

AUSTRALIAN NUCLEAR SCIENCE  
AND TECHNOLOGY ORGANISATION  
LUCAS HEIGHTS SCIENCE AND TECHNOLOGY CENTRE

**A REPORT TO  
NuPOWER RESOURCES**

**ON**

**METALLURGICAL TEST PROGRAM ON LUCY CREEK  
SURFACE URANIUM MINERALISED ROCK**

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## EXECUTIVE SUMMARY

Two samples of uranium bearing RC drill core from the Lucy Creek project site were supplied to ANSTO Minerals. The samples were very low grade (164 and 114 ppm  $U_3O_8$  respectively for the composites shown below). The identification of uranium containing minerals, consequently, proved difficult.

The gangue minerals were identified as follows.

	Composite 1	Composite 2
Major mineral phases	quartz	quartz illite
Minor mineral phases	clinochlore goethite wavellite*	wavellite*

\*  $Al_3(PO_4)_2(OH)_3(H_2O)_5$ .

Several accessory minerals, which could also host low concentrations of uranium, were observed.

Leaching of the low grade Lucy Creek rock proved to be problematic. It is likely that acceptable uranium extraction could only be achieved by uneconomic, aggressive acid leach conditions. Although mineralogical investigation identified some uranium present as leachable uraninite, more than half of the small amount of uranium present may be hosted by more refractory accessory minerals.

Slurry leach test results are summarised as follows.

Ore	Test No.	Temp. (°C)	ORP (mV)	pH	Acidity (g/L $H_2SO_4$ )	U Extraction (%)	Acid (kg/t)	Pyrolusite (kg/t)
<i>Composite 1</i>	NU 1-A	40	460-570	1.8	3	12.9	33	1.7
	NU 1-B	40	450-470	1.2	11	25.9	49	0.4
	NU 2-A	60	450-490	1.2	15	32.4	68	none
<i>Composite 2</i>	NU 3-A	60	400-450	1.2	16	18.6	17	1.3
	NU 5-A	60	450-470	50 g/L $H_2SO_4$	47	46.4	140	2 g/L $Fe^{3+}$

\* All tests were conducted for 24 h at 50 wt% slurry density

As severe acidic leaching in an agitated vessel did not achieve satisfactory uranium extraction, it is not considered likely that the material would be amenable to the less aggressive conditions used in heap leaching, as was being considered by the client for the treatment of this low grade material. The fine clay content of the ore would require that ores would need to be agglomerated before heap leaching. This would make a heap leach process less viable.



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## 1. INTRODUCTION

NuPower has intersected potentially extensive low grade uranium mineralisation in surface material at the Lucy Creek site in the Northern Territory. This mineralised surface material contains 100-200 ppm  $U_3O_8$ , and treatment by heap leaching is considered by the client to be potentially economically feasible.

Although very little is known about the nature of the deposit and the mineralisation, considerable sample was available for preliminary metallurgical testing as composite samples taken from selected RC drilling holes.

ANSTO Minerals carried out a testwork program to identify the uranium host minerals, important gangue minerals and the mineral associations and to assess whether the material is amenable to leaching.

## 2. SCOPE OF WORK

The scope of work was as follows:

- Preparation of two samples for head assay, leach testwork and mineralogical examination;
- Mineralogical investigation of two ore samples;
- Carry out ~ 16 batch milling and agitation leach tests to determine appropriate leaching conditions, as assessed by the extraction of uranium and gangue elements, and reagent consumptions;
- Two dilute leach tests to determine the limits for uranium extraction;
- Prepare a final report which presents the results and an assessment of the amenability of the sample to processing for uranium recovery; and
- Return of all samples to the client.

## 3. SAMPLES FOR TESTWORK AND ANALYSIS

Two samples, representing the most common ore types, were provided for the study. The mineralisation is hosted in the Tertiary regolith overlying sediments of the Georgina Basin that include some phosphatic horizons. It is believed that this secondary uranium mineralisation is the result of dissolution of uranium, present at low concentrations within the phosphatic rocks and re-precipitation within the regolith. Significant dis-equilibrium was expected in the ore types. The 2 rock types were described by NuPower as:

- highly ferruginous/manganiferous, locally brecciated and silicified laterite; and
- saprolitic, locally weakly ferruginous, kaolinised, locally siliceous and brecciated material with minor wavellite and local turquoise.

ANSTO Minerals produced two composite samples from RC drill samples provided by the client – see **Table 3.1**. These were made by blending equal portions of the samples supplied as follows.

The individual samples were dried to constant weight at low temperature  $< 50^{\circ}\text{C}$ . They were each crushed to pass 1-2 mm. Equal portions of each sample were then blended, to give the maximum composite sample size possible.

**TABLE 3.1**  
**Lucy Creek Ore Samples**

Sample N <sup>o</sup> .	Weight Received (kg)	Client Description	Indicated Grade (ppm U)
<i>Composite Sample 1</i>			
760924	2.98	ferruginous	231
760925	3.06	ferruginous	163
761650	3.75	ferruginous	134
761108	2.5	ferruginous	92
761648	4.62	ferruginous	90
761620	4.06	kaolinitic-weakly ferruginous	87
760934	approx. 3.0	kaolinitic-weakly ferruginous	85
<i>Composite Sample 2</i>			
760927	3.19	kaolinitic	119
761440	4.76	kaolinitic	104
760930	2.77	kaolinitic	97
760931	3.55	kaolinitic	88
760912	2.83	kaolinitic	88
761442	4.15	kaolinitic	87
761666	3.06	kaolinitic	86
760929	3.75	kaolinitic	84
760490	2.96	kaolinitic	84

The two composite samples ( $> 15$  kg each) were then each riffled, as shown in **Figure 3.1**, to provide:

- a sample for head analysis (pulverised) – approximately 200 g;
- a sample for mineralogical analysis ( $< 1\text{-}2$  mm but not pulverised) – approximately 200 g; and
- 700 g portions (crushed to  $< 1\text{-}2$  mm) for milling and leaching tests.



**FIGURE 3.1** Crushed Samples (siliceous Composite 2 sample on left side)

### 3.1 Sample Analysis

Pulverised head samples were assayed by XRF (Uniquant) and for uranium by delayed neutron counting (DNA), as shown in **Table 3.2**. Samples of the composites were also analysed by Leco CNS2000 for total carbon as shown in **Table 3.3**.

Assays for decay chain progeny radionuclides were obtained for the two composites by gamma spectrometry. Results are summarised in **Table 3.4**. Gamma assay data are supplied in **Appendix A**. The uranium decay chain is in secular equilibrium in the composite ore samples.

### 3.2 Grindability

700 g riffled portions of the ore composites were wet milled in a rod mill to achieve a target  $P_{80}$  of 180  $\mu\text{m}$ . Grindability data is given in **Appendix B** and particle size distributions of milled ore are shown in **Figures 3.2** and **3.3** for composite 1 and composite 2 ores, respectively. As indicated by the assays and the appearance of the samples, the pale cream siliceous ore (composite 2) was more difficult to mill than the orange-brown coloured, high iron sample (composite 1).

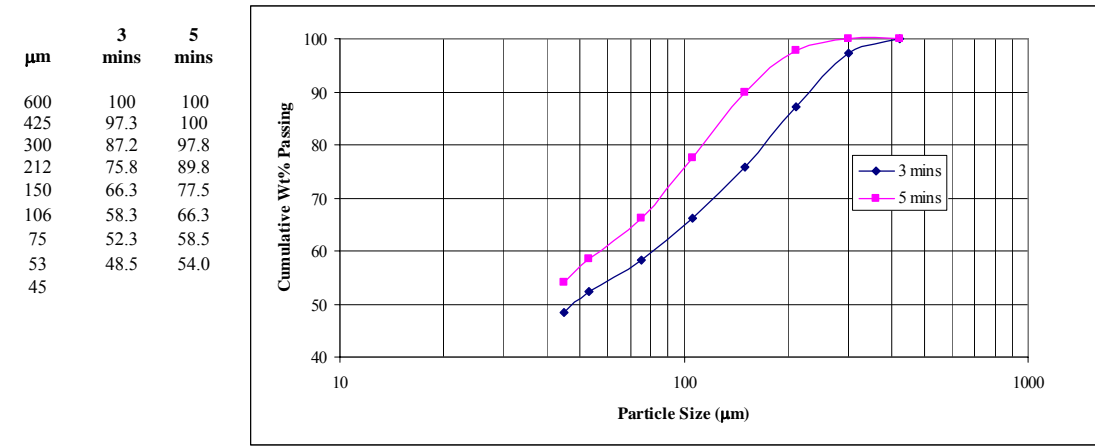


FIGURE 3.2 Milled Ore Particle Size Distribution – Composite 1

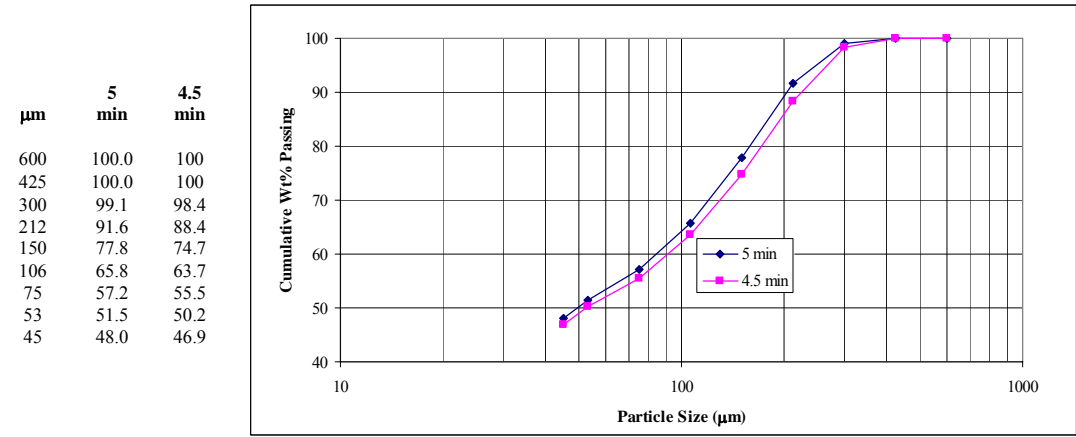


FIGURE 3.3 Milled Ore Particle Size Distribution – Composite 2

**TABLE 3.2**  
**Composite Sample Assay by XRF (wt%) and DNA**

Sample ID	LOI*	Na	Mg	Al	Si	P	S	K	Ca	Sc	Ti	V	Cr	Mn	Fe
NUPOWER COMP 1	6.8	0.31	0.12	5.50	21.0	2.74	0.19	0.42	1.83	0.021	0.16	0.065	0.093	0.049	16.9
NUPOWER COMP 2	4.8	0.16	0.16	7.17	30.3	4.10	0.14	0.55	1.21	0.022	0.14	0.031	0.088	0.011	0.68
	Co	Ni	Cu	Zn	As	Sr	Y	Zr	Nb	Ba	Pb	Ce	Th		U <sub>3</sub> O <sub>8</sub>
NUPOWER COMP 1	<0.001	0.007	0.027	0.13	0.007	0.30	0.031	0.21	0.22	0.054	0.017	0.14	0.01		(DNA ppm) 164
NUPOWER COMP 2	<0.001	<0.001	0.008	0.016	<0.001	0.33	0.023	0.25	0.32	0.074	0.016	0.18	0.008		114

\* calculated by difference, assuming the elements are present as the oxides shown.

**TABLE 3.3**  
**Composite Sample Assay by Leco (wt%)**

Sample ID	Total C	Total N	Total S
NUPOWER COMP 1	0.2	0.1	<0.1
NUPOWER COMP 2	0.1	<0.1	<0.1

**TABLE 3.4**  
**Summary of Composite Sample Assays by Gamma Spectrometry (Bq/kg)**

Sample	DNA		Gamma - U-238 Decay Chain				U-235**
	(ppm U <sub>3</sub> O <sub>8</sub> )	(Bq/kg)	Th-234	Pa-234m	Ra-226*	Pb-210	
NUPOWER Composite 1	164	1720	1740	1670	1510	1620	74
NUPOWER Composite 2	114	1200	1130	1280	1010	1070	51

\* average of values for short lived progeny <sup>214</sup>Pb and <sup>214</sup>Bi

\*\* inferred from Th-227 in the U-235 decay chain

Sample	Gamma - Th-232 Decay Chain	
	Ra-228 <sup>#</sup>	Th-228***
NUPOWER Composite 1	38	36
NUPOWER Composite 2	34	25

<sup>#</sup> from short lived progeny <sup>228</sup>Ac

\*\*\* from short lived progeny <sup>212</sup>Pb

## 4. MINERALOGY

A portion of each of the < 1 – 2 mm unpulverised composite samples of Lucy Creek ore (LCC1 and LCC2) were taken for mineralogical assessment. Major mineralogical phases present were identified by X-ray diffraction (XRD). Uranium ore minerals and other minor constituents were examined using a scanning electron microscope (SEM) equipped with an energy dispersive system (EDS).

### 4.1 Analysis

#### 4.1.1 X-Ray Diffraction

##### Method

The samples provided were analysed using a Siemens D500 diffractometer using Co K $\alpha$  radiation and a graphite monochromator. Data was collected in the angular range of 5° to 80°. The resulting spectrum was analysed with the PANalytical analysis package High Score Pro to locate peak positions, identify phases and determine lattice parameters.

##### Experimental

Composite 1 was concluded to be primarily composed of four crystalline phases; the major phase being quartz (SiO<sub>2</sub>) and the minor phases being clinocllore (Mg<sub>5</sub>Al<sub>7</sub>Fe<sub>3</sub>FeCrNi)O<sub>10</sub>(OH)<sub>8</sub>, goethite FeO(OH) and wavellite Al<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>(OH)<sub>3</sub>(H<sub>2</sub>O)<sub>5</sub>.

Composite 2 was concluded to be primarily composed of three crystalline phases; the major phases being quartz (SiO<sub>2</sub>) and illite K(Al<sub>4</sub>Si<sub>2</sub>O<sub>9</sub>(OH)<sub>3</sub>) and the minor phase being wavellite Al<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>(OH)<sub>3</sub>(H<sub>2</sub>O)<sub>5</sub>.

Uranium minerals were below the detection limits of the XRD instrument.

The results for each sample are presented in **Appendix C, Figures 1-2**.

#### 4.1.2 Scanning Electron Microscopy

##### Method

SEM and X-ray microanalysis was carried out on an epoxy resin impregnated portion of the unpulverised samples using a JEOL JSM-6300 SEM and an attached Noran Instruments Voyager Series IV X-ray microanalysis system. The SEM was operated at an accelerating voltage of 15 kV with a working distance of 15 mm. The images were acquired in both secondary electron and backscattered electron (BSE) imaging mode. BSE mode 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.* Fe, U) than compositions producing the darker grey levels (*e.g.* Si, Mg). The black background in the images is the epoxy resin grain mount. X-ray analysis (energy dispersive system – EDS) was undertaken to confirm mineralogy as far as was possible given the small grain size and the intimately intergrown nature of the Lucy Creek material.

## Experimental

Lucy Creek composite sample 1 (LCC1) is composed of individual grains, and grain aggregates, which have a widely variable range of grain sizes ( $< 2 \mu\text{m}$  to  $> 300 \mu\text{m}$ ); **Appendix D, Figures 1 and 2**. The dominant phases present are quartz, iron oxide and phosphate (both Al-rich and Ca-Al rich phosphates have been identified by SEM). The finer grained material is largely comprised of mixtures of quartz, iron oxide, clay (Fe-rich chlorite, kaolinite), sericite and phosphate. Rims of the finer grained material are frequently observed surrounding larger grains (particularly quartz). Accessory phases identified include rutile, cassiterite, spinel group minerals (e.g. chromite), zircon, barytes, galena, gypsum and uranium and thorium bearing minerals. The uranium minerals are very sparsely distributed within the sample ( $< 0.5\%$  modal abundance). The observed uranium minerals were generally between 1 and 5  $\mu\text{m}$  and appear as free grains (i.e. they are not inclusions within other phases). The located uranium minerals (**Appendix D, Figure 4**) are surrounded/supported by clay (though, since this is a composite sample, this observation does not necessarily reflect their disposition in the primary ore). The in-situ EDS analysis of the uranium minerals suggests that they may contain a little silicon, however, the grains are so small that it is likely that the silicon peak is derived from overlap of the electron beam into adjacent silicate phases. It seems most likely that the majority of the uranium is present as uraninite. There is the slight suggestion of an additional uranium phase rich in Ca-Ti-U (perhaps brannerite), however it is significantly less abundant than the uraninite.

Lucy Creek composite sample 2 (LCC2) is generally similar to LCC1, however, it contains significantly less abundant iron oxide. This is also suggested by the obvious white colour of LCC2 as compared to the yellow-brown hue of LCC1. The composite is dominated by larger grains of quartz and phosphates (both Ca-Al rich and Al-rich phosphates are present) again with widely varying grain sizes ( $< 5 \mu\text{m}$  to  $> 450 \mu\text{m}$ ); **Appendix D Figure 3**. Finer grained material is again evident surrounding and between the larger particles. The finer material (1  $\mu\text{m}$  to 5  $\mu\text{m}$ ) is a mixture of phosphate, quartz, sericite, iron oxide and clay (kaolinite and illite). Accessory minerals identified include zircon, cassiterite and uraninite. Only one particle of uraninite was located in LCC2 (suggesting the total uranium content of this composite to be generally lower than LCC1). The uraninite (**Appendix D, Figure 5 A and B**) is approximately 2  $\mu\text{m}$  long and surrounded by clay.

The results of the SEM examination on the two composite samples are presented in **Appendix D, Figures 1-5**.

### 4.2 Conclusions from the Mineralogical Study

- Lucy Creek composite samples 1 and 2 contain significant quartz, wavellite (Al-rich phosphate) and a more minor Ca-Al-rich phosphate phase (not identified by XRD).
- Composite 1 contains a significant iron content manifested in the minerals goethite and clinocllore.
- Composite 2 contains abundant illite and more minor kaolinite.
- The uranium in both samples appears to be present as small ( $< 5 \mu\text{m}$ ), sparsely distributed, particles of uraninite.
- The abundance of fine grained phosphate and clays within the composite samples may cause difficulties with the successful leaching of the uranium.



## 5. TESTWORK DESCRIPTION

700 g sample portions of crushed ore were used in agitated slurry leach tests. The leach tests were carried out in small agitated stainless steel baffled tanks with lids under conditions of controlled pH, ORP and temperature. Dilute leach tests were also carried out on smaller samples of more finely milled ore samples.

### 5.1 Leaching Testwork

The composite 1 ore was easily agitated as a 50 wt% slurry. Frothing was observed during the initial period of leaching at standard conditions at 40°C, but was not significant at 60°C.

In the acid leaching of uranium ores, the dissolution of uranium and gangue minerals is very sensitive to the acidity and oxidising potential of the leach solution. To maintain optimum conditions, these conditions were closely controlled for the duration of leaching. For example, for typical ores, a change in leach pH from 1.8 to 1.5 at 45°C could increase acid addition from 35 to 60 kg/t. Similarly, failure to maintain a ferric ion concentration in the range 1.5 – 2 g/L could result in a loss in uranium extraction of 5%. Such changes in leach conditions could occur within 15 minutes at the start of leaching, if leach conditions are not continuously controlled.

Ideally leach tests should be carried out at a number of grind sizes. As the ore was only available as RC drilling samples, it was proposed that all tests be carried out at a typical industry grind size used for uranium leaching. The mineralogical examination indicated the need for fine grinding for uranium mineral liberation.

Agitation leach tests were carried out on composite ore ground to a P<sub>80</sub> of 180 µm. Standard acid leach conditions were as follows:

Slurry density	:	50 wt%, initial slurry in tap water <sup>1</sup> .
Temperature	:	controlled at 40-60°C for 24 h.
pH	:	Controlled for 24 h by addition of conc. sulphuric acid.
ORP	:	Controlled for 12 h by addition of pyrolusite.
Samples	:	Samples were taken after 1, 4, 8, 12 and 24 h for liquor and solid assays.

All liquor samples were analysed for U, P, Fe, Si, Mg, Al, S, K, Ca, Mn by ICP/OES, and free acid and Fe<sup>2+</sup> by titration. Solids samples were also assayed for U by DNA.

If acid leaching **proved effective but** required too high a consumption of acid, the samples could alternatively be leached under alkaline conditions, although extraction is usually poorer. A major advantage of alkaline leaching is the composition of leach liquor and its process and environmental implications.

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<sup>1</sup> Ideally local ground water should be used, as water composition may impact on leaching

All final leach residues were analysed by XRF. Leach residues were not examined by SEM in this study to identify undissolved uranium minerals, and to obtain possible explanation for their non-dissolution. This would have been difficult, in any case, because of the low concentrations of uranium and therefore the small occurrence of uranium host minerals.

The conditions used in the tests are given in **Table 5.1**.

Different oxidant types were not tested, as, in our experience, this has no impact on leaching, provided that similar oxidising conditions are maintained.

**TABLE 5.1**  
**Leach Test Conditions – 24 h leach duration**

Test N <sup>o</sup> .	pH	Temperature (°C)	ORP (mV)	Acid Addition (kg/t)	Comments
<i>Composite 1</i>					
<i>Slurries</i>					
NU 1-A	1.8	40 <sup>#</sup>	456-569	33	Oxidant over addition
NU 1-B	1.2	40	452-466	49	
NU 2-A	1.2	60	450	68	Impact of temperature
<i>Dilute</i>					
NU 2-B	1.5	60	541-570	NA	Dilute, pulverised ore
NU 4-A	50 g/L	70	660-642	NA	Dilute, 2 g/L Fe <sup>3+</sup>
NU 4-B	25 g/L	70	679-649	NA	Dilute, 2 g/L Fe <sup>3+</sup>
<i>Composite 2</i>					
<i>Slurries</i>					
NU 3-A	1.2	60	450	53	
NU 5	50 g/L	60	450	140	2 g/L Fe <sup>3+</sup>
<i>Dilute</i>					
NU 3-B	1.5	60	575-523	NA	Dilute, pulverised ore
NU 4-C	50 g/L	70	660-635	NA	Dilute, 2 g/L Fe <sup>3+</sup>
NU 4-D	25 g/L	70	664-633	NA	Dilute, 2 g/L Fe <sup>3+</sup>

<sup>#</sup> Because of ambient temperatures, heat from grinding and dilution of conc. acid, 40°C is typically the lowest temperature achieved in practice

NA not applicable

Dilute tests are normally carried out on milled ore to determine the limit for extraction under typical conditions. The dilute test is carried out first to give a guide as to the suitability of the agitation tests conditions. Dilute tests are conducted at low slurry density to determine the maximum extraction of uranium obtainable under ideal conditions. Because of the low slurry density used, dissolution of gangue does not impact on the leach liquor composition, with the result that constant leach conditions are maintained, without the need for constant supervision.

Initial dilute acid leach conditions were as follows:

Slurry density	:	40 g of ore in 2 L of Sydney tap water
Temperature	:	40 - 60°C
Acidity	:	pH 1.2-1.5 (sulphuric acid)
iron addition	:	total iron of 2 g/L by addition of iron sulphate
Ferric/ferrous ratio	:	2/1, set by adding ferric and ferrous sulphate
Leach Duration	:	24 h
Samples	:	Samples were taken after 4, 8, 12 and 24 h for liquor assay. After 24 h, all solids were recovered, washed and assayed for U by DNA.

## 6. TESTWORK RESULTS

The study results are as follows.

### 6.1 Analysis

The major components of the ore are Si, Fe, Al and P, as shown in **Table 6.1**. Of note is the very high P content and the very different iron contents.

The uranium grades are very low, 164 and 114 ppm  $U_3O_8$  for the composites 1 and 2 respectively, as determined by DNA.

**TABLE 6.1**  
**Major Components of the ore**

Sample ID	Si	Fe	Al	P	Ca
NUPOWER COMP 1	21.0	16.9	5.50	2.74	1.83
NUPOWER COMP 2	30.3	0.68	7.17	4.10	1.21

### 6.2 Leach Testwork

The results of leach tests are provided in this section and are summarised in **Tables 6.2** and **6.3**. Detailed results are given in **Appendix D**.

#### 6.2.1 Dilute Leach Testwork

Dilute tests on pulverised samples were carried out to determine the extraction of uranium under ideal solution chemistry conditions. Results are shown in **Table 6.2**.

**TABLE 6.2**  
**Leach Results for Dilute Leach Conditions\***

Ore	Test N <sup>o</sup> .	Temp. (°C)	ORP (mV)	pH	Uranium Extraction (%)	Oxidant
<i>Composite 1</i>	NU2-B	60	541-570	1.5	33.1	none
	NU4-B	70	650-680	25 g/L H <sub>2</sub> SO <sub>4</sub>	46.8	2 g/L Fe <sup>3+</sup>
	NU4-A	70	640-660	50 g/L H <sub>2</sub> SO <sub>4</sub>	61.2	2 g/L Fe <sup>3+</sup>
<i>Composite 2</i>	NU3-B	60	520-580	1.5	3.1	pyrolusite
	NU4-D	60	630-660	25 g/L H <sub>2</sub> SO <sub>4</sub>	5.2	2 g/L Fe <sup>3+</sup>
	NU4-C	70	640-660	50 g/L H <sub>2</sub> SO <sub>4</sub>	45.4	2 g/L Fe <sup>3+</sup>

\* All tests were conducted for 24 h, 2 wt% slurry density

At less acidic conditions, composite 2 showed a significantly lower uranium extraction, 3.1%, than composite 1, 33.1%, while its response to increasing free acidity confirmed the more refractory nature of the composite 2 ore.

The dilute leach uranium extractions were unsatisfactory and showed that even if the leach solution chemistry was ideal, extraction was poor and probably due to the uranium host mineralogy.

### 6.2.2 Conventional Agitated Leach Testwork

Slurry leaching tests were also carried out as shown in **Table 6.3**. For the high iron composite 1, the slurry leach extractions, 13-32%, were generally below those observed in dilute leaches, 33-61%; albeit achieved at very high acidities. For the low iron composite 2, the slurry leach extractions, 19 and 46%, were in fact higher than those attained in dilute leaches, which achieved a maximum uranium extraction of 45%. Ferric addition was required for the low iron ore. High acidity improved the uranium extraction.

**TABLE 6.3**  
**Leach Results for Conventional Leach Conditions**

Ore	Test No.	Temp. (°C)	ORP (mV)	pH	Acidity (g/L H <sub>2</sub> SO <sub>4</sub> )	U Extraction (%)	Acid (kg/t)	Pyrolusite (kg/t)
<i>Composite 1</i>	NU 1-A	40	460-570	1.8	3	12.9	33	1.7
	NU 1-B	40	450-470	1.2	11	25.9	49	0.4
	NU 2-A	60	450-490	1.2	15	32.4	68	none
<i>Composite 2</i>	NU 3-A	60	400-450	1.2	16	18.6	17	1.3
	NU 5-A	60	450-470	50 g/L H <sub>2</sub> SO <sub>4</sub>	47	46.4	140	2 g/L Fe <sup>3+</sup>

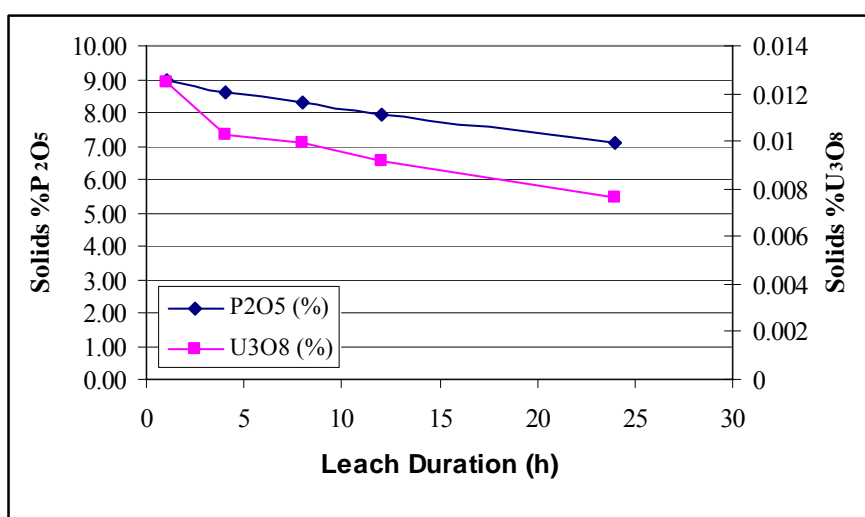
\* All tests were conducted for 24 h at 50 wt% slurry density

Final solution compositions in slurry leach tests are shown in **Table 6.4**.

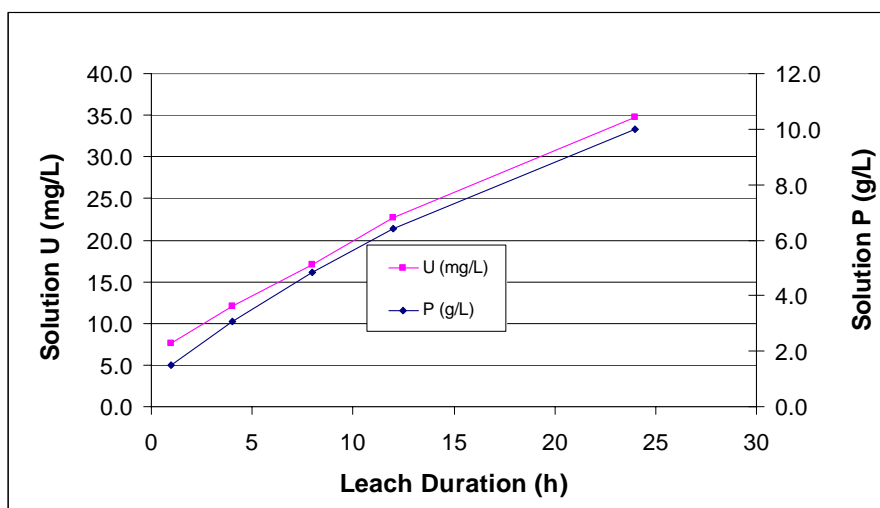
**TABLE 6.4**  
**Final Liquor Compositions in Conventional Slurry Leaches**

Ore	Test No.	Solution composition (mg/L)										
		Al	Ca	Fe	Fe <sup>3+</sup>	K	Mg	Mn	P	S	Si	U
<i>Composite 1</i>	NU 1-A	700	534	62	56	127	512	329	801	3440	266	9.6
	NU 1-B	1420	634	698	466	124	582	179	1720	8120	305	25.5
	NU 2-A	3340	813	1690	1080	226	727	39	208	13800	402	40
<i>Composite 2</i>	NU 3-A	5970	684	719	471	224	216	692	3420	14900	456	16
	NU 5-A	14100	771	4430	2810	182	272	571	10000	40000	278	34.7

Uranium leaching continues with phosphate dissolution, as the leach residue assays indicate in **Figure 6.1** for the aggressive slurry leach test NU 5-A on composite 2. The corresponding solution assays are given in **Figure 6.2**. Further analytical data is presented in **Appendix E**. The accountability for uranium in test 5-A ((leach solution + leach residue)/ore) was 90%.



**FIGURE 6.1**    **Residue Grades in Slurry Leach – Composite 2**



**FIGURE 6.2 Test No. NU5-A Solution Assay Trends with Leach Duration**

## 7. CONCLUSIONS

Leaching of low grade Lucy Creek rock has proven to be problematic. This is most likely due to the uranium being hosted, to a large extent, by refractory minerals, possibly phosphate minerals. It is likely that acceptable uranium extraction could only be achieved by uneconomically aggressive acid leach conditions. Although mineralogical investigation identified some uranium present as leachable uraninite, more than half of the small amount of uranium present may be hosted by more refractory (possibly phosphate) minerals.

## 8. ACKNOWLEDGEMENTS

The authors would like to acknowledge the assistance of the following staff:

Leach testwork - Kelly Hilliard, Mervyn Ovinis

Leach data compilation - Mervyn Ovinus

XRF analysis - Patricia Gadd

Gamma - Gordon McOrist

ICP - Chris Chipeta

XRD - Ian Kelly

## **APPENDIX A**

### **Gamma Spectrometry Assays**





## B21\_9 - Natural radioactivity calculation (IAEA)

NUPOWER Composite 1 Head 41.99g 17/9/07

Radionuclide	GammaVision Activity (Bq/Kg)	Corrected Activity (Bq/Kg)	% Uncertainty (1 $\sigma$ )
Th-234	1335.40	1736.89	10
Pa-234m	1636.90	1669.68	10
Th-230	1348.50	1715.01	10
Pb-214	1457.70	1496.32	10
Bi-214	1478.90	1514.12	10
Pb-210	1120.80	1621.08	10
Ac-228	37.35	38.40	14
Th-228	398.15	-419.12	
Ra-224	96.59	-101.65	
Pb-212	34.09	35.88	10
Bi-212	-23.03	-23.75	
Tl-208	11.71	12.12	10
U-235	74.61	77.66	12
Th-227	71.55	74.34	10
K-40	164.77	167.51	12

## B21\_9 - Natural radioactivity calculation (IAEA)

NUPOWER Composite 2 Head 37.30g 19/9/07

Radionuclide	GammaVision Activity (Bq/Kg)	Corrected Activity (Bq/Kg)	% Uncertainty (1 $\sigma$ )
Th-234	1050.90	1131.99	10
Pa-234m	1277.90	1282.19	11
Th-230	998.72	1071.03	10
Pb-214	991.39	1005.33	10
Bi-214	1008.40	1023.49	10
Pb-210	1013.60	1067.28	10
Ac-228	33.86	34.28	14
Th-228	-421.83	-437.91	
Ra-224	-87.62	-91.12	
Pb-212	23.64	24.58	10
Bi-212	-27.55	-28.07	
Tl-208	8.40	8.61	13
U-235	46.94	48.13	19
Th-227	49.22	50.51	10
K-40	161.95	163.32	10

## **APPENDIX B**

### **Grindability Data**



## GRINDING TEST LOGSHEET

Test No. : **1** Test Date : **21/09/2007**

Ore sample : Description : **NU Power Composite 1**

Sample ID: **NUP-010807-1**

Weight : **700 g** A

Mill : Description : Type : Rod Dimensions : 200 mm ID x mm L  
 Mill No. Media Type : 10 off rods mm ø Weight : g  
 Total charge volume : 30 - 40 %  
 Speed : **66 rpm** 70 % Critical, Nc

Water : **467 mL** B Type : **Sydney tap water**  
 % solids S.G. =

Milling Time : **5** minutes

Leaching ? **NO**

Wet screen (µm) 106 and 45

Dry oversize = g dry solids

Fines(<53µm) = g dry solids

Gross  
dry weights :

Coarse

G g

T g

N 354.3 g

Dry oversize solids riffled to 100 g for sizing

Sizing : Size (µm)	Weight (g)	Weight (%)	Cum. Weight % Passing
600		0.0	100.0
425		0.0	100.0
300		0.0	100.0
212	4.4	2.2	97.8
150	15.7	8.0	89.8
106	24.4	12.4	77.5
75	22.1	11.2	66.3
53	15.3	7.8	58.5
45	8.9	4.5	54.0
<45	9.2	4.7	49.3
fines (dry) <45	106.5	54.0	
Total	197.3	100.0	

Fines

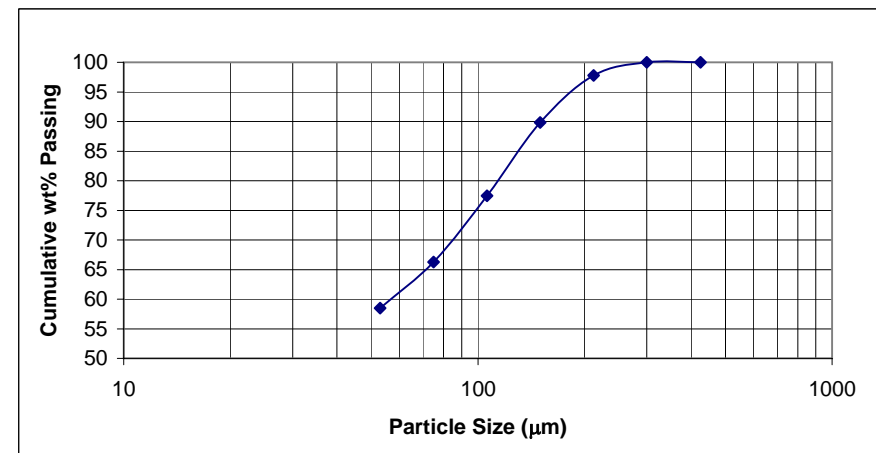
G g

T g

N 344.9 g

Objective

P80 ~ 180 µm



µm	Wt% Passing
600	100.0
425	100.0
300	100.0
212	97.8
150	89.8
106	77.5
75	66.3
53	58.5
45	54.0

Test No. : 2 Test Date : 27/09/2007

Test No. : 2

Test Date : **27/09/2007**

Ore sample :      Description :    **NU Power Composite 1**

Sample ID: **NUP-010807-1**

Weight : **700 g** A

Mill : Description : Type : Rod Dimensions : 200 mm ID x mm L

Mill No.      Media Type :    10 off rods      mm  $\phi$       Weight :      g

Total charge volume : 30 - 40 %

Speed : 66 rpm 70 % Critical, Nc

Water : 467 mL B Type : Sydney tap water

ME	D	Type I Syntex
% solids		S.G. =

Milling Time : **3** minutes

Leaching ? **NO**

Wet screen (μm)	106 and 45
-----------------	------------

Dry oversize = \_\_\_\_\_ g dry solids

Fines( $<53\mu\text{m}$ ) = g dry solids

Gross

dry weights :

Coarse

G

T

N 397.1 g

Dry oversize solids riffled to 100 g for sizing

## Fines

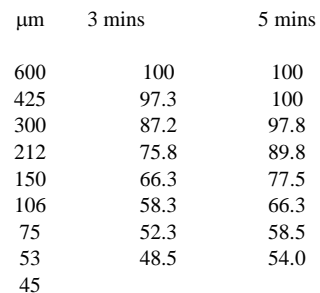
G

T

N 302.9 g

## Objective

P80 ~ 180  $\mu\text{m}$



GRINDING TEST LOGSHEET

Test No. : 3

Ore sample :

Description : NU Power Composite 2

Sample ID: NUP-010807-2

Weight : 700 g

A

Mill :

Description : Type : Rod

Media Type : 10 off rods

Total charge volume :

Speed : 66 rpm

Dimensions : 200 mm ID x mm L

Weight : g

30 - 40 %

70 % Critical, Nc

Water :

467 mL

B

Type : Sydney tap water

% solids

S.G. =

Milling Time :

5 minutes

Leaching ?

NO

Wet screen (µm)

106 and 45

Dry oversize =

g dry solids

Fines(<53µm) =

g dry solids

Gross dry weights :

Coarse

G

T

N

388.2 g

Dry oversize solids riffled to

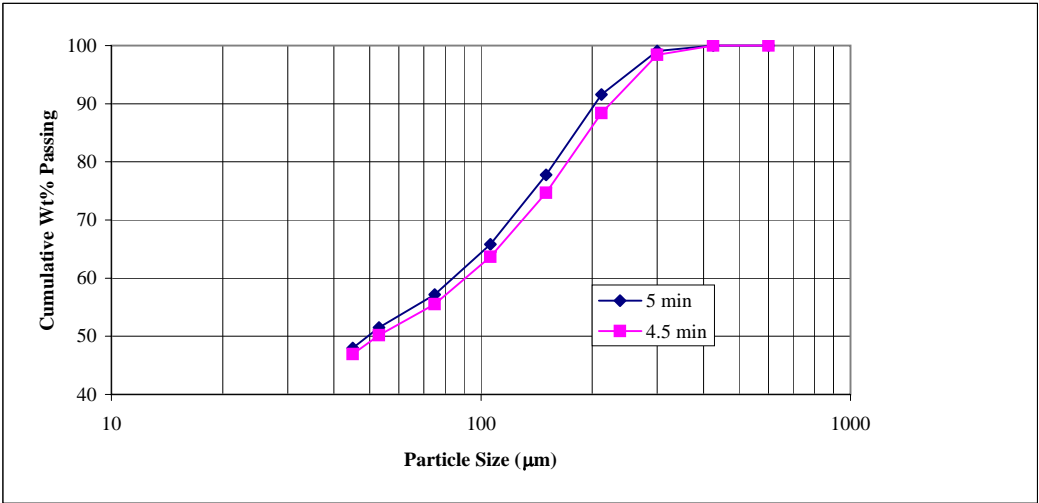
100

g for sizing

Sizing : Size (µm)	Weight (g)	Weight (%)	Cum. Weight % Passing
600		0.0	100.0
425		0.0	100.0
300	1.7	0.9	99.1
212	13.5	7.5	91.6
150	24.8	13.8	77.8
106	21.5	11.9	65.8
75	15.6	8.7	57.2
53	10.2	5.7	51.5
45	6.3	3.5	48.0
<45	6.4	3.6	44.4
fines (dry) <45	86.38454405	48.0	
Total	180.0	103.6	

Fines	G	T	N	310.5 g
-------	---	---	---	---------

Objective  
P80 ~ 180 µm



µm	5 min	4.5 min
600	100.0	100
425	100.0	100
300	99.1	98.4
212	91.6	88.4
150	77.8	74.7
106	65.8	63.7
75	57.2	55.5
53	51.5	50.2
45	48.0	46.9

GRINDING TEST LOGSHEET

Test No. : 4

Ore sample :

Description : NU Power Composite 2

Sample ID: NUP-010807-2

Weight : 700 g

A

Test Date : 13/09/2007

Mill :

Mill No.

Description : Type : Rod

Media Type : 10 off rods

Total charge volume :

Speed :

Dimensions : 200 mm ID x mm L

mm ø

30 - 40 %

66 rpm

Weight : g

70 % Critical, Nc

Water :

467 mL

B

Type : Sydney tap water

% solids

S.G. =

Milling Time :

4.5 minutes

Leaching ?

NO

Wet screen (µm)

106 and 45

Dry oversize =

g dry solids

Fines(<53µm) =

g dry solids

Gross dry weights :

Coarse

G

T

N

399.6 g

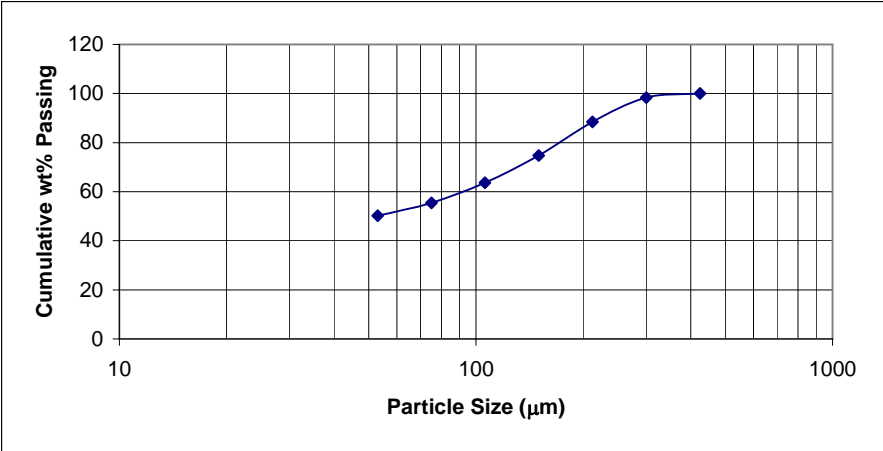
Dry oversize solids riffled to

100

g for sizing

Sizing : Size (µm)	Weight (g)	Weight (%)	Cum. Weight % Passing
600	0	0.0	100.0
425	0	0.0	100.0
300	2.8	1.6	98.4
212	17.5	10.0	88.4
150	24	13.7	74.7
106	19.3	11.0	63.7
75	14.3	8.2	55.5
53	9.3	5.3	50.2
45	5.7	3.3	46.9
<45	7.1	4.1	42.9
fines (dry) <45	82.15005005	46.9	
Total	175.1	104.1	

Fines	
G	g
T	g
N	299.9 g
Objective	
P80 ~ 180 µm	



µm	Wt% Passing
600	100
425	100
300	98.4
212	88.4
150	74.7
106	63.7
75	55.5
53	50.2
45	46.9



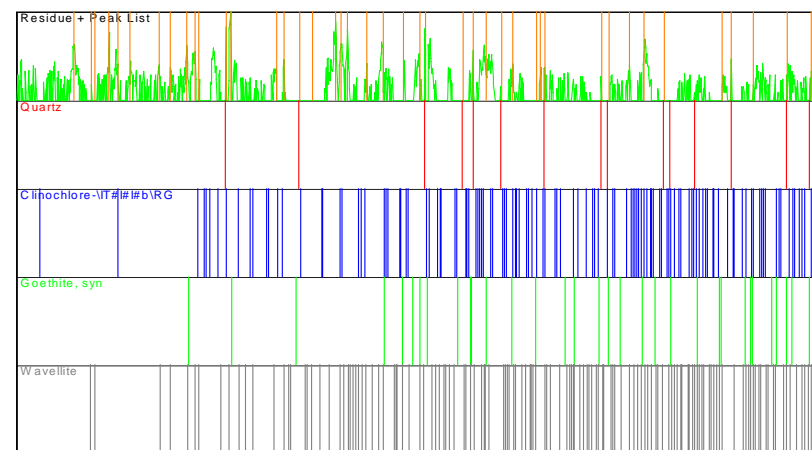
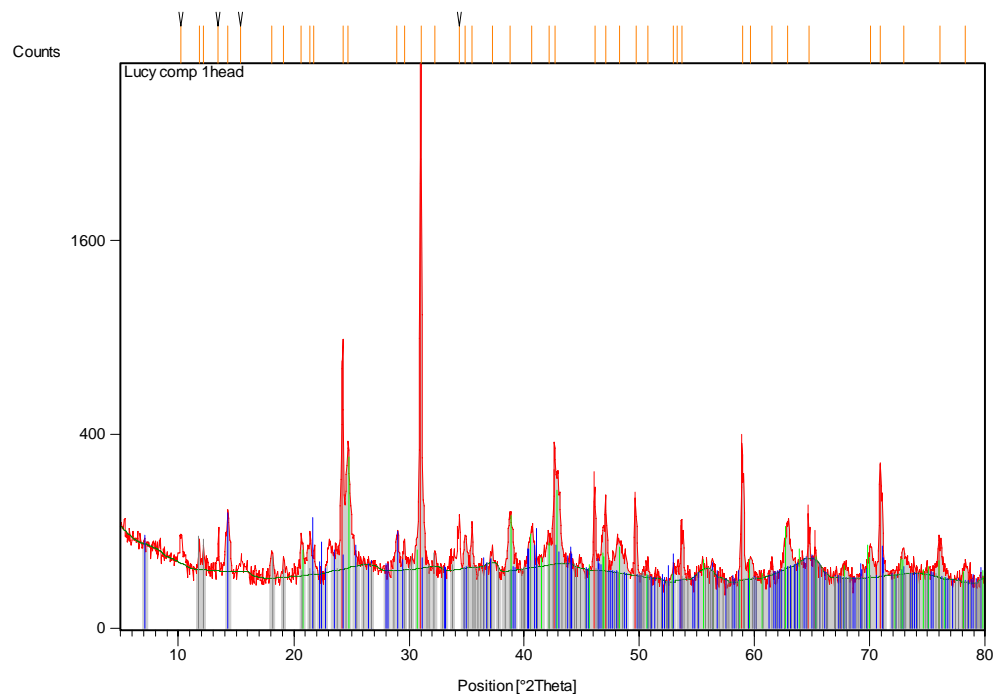
## **APPENDIX C**

### **XRD Patterns for Lucy Creek Samples**



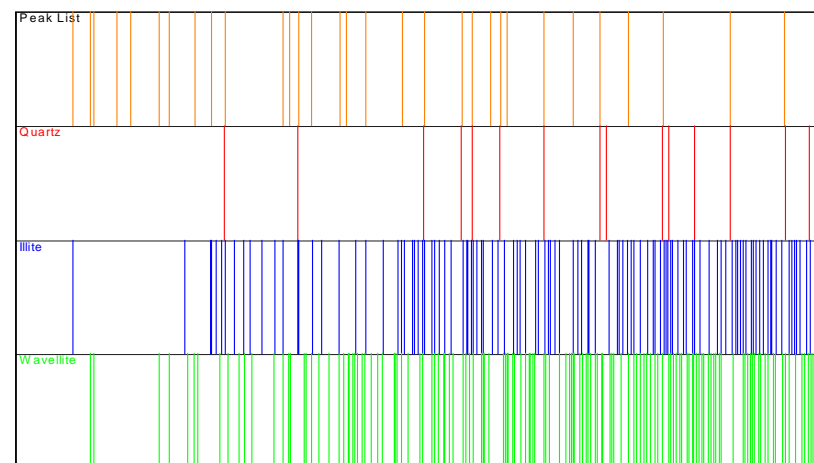
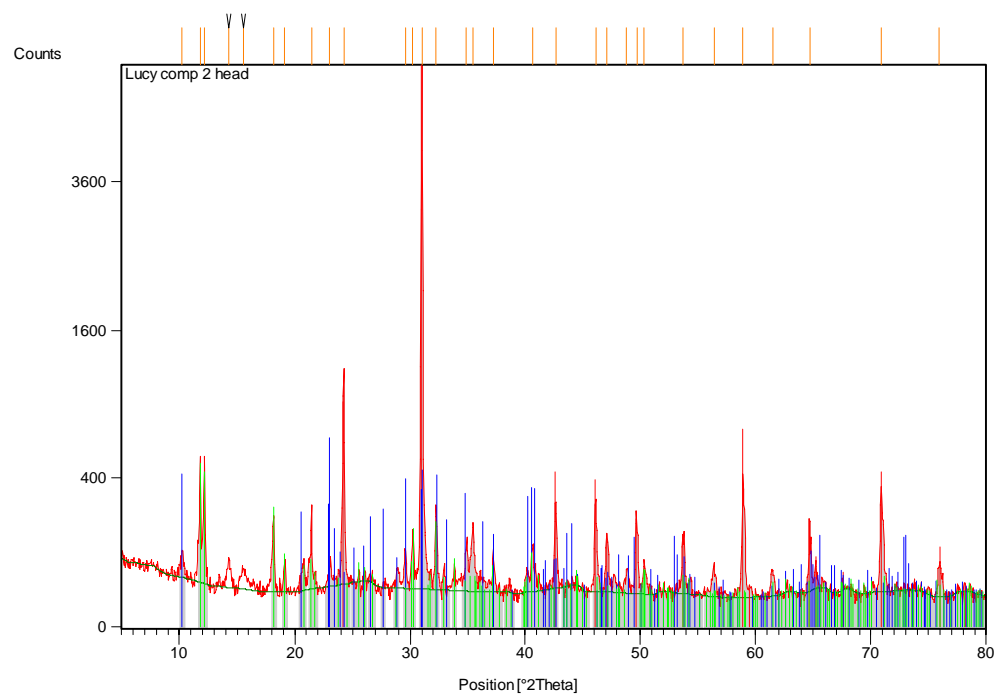
**FIGURE 1: Lucy Creek Composite 1**

**Composite 1:** composed of four crystalline phases, the major being Quartz  $\text{SiO}_2$  (indicated by the red stick pattern) and the minor phases being Clinocllore ( $\text{Mg}_5 \text{Al}_7 \text{Fe}_3 \text{Fe Cr Ni} \text{O}_{10} (\text{OH})_8$ ) (indicated by the blue stick pattern), Goethite  $\text{Fe O} (\text{OH})$  (indicated by the green stick pattern) and Wavellite  $\text{Al}_3 (\text{PO}_4)_2 (\text{OH})_3 (\text{H}_2\text{O})_5$  (indicated by the grey stick pattern).



**FIGURE 2: Lucy Creek Composite 2**

**Composite 2:** composed of three crystalline phases, the major being Quartz  $\text{SiO}_2$  (indicated by the red stick pattern) and Illite  $\text{K}(\text{Al}_4 \text{Si}_2 \text{O}_9(\text{OH})_3)$  (indicated by the blue stick pattern) with a minor phase of Wavellite  $\text{Al}_3 (\text{PO}_4)_2(\text{OH})_3(\text{H}_2\text{O})_5$  (indicated by the green stick pattern).



## **APPENDIX D**

### **SEM IMAGES and EDS SPECTRA**



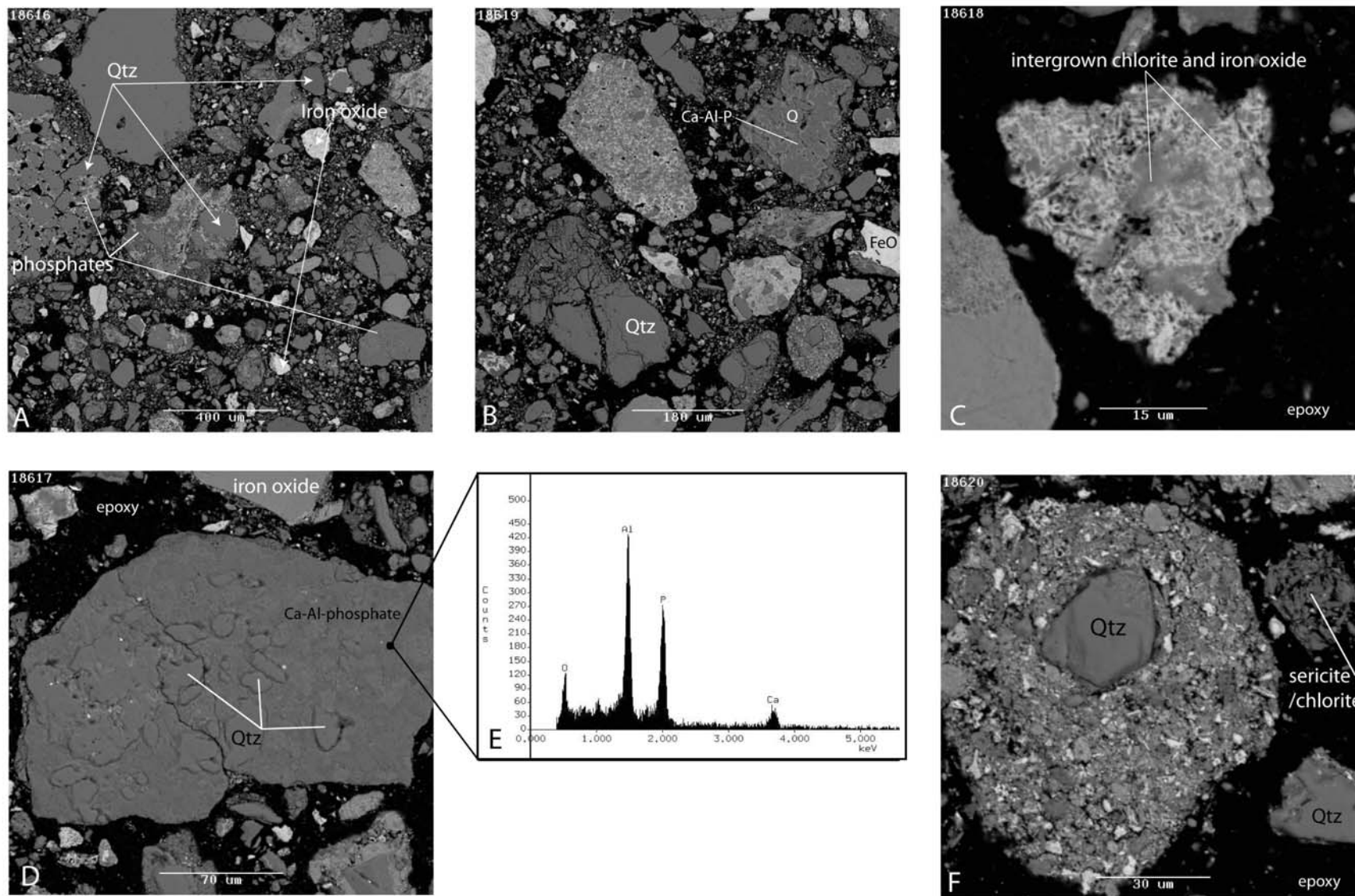
**FIGURE 1: Lucy Creek Composite 1 - General mineralogy**

Backscattered (BSE) electron micrographs and energy dispersive spectra (EDS) from sample LCC 1:

- A** BSE image, x60, low magnification view of composite sample LCC 1. The sample is predominantly comprised of quartz, iron oxide, fine grained clay (largely Fe-rich chlorite) and altered phosphates (often observed surrounding the other particles).
- B** BSE image, x130, general view of the composite illustrating the aggregate nature of many of the larger particles.
- C** BSE image, x1500, higher magnification image illustrating the heterogeneous nature of the finer grained material. The 'white' particulates are rich in iron, and appear to be surface coatings to fine grained material which is intergrown with clay/chlorite.
- D** BSE images, x370, an aggregate particle composed of semi-rounded quartz grains (some labelled) surrounded by a poorly crystalline Ca-Al rich phosphate phase.
- E** EDS spectrum of phosphate phase shown in D.
- F** BSE image, x800, quartz grain rimmed by fine grained material comprised of smaller quartz, iron oxides, clays, phosphates and sericite. Note the cluster of sericite and chlorite particles to the right of the main aggregate.

## Lucy Creek Composite 1 - General mineralogy

Figure 1 A-F





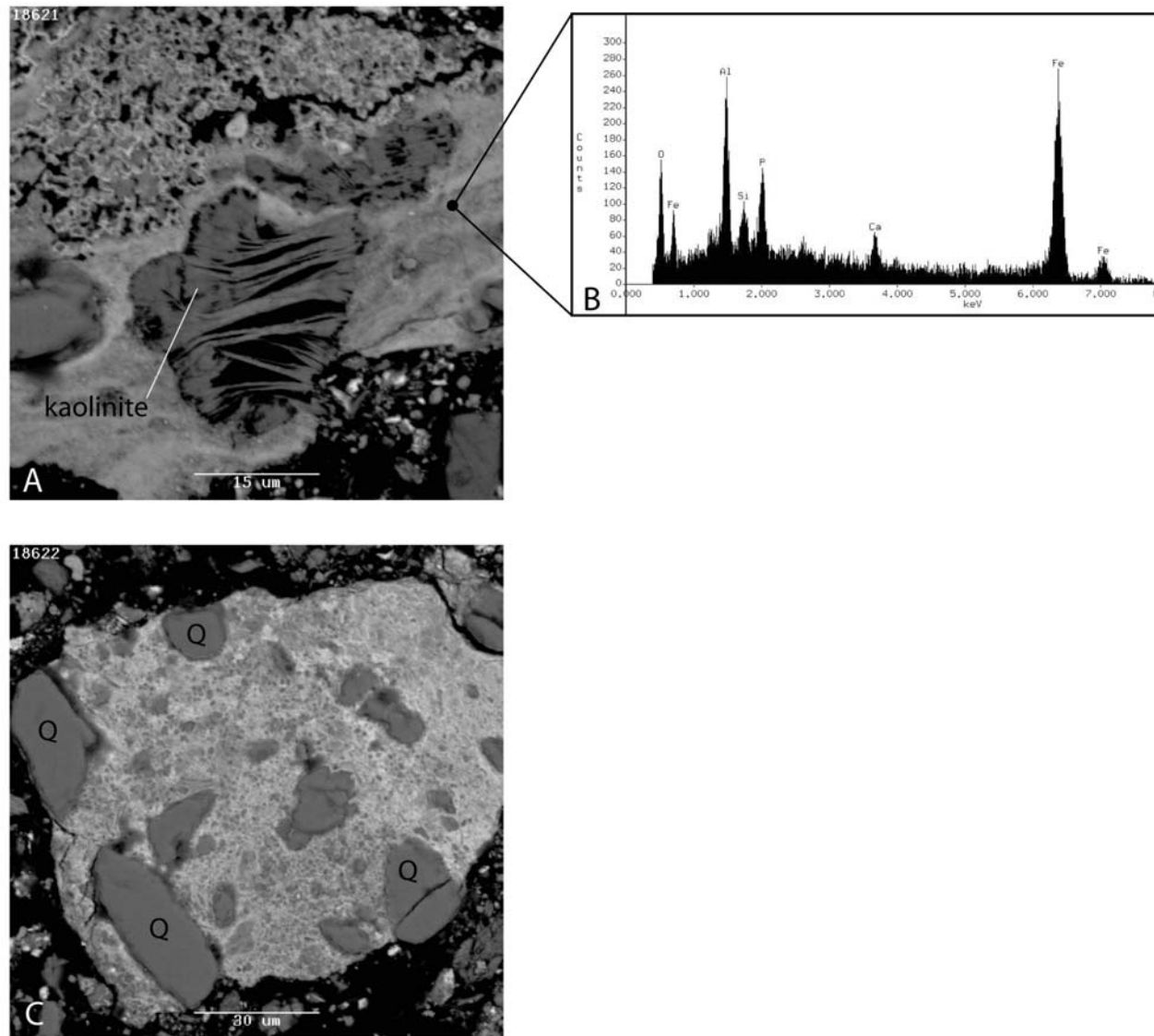
**FIGURE 2: Lucy Creek Composite 1 – General mineralogy**

Backscattered (BSE) electron micrographs and energy dispersive spectra (EDS) from LCC 1:

- A** BSE image, x1500, relatively large flakes of clay (probably kaolinite) surrounded by very fine, apparently iron rich, phosphate. Note the surficial coating of iron (white) to the fine grained particles top left in the image.
- B** EDS spectrum iron rich phosphate depicted in A, perhaps reflecting a mixed analysis from cryptocrystalline/intergrown iron oxide and Ca-Al-phosphate.
- C** BSE image, x750, aggregate grain comprised of quartz particles surrounded by finer-grained, iron rich particles largely of clay and phosphate.

## Lucy Creek Composite 1 - General mineralogy

Figure 2 A-C



**FIGURE 3: Lucy Creek Composite 2 – General mineralogy**

Backscattered (BSE) electron micrographs and energy dispersive spectra (EDS) from LCC 2:

**A** BSE image, x60, low magnification view of composite sample LCC 2. The sample is predominantly comprised of quartz, fine grained clay (largely Fe-rich chlorite) and altered phosphates (often observed surrounding the other particles). Note: iron oxide is present as a very minor constituent of this sample (*cf* LCC 1 where it is abundant).

**B** BSE image, x400, quartz particles surrounded by fine-grained Ca-Al rich phosphate

**C** BSE image, x900, higher magnification image of the finer grain size material illustrating that it is constituted quartz, clay (kaolinite, chlorite and sericite), laths of sericite, and very fine phosphate (frequently the interstitial infill).

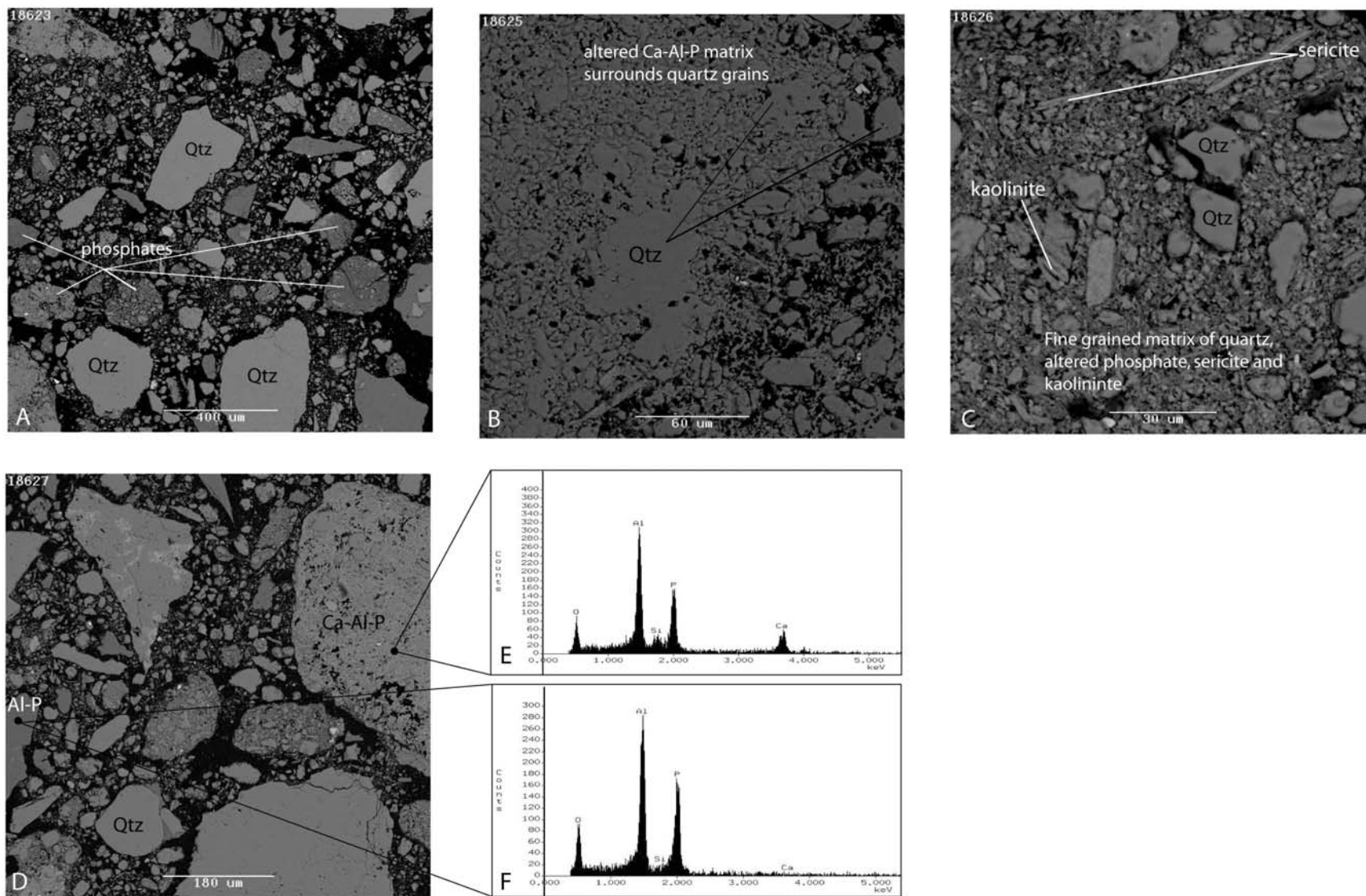
**D** BSE image, x130, aggregates of quartz and Ca-Al phosphate are abundant (as LCC1), but crystalline Al-phosphate is also evident.

**E** EDS spectrum of Ca-Al phosphate shown in D.

**F** EDS spectrum of Al-phosphate shown in D.

## Lucy Creek Composite 2 - General mineralogy

Figure 3 A-F



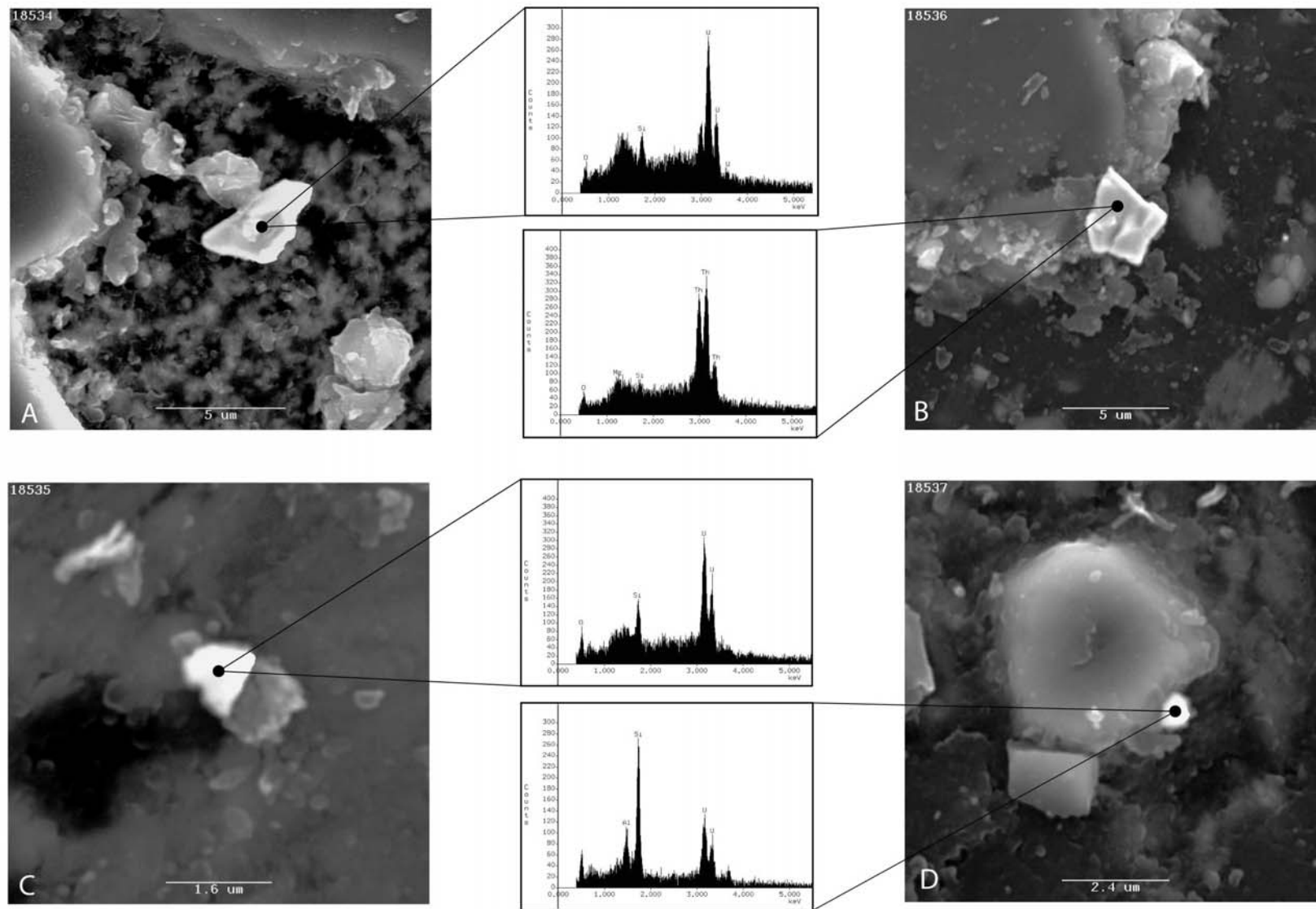
**FIGURE 4: Lucy Creek Composite 1 – Uranium mineralogy**

Secondary (SE) electron micrographs and energy dispersive spectra (EDS) from LCC 1:

- A** SE image, x5500, of uranium mineral observed in LCC 1. The mineral is liberated (ie not enclosed in another phase). It's EDS spectrum suggests it is likely to be uraninite. The small Si peak observed is believed to be due to the proximity of adjacent silicate phases.
- B** SE image, x4500, a cleaved, high relief mineral observed toward the margin of a larger quartz grain is shown by the EDS spectrum obtained to be rich in Th suggesting it is likely to be a "thorite" or other Th rich phase.
- C** SE image, x14,000, very small uranium mineral surrounded by silicate (clay). The composition shown in the EDS spectrum suggests it could be either uraninite (assuming the Si is contributed from an adjacent phase), or coffinite (if the Si is not from adjacent phases).
- D** SE image, x9500, very small uranium mineral observed at the rim of a quartz grain, and surrounded by clay minerals. The EDS spectrum suggests the mineral could be a uraninite with Al and Si peaks being contributed from the adjacent clay and quartz.

## Lucy Creek Composite 1 - Uranium mineralogy

Figure 4 A-D



**FIGURE 5: Lucy Creek Composite 2 – Uranium mineralogy**

Secondary (SE) electron micrographs and energy dispersive spectra (EDS) from LCC 2:

**A** SE image, x2700, only one particle of uranium bearing material was located in LCC 2. Again the uranium mineral is in close proximity to a quartz grain, and surrounded by fine grained clay.

**B** Higher magnification SE image, x10,000, of the small uraninite particle shown in A.

**C** EDS spectrum collected from particle suggesting that this mineral is uraninite.

**Lucy Creek Composite 2 - Uranium mineralogy**

Figure 5 A-C







## **APPENDIX E**

### **Leach Spreadsheets**



Run	NU 1-A pH 1.8 450 mV for 12h							Solids: 700 g Tap Water: 700 g Slurry: 50 wt%		NUP-010807-1	Oxidant: Pyrolusite Leach Duration: 24 h Temperature: 40 °C ORP: 450 mV							ICP/OES Request No: 071056 XRF Request No: 071057			
								Solids Assays ppm	Extraction %	Solution Assays											mg/L
	Time h	Temp. °C	Acid kg/t	Pyrolusite kg/t	pH	Acidity g/L H <sub>2</sub> SO <sub>4</sub>	ORP mV	U <sub>3</sub> O <sub>8</sub>	U												
								DNA		Al	Ca	Fe	Fe <sup>3+</sup>	K	Mg	Mn	P	S	Si	U	
Head								164													
A1	1	40	30	1.7	1.80	3.10	456	143	12.9	372	614	48	39	34	358	216	1070	2320	306	6.48	
A2	4	40	32	1.7	1.80	3.36	544	144	12.2	466	581	51	43	48	413	252	999	2710	318	8.25	
A3	8	40	32	1.7	1.78	3.29	549	143	12.9	527	567	52	46	62	448	273	951	2780	287	8.27	
A4	12	40	32	1.7	1.80	3.29	555	144	12.2	576	574	55	48	79	474	289	899	3140	284	9.04	
A5	24	40	33	1.7	1.80	3.39	568	143	12.9	700	534	62	56	127	512	329	801	3440	266	9.64	

Comments: Substantial frothing upon initial acid addition.  
 Slurry agitation is good  
 Excess pyrolusite added was slow to react in slurry causing ORP overshoot and continual rise over the course of the leach.

Run	NU 1-B pH 1.2 450 mV for 12h							Solids: 700 g Tap Water: 700 g Slurry: 50 wt%		NUP-010807-1		Oxidant: Pyrolusite Leach Duration: 24 h Temperature: 40 °C ORP: 450 mV					ICP/OES Request No: 071056 XRF Request No: 071057				
								Solids Assays ppm	Extraction %	Solution Assays										mg/L	
	Time h	Temp. °C	Acid kg/t	Pyrolusite kg/t	pH	Acidity g/L H <sub>2</sub> SO <sub>4</sub>	ORP mV	U <sub>3</sub> O <sub>8</sub>	U												
								DNA		Al	Ca	Fe	Fe <sup>3+</sup>	K	Mg	Mn	P	S	Si	U	
Head								164													
B1	1	40	40	0.3	1.20	10.50	463	131	20.1	553	673	421	333	37	399	156	1900	5580	338	19.0	
B2	4	40	44	0.4	1.20	11.25	466	126	23.0	785	673	740	479	54	477	176	1960	6720	305	23.1	
B3	8	40	45	0.4	1.19	10.94	463	120	26.6	918	624	650	512	66	489	167	1950	6680	284	23.0	
B4	12	40	46	0.4	1.20	11.08	460	125	23.7	1080	650	693	528	81	533	176	1940	7280	288	23.8	
B5	24	40	49	0.4	1.20	11.45	452	121	25.9	1420	634	698	466	124	582	179	1720	8120	305	25.5	

Comments: Substantial frothing upon initial acid addition.  
 Slurry agitation is good

Run	NU 2-A pH 1.2 450 mV for 12h							Solids: 700 g Tap Water: 700 g Slurry: 50 wt%		NUP-010807-1		Oxidant: Pyrolusite Leach Duration: 24 h Temperature: 60 °C ORP: 450 mV					ICP/OES Request No: 071120 XRF Request No: 071130				
								Solids Assays ppm	Extraction %	Solution Assays mg/L											
	Time h	Temp. °C	Acid kg/t	Pyrolusite kg/t	pH	Acidity g/L H <sub>2</sub> SO <sub>4</sub>	ORP mV	U <sub>3</sub> O <sub>8</sub> DNA	U	Al	Ca	Fe	Fe <sup>3+</sup>	K	Mg	Mn	P	S	Si	U	
Head								164													
A1	1	60	46	0.0	1.20	13.84	452	126	23.0	933	929	818	531	47	562	30	930	7780	462	25.7	
A2	4	60	50	0.0	1.20	13.62	454	125	23.7	1360	829	790	451	71	606	30	681	8480	379	27.1	
A3	8	60	54	0.0	1.20	14.47	457	118	28.1	1820	809	822	425	103	656	33	474	9500	374	31.1	
A4	12	60	57	0.0	1.20	14.04	464	113	30.9	2270	814	930	478	132	680	34	341	10500	375	33.6	
A5	24	60	68	0.0	1.19	16.87	487	111	32.4	3340	813	1690	1080	226	727	39	208	13800	402	40.1	

Comments: Gas evolved upon acid addition.  
A2 sample centrifuge tube cracked and lost approximately 1g of solids.

Run	NU 2-B pH 1.5 Monitor							Solids: 40 g Tap Water: 2000 g Slurry: 2 wt%		NUP-010807-1		Oxidant: Pyrolusite Leach Duration: 24 h Temperature: 60 °C ORP: Monitor							ICP/OES Request No: 071120 XRF Request No: 071130	
								Solids Assays ppm	Extraction %	Solution Assays mg/L										
	Time h	Temp. °C	Acid kg/t	Pyrolusite kg/t	pH	Acidity g/L H <sub>2</sub> SO <sub>4</sub>	ORP mV	U <sub>3</sub> O <sub>8</sub> DNA	U	Al	Ca	Fe	Fe <sup>3+</sup>	K	Mg	Mn	P	S	Si	U
Head								164												
B1	1	60	269	0.0	1.51	4.84	570			25	288	25	25	7	20.1	2.1	28.3	1820	38	<1
B2	4	60	285	0.0	1.49	4.82	561			35	290	38	38	11	22.1	2.2	31.8	1960	55.4	<1
B3	8	60	285	0.0	1.50	4.82	553			43	295	47	47	17	23.5	2.4	35.0	1940	62.8	<1
B4	12	60	296	0.0	1.49	5.00	548			51	298	55	55	23	24.6	2.5	37.5	2030	71.2	<1
B5	24	60	309	0.0	1.47	5.38	541	110	33.1	65	306	74	74	40	26.5	2.8	44.0	2240	83.3	1

Comments:

Run	NU 3-A pH 1.2 450 mV for 12h							Solids: 700 g Tap Water: 700 g Slurry: 50 wt%	NUP-010807-2	Oxidant: Pyrolusite Leach Duration: 24 h Temperature: 60 °C ORP: 450 mV	ICP/OES Request No: 071171 XRF Request No: 071176									
								Solids Assays ppm	Extraction %	Solution Assays mg/L										
								U <sub>3</sub> O <sub>8</sub> DNA	U											
	Time h	Temp. °C	Acid kg/t	Pyrolusite kg/t	pH	Acidity g/L H <sub>2</sub> SO <sub>4</sub>	ORP mV			Al	Ca	Fe	Fe <sup>3+</sup>	K	Mg	Mn	P	S	Si	U
Head								114												
A1	1	60	30	0.3	1.20	13.19	404	105	8.2	1220	831	1240	170	46	160	173	1080	7530	320	7
A2	4	60	35	0.9	1.20	15.00	440	103	10.3	2020	849	1240	701	76	185	452	1480	9370	442	9
A3	8	60	39	1.2	1.20	16.24	448	101	11.3	2660	746	878	507	102	187	550	1660	10300	448	9
A4	12	60	43	1.3	1.20	17.04	450	50	56.7	3530	745	666	453	132	193	638	2030	11800	446	10
A5	24	60	53	1.3	1.20	16.96	428	93	18.6	5970	684	719	471	224	216	692	3420	14900	456	16

Comments:

Run	NU 3-B pH 1.5 Monitor							Solids: 40 g Tap Water: 2000 g Slurry: 2 wt%	NUP-010807-2	Oxidant: Pyrolusite Leach Duration: 24 h Temperature: 60 °C ORP: Monitor	ICP/OES Request No: 071171 XRF Request No: 071176								
								Solids Assays ppm	Extraction %	Solution Assays mg/L									
								U <sub>3</sub> O <sub>8</sub> DNA	U										
	Time h	Temp. °C	Acid kg/t	Pyrolusite kg/t	pH	Acidity g/L H <sub>2</sub> SO <sub>4</sub>	ORP mV			Al	Ca	Fe	Fe <sup>3+</sup>	K	Mg	Mn	P	S	Si
Head								114											
B1	1	60	252	0.5	1.52	4.72	575	32		92.3	20	20	10	7.7	3.4	25.3	1600	44.4	<1
B2	4	60	259	0.5	1.50	4.89	560	53		99.5	27	27	15	8.4	5.3	38.5	1670	48.8	<1
B3	8	60	276	0.5	1.50	4.88	548	70		102	33	24	21	8.9	6.0	49.5	1740	52.0	<1
B4	12	60	289	0.5	1.50	4.97	539	105		102	39	31	27	9.4	6.3	59.6	1840	55.7	<1
B5	24	60	306	0.5	1.50	5.37	523	111		110	50	44	42	10.4	6.4	80.3	1960	63.2	<1

Comments: Initial pyrolusite added due to multimeter reading incorrect ORP.  
 Dosimat rezeroed between 1700-2100 (0.15 ml acid addition assumed).

Run	NU 4-A 50 g/L H <sub>2</sub> SO <sub>4</sub> 450 mV for 12h						Solids: 40 g Tap Water: 2000 g Slurry: 2 wt%		NUP-010807-1		Oxidant: Ferric Sulphate (2 g/L Fe <sup>3+</sup> ) Leach Duration: 24 h Temperature: 70 °C ORP: Monitor								ICP/OES Request No: 071320 XRF Request No: 071335	
	Time h	Temp. °C	Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> kg/t	pH	Acidity g/L H <sub>2</sub> SO <sub>4</sub>	ORP mV	Solids Assays ppm	Extraction %	Solution Assays mg/L											
							U <sub>3</sub> O <sub>8</sub> DNA	U	Al	Ca	Fe	Fe <sup>3+</sup>	K	Mg	Mn	P	S	Si	U	
Head							164													
A1	1	70	0.0	0.43	50.48	660			48	239	2590	2590	19	20	7	42	17900	56	1.43	
A2	4	70	0.0	0.44	50.29	654			103	258	2880	2880	30	25	8	75	18200	85	1.59	
A3	8	70	0.0	0.45	50.78	650			158	273	3210	3210	43	28	8	113	18700	105	1.92	
A4	12	70	0.0	0.47	50.29	646			201	295	3500	3500	55	31	8	142	18700	119	1.97	
A5	24	70	0.0	0.48	48.97	642	64	61.2	293	324	4040	4040	63	34	9	196	19000	145	2.38	

Comments:

Run	NU 4-B 25 g/L H <sub>2</sub> SO <sub>4</sub> 450 mV for 12h						Solids: 40 g Tap Water: 2000 g Slurry: 2 wt%		NUP-010807-1		Oxidant: Ferric Sulphate (2 g/L Fe <sup>3+</sup> ) Leach Duration: 24 h Temperature: 70 °C ORP: Monitor						ICP/OES Request No: 071320 XRF Request No: 071335		
							Solids Assays ppm	Extraction %	Solution Assays mg/L										
	Time h	Temp. °C	Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> kg/t	pH	Acidity g/L H <sub>2</sub> SO <sub>4</sub>	ORP mV	U <sub>3</sub> O <sub>8</sub> DNA	U	Al	Ca	Fe	Fe <sup>3+</sup>	K	Mg	Mn	P	S	Si	U
Head							164												
B1	1	70	0.0	0.71	25.08	679		27.8	220	2410	2410	8	15.4	6.65	30.8	9890	41.4	1.35	
B2	4	70	0.0	0.72	24.23	671		50.5	219	2450	2450	13	18.4	6.67	41.7	9820	61.2	1.40	
B3	8	70	0.0	0.74	25.08	665		77.4	235	2660	2660	20	21.2	7.14	56.3	10500	78.6	1.65	
B4	12	70	0.0	0.76	26.06	661		92	229	2580	2580	26	21.5	6.88	64.2	9850	86.2	1.71	
B5	24	70	0.0	0.77	24.72	649	87	46.8	133	235	2770	2770	30	23.2	7.06	89.2	9920	103	1.80

Comments:

Run	NU 4-C 50 g/L H <sub>2</sub> SO <sub>4</sub> 450 mV for 12h						Solids: 40 g Tap Water: 2000 g Slurry: 2 wt%		NUP-010807-2		Oxidant: Ferric Sulphate (2 g/L Fe <sup>3+</sup> ) Leach Duration: 24 h Temperature: 70 °C ORP: Monitor						ICP/OES Request No: 071320 XRF Request No: 071335		
								Solids Assays	Extraction %	Solution Assays									
								U <sub>3</sub> O <sub>8</sub> DNA	U	mg/L									
		Al	Ca	Fe	Fe <sup>3+</sup>	K	Mg			Mn	P	S	Si	U					
		Head								114									
C1	1	70	0.0	0.37	50.04	660			102	97	2390	2390	14	11	7	76	17400	40	<1
C2	4	70	0.0	0.39	47.23	651			268	122	2480	2480	25	15	7	195	18100	66	1.2
C3	8	70	0.0	0.39	50.65	646			399	147	2500	2500	37	19	7	284	18200	87	1.4
C4	12	70	0.0	0.40	51.02	643			506	166	2530	2530	47	21	7	352	18400	104	1.7
C5	24	70	0.0	0.40	51.70	635	63	45.4	722	211	2670	2670	59	26	8	484	18800	139	1.9

Comments:

Run		NU 4-D 25 g/L H <sub>2</sub> SO <sub>4</sub> 450 mV for 12h					Solids: 40 g Tap Water: 2000 g Slurry: 2 wt%		NUP-010807-2		Oxidant: Ferric Sulphate (2 g/L Fe <sup>3+</sup> ) Leach Duration: 24 h Temperature: 60 °C ORP: Monitor								ICP/OES Request No: 071320 XRF Request No: 071335	
	Time    Temp.    Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> pH    Acidity    ORP h           °C           kg/t           g/L H <sub>2</sub> SO <sub>4</sub> mV						Solids Assays	Extraction %	Solution Assays mg/L											
							U <sub>3</sub> O <sub>8</sub> DNA	U												
Head							114													
D1	1	70	0.0	0.64	25.57	664			54	82.5	2320	2320	22	5.6	6.4	44	9620	30.1	<1	
D2	4	70	0.0	0.65	24.84	656			120	87.9	2390	2390	47	6.0	6.4	89	9960	41.9	<1	
D3	8	70	0.0	0.67	25.82	650			183	97.3	2380	2380	78	6.6	6.6	136	9950	52.5	<1	
D4	12	70	0.0	0.68	25.45	647			235	103	2410	2410	105	7.2	6.6	170	10000	61.9	<1	
D5	24	70	0.0	0.73	24.47	633	108	5.2	369	121	2460	2460	115	8.1	6.8	258	10200	83	1.1	

Comments:

Run	NU 5-A 50 g/L H <sub>2</sub> SO <sub>4</sub> 450 mV for 12h							Solids: 700 g Tap Water: 700 g Slurry: 50 wt%		NUP-010807-2		Oxidant: Ferric Sulphate (2 g/L Fe <sup>3+</sup> ) Leach Duration: 24 h Temperature: 60 °C ORP: Monitor										ICP/OES Request No: 071556 XRF Request No: 071575	
								Solids Assays ppm	Extraction %	Solution Assays mg/L													
	Time h	Temp. °C	Acid kg/t	Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> kg/t	pH	Acidity g/L H <sub>2</sub> SO <sub>4</sub>	ORP mV	U <sub>3</sub> O <sub>8</sub> DNA	U	Al	Ca	Fe	Fe <sup>3+</sup>	K	Mg	Mn	P	S	Si	U			
Head								114		g/L													
A1	1	60	50	0.0	0.93	32.49	474	101	11.3	1620	992	3320	1980	42	195	427	1.48	15500	367	7.6			
A2	4	60	79	0.0	0.71	50.07	473	93	18.6	3720	1080	3520	2080	65	218	451	3.06	23900	394	12.1			
A3	8	60	91	0.0	0.75	45.80	457	90	21.6	6250	1030	3580	1930	87	226	466	4.82	26600	350	17.1			
A4	12	60	108	0.0	0.71	51.91	452	79	30.9	9410	970	3990	2240	114	243	517	6.41	32500	356	22.7			
A5	24	60	140	0.0	0.69	52.40	448	61	46.4	14100	771	4430	2810	182	272	571	10.00	40000	278	34.7			

Comments:



## **APPENDIX F**

### **XRF Assays on Leach Residue Solids**



Request Number 070911

Sample name	LOI (%)	Na (%)	Mg (%)	Al (%)	Si (%)	P (%)	S (%)	K (%)	Ca (%)	Sc (%)	Ti (%)	V (%)	Cr (%)	Mn (%)	Fe (%)
NUPOWER COMP 1	6.8	0.31	0.20	5.50	20.99	2.74	0.19	0.42	1.83	0.021	0.16	0.065	0.093	0.049	16.88
NUPOWER COMP 2	4.8	0.16	0.16	7.17	30.32	4.10	0.14	0.55	1.21	0.022	0.14	0.031	0.088	0.011	0.68
	Co (%)	Ni (%)	Cu (%)	Zn (%)	As (%)	Sr (%)	Y (%)	Zr (%)	Nb (%)	Ba (%)	Pb (%)	Ce (%)	Th (%)	U3O8 (%)	U µg/g
NUPOWER COMP 1	<0.001	0.007	0.027	0.128	0.007	0.031	0.208	0.221	0.164	0.054633	0.054	0.017	0.017	0.020	170
NUPOWER COMP 2	<0.001	<0.001	0.008	0.016	<0.01	0.023	0.248	0.324	0.194	0.074337	0.044	0.016	0.01	0.012	102

Request Number 071057

Sample name	LOI (%)	Na (%)	Mg (%)	Al (%)	Si (%)	P (%)	S (%)	K (%)	Ca (%)	Sc (%)	Ti (%)	V (%)	Cr (%)	Mn (%)	Fe (%)
NU-1 A1	6.5	0.24	0.14	5.59	21.61	2.66	0.31	0.45	0.94	0.023	0.17	0.077491	0.104	0.11	16.544
NU-1 A2	6.4	0.24	0.13	5.50	21.42	2.75	0.35	0.42	1.00	0.022	0.17	0.078171	0.105	0.105	16.781
NU-1 A3	6.4	0.23	0.13	5.50	21.71	2.67	0.41	0.45	1.03	0.023	0.17	0.076131	0.104	0.109	16.242
NU-1 A4	6.0	0.23	0.14	5.58	21.79	2.68	0.36	0.45	0.97	0.022	0.17	0.077491	0.108	0.11	16.40
NU-1 A5	7.0	0.24	0.12	5.40	21.46	2.70	0.38	0.50	0.99	0.022	0.17	0.074772	0.112	0.099	16.38
NU-1 B1	7.0	0.26	0.13	5.45	21.54	2.67	0.31	0.43	0.90	0.021	0.17	0.075452	0.104	0.054	16.62
NU-1 B2	6.7	0.23	0.13	5.50	21.59	2.63	0.45	0.45	1.10	0.022	0.17	0.069334	0.113	0.054	16.22
NU-1 B3	6.3	0.24	0.14	5.71	21.64	2.60	0.45	0.47	1.07	0.022	0.18	0.072733	0.097	0.055	16.27
NU-1 B4	6.8	0.24	0.13	5.43	21.78	2.65	0.41	0.43	1.02	0.022	0.17	0.072053	0.102	0.053	16.23
NU-1 B5	6.6	0.24	0.11	5.30	22.00	2.67	0.45	0.41	1.02	0.022	0.17	0.072733	0.099	0.051	16.10
	Co (%)	Ni (%)	Cu (%)	Zn (%)	As (%)	Sr (%)	Y (%)	Zr (%)	Nb (%)	Cs (%)	Ba (%)	Pb (%)	Ce (%)	Th (%)	U3O8 (%)
NU-1 A1	<0.001	0.006	0.023	0.121	0.018	0.287	0.033	0.262	0.239	0.177	0.068	0.009	0.182	0.005	0.014
NU-1 A2	<0.001	0.006	0.025	0.12	0.017	0.285	0.03	0.258	0.237	0.179	0.069	0.008	0.181	0.005	0.015
NU-1 A3	<0.001	0.006	0.022	0.119	0.017	0.28	0.027	0.26	0.241	0.174	0.065	0.008	0.185	0.005	0.015
NU-1 A4	<0.001	0.007	0.022	0.12	0.017	0.283	0.03	0.264	0.24	0.178	0.067	0.01	0.183	0.006	0.015
NU-1 A5	<0.001	0.008	0.023	0.118	0.017	0.285	0.028	0.261	0.237	0.174	0.066	0.009	0.186	0.005	0.015
NU-1 B1	<0.001	0.006	0.023	0.12	0.017	0.278	0.031	0.264	0.239	0.167	0.065	0.007	0.183	0.004	0.014
NU-1 B2	<0.001	0.014	0.023	0.117	0.017	0.284	0.028	0.262	0.237	0.175	0.065	0.009	0.174	0.005	0.014
NU-1 B3	<0.001	0.005	0.022	0.121	0.017	0.278	0.029	0.262	0.236	0.172	0.065	0.009	0.187	0.005	0.013
NU-1 B4	<0.001	0.006	0.022	0.116	0.017	0.286	0.027	0.256	0.235	0.173	0.065	0.008	0.181	0.005	0.013
NU-1 B5	<0.001	0.005	0.023	0.114	0.017	0.281	0.026	0.256	0.236	0.170	0.061	0.008	0.178	0.005	0.013

Request Number 071130

Sample name	LOI (%)	Na (%)	Mg (%)	Al (%)	Si (%)	P (%)	S (%)	K (%)	Ca (%)	Sc (%)	Ti (%)	V (%)	Cr (%)	Mn (%)	Fe (%)
NU-2 A1	7.2	0.25	0.13	5.54	21.50	2.63	0.45	0.41	1.12	0.019	0.16	0.059817	0.106	0.049	16.338
NU-2 A2	6.4	0.25	0.12	5.56	22.03	2.70	0.30	0.41	0.92	0.019	0.16	0.064576	0.106	0.048	16.369
NU-2 A3	6.7	0.24	0.12	5.57	21.84	2.70	0.27	0.42	0.88	0.019	0.17	0.063896	0.111	0.049	16.541
NU-2 A4	6.9	0.24	0.12	5.41	21.82	2.73	0.19	0.41	0.74	0.02	0.16	0.069334	0.123	0.049	16.744
NU-2 A5	7.3	0.23	0.11	5.26	21.73	2.70	0.45	0.40	1.01	0.019	0.16	0.062536	0.11	0.047	16.272
NU-2 B FINAL SOLIDS	6.4	0.26	0.11	5.48	22.23	2.65	0.15	0.46	0.69	0.02	0.18	0.066615	0.111	0.049	16.654
	Co (%)	Ni (%)	Cu (%)	Zn (%)	As (%)	Sr (%)	Y (%)	Zr (%)	Nb (%)	Cs (%)	Ba (%)	Pb (%)	Ce (%)	Th (%)	U3O8 (%)
NU-2 A1	<0.001	0.004	0.022	0.115	0.018	0.293	0.027	0.212	0.215	0.185	0.06	0.006	0.145	0.004	0.0136
NU-2 A2	<0.001	0.005	0.024	0.115	0.017	0.299	0.027	0.213	0.222	0.201	0.053	0.007	0.148	0.004	0.0131
NU-2 A3	<0.001	0.006	0.023	0.116	0.018	0.294	0.028	0.218	0.226	0.2000	0.055	0.007	0.153	0.004	0.0121
NU-2 A4	<0.001	0.015	0.024	0.117	0.017	0.298	0.028	0.225	0.222	0.202	0.057	0.007	0.152	0.005	0.0125
NU-2 A5	<0.001	0.008	0.022	0.112	0.017	0.292	0.027	0.222	0.226	0.199	0.055	0.006	0.156	0.004	0.0116
NU-2 B FINAL SOLIDS	<0.001	0.004	0.023	0.115	0.017	0.294	0.029	0.221	0.225	0.201	0.057	0.008	0.154	0.004	0.0123

Request Number 071176

Sample name	LOI (%)	Na (%)	Mg (%)	Al (%)	Si (%)	P (%)	S (%)	K (%)	Ca (%)	Sc (%)	Ti (%)	V (%)	Cr (%)	Mn (%)	Fe (%)
NU3 A1	-0.2	1.68	0.17	7.13	31.21	4.13	0.26	0.66	0.95	0.03	0.16	<0.001	0.141	0.02	0.63
NU3 A2	3.0	0.09	0.13	7.10	31.04	4.07	0.18	0.55	0.88	0.03	0.16	<0.001	0.129	0.018	0.65
NU3 A3	2.8	0.09	0.14	7.16	30.97	4.09	0.18	0.57	0.88	0.03	0.16	<0.001	0.128	0.018	0.69
NU3 A4	6.5	0.03	1.51	1.20	16.51	0.11	11.09	0.35	14.29	0.025	0.13	<0.001	0.141	0.021	1.06
NU3 A5	4.7	0.10	0.13	6.78	30.91	3.89	0.18	0.56	0.83	0.029	0.16	<0.001	0.128	0.018	0.70
NU3 B FINAL SOLIDS	3.4	0.08	0.13	6.80	31.56	3.86	0.17	0.54	0.80	0.028	0.17	<0.001	0.121	0.016	0.70
	Co (%)	Ni (%)	Cu (%)	Zn (%)	As (%)	Sr (%)	Y (%)	Zr (%)	Nb (%)	Cs (%)	Ba (%)	Pb (%)	Ce (%)	Th (%)	U3O8 (%)
NU3 A1	<0.05	0.001	0.01	0.020	<0.001	0.32	0.022	0.28	0.358	0.289	0.094	0.026	0.257	0.014	0.014151
NU3 A2	<0.05	0.001	0.014	0.017	<0.001	0.31	0.024	0.27	0.352	0.275	0.093	0.023	0.247	0.012	0.012972
NU3 A3	<0.05	<0.001	0.015	0.018	<0.001	0.321	0.022	0.267	0.355	0.274	0.095	0.024	0.25	0.013	0.012972
NU3 A4	<0.05	<0.001	0.002	0.005	0.011	0.242	0.014	0.263	0.262	0.289	0.121	0.005	0.236	0.003	0.008255
NU3 A5	<0.05	<0.001	0.021	0.017	<0.001	0.315	0.02	0.274	0.352	0.277	0.095	0.022	0.24	0.012	0.011793
NU3 B FINAL SOLIDS	<0.05	<0.001	0.009	0.016	<0.001	0.301	0.02	0.265	0.345	0.258	0.089	0.024	0.224	0.009	0.010613

Request Number 071335

Sample name	LOI (%)	Na (%)	Mg (%)	Al (%)	Si (%)	P (%)	S (%)	K (%)	Ca (%)	Sc (%)	Ti (%)	V (%)	Cr (%)	Mn (%)	Fe (%)
NU A Final Solids	7.32	0.29	0.15	5.18	26.16	2.12	0.20	0.56	0.63	0.007	0.18	0.031268	0.02	0.039	12.48
NU4 B Final Solids	9.46	0.29	0.12	5.23	22.68	2.41	0.14	0.42	0.66	0.006	0.16	0.039425	0.041	0.041	15.90
NU4 C Final Solids	9.20	0.11	0.16	4.44	34.57	1.93	0.28	0.60	0.42	0.004	0.16	0.004078	0.006	<0.001	0.37
NU4 D Final Solids	12.0	0.14	0.21	5.84	30.87	2.86	0.13	0.56	0.65	0.004	0.14	0.005438	0.009	<0.001	0.54
	Co (%)	Ni (%)	Cu (%)	Zn (%)	As (%)	Sr (%)	Y (%)	Zr (%)	Nb (%)	Cs (%)	Ba (%)	Ce (%)	Pb (%)	Th (%)	U3O8 (%)
NU A FINAL SOLIDS	<0.001	0.008	0.019	0.103	0.007	0.161	0.025	0.126	0.003	0.008	0.073	0.005	0.014	0.006	0.010
NU4 B FINAL SOLIDS	<0.001	0.008	0.03	0.117	0.008	0.158	0.032	0.119	0.005	0.011	0.051	0.002	0.01	0.005	0.013
NU4 C FINAL SOLIDS	<0.001	<0.001	0.008	0.008	0.001	0.214	0.017	0.155	<0.001	0.008	0.075	0.001	0.005	<0.001	0.002
NU4 D FINAL SOLIDS	<0.001	<0.001	0.007	0.009	0.001	0.225	0.019	0.143	0.002	0.007	0.066	<0.001	0.003	<0.001	0.005

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Sample name	LOI (%)	Na (%)	Mg (%)	Al (%)	Si (%)	P (%)	S (%)	K (%)	Ca (%)	Sc (%)	Ti (%)	V (%)	Cr (%)	Mn (%)	Fe (%)
NU5 A1	6.5	0.23	0.15	7.087	31.06	3.90	0.07	0.53	0.825	0.005	0.14	0.004078	0.005	0.001	0.59
NU5 A2	7.3	0.12	0.14	6.77	31.31	3.74	0.05	0.51	0.786	0.005	0.13	0.003399	0.01	<0.001	0.57
NU5 A3	5.9	0.12	0.16	6.803	31.95	3.62	0.08	0.55	0.776	0.005	0.14	0.003399	0.026	0.001	0.59
NU5 A4	5.8	0.12	0.15	6.548	32.46	3.46	0.05	0.55	0.734	0.005	0.15	0.003399	0.017	<0.001	0.57
NU5 A5	5.4	0.12	0.15	6.054	33.48	3.10	0.15	0.57	0.65	0.005	0.15	0.003399	0.003	<0.001	0.52
	Co (%)	Ni (%)	Cu (%)	Zn (%)	As (%)	Sr (%)	Y (%)	Zr (%)	Nb (%)	Cs (%)	Ba (%)	Ce (%)	Pb (%)	Th (%)	U3O8 (%)
NU5 A1	<0.001	0.002	0.007	0.012	0.001	0.259	0.022	0.146	0.014	0.008	0.067	<0.001	0.006	0.004	0.013
NU5 A2	<0.001	0.002	0.007	0.011	0.001	0.251	0.021	0.141	0.013	0.006	0.063	<0.001	0.005	0.002	0.010
NU5 A3	<0.001	0.008	0.006	0.012	0.001	0.251	0.022	0.144	0.012	0.007	0.066	<0.001	0.006	0.003	0.010
NU5 A4	<0.001	0.005	0.007	0.011	0.001	0.253	0.021	0.149	0.013	0.008	0.067	<0.001	0.006	0.003	0.009
NU5 A5	<0.001	0.001	0.007	0.011	0.001	0.253	0.022	0.149	0.012	0.01	0.07	<0.001	0.007	0.003	0.008