), alkali feldspar (16 wt%) and gypsum/sulfate (22 wt%), see **Table 1**. The gypsum/sulfate abundance also contains some portion of mixed gypsum/silicates which were too fine grained and intermixed to be able to resolve fully by QEMSCAN. Minor constituents include muscovite (9 wt%), kaolinite (3 wt%), smectite (1 wt%). Trace quantities of carbonates, barytes, pyrite, ilmentite/rutile, biotite and amphibole are present. No uranium bearing minerals were detected in the leach residue. Roscoelite is present in a slightly reduced quantity of 0.2 wt% (compared with 0.37 wt% in the composite head). The vanadium bearing minerals montroseite and bokite were not detected, however, sparse concentrations of vandiferous rutile remain (0.02 wt%).

Mineral association data for the uranium and vanadium minerals are presented in **Tables 2A** and **2B**. For the purposes of the QEMSCAN mineral association calculation, two minerals are "associated" if a pixel of one mineral occurs adjacent to a pixel of the other in either the vertical or horizontal direction. The values presented in tables are the proportions of transitions between the phases of interest (listed along the top of the table) with associated minerals (listed down the side of the table). The "background' category in the table refers to the epoxy resin mounting material. A mineral with a large percentage of associations with the background will often be present as particles with a relatively high degree of liberation. Minerals with a relatively low percentage of associations with the background but a high percentage of associations with another mineral are likely to be present as inclusions within that particular mineral. It is important to bear in mind the relative modal abundances of phases when assessing the significance of mineral association data[1].

In the AN4/15 composite (**Table 2A**) uraninite has main associations with background (46%), coffinite (13%), unclassified uranium phases (8.7%), quartz (10.7%), roscoelite (4.7%) and other micas/clays (1 – 4 %). Coffinite has main associations with background (28%), quartz (32%), uranium phase (9%), biotite (7.7%), muscovite (4.7%) and smectite (4.9%). Roscoelite has main associations with background (43%), quartz (13.8%), alkali feldspar (8.7%), muscovite (8%) and smectite (9.6%). Bokite and montroseite have main association with each other, the unclassified vanadium phase component and with background (50 and 65%, respectively). Vandiferous rutile has main associations with background (23%), quartz (12.9%), and ilmenite (10%).

In the BV-3A <38 μm residue (**Table 2B**) there were no uranium minerals detected therefore these "associations" all read zero. Roscoelite has main associations with background (45%), quartz (17%), alkali feldspar (11%), biotite (7.4%) and muscovite (8%). There was no bokite or montroseite in the residue and therefore their associations are all zero. Vandiferous rutile has main associations with background (78%), roscoelite (6%) and smectite (9.4%). Unclassified vanadium phases have main associations with background (92%) and gypsum (8%).

[1] **Note**: associations are expressed in percent "transitions" and these may not be simply related to abundance, however, abundances can be important especially when one is dealing with trace species.

Table 2A
Mineral Associations in the Bigrlyi Composite (% Transitions)

	Bigrlyi AN4/15 Comp								
	Background	Uraninite	Coffinite	Uranium Phase	Roscoelite	Bokite	Montroseite	V Rutile	V Phase
Background	-	46.00	28.21	35.29	43.19	50.00	65.52	23.15	47.53
Uraninite	0.04	-	3.66	2.39	0.34	0.00	0.00	0.00	0.00
Coffinite	0.09	13.33	-	9.19	0.48	0.00	0.00	0.93	0.00
Uranium Phase	0.12	8.67	9.16	-	0.43	0.00	0.00	3.70	0.55
Carbonates	8.66	0.00	0.73	3.86	1.25	0.94	0.00	0.00	4.40
Barytes	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	54.85	10.67	31.68	17.46	13.85	0.00	2.59	12.96	8.24
Plagioclase	0.08	0.00	0.00	0.55	0.19	0.00	0.00	0.00	0.27
K Feldspar	17.29	2.67	2.38	4.78	8.77	0.00	0.00	3.70	3.85
Pyrite	0.13	0.00	0.37	0.37	0.05	0.00	0.00	0.00	0.00
Gypsum	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.03	0.00	0.00	0.00	0.00	0.00	0.00	10.19	4.95
Rutile	0.03	0.00	0.00	0.00	0.00	0.00	0.00	2.78	1.10
Biotite	1.59	3.33	7.69	6.07	4.65	0.00	0.00	0.93	1.65
Muscovite	6.83	3.33	4.76	6.07	8.01	1.89	0.00	1.85	1.92
Roscoelite	0.56	4.67	1.83	1.65	-	2.83	3.45	1.85	5.49
Kaolinite	2.09	1.33	1.10	1.10	2.11	2.83	0.00	0.93	0.27
Smectite	2.21	4.00	4.95	3.31	9.64	0.94	0.00	6.48	1.92
Chlorite	1.02	0.00	2.38	2.02	1.25	0.00	0.00	6.48	0.55
Amph/Pyro	0.53	0.67	0.73	0.55	1.49	0.00	0.00	0.00	0.27
Bokite	0.03	0.00	0.00	0.00	0.14	-	17.24	0.00	6.32
Montroseite	0.05	0.00	0.00	0.00	0.19	18.87	-	0.00	3.57
V Rutile	0.02	0.00	0.18	0.74	0.10	0.00	0.00	-	5.77
V Phase	0.11	0.00	0.00	0.37	0.96	21.70	11.21	19.44	-
Unclassified	3.33	1.33	0.18	2.02	2.83	0.00	0.00	4.63	1.10
Other	0.29	0.00	0.00	2.21	0.10	0.00	0.00	0.00	0.27

Table 2B
Mineral Associations in the Bigrlyi Leach Residue (% Transitions)

	BV-3A Final <38 µm								
	Background	Uraninite	Coffinite	Uranium Phase	Roscoelite	Bokite	Montroseite	V Rutile	V Phase
Background	-	0.00	0.00	0.00	45.06	0.00	0.00	78.13	91.67
Uraninite	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coffinite	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00
Uranium Phase	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00
Carbonates	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barytes	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	33.24	0.00	0.00	0.00	17.15	0.00	0.00	3.13	0.00
Plagioclase	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K Feldspar	11.85	0.00	0.00	0.00	11.19	0.00	0.00	0.00	0.00
Pyrite	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum	31.02	0.00	0.00	0.00	3.49	0.00	0.00	0.00	8.33
Ilmenite	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.10	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00
Biotite	0.84	0.00	0.00	0.00	7.41	0.00	0.00	0.00	0.00
Muscovite	10.19	0.00	0.00	0.00	8.14	0.00	0.00	3.13	0.00
Roscoelite	0.14	0.00	0.00	0.00	-	0.00	0.00	6.25	0.00
Kaolinite	3.56	0.00	0.00	0.00	1.16	0.00	0.00	0.00	0.00
Smectite	1.64	0.00	0.00	0.00	5.81	0.00	0.00	9.38	0.00
Chlorite	0.30	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00
Amph/Pyrox	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bokite	0.00	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00
Montroseite	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00	0.00
V Rutile	0.01	0.00	0.00	0.00	0.29	0.00	0.00	-	0.00
V Phase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Unclassified	3.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	2.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The liberation statistics for the phases of interest are presented in **Tables 3A** and **3B**. Liberation is calculated for a particular mineral by determining the proportion of the surface area of each grain of that mineral that is in contact with the background (*i.e.* the outer surface of the particle, the epoxy mounting resin). For example, a uraninite particle that exhibits 100% liberation will have its entire surface area in contact with the epoxy mounting resin. 50% liberation means that half of the particles surface is in contact with the mounting resin, while the other half is in contact with other minerals. A particle with 0% liberation is completely surrounded by other minerals.

The horizontal axis in **Tables 3A** and **B** are divided into ranges that refer to the degree of liberation. The numbers in the table in each of the liberation ranges refer to the proportion (wt%) of each mineral that falls in each range. For example, 14 % of the uraninite in the composite sample is contained in grains that have a degree of liberation of 90-100%. For simplification, the more minor vanadium bearing phases (bokite, montroseite, vandiferous rutile and unclassified vanadium bearing phases) have been grouped together as "Vanadium Phase" in **Tables 3A** and **3B**.

The liberation statistics for the uranium bearing phases in the composite sample indicate that a significant portion of these phases are present as poorly liberated particles (< 30% liberation), with a lesser proportion present as partially liberated particles (30-70% liberation), and some present as well liberated particles (> 70%) liberation, see **Tables 3A** and **3B**. The roscoelite in the composite sample is 54% poorly liberated, 31% partially liberated ("middlings"), and 14% well liberated. The particles which are not well liberated are found in association with other micaceous phases (muscovite/smectite), alkali feldspar or quartz (refer to **Table 2A**). The other, more minor modally, vanadium bearing phases present in the composite are 55% well liberated (>70% liberation), with 13% partially liberated (30-70% liberated), and 32% poorly liberated (<30% liberation), see **Tables 3A** and **3B**.

In the residue sample 44% of the roscoelite particles are poorly liberated, 29% are partially liberated and 27% are well liberated see **Tables 3A** and **3B**. The less well liberated particles of roscoelite are largely found in association with quartz, alkali feldspar and other mica/smectite phases (refer to **Table 2B**). For the more minor vanadium phases (largely V-rutile) 62% are well liberated with 19% well liberated and 19% poorly liberated.

Table 3A
U and V Mineral Liberations in the Bigrlyi Composite and Leach Residue Samples

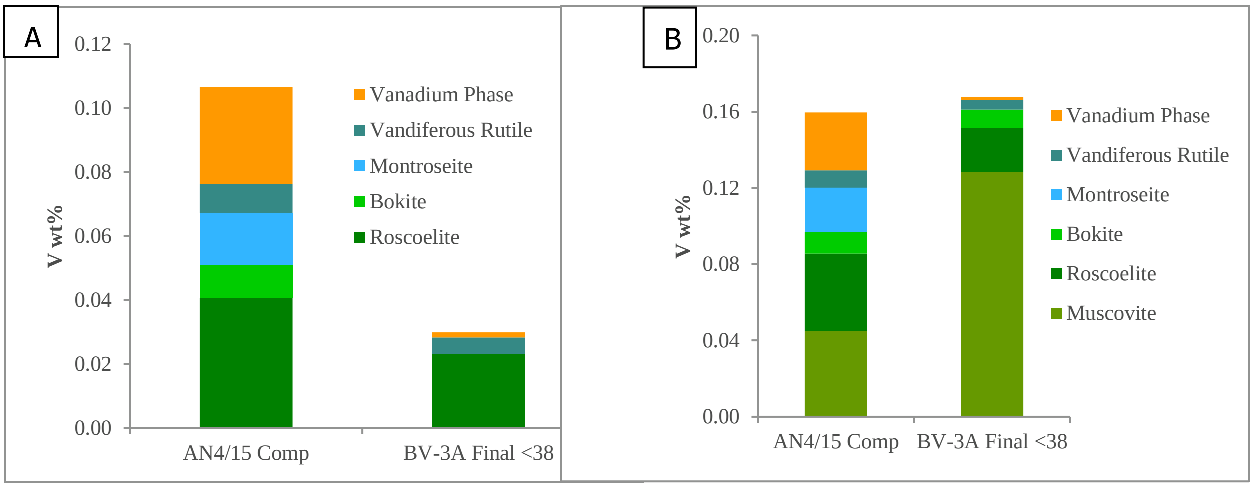
	Liberation/Mineral % In Sample									
AN4/15 Comp	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
Uraninite	48.6	3.7	6.5	1.9	3.7	3.7	1.9	10.3	5.6	14.0
Coffinite	64.2	8.5	10.1	2.6	2.1	1.8	2.1	3.1	1.8	3.9
Uranium Phase	69.4	4.8	7.1	3.8	1.5	0.0	0.5	0.0	0.0	12.8
Roscoelite	36.5	11.4	6.3	13.5	8.4	4.4	4.9	5.8	1.1	7.6
Vanadium Phases	28.9	2.6	0.0	6.0	2.4	3.5	0.7	2.4	5.3	48.1
BV-3A Final <38 µm	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
Roscoelite	21.8	16.2	5.6	9.8	4.6	0.0	14.5	6.2	18.3	2.9
Vanadium Phases	6.1	0.0	12.7	6.3	3.2	9.5	0.0	0.0	0.0	62.2

Table 3B
Summary Mineral Liberations in the Bigrlyi Composite and Leach Residue

	Liberation/Mineral % In Sample		
Bigrlyi AN4/15 Comp	0-30%	30-70%	70-100%
Uraninite	58.9	11.2	29.9
Coffinite	82.7	8.5	8.8
Uranium Phase	81.4	5.8	12.8
Roscoelite	54.2	31.3	14.6
Vanadium Phases	31.5	12.6	55.9
BV-3A Final <38 µm	0-30%	30-70%	70-100%
Roscoelite	43.6	29.0	27.4
Vanadium Phases	18.8	19.0	62.2

The QEMSCAN data has been used to examine the deportment of elemental vanadium within the samples. The results are presented in **Figure 1**. It is quite evident from **Figure 1A** that there is a discrepancy between the calculated vanadium concentrations generated by QEMSCAN for the minerals identified in the composite and residue samples (0.11 and 0.03 wt%, respectively) as compared to their respective chemical assays (0.27 and 0.15 wt%). Upon closer examination by manual SEM with EDS, it was observed that some of the phases classified as "muscovite" by QEMSCAN did also contain low levels of vanadium, see **Section 3.2**. When these low levels of vanadium are included in the formulae for muscovite in the QEMSCAN datastore the calculated vanadium concentrations for the composite and residue samples increase to 0.16 and 0.17 wt% respectively, as shown in **Figure 1B**. There remains an unresolved discrepancy between the QEMSCAN and chemical vanadium assay for the composite sample.

Figure 1 Vanadium Deportment within the Bigrlyi Samples



(with (A) and without (B) muscovite)

3.2 Scanning Electron Microscopy

SEM and X-ray microanalysis were carried out on an epoxy resin impregnated portion of the sample using a Quanta 650F electron microscope with dual Bruker XFlash 5030 energy dispersive detectors. The SEM was operated at an accelerating voltage of 15 keV with a working distance of 13 mm and using a beam current of approximately 10 nA. The images were acquired in backscattered electron (BSE) imaging modes. BSE imaging is commonly used to examine variation in chemical composition (evidenced through changing mean atomic number) between and within minerals. Lighter grey levels in the micrographs indicate compositions containing higher mean atomic number elements (e.g. U, Th, Fe) than compositions producing the darker grey levels (e.g. Al, Si, Ca). The black background in the images is the epoxy resin grain mount. X-ray analysis (energy dispersive system – EDS) was undertaken to confirm mineralogy. The Bruker EDS analysis software's standardless analysis package was used to give indicative normalised elemental concentrations.

The detailed results of the SEM examination of the samples are presented in **Appendix A**. A summary of findings is given below.

3.2.1 Summary of Findings

AN4/15 Composite

The composite sample is dominated by particles of quartz, feldspar and clays/micas. Vanadium and uranium bearing minerals are sparse. Coffinite and uraninite are the predominant uranium bearing minerals present. Examples of uraninite mineralisation are shown in **Appendix A** (**Figure 1 C**, **D** and **E**). Vanadium bearing minerals with compositions similar to montroseite, bokite and roscoelite are present. Examples of each of these are shown in **Appendix A** (**Figure 1 A**, **B, D,** and **E**). Typical EDS spectra from montroseite, bokite and roscoelite particles are presented in **Appendix A** (**EDS spectra S1, S2 and S3**). Some of the rutile present in the sample contains vanadium, **Appendix A** (**Figure 1 F**) and EDS spectrum **S4.**

BV-3A Final < 38

The residue sample is dominated by particles of quartz, alkali feldspar, gypsum and mica/clays. No uranium bearing minerals could be located in the sample. No montroseite or bokite particles are present. Vanadium bearing minerals observed include vandiferous rutile and ilmenite, see **Appendix A** (**Figure 2 A** and **B** and **EDS spectra S5** and **S6**). Liberated particles of roscoelite are evident within the sample, (**Appendix A Figure 2 C** and **D** and **EDS spectrum S7**). Some roscoelite was also intermixed with other mica/clay phases. A typical spectrum from a particle classified as "muscovite" by QEMSCAN is shown in **Appendix A** (**EDS spectrum S8**). An additional spectrum from a muscovite/phengite particle containing approximately 1.2 wt% vanadium is shown at **Appendix A** (**EDS spectrum S9**). The vanadium content in the muscovite/phengite is heterogeneous.

4. Conclusions

1. The AN4/15 composite sample is dominated by quartz and alkali feldspar (71 wt% and 14 wt%, respectively). Other constituents include carbonates (5 wt%), muscovite (3 wt%) and smectite clays (1 wt%). Trace constituents include pyrite, ilmenite/rutile, biotite, chlorite clays, amphibole/pyroxene, and roscoelite (0.37 wt%).

2. Vanadium bearing minerals identified in the composite are roscoelite (0.37 wt%), montroseite (0.04 wt%), bokite (0.02 wt%) and vandiferous rutile (0.03 wt%).

3. Uraninite (0.06 wt%) and coffinite (0.16 wt%) are the predominant uranium bearing phases identified within the composite.

4. The roscoelite in the composite sample is 54% poorly liberated, 31% partially liberated ("middlings"), and 14% well liberated. The particles which are not well liberated are found in association with other micaceous phases (muscovite/smectite), alkali feldspar or quartz. The other, more minor modally, vanadium bearing phases present in the composite are 55% well liberated, 13% partially liberated, and 32% poorly liberated.
5. The <38 µm leach residue is dominated by quartz (44 wt%), alkali feldspar (16 wt%) and gypsum/sulfate (22 wt%). Minor constituents include muscovite (9 wt%), kaolinite (3 wt%), smectite (1 wt%). Trace quantities of carbonates, barytes, pyrite, ilmentite/rutile, biotite, roscoelite and amphibole are present.
6. No uranium bearing minerals were detected in the leach residue.
7. Roscoelite is present in a slightly reduced quantity of 0.2 wt% (compared with 0.37 wt% in the composite head). 44% of the roscoelite particles are poorly liberated, 29% are partially liberated and 27% are well liberated. The less well liberated particles of roscoelite are largely found in association with quartz, alkali feldspar and other mica/smectite phases.
8. The vanadium bearing minerals montroseite and bokite were not detected in the residue, however, sparse concentrations of vandiferous rutile remain (0.02 wt%).
9. Some of the muscovite/phengite in the samples has been shown to contain low levels of vanadium (~ 1 - 2 wt%).

Appendix A

Scanning Electron Microscopy Images and EDS Spectra

FIGURE 1: AN4/15 Composite

Backscattered electron (BSE) micrographs from the Composite sample. Use the zoom function on the electronic version to view the images in more detail.

A Example of a liberated vanadium iron oxide mineral with composition similar to montroseite, a typical EDS spectrum is show at **S1.**

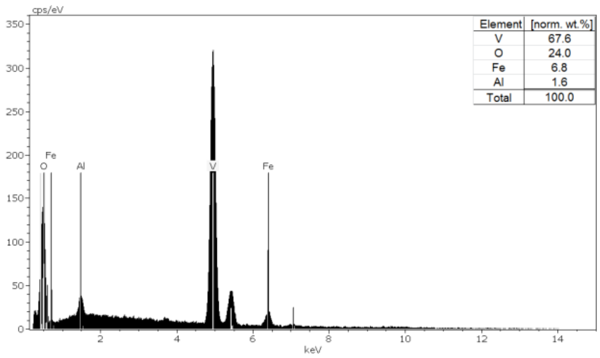
B Example of a liberated vanadium aluminium iron oxide mineral with composition similar to bokite, a typical EDS spectrum shown at **S2**.

C Finely intergrown uranium rich phase (uraninite) intergrown with rutile hosted by quartz.

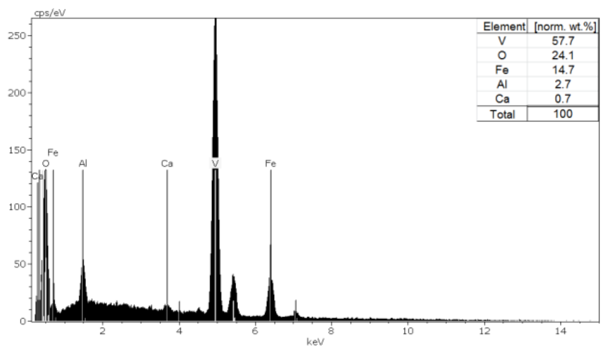
D Example of Roscoelite hosted by alkali feldspar, a typical EDS spectrum is shown at **S3**.

E Roscoelite rim to a large quartz particle hosting small particles of uraninite with adjacent liberated bokite and uraninite grains.

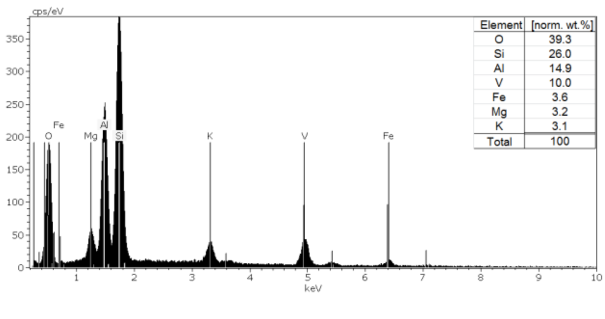
F Vanadium rich rutile (EDS spectrum shown at **S4**) hosted by a large alkali feldspar particle. Note inclusions of uraninite.



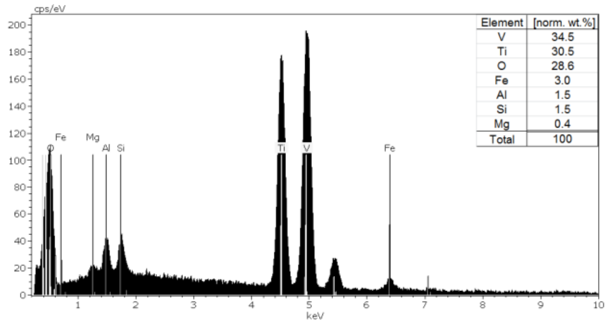
S1. EDS spectrum from a montroseite particle shown in Fig 1A.



S2. EDS spectrum from the bokite particle shown in Fig 1B.

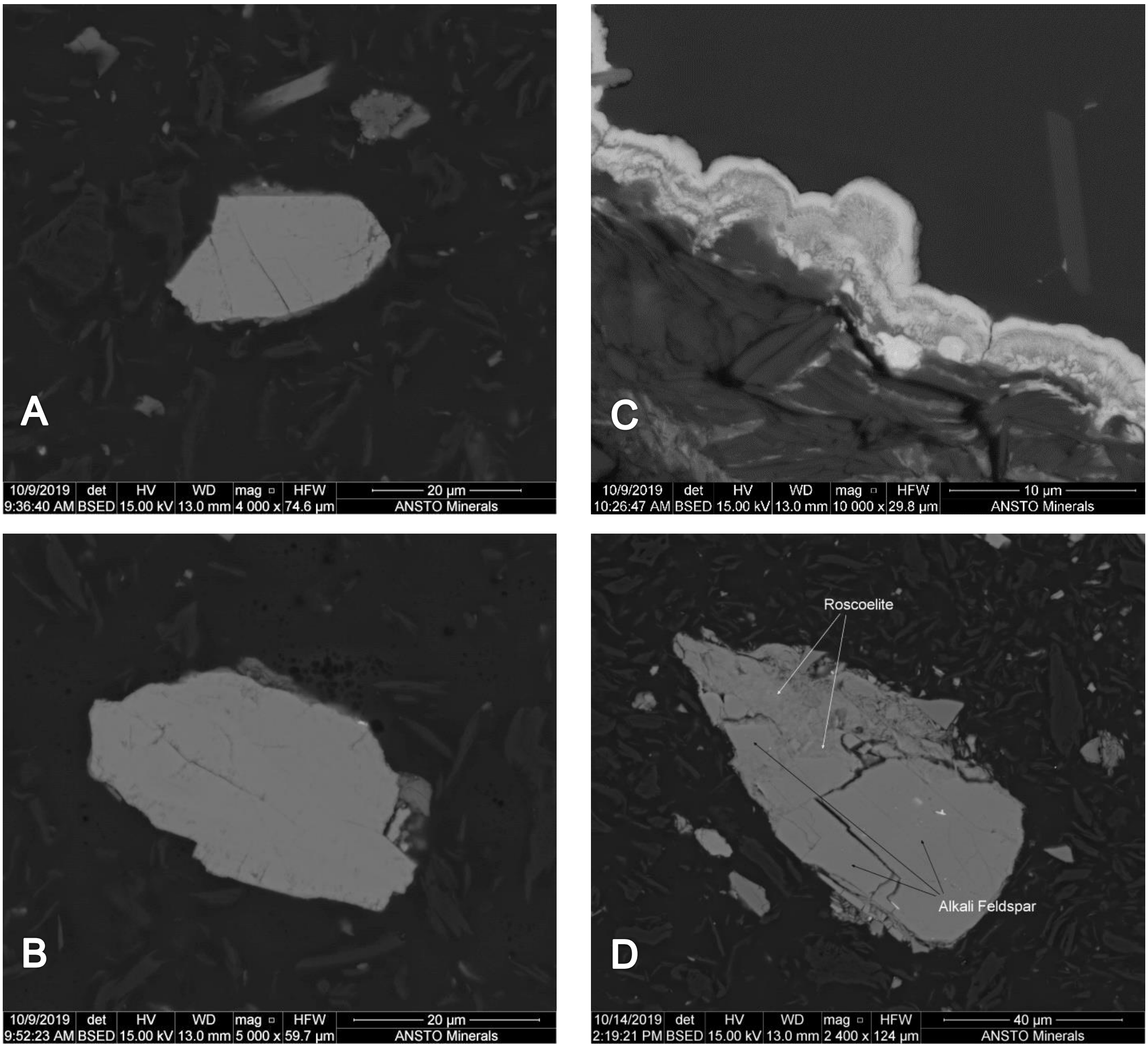


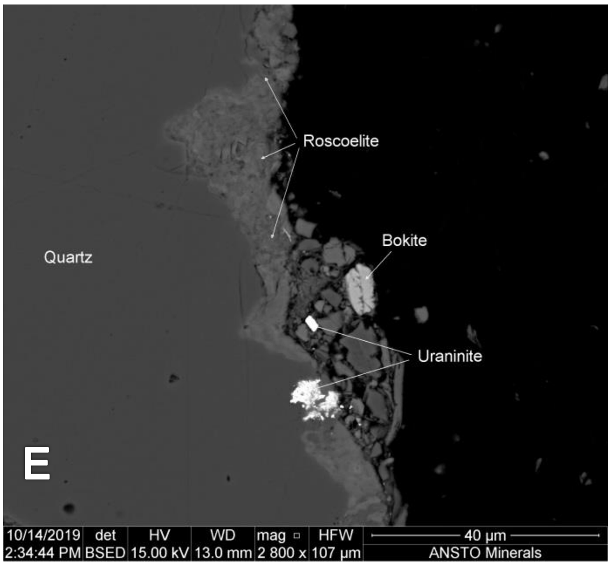
S3. EDS spectrum the roscoelite particle shown in Fig 1D.



S4. EDS spectrum from the vandiferous rutile shown in Fig 1 F. (Some peak overlap from adjacent phases).

FIGURE 1 A-F **AN4/15 Composite**




Roscoelite
Bokite
Quartz
Uraninite
E
10/14/2019 det HV WD mag HFW 40 µm
2:34:44 PM BSED 15.00 kV 13.0 mm 2 800 x 107 µm ANSTO Minerals

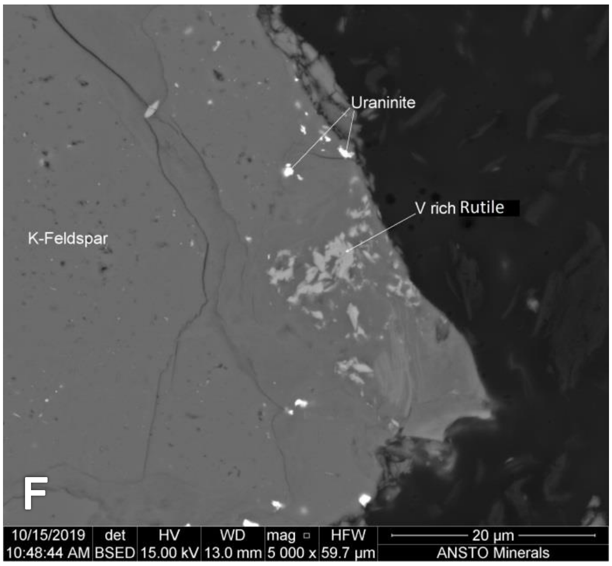

Uraninite
V rich Rutile
K-Feldspar
F
10/15/2019 det HV WD mag HFW 20 µm
10:48:44 AM BSED 15.00 kV 13.0 mm 5 000 x 59.7 µm ANSTO Minerals

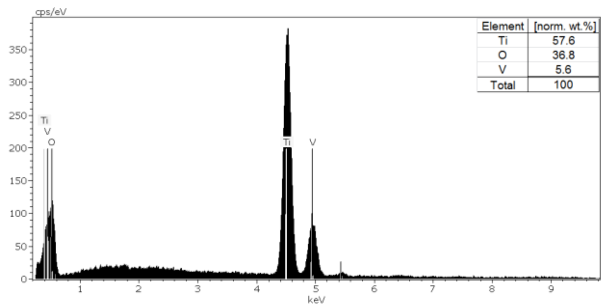
FIGURE 2: BV-3A Final <38

Backscattered electron (BSE) micrographs from the residue sample. Use the zoom function on the electronic version to view the images in more detail.

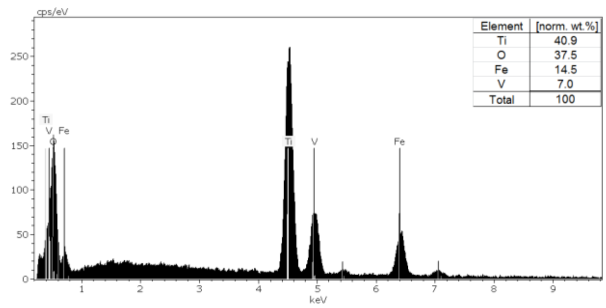
A Example of liberated V-rich rutile in the residue. The lobate grain edges are indicative of reaction/alteration during the leaching process. A typical EDS spectrum is shown at **S5**.

B Example of liberated V-rich ilmenite in the residue. A typical EDS spectrum is shown at **S6**.

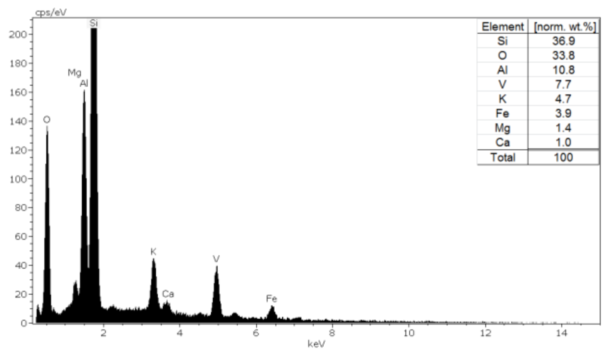
C –D Examples of liberated roscoelite particles in the residue. An EDS spectrum from particle shown in **C** is presented in **S7**.



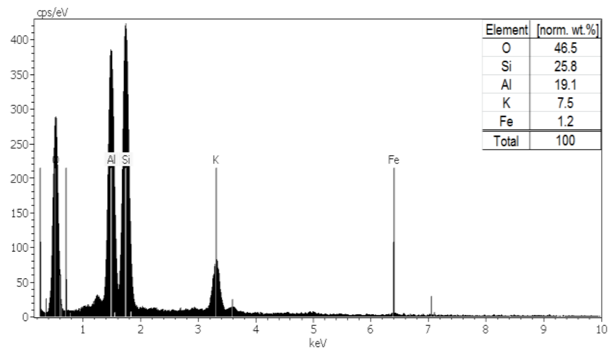
S5. EDS spectrum from the V-rutile particle shown in Fig 2A.



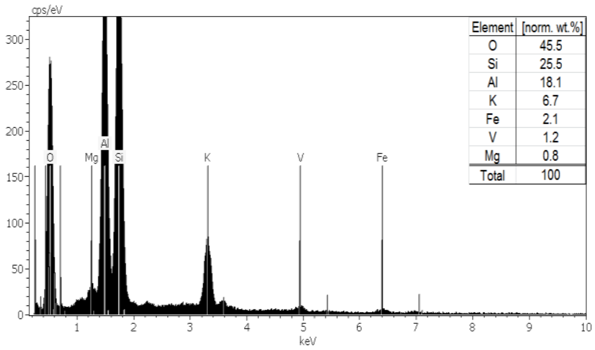
S6. EDS spectrum from the V-ilmenite particle shown in Fig 2B.



S7. EDS spectrum from the roscoelite particle shown in Fig 2 C.



S8. Typical EDS spectrum from a muscovite particle in the residue.



S9. EDS spectrum from a V bearing muscovite/phengite in the residue.

FIGURE 2 BV-3A Final <38