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ADSORPTION CAPABILITIES OF SELECTED CLINOPTILOLITE-RICH ROCKS AS IT RELATES TO MINE DRAINAGE REMEDIATION

by

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CONTENTS

LIST OF TABLES AND FIGURES

ABSTRACT

This study concerns the possible application of 11 natural zeolites of the clinoptilolite variety to the remediation of acid/metal mine drainage. Laboratory experiments consisted of equilibrating each zeolite with the following single element solutions: Ag, Al, As, Ca, Cd, Cs, Cu, Fe^{2+}, Fe^{3+}, K, Mg, Mn, Pb, Rb, SO_4, and U. Also, de-ionized water and two mine drainage samples were equilibrated with each zeolite. Metal adsorption on a per gram zeolite basis was calculated using inductively coupled plasma – mass spectroscopy (ICP – MS) and inductively coupled plasma – atomic emission spectroscopy (ICP – AES) analytical data, and shows that some of these natural zeolites are extremely effective at sequestering metals. However, in response to adsorption, there is substantial desorption of Na, Al, and Ca by the zeolites causing possible environmental concern. Zeolite composition obtained by X-ray fluorescence (XRF) seems to show a correlation between the element desorbed and abundance in the zeolite. It is important to note that the various zeolites behaved differently in terms of metal adsorption/desorption, permitting selection of a few that would be best suited for use in the field to remediate acid mine drainage (AMD).

INTRODUCTION

Mining operations and undisturbed, natural mineral occurrences throughout the world are responsible for contaminating watersheds with potentially toxic metals; pollution which, if not contained, is able to migrate downstream and affect other localities. The source of much of this contamination is various metal sulfide minerals, particularly pyrite (FeS_2). When exposed to air and water, sulfide minerals undergo reactions that generate significant amounts of acidity and soluble heavy-metals. The resulting solution, being highly acidic – a pH around 3 is common – is very reactive and thus is able to dissolve or leach more metals from rock it comes in contact with. Also, the acidic nature of the solution allows the metals to be transported in their most soluble form/valence.

Many studies have demonstrated that natural clinoptilolite-rich rocks (CRRs) with their ion-exchange capabilities are very effective at removing metals from solution (Desborough 1994; Bremner and Schultze 1995; Zamzow and Schultze 1995). Once adsorbed, the degree of metal retention or exchangeability seems to be a function of the pH of the initial, metal rich water; the pH and concentration of the exchange medium; the CRR to exchange solution ratio; and the CRR (Desborough 1995). The focus of this study is the adsorption/desorption characteristics of 11 clinoptilolite-rich rocks (CRRs) from 10 deposits in the Western U. S. and 1 deposit in Canada (Table 1). These characteristics will help assess the feasibility of using CRRs to remediate heavy metal mine drainage during storm runoff situations. Specifically, laboratory experiments were designed to determine CRR total compositions and the effects of pre- and post-CRR exposure to acidic, single element stock solutions within a sulfate matrix. Also, two mine drainage samples were treated with the CRRs in order to determine the effect of multi-ion competition since it is well noted that Ca^{2+} and other cations, commonly present in large concentrations in mine drainage, can significantly interfere with metal uptake (Desborough 1994; Zamzow and Schultze 1995).

The goals of these experiments and those in the future are to determine: 1) the total amount of metal able to be adsorbed by a given CRR; 2) the retention of the metal(s) by the CRR and the major controlling factor(s); and 3) the rate of metal uptake, i.e., the time necessary to achieve equilibrium. The performance of the CRRs was quite variable and seemed to be a function of their compositions, especially in terms of the adsorption capacity and dominant cation(s) desorbed by a particular CRR. These variations in effectiveness permit selection of a few of the most promising CRRs for future laboratory/field studies.

Table 1. Abbreviations, deposit locations, and diluent minerals in raw clinoptilolite-rich rock (CRR) samples used in this study. Minerals, in decreasing order of abundance, determined by X-ray diffraction by G.A. Desborough and Richard Sheppard, U. S. Geological Survey [clay signifies layer silicates with a 10-angstrom spacing; tr.-trace] (Adapted from Desborough 1996 and 1994).

Locality and CRR abbreviation	Diluent minerals
British Columbia	
Princenton-PBC	Opal, feldspar, mordenite, quartz (tr.)
Colorado	
Creede-CCO	Opal, K-feldspar, plagioclase, quartz, clay
Idaho	
Crisman Hill-CHI	Opal, K-feldspar
Preston-PWI	Opal
Montana	
Grasshopper Creek-GCM	Opal, K-feldspar, plagioclase
Nevada	
Fish Creek-FCWN	K-feldspar, quartz, plagioclase
New Mexico	
Winston-SNM	Opal, clay (tr.)
South Dakota	
Rocky Ford-SDH	Plagioclase, calcite, quartz, opal, K-feldspar,clay-tr.
Texas	
Alamito Creek-ACT	Opal, plagioclase, clay
Tilden-ZEO	Opal, clay, calcite
Wyoming	
Ft. LaClede-FLW	Plagioclase

ION-EXCHANGE AND COMPOSITION OF CLINOPTILOLITE-RICH ROCKS

Ion-exchange behavior of zeolites is primarily due to a fixed, negative surface charge which attracts and adsorbs certain cations, exchanging them when other cations more preferred by the zeolite are present. This fixed or constant charge is the result of a deficiency in positive charge from structural replacement of cations with lower valence states or presence of crystal imperfections (Zelazny and others 1996). The strong affinities or selectivities of clinoptilolite for certain cations have been reported by many researchers – Zamzow and Schultze (1995); Bremner and Schultze (1995); and Boylan (1995). The relative affinities of different clinoptilolites for different cations become important when considering the specific application of the CRR. For example, if a particular CRR had a high affinity for Ca, use of this CRR in the treatment of acid mine drainage (AMD) with large amounts of Ca and other heavy metals might not be advantageous because of the greater exchange capacity required to capture the heavy-metals, in addition to the Ca. The same logic would apply to other cations such as Al, Fe, and Mg which are known to compete with heavy metals for exchange sites (Bremner and Schultze 1995). Important to note is that affinities reported for clinoptilolite should be considered general in the sense that it is possible for others to have different affinities presumably due to their specific composition, i.e., major exchangeable cations.

The CRRs vary in clinoptilolite content, and the composition of clinoptilolite is also variable primarily due to differences in the major exchangeable cations (Ca, K, Na) and trace elements present. Total elemental composition was determined using a wavelength dispersive X-ray fluorescence (XRF) method (Table 2) and inductively coupled plasma – atomic emission spectroscopy (ICP –AES) (Appendix, Table A 21) on powdered and digested samples (Arbogast 1996). The results from the two different analytical techniques seem to compare reasonably well. Major cation content proved to be variable in the samples; some CRRs were enriched in either Na, K, or Ca while others contained a mixture of 2 or 3 of these elements. Desborough (1994 and 1996) also reports compositions of some of the CRRs used in this study.

Table 2. Composition of clinoptilolite-rich rocks determined by x-ray fluorescence (XRF).

Sample	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)
FLW	63.3	12.9	1.28	0.59	1.49	4.45	1.60
ACT	63.5	12.7	2.82	0.89	4.25	1.77	2.42
CHI	67.4	11.0	2.27	0.23	1.23	0.94	4.85
CCO	67.4	12.5	1.35	0.72	2.42	1.18	3.85
GCM	66.4	12.5	0.76	0.78	2.39	1.64	3.26
FCWN	66.9	13.9	0.72	0.46	2.10	2.94	3.93
ZEO	65.4	12.1	1.11	0.94	4.39	1.11	1.18
PWI	67.4	10.6	1.70	0.45	2.23	0.59	4.19
SNM	65.7	12.0	1.28	1.27	3.08	0.60	2.27
SDH	63.9	11.9	2.00	0.81	2.20	2.97	4.01
PBC	66.3	12.2	2.42	0.76	2.21	2.54	2.51
Average	65.8	12.2	1.61	0.72	2.54	1.88	3.10

Sample	TiO_2 (%)	P_2O_5 (%)	MnO (%)	Loss on Ignition-925 C	Total (%)
FLW	0.20	0.15	0.01	13.7	99.67
ACT	0.36	0.15	0.05	10.1	99.01
CHI	0.28	0.24	0.03	10.1	98.57
CCO	0.23	0.13	0.01	9.04	98.83
GCM	0.08	0.11	0.03	11.0	98.95
FCWN	0.24	0.09	0.01	7.71	99.00
ZEO	0.19	0.09	0.10	12.2	98.81
PWI	0.27	0.10	< 0.01	11.4	98.93
SNM	0.22	0.12	0.06	12.3	98.90
SDH	0.27	0.20	0.05	10.7	99.01
PBC	0.23	0.11	0.04	9.27	98.59
Average	0.23	0.14	0.04	10.7	98.94

Table 3. Stock solutions, concentrations (mg/L), and pH.

Solution:	Ag	Al	As	Cd	Cu	Fe^{2+}	Fe^{3+}	Mg	Pb	SO_4	Zn	Cs & Rb	U (VI)	Ca	K	Mn
Concentration	7.2	190	18	15	360	820	180	280	2.5	5200	430	1.3	2.6	430	22	36
pH[a]	2.5	2.5	3.0	3.0	3.0	2.0	2.5	2.5	3.0	2.5	2.5	3.0	2.5	2.0	2.5	2.0

[a]A matrix of 5000 μg/L sulfate was created using concentrated H_2SO_4 (aq); pH adjusted to 2-3 with NaOH (aq).

LABORATORY METHODS

Sized samples of the CRRs were obtained by screening crushed material through a minus 10-mesh (2 mm) sieve. Five grams of this < 2 mm fraction were then mixed (in 50 mL Nalgene™ centrifuge tubes) with 25 mL of the various single element stock solutions (Table 3), discussed below, and two natural mine drainage samples from Clear Creek County, Colorado (Burleigh and McClelland Tunnels). The tubes containing the 5.00 g of CRR and 25 mL of solution were then horizontally shaken (80 cycles per minute) for 4 hours, a duration long enough for the exchange reaction to equilibrate as determined by preliminary studies not shown here and by other researchers (Zamzow and Schultze 1995). After the 4-hour time period, aliquots of the exchange solution were centrifuged at 5000 rpm for 15 minutes, filtered through a 0.45 μm filter, acidified with nitric acid, and then analyzed by inductively coupled plasma – mass spectroscopy (ICP – MS) (Crock and others, 1998) or ICP – AES depending on the element of interest. Some of the aliquots analyzed by ICP – MS had to be diluted to prevent saturation of the instrument's detector. The specific solutions diluted and the extent of dilution were element specific. The pre- and post- exchange stock solution compositions in raw form are all located in the Appendix (Tables A1 through A20). The pre-exchange stock solution concentrations reported are an average of 3 values. These data were used to calculate micrograms of metal adsorbed per gram of CRR in order to evaluate the performance of each CRR relative to one another.

The concentrations of the elements in the solutions were chosen to simulate a worst case scenario in terms of values normally seen in AMD. All stock solutions (except mine drainage samples) contained a 5,000-mg/L sulfate matrix made from the addition of concentrated H_2SO_4 (aq), after which the pH of each solution was adjusted to 2-3 with NaOH (aq). Different amounts of NaOH were needed to achieve the desired pH; therefore, the Na concentration in the individual solutions is variable; a point that may seem trivial but turns out to be quite important in terms of Na desorption. Measurements of pH were taken prior to exchange and are shown in Table 3.

Table 4. Summary of CRR adsorption/desorption[a] for various stock solution elements.

CRR	Ag	Al	As	Ca	Cd	Cs	Cu	Fe^{2+}	Fe^{3+}
FLW	-36	-400	-82	-670	-75	-8.0	-890	-2700	-740
ACT	-35	-950	-83	4800	-76	-8.0	-1700	-3900	-910
CHI	-35	-400	-84	1700	-71	-8.0	-180	-1250	-850
CCO	-35	-150	-83	1000	-71	-7.9	-180	-1350	-630
GCM	-36	-250	-78	1300	-71	-8.0	120	-500	-570
FCWN	-36	-250	-82	900	-75	-8.0	-230	-600	-520
ZEO	-36	-950	-84	1300	-76	-8.0	-1700	-3985	-910
PWI	-35	0	-82	1200	-69	-8.0	-380	-1400	-520
SNM	-36	-250	-82	1800	-70	-8.0	120	-900	-570
SDH	-36	-950	-83	780	-76	-8.0	-1100	-3350	-910
PBC	-36	-300	-85	1500	-75	-8.0	-330	-1600	-470

CRR	K	Mg	Mn	Pb	Rb	SO_4	U	Zn
FLW	-60	-620	-180	-12	-4.7	-23000	-12	-1700
ACT	22	-570	-170	-12	-4.7	-23000	-12	-1100
CHI	1700	-370	-180	-12	-4.2	-23000	-12	-900
CCO	540	-220	-170	-12	-4.5	-24000	-12	-750
GCM	270	-17	-170	-12	-4.6	-23000	-13	-500
FCWN	310	-170	-170	-12	-4.4	-23000	-13	-450
ZEO	840	-820	-180	-12	-4.5	-22000	-12	-1400
PWI	1300	-170	-170	-12	-4.5	-24000	-12	-750
SNM	160	-17	-140	-12	-4.7	-23000	-12	-500
SDH	240	-520	-170	-12	-4.7	-23000	-12	-1400
PBC	12	-320	-180	-12	-4.7	-23000	-13	-700

[a]μg element adsorbed (-) or desorbed (+) per gram of CRR.

RESULTS AND DISCUSSION

Ion Exchange in Single Element Stock Solutions

As mentioned, metal adsorptions were calculated on a microgram metal adsorbed per gram of CRR basis. Adsorption/desorption was calculated with respect to the solution; therefore, a negative value signifies removal from solution, which was assumed to be accomplished by CRR adsorption. However, direct precipitation of a metal bearing phase could also account for metal removal from solution.

Table 4 is a summary of the adsorption/desorption values for the element of interest in each stock solution, e.g., Zn capture from the 430 mg/L Zn stock solution, Cu capture from the 360 mg/L stock solution, etc. The data in this table clearly show that some of the CRRs, namely FLW, ACT, ZEO, SDH, have adsorption capacities which are much greater than the rest. For example, the amount of Zn adsorbed by FLW is almost four times larger than what was removed by GCM. ZEO and SDH showed almost three times and ACT around two times larger amounts adsorbed relative to GCM. The same pattern holds true for Cu, Fe(II), Fe(III), as well as Al and Mg to

some extent. Results for Pb, Cs, Rb, U, Ag, and As are not as useful in making comparisons between the CRRs because the values are all very similar. Presumably, the concentration in each of these solutions was not high enough to show differences in removal of these specific metals because each CRR removed about the same amount which accounted for all that was in solution.

To begin to understand the variations in adsorption properties, consider FLW, which is Na-rich; ACT and ZEO, which are Ca-rich; and SDH which is Ca-/K-rich. These compositional differences relative to the other CRRs seem to account for the wide variation in metal removal seen between the CRRs. More specifically, the Na- and Ca-rich CRRs appear to capture more metals than the K-rich CRRs. Also, closely related to this observed composition/adsorption interdependence is the relationship between composition of CRR and desorption.

For a Na-rich CRR, one would expect most of the exchangeable cations to be Na; therefore, in an ion-exchange reaction, when a cation preferred over Na is present, the CRR would be expected to desorb Na and adsorb the more preferred cation. This is exactly what is seen for FLW, a Na-rich CRR. For example, in the Fe(II) stock solution, FLW adsorbed 2700 μg of Fe(II) per gram of CRR. In keeping with the laws of solutions and their mandatory charge balance constraint, there must be a release of cations by FLW. Table 5 shows that a large amount of Na, 8600 μg/g, was indeed desorbed by FLW; thus, most Fe(II) displaced Na from FLW because the amounts of Ca (Table 6), Al (Table 7), and K (Table 8) (Appendix, Table A8) desorbed were substantially smaller than the value for Na (Na concentrations were not determined in the As, Cd, Pb, SO_4, and U stock solutions). Figure 1 displays these values graphically and shows the relationships very well, note the large amount of Na desorbed. The same pattern holds true for ACT, a Ca-rich CRR, which desorbs substantial Ca, and to some extent Na, in response to exchange with large amounts Fe(II) (Figure 2).

Important to note is that the values in Table 4 do not necessarily represent maximum metal capture abilities of the CRRs. The results do show that some of the CRRs have greater affinities for certain metals than others, e.g., Mg, Al, Zn, and in some cases, the results are such that one can assume a CRR has reached adsorption capacity of a certain metal because it removed << 50 % of the element of interest from solution. This is demonstrated by GCM adsorption of Mg which is approximately 50 times less than the value for ZEO (Table 4). These data allow comparisons to be made between CRRs, permitting selection of those with the best performance. Those selected will then be studied more thoroughly in the future.

Some elements of principal concern in AMD are Cu, Zn, Ag, Pb, Cd, Hg, Fe, and As. For the most part, the CRRs that adsorbed the largest amounts of these metals were FLW, ACT, ZEO, and SDH. These CRRs in turn also desorbed the largest amounts of cations such as Al, Na, and Ca. Al and Na desorption causes some concern because of fish and plant toxicity (Drever 1997; Kesler 1994; Driscoll and others 1980). Of these two elements, Al would be considered more toxic but less mobile (Kesler 1994) while Na would be less toxic but more mobile. Increased mobility or solubility of Al occurs at low pH values. Ca desorption is not of great concern for two reasons. First, Ca desorption increases water hardness which increases the tolerance of trout for heavy metals. Second, trout need at least 15-25 mg/L Ca, in the absence of heavy metals, to survive (Desborough 1994). With this in mind, it is extremely important to pay close attention to those CRRs that readily adsorb Ca. In this study, FLW was the only CRR to remove Ca from the Ca stock solution, and similar behavior, of this specific CRR, was seen by Desborough (1994).

Table 5. Summary of CRR Na adsorption/desorption[a] in various stock solutions.

CRR	Na - Ag	Na - Al	Na - Ca	Na - Cu	Na - Fe^{2+}	Na - Fe^{3+}	Na - K
mg/L Na[b]:	n/a[c]	2.3	2.3	2.6	0.17	0.92	2.2
FLW	n/a	1500	3200	5000	8600	2400	1800
ACT	-5800	-2000	-1800	-1500	830	-1200	-1200
CHI	-5800	-2000	-1800	1000	1900	-720	-1200
CCO	-5800	-3000	-2300	-2000	830	-1700	5800
GCM	n/a	-1500	-1300	1000	2600	-220	2800
FCWN	n/a	-1000	-830	2000	2500	-270	-170
ZEO	n/a	1000	670	3000	3800	1400	7300
PWI	-5900	-4500	-3800	-3000	530	-2100	2800
SNM	-5800	-2500	-1800	-500	180	-1500	-1200
SDH	n/a	1500	2200	5000	6100	3400	1300
PBC	n/a	-500	-330	2000	2900	880	-170

CRR	Na - Mg	Na - Mn	Na - Zn	Na – DI[d]	Na - Burl.[e]	Na - McC.[f]
mg/L Na:	2.6	BDL	2.7	0.05	11	12
FLW	500	600	1000	24	1400	1500
ACT	-3000	320	-3000	14	440	440
CHI	-2500	330	-3000	3.5	650	690
CCO	-3500	270	-4000	6.0	390	440
GCM	-2000	360	-2500	15	700	740
FCWN	-2000	500	-1500	22	800	940
ZEO	-1000	750	-500	45	1200	1300
PWI	-5500	200	-5000	2.2	320	350
SNM	-2500	110	-2500	6.5	150	160
SDH	500	750	500	55	1400	1500
PBC	-1500	440	-1000	20	1000	1100

[a]µg element adsorbed (-) or desorbed (+) per gram of CRR. [b]Na concentration in stock solution prior to ion exchange. [c]n/a – Na not analyzed for. [d]De-ionized water control. [e]Burleigh tunnel mine drainage, 11 mg/L Na. [f]McClelland tunnel mine drainage, 12 mg/L Na.

Table 6. Summary of CRR Ca adsorption/desorption[a] in various stock solutions.

CRR	Ca - Ag	Ca - Al	Ca - As	Ca	Ca - Cd	Ca - Cu	Ca - Fe^{2+}	Ca - Fe^{3+}	Ca - K
FLW	50	700	50	-670	31	1100	700	310	650
ACT	500	3400	280	4800	240	2900	2300	2800	3500
CHI	220	2500	160	1700	130	2800	2100	1600	1900
CCO	290	3800	310	1000	260	3300	2600	2300	6000
GCM	190	2500	190	1300	150	3400	2500	1600	2900
FCWN	190	2100	130	930	110	2900	2300	1600	1700
ZEO	270	3100	95	1300	75	3000	2700	2300	2800
PWI	310	4500	360	1200	280	3000	2800	2800	7500
SNM	230	2700	200	1800	160	3700	2900	1900	2400
SDH	200	2100	45	780	32	1500	2000	1700	900
PBC	160	2200	150	1500	130	2900	1800	1500	1800

CRR	Ca - Mg	Ca - Mn	Ca - Pb	Ca - SO_4	Ca - U	Ca - Zn	Ca – DI[b]	Ca - Burl.[c]	Ca - McC.[d]
FLW	650	0	60	55	40	750	0.50	-400	-600
ACT	3500	320	300	390	280	4700	4.4	140	140
CHI	2000	31	160	180	140	2200	3.1	-260	-370
CCO	3900	190	300	210	270	3600	1.0	27	-7.5
GCM	2100	60	180	220	160	2300	1.0	-180	-230
FCWN	1400	50	150	190	131	2300	1.0	-240	-350
ZEO	1500	30	120	200	120	2400	6.0	-310	-470
PWI	4300	200	350	190	320	4200	0.40	42	-7.5
SNM	2200	255	190	260	170	2600	1.5	140	140
SDH	750	11	70	100	60	1200	2.0	-390	-580
PBC	1800	29	150	190	130	2100	1.5	-250	-360

[a]µg element adsorbed (-) or desorbed (+) per gram of CRR. [b]De-ionized water control. [c]Burleigh tunnel mine drainage, 82 mg/L Ca. [d]McClelland tunnel mine drainage, 120 mg/L Ca.

Table 7. Summary of CRR Al adsorption/desorption[a] in various stock solutions.

CRR	Al - Ag	Al	Al - As	Al - Ca	Al - Cd	Al - Cs, Rb	Al - Cu	Al - Fe^{2+}	Al - Fe^{3+}
FLW	78	-400	0.035	200	-1.9	2.5	28	120	270
ACT	-1.7	-950	0.0029	0	-2.1	-0.20	0	0	0
CHI	53	-400	0.014	200	-2.0	3.4	55	150	190
CCO	93	-150	0.0024	300	-2.1	7.8	70	210	340
GCM	68	-250	-0.0061	200	-2.1	2.0	43	190	250
FCWN	58	-250	0.017	110	-2.1	-0.15	0	45	180
ZEO	-1.7	-950	-0.0059	0	-2.0	-0.12	0	0	0
PWI	100	0	-0.0053	380	-1.2	15.3	180	320	400
SNM	83	-250	0.0034	260	-2.1	5.3	50	160	260
SDH	-1.7	-950	0.042	0	-2.1	-0.19	0	0	0
PBC	73	-300	0.013	190	-2.1	0.040	4.0	130	290

CRR	Al - K	Al - Mg	Al - Mn	Al - Pb	Al - SO_4	Al - U	Al - Zn	Al - DI[b]	Al - Burl.[c]
FLW	8.0	0	11	0.70	-10	0.44	60	6.5	4.0
ACT	0	0	0	0	-13	-0.69	0	6.0	-0.14
CHI	24	4.5	1.5	1.8	-6.0	2.0	90	14	-0.25
CCO	65	1.0	0	1.8	-1.5	4.2	160	2.5	-0.18
GCM	9.5	0	0	0.23	-8.0	-0.28	95	2.0	-0.23
FCWN	0	0	0	0.037	-13	-0.70	5.0	0.87	-0.23
ZEO	12	0	85	0.30	-13	-0.65	0	18	-0.16
PWI	180	27	10	10	12	12	220	1.1	-0.18
SNM	16	0	0	0.70	-11	1.7	95	0.67	0.24
SDH	0	0	190	0.020	-13	-0.68	0	18	3.1
PBC	0	0	14	0.0031	-12	-0.66	60	6.0	-0.19

[a]µg element adsorbed (-) or desorbed (+) per gram of CRR. [b]De-ionized water control. [c]Burleigh tunnel mine drainage, .051 mg/L Al.

Table 8. Summary of CRR K adsorption/desorption[a] in various stock solutions.

CRR	K - Ag	K - Al	K - As	K - Ca	K - Cd	K - Cu	K - Fe^{2+}	K - Fe^{3+}	K
FLW	-2.5	55	-52	65	-1.2	89	70	33	-60
ACT	5.5	160	-44	150	5.3	120	95	90	22
CHI	140	2100	130	2100	160	2600	1800	1400	1700
CCO	20	350	-24	350	23	360	280	210	540
GCM	16	320	-27	300	21	360	260	200	270
FCWN	25	470	-10	500	32	540	430	270	310
ZEO	48	800	2.5	650	48	800	650	550	840
PWI	53	950	33	900	68	900	600	500	1300
SNM	12	290	-32	270	17	220	190	170	160
SDH	25	430	-25	430	23	540	460	370	240
PBC	3.0	150	-43	140	6.3	180	120	110	12

CRR	K - Mg	K - Mn	K - Pb	K - SO_4	K - U	K - Zn	K - DI[b]	K - Burl.[c]	K -McC.[d]
FLW	55	0	2.2	-80	2.2	84	0.14	-2.2	-2.5
ACT	160	5.5	10	-77	8.4	210	1.3	21	23
CHI	2100	130	170	85	140	2400	2.9	330	360
CCO	370	21	29	-68	20	420	0.55	54	63
GCM	320	7.0	22	-67	18	410	0.56	36	42
FCWN	450	30	36	-57	29	640	1.5	54	63
ZEO	750	45	57	-41	39	940	4.9	99	110
PWI	950	65	72	-44	53	1100	1.4	150	170
SNM	310	8.0	20	-73	16	330	0.56	24	30
SDH	360	55	26	-54	21	540	6.4	42	48
PBC	140	1.0	10	-77	6.9	200	0.61	17	22

[a]µg element adsorbed (-) or desorbed (+) per gram of CRR. [b]De-ionized water control. [c]Burleigh tunnel mine drainage, 1.3 mg/L K. [d]McClelland tunnel mine drainage, 1.3 mg/L K.

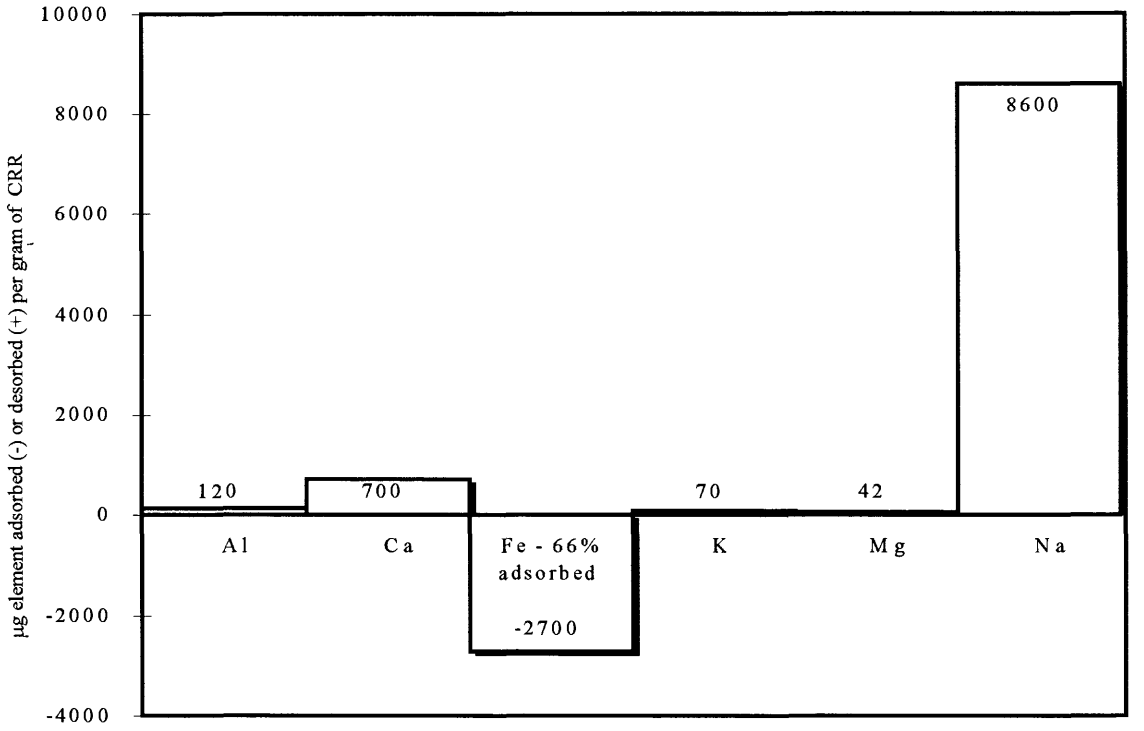

Figure 1. FLW adsorption/desorption in 820 mg/L Fe^{2+} stock solution.

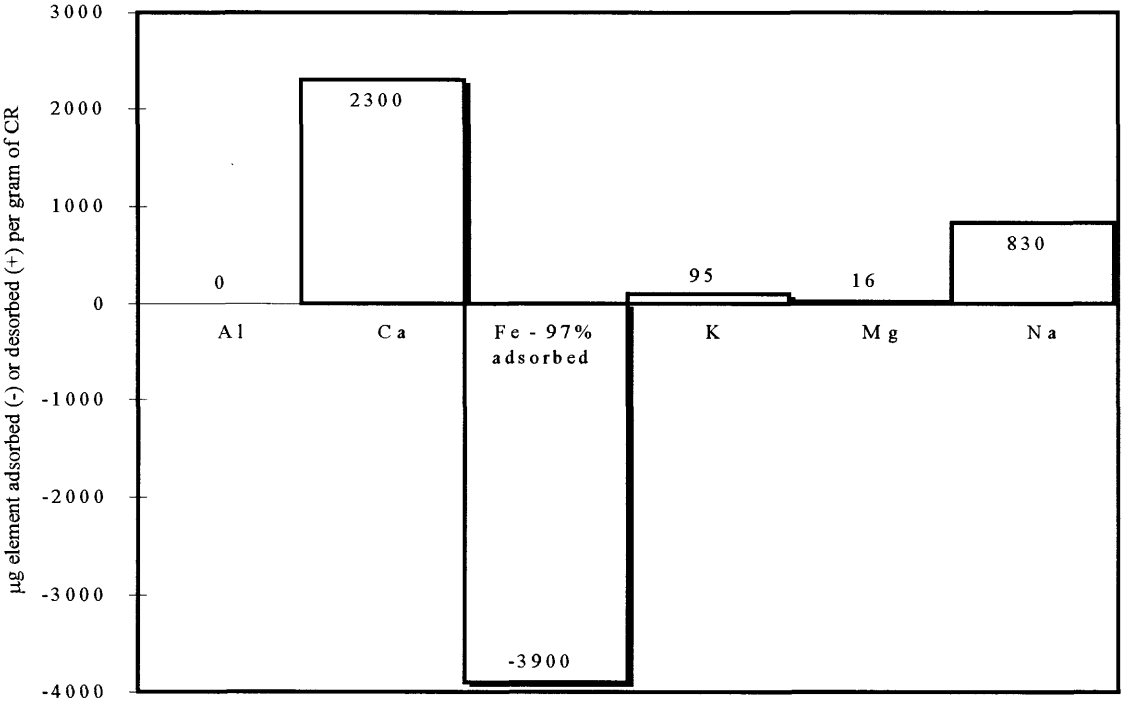

Figure 2. ACT adsorption/desorption in 820 mg/L Fe^{2+} stock solution.

Table 9. Selected elemental concentrations (mg/L) in McClelland and Burleigh mine drainage.

	Na	Mg	Al	SO_4	K	Ca	Mn	Fe	Zn	Cd	Pb	U	Ni	Rb	Sr	Cu
McClelland	12	46	5	450	1.3	120	18	1.5	7.4	0.045	0.024	0.032	0.17	0.01	1.5	1.3
Burleigh	11	37	0.051	350	1.3	82	3.6	0.26	70	0.15	0.023	0.016	0.05	0.009	1.7	0.0003

Ion Exchange in Mine Drainage Samples

The compositions of the Burleigh and McClelland mine drainage solutions are shown in Table 9. Both contain large amounts of sulfate but the McClelland water is enriched in Ca, Al, Fe, Mn, and Cu relative to Burleigh which is enriched in Zn.

The performance of the CRRs in McClelland drainage was quite variable (Table 10). All adsorbed approximately the same amount of Al, Fe, Pb, Cd, and Cu while they varied widely in the quantity of Mg, SO_4, Ca, Mn, Zn, and Ni captured. The largest removals of Mg, Mn, Zn, and Ni were accomplished by FLW, ZEO, and SDH. ACT also removed large amounts of these metals, especially Zn. Sulfate was adsorbed in large amounts by all CRRs except FLW, the only sample to adsorb K. The main elements released in response to adsorption were Na and Ca. K was also desorbed; however, not in large quantities. If a particular CRR desorbed a large amount of Na, then it seemed to adsorb Ca, and this was the case for FLW, CHI, GCM, FCWN, ZEO, SDH, AND PBC. Generally, the more Na desorbed, the more Ca adsorbed. If Na was not released in very large quantities, then Ca was desorbed. This was seen in ACT, CCO, PWI, and SNM. Of all the CRRs, FLW, ACT, SDH, and ZEO desorbed the most Na and adsorbed the most Ca, and of these 3, FLW showed the largest values with respect to Na and Ca. Important to note is that these 4 CRRs performed the best in terms of metal uptake showing that there is a definite relationship between the amount of metal adsorbed by and desorbed from the CRR. In summary, the more metal adsorbed from the AMD, the more metal desorbed.

The results of CRR exposure to Burleigh mine drainage (Table 11) were very similar to those for McClelland. The desorption patterns for Na, Ca, and K mentioned above are very similar to those seen here. Again, sulfate was removed in large quantities by all CRRs except FLW. Zn removals were substantial, and were one order of magnitude greater than that seen in McClelland which had one order of magnitude less Zn than Burleigh. This shows that in most cases, the amount of a certain metal removed is proportional to its concentration in solution simply because there is more available. This relationship breaks down if a CRR shows high affinity for a specific metal, no matter what its concentration. For example, the concentration of sulfate was 5 times greater than that of Zn; however, the amount of Zn removed per gram of CRR was greater than sulfate. This could be because sulfate is an anion while Zn is a cation. In another example, the concentration of Ca was also higher than that of Zn, but some CRRs adsorbed while others desorbed Ca. The same 4 CRRs – FLW, ACT, ZEO, and SDH - showed the best performance in terms of amount of metals removed from solution.

SUMMARY AND CONCLUSIONS

The results of the experiments proved to be very useful in making comparisons of 11 different CRRs. All of the samples showed varied ion-exchange behaviors in single element stock and mine drainage solutions. The CRRs that seemed to adsorb more metals from solution were FLW, ACT, ZEO, and SDH. These samples also desorbed the most Na and Ca. These data indicate that the metals are predominantly exchanging with Na and Ca, that Na- and Ca-rich CRRs are more effective at metal removal, and that substantial adsorption results in substantial desorption. Another important finding is the correlation between CRR composition, in terms of Na, Ca, and K, and the dominant cation desorbed. For example, FLW, the most Na-rich CRR, consistently released the most Na in the exchange reactions.

Therefore, further tests will be done on FLW, ACT ZEO, and SDH in order to determine which of these CRRs is best suited for use in a treatment system. The CRRs PWI and CHI will also be tested in the future because of their behavior in mine drainage solutions and their compositions (K-rich). These 2 CRRs demonstrated relatively good adsorption capabilities without the release of large amounts of Na.

Table 10. Summary of CRR adsorption (-) and desorption (+) in McClelland tunnel water. Values are μg element ads./des. per gram of CRR.

CRR	Na (+/-)	Mg (+/-)	Al (+/-)	SO_4 (+/-)	K (+/-)	Ca (+/-)	Mn (+/-)	Fe (+/-)
FLW	1600	-220	-23	-35	-2.1	-590	-88	-7.3
ACT	490	-170	-25	-240	25	140	-75	-6.2
CHI	790	-180	-25	-190	400	-340	-76	-7.3
CCO	440	-130	-25	-190	63	42	-64	-6.6
GCM	740	-97	-25	-140	38	-190	-59	-7.3
FCWN	840	-68	-25	-240	58	-310	-62	-7.3
ZEO	1300	-210	-25	-240	110	-470	-85	-7.3
PWI	350	-120	-25	-240	160	43	-65	-6.5
SNM	180	-43	-25	-190	29	140	-48	-6.1
SDH	1500	-220	-24	-240	43	-580	-87	-7.3
PBC	1000	-160	-25	-240	18	-340	-78	-7.3

CRR	Zn (+/-)	Cd (+/-)	Pb (+/-)	U (+/-)	Ni (+/-)	Rb (+/-)	Sr (+/-)	Cu (+/-)
FLW	-36	-0.22	-0.12	-0.13	-0.78	-0.025	-7.3	-5.9
ACT	-36	-0.22	-0.12	-0.087	-0.70	0.075	-6.1	-6.2
CHI	-34	-0.20	-0.12	-0.16	-0.68	0.90	-6.7	-6.1
CCO	-32	-0.19	-0.12	-0.16	-0.58	0.30	-5.5	-5.9
GCM	-33	-0.19	-0.12	-0.10	-0.56	0.065	-5.9	-5.8
FCWN	-35	-0.21	-0.12	-0.11	-0.57	0.30	-6.7	-5.9
ZEO	-37	-0.22	-0.12	-0.12	-0.80	0.24	-5.9	-6.3
PWI	-32	-0.18	-0.11	-0.16	-0.45	0.34	-6.8	-5.9
SNM	-29	-0.16	-0.12	-0.14	-0.47	0.050	0.17	-6.1
SDH	-37	-0.22	-0.12	-0.082	-0.81	0.015	-7.2	-6.2
PBC	-36	-0.22	-0.12	-0.082	-0.77	-0.0064	-6.7	-6.2

Table 11. Summary of CRR adsorption (-) and desorption (+) in Burleigh tunnel water. Values are μg element ads./des. per gram of CRR.

CRR	Na (+/-)	Mg (+/-)	Al (+/-)	SO4 (+/-)	K (+/-)	Ca (+/-)	Mn (+/-)	Fe (+/-)
FLW	1400	-180	7.2	-75	-2.3	-380	-18	-1.3
ACT	500	-150	-0.15	-280	19	140	-15	-0.74
CHI	700	-160	-0.09	-280	330	-240	-16	-1.3
CCO	420	-120	-0.25	-280	54	82	-14	-1.3
GCM	700	-95	-0.25	-230	36	-140	-13	-1.3
FCWN	750	-65	-0.25	-230	49	-210	-13	-1.3
ZEO	1200	-180	-0.20	-230	99	-330	-17	-1.3
PWI	310	-110	-0.11	-280	140	92	-14	-0.78
SNM	170	-45	-0.25	-280	26	140	-11	-0.79
SDH	1400	-180	7.7	-230	41	-390	-18	2.7
PBC	1000	-140	-0.26	-280	16	-240	-13	-1.3

CRR	Zn (+/-)	Cd (+/-)	Pb (+/-)	U (+/-)	Ni (+/-)	Rb (+/-)	Sr (+/-)
FLW	-350	-0.77	-0.10	0.0025	-0.22	-0.025	-8.3
ACT	-330	-0.75	-0.11	-0.0075	-0.19	0.065	-7.3
CHI	-330	-0.73	-0.11	-0.067	-0.22	0.70	-7.8
CCO	-310	-0.69	-0.11	-0.052	-0.17	0.25	-6.9
GCM	-300	-0.68	-0.11	-0.023	-0.18	0.060	-7.2
FCWN	-310	-0.72	-0.12	-0.013	-0.17	0.24	-7.8
ZEO	-350	-0.76	-0.11	-0.032	-0.14	0.20	-7.5
PWI	-310	-0.67	-0.11	-0.012	-0.16	0.25	-7.9
SNM	-260	-0.58	-0.12	-0.028	-0.15	0.050	-1.8
SDH	-350	-0.77	-0.11	0.0075	-0.24	0.020	-8.2
PBC	-340	-0.76	-0.11	0.033	-0.22	-0.0065	-7.9

REFERENCES

Arbogast, B.F., 1996, Analytical methods for the mineral resource surveys program. U.S. Geological Survey Open-File Report 96-525, 248 p.

Boylan, J.A. Jr., 1995, Decreased permeability of clinoptilolite-rich tuffs resulting from cation exchange and associated precipitation reactions. *in* Natural Zeolites '93: Occurrence, Properties, Use, eds. D.W. Ming and F.A. Mumpton. International Committee on Natural Zeolites, p.325-337.

Bremner, P.R. and Schultze, L.E., 1995, Ability of clinoptilolite-rich tuffs to remove metal cations commonly found in acidic drainage. *in* Natural Zeolites '93: Occurrence, Properties, Use, eds. D.W. Ming and F.A. Mumpton. International Committee on Natural Zeolites, p.397-403.

Desborough, G.A., 1996, Potential use of clinoptilolite-rich rocks for capture and retention of soluble lead in aqueous systems such as soils, contaminated drainages, and waste water: U.S. Geological Survey Open-File Report 96-715, 14 p.

_____1995, Extraction of metals from raw clinoptilolite-rich rocks exposed to water in heavy-metal polluted drainages: U.S. Geological Survey Open-File Report 95-56, 14 p.

_____1994, Efficacy of heavy-metal capture by clinoptilolite-rich rocks from heavy-metal-polluted water in five drainages in Colorado: U.S. Geological Survey Open-File Report 94-140, 25 p.

Drever, J.I., 1997, The geochemistry of natural waters, p 292-293.

Driscoll, C.T., Baker, J.P., Bisogni Jr., J.J., and Schofield, C.L., 1980, Effect of aluminum speciation on fish in dilute acidified water: Nature, v. 284, p. 161-164.

Crock, J.G., Arbogast, B.F., and Lamothe, P.J., 1998, Laboratory methods for the analysis of environmental samples. *in* Economic Geology, special issue, ed. G.S. Plumlee. Chapter 13, 23 p.

Kesler, S.J. 1994. Mineral resources, economics and the environment, p. 203, 275.

Zamzow, M.J. and Schultze, L.E., 1995, Treatment of acid mine drainage using natural zeolites. *in* Natural Zeolites '93: Occurrence, Properties, and Use, eds. D.W. Ming and F.A. Mumpton. International Committee on Natural Zeolite, p.405-413.

Zelazny, L.W., Liming, H. and Vanwormhoudt, A., 1996, Charge analysis of soils and anion exchange. *in* Methods of Soil Analysis: Part 3 – Chemical Methods, ed., D.L. Sparks. Soil Society of America, Inc., p.1231-1253.

APPENDIX

Table A1. ICP - MS Results[a] for Pre- and Post- Exchange Silver Stock Solution

Field No	Solution	Ag ug/L	Al ug/L	As ug/L	Ba ug/L	Be ug/L	Bi ug/L	Ca mg/L	Cd ug/L	Ce ug/L	Co ug/L
FLW 9	CRR extract: 7.2 mg/L Ag	44	16000	3.5	5.0	3.1	< 0.01	10	0.2	30	0.4
ACT 9	CRR extract: 7.2 mg/L Ag	80	5.8	2.0	23	< 0.05	< 0.01	100	0.06	0.5	0.1
CHI 9	CRR extract: 7.2 mg/L Ag	110	11000	1	56	9.5	0.03	44	0.3	20	0.2
CCO 9	CRR extract: 7.2 mg/L Ag	89	19000	6.6	20	2.1	0.01	58	0.2	22	1.4
GCM 9	CRR extract: 7.2 mg/L Ag	57	14000	2.6	18	0.6	< 0.01	37	0.1	31	0.2
FCWN 9	CRR extract: 7.2 mg/L Ag	17	12000	5.2	17	6.6	< 0.01	38	0.2	10	1.3
ZEO 9	CRR extract: 7.2 mg/L Ag	33	3.6	0.7	18	< 0.05	< 0.01	54	0.2	0.93	0.1
PWI 9	CRR extract: 7.2 mg/L Ag	72	21000	2.7	25	1.3	< 0.01	62	0.2	56	0.60
SNM 9	CRR extract: 7.2 mg/L Ag	64	17000	2.0	13	0.4	< 0.01	47	0.2	33	0.55
SDH 9	CRR extract: 7.2 mg/L Ag	63	1.0	6.5	13	< 0.05	< 0.01	41	0.2	0.08	0.04
PBC 9	CRR extract: 7.2 mg/L Ag	23	15000	0.9	6.7	1.4	< 0.01	32	0.60	8.4	5.4
PMO8	Ag stock solution[b]	72	3.4	0.4	1.0	< 0.05	< 0.01	< 0.05	0.03	< 0.01	< 0.02

Field No	Cs ug/L	Cu ug/L	Dy ug/L	Er ug/L	Eu ug/L	Fe ug/L	Ga ug/L	Gd ug/L	Ge ug/L	Ho ug/L	In ug/L	K ug/L
FLW 9	0.08	2	6.2	3.4	0.77	200	0.06	5.8	0.06	1.3	0.02	900
ACT 9	1.3	0.8	0.19	0.12	0.01	300	< 0.02	0.21	0.03	0.04	< 0.01	2500
CHI 9	0.90	2	19	12	0.66	290	0.1	14	0.08	4.3	0.06	30000
CCO 9	8.7	15	2.3	1.6	0.27	610	0.06	2.5	0.04	0.51	0.04	5300
GCM 9	0.07	18	6.5	3.7	1.4	190	0.06	5.2	0.04	1.3	0.01	4500
FCWN 9	0.78	17	1.7	1.0	0.16	240	0.04	1.6	0.03	0.35	0.05	6400
ZEO 9	0.38	< 0.5	0.13	0.15	0.01	150	< 0.02	0.092	< 0.02	0.04	< 0.01	11000
PWI 9	0.31	3	3.9	2.3	0.39	380	0.1	4.2	0.05	0.81	0.05	12000
SNM 9	0.2	4	7.6	3.1	1.1	190	0.1	9.9	0.09	1.3	< 0.01	3800
SDH 9	0.04	< 0.5	0.008	0.007	< 0.005	110	< 0.02	0.008	< 0.02	< 0.005	< 0.01	6400
PBC 9	0.2	14	17	13	0.076	3300	0.1	7.2	< 0.02	4.1	0.34	2000
PMO8	< 0.01	< 0.5	< 0.005	< 0.005	< 0.005	< 10	< 0.02	< 0.005	< 0.02	< 0.005	< 0.01	14

[a]Au (< 0.01), Cr (< 0.5), Hf (< 0.05), Nb (< 0.02), Re (< 0.02), and Te (< 0.1), have been omitted because the concentrations were less than the detection limits shown in parentheses.

[b]Average of 3; a 1:100 dilution.

Field No	La ug/L	Li ug/L	Mg mg/L	Mn ug/L	Mo ug/L	Na mg/L	Nd ug/L	Ni ug/L	P ug/L	Pb ug/L	Pr ug/L	Rb ug/L
FLW 9	13	6.6	0.46	33	0.3	-	18	1.3	1100	0.5	4.0	2.7
ACT 9	1.0	11	0.35	23	0.3	110	0.75	2.8	520	0.2	0.2	9.3
CHI 9	6.4	2.7	0.84	210	0.2	110	30	1.5	51000	0.65	5.0	71
CCO 9	9.9	24	1.2	60	0.3	98	14	3.5	3500	1.7	3.0	30
GCM 9	16	2.5	3.1	170	0.1	-	18	1.8	6800	0.57	4.6	12
FCWN 9	6.0	16	2.7	71	0.1	-	5.8	2.9	270	1.4	1.3	36
ZEO 9	0.73	5.1	1.6	1100	0.3	-	0.39	1.5	26	0.2	0.1	27
PWI 9	41	2.8	0.93	20	0.1	78	25	2.2	850	1.1	6.5	28
SNM 9	32	1.4	4.7	130	0.07	110	42	2.0	5200	0.52	9.7	8.8
SDH 9	0.08	4.4	0.35	420	0.3	-	0.02	1.3	2900	0.07	< 0.01	7.7
PBC 9	3.4	17	2.3	1700	0.07	-	8.0	5.3	79	0.55	1.5	3.4
PMO8	< 0.01	< 0.1	< 0.01	0.18	0.06	13	< 0.01	0.13	15	0.13	< 0.01	< 0.01

Field No	Sb ug/L	Sc ug/L	Se ug/L	SiO2 mg/L	Sm ug/L	Sn ug/L	SO4 mg/L	Sr ug/L	Ta ug/L	Tb ug/L	Th ug/L	Ti ug/L
FLW 9	0.1	5	0.8	7.2	4.9	0.2	290	26	0.08	1.0	1.7	2.3
ACT 9	0.2	0.1	0.6	3	0.2	0.1	290	150	0.05	0.03	0.08	2.4
CHI 9	0.1	2	1	9.0	9.1	0.09	280	93	0.06	2.8	0.27	2.4
CCO 9	0.1	6.3	0.5	8.2	2.8	0.1	290	290	0.04	0.37	2.6	2.3
GCM 9	0.04	3	0.6	4	4.6	0.1	280	200	0.03	1.0	6.4	2.2
FCWN 9	0.09	4	0.6	4	1.3	0.08	280	100	0.02	0.28	2.2	2.2
ZEO 9	0.4	< 0.1	0.6	2	0.06	< 0.05	270	330	0.02	0.02	0.15	2.1
PWI 9	0.06	2	0.6	5.7	4.0	0.1	270	64	< 0.02	0.66	3.4	2.2
SNM 9	0.05	3	0.8	5.0	10	< 0.05	280	1100	0.02	1.5	6.5	2.3
SDH 9	0.04	< 0.1	1	3	0.01	< 0.05	290	130	< 0.02	< 0.005	0.33	2.3
PBC 9	0.03	10	1	9.5	3.2	< 0.05	280	110	0.02	2.1	21	2.2
PMO8	< 0.02	< 0.1	0.27	< 0.5	< 0.01	< 0.05	21	0.20	< 0.02	< 0.005	0.11	0.27

Field No	Tl ug/L	Tm ug/L	U ug/L	V ug/L	W ug/L	Y ug/L	Yb ug/L	Zn ug/L	Zr ug/L
FLW 9	0.2	0.46	10	0.2	0.07	39	2.5	20	0.4
ACT 9	0.1	0.02	2.3	1	0.04	1.5	0.1	36	< 0.05
CHI 9	0.07	1.6	11	0.8	0.04	200	9.3	23	0.2
CCO 9	0.1	0.32	10	4	0.02	13	2.5	33	0.3
GCM 9	< 0.05	0.52	2.5	2	0.02	40	3.1	9	0.2
FCWN 9	0.1	0.17	7.5	6.4	0.02	8.2	1.1	37	0.4
ZEO 9	0.08	0.03	2.1	0.2	< 0.02	2.1	0.2	4	< 0.05
PWI 9	0.06	0.31	5.8	0.4	< 0.02	37	1.7	40	0.2
SNM 9	< 0.05	0.38	1.8	1	< 0.02	38	2.0	20	0.3
SDH 9	< 0.05	< 0.005	0.44	2	< 0.02	0.1	< 0.01	4	< 0.05
PBC 9	< 0.05	2.3	5.6	0.5	< 0.02	180	16	84	0.2
PMO8	< 0.05	< 0.005	0.02	< 0.1	< 0.02	< 0.01	< 0.01	3.0	< 0.05

Table A2. ICP - AES Results[a] for Pre- and Post- Exchange Aluminum Stock Solution

Field No	Solution	Al mg/L	Ba mg/L	Ca mg/L	Ce mg/L	Fe mg/L	K mg/L	La mg/L	Li mg/L	Mg mg/L	Mn mg/L
ZEO13	CRR extract: 190 mg/L Al	< 1	0.17	630	< 0.1	< 1	160	< 0.1	< 0.1	30	9.6
CHI13	CRR extract: 190 mg/L Al	110	0.24	500	0.12	< 1	420	< 0.1	< 0.1	13	1.6
FLW13	CRR extract: 190 mg/L Al	110	< 0.1	140	0.24	< 1	12	0.12	< 0.1	5.9	0.48
FCWN13	CRR extract: 190 mg/L Al	140	0.10	420	< 0.1	< 1	95	< 0.1	0.16	33	0.40
PBC13	CRR extract: 190 mg/L Al	130	0.16	440	< 0.1	4.4	31	< 0.1	0.17	28	14
ACT13	CRR extract: 190 mg/L Al	< 1	0.18	690	< 0.1	< 1	32	< 0.1	< 0.1	4.2	0.10
PWI13	CRR extract: 190 mg/L Al	190	0.23	900	0.26	1.8	190	0.22	< 0.1	14	0.17
SNM13	CRR extract: 190 mg/L Al	140	0.21	540	0.16	< 1	59	0.25	< 0.1	63	0.96
CCO13	CRR extract: 190 mg/L Al	160	0.22	770	< 0.1	1.7	71	< 0.1	0.28	18	0.32
GCM13	CRR extract: 190 mg/L Al	140	0.14	500	0.22	< 1	65	0.13	< 0.1	43	1.2
SDH13	CRR extract: 190 mg/L Al	< 1	0.14	430	< 0.1	< 1	86	< 0.1	< 0.1	5.1	3.7
PMO11	Al Stock Solution (average	190	< 0.1	< 1	< 0.1	< 1	< 1	< 0.1	< 0.1	< 1	< 0.1

Field No	Na mg/L	Nd mg/L	P mg/L	Sr mg/L	Y mg/L	Zn mg/L
ZEO13	2500	< 0.1	< 1	4.3	< 0.1	0.10
CHI13	1900	0.23	19	1.1	1.1	0.12
FLW13	2600	0.19	< 1	0.30	0.36	0.17
FCWN13	2100	< 0.1	< 1	1.1	< 0.1	0.28
PBC13	2200	< 0.1	< 1	1.5	1.1	0.64
ACT13	1900	< 0.1	< 1	1.4	< 0.1	< 0.1
PWI13	1400	0.17	1.0	0.79	0.30	0.42
SNM13	1800	0.32	2.4	12	0.29	0.16
CCO13	1700	< 0.1	< 1	4.0	< 0.1	0.32
GCM13	2000	0.17	2.6	2.4	0.34	0.19
SDH13	2600	< 0.1	< 1	1.7	< 0.1	0.11
PMO11	2300	< 0.1	< 1	< 0.1	< 0.1	< 0.1

[a]Ag (< 0.1), As (< 0.2), Au (< 0.1), Be (< 0.1), Bi (< 0.2), Cd (< 0.1), Co (< 0.1), Cr (< 0.1), Eu (< 0.1), Ga (< 0.1), Ho (< 0.1), Mo (< 0.1), Nb (< 0.1), Pb (< 0.1), Sc (< 0.1), Sn (< 0.5), Ta (< 1), Th (< 0.1), Ti (< 1), U (< 1), V (< 0.1), and Yb (< 0.1) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Table A3. ICP - MS Results[a] for Pre- and Post- Exchange Arsenic Stock Solution

Field No	Solution	Al ug/L	As ug/L	Ba ug/L	Ca mg/L	Cd ug/L	Ce ug/L	Co ug/L	Cs ug/L	Cu ug/L	Dy ug/L
FLW 7	CRR extract: 20 mg/L As	8.4	1200	4	10	< 0.02	0.06	0.08	0.06	1	0.008
ACT 7	CRR extract: 20 mg/L As	2.0	1100	21	56	< 0.02	0.02	0.07	1.5	0.7	< 0.005
CHI 7	CRR extract: 20 mg/L As	4.3	900	27	31	0.06	0.2	0.05	1.1	0.6	0.10
CCO 7	CRR extract: 20 mg/L As	1.9	1000	26	62	< 0.02	0.02	0.1	10	2	< 0.005
GCM 7	CRR extract: 20 mg/L As	0.19	2000	40	37	< 0.02	0.02	0.05	0.09	3	0.008
FCWN 7	CRR extract: 20 mg/L As	4.9	1200	12	26	< 0.02	0.02	0.04	1.0	2	< 0.005
ZEO 7	CRR extract: 20 mg/L As	0.23	870	13	19	< 0.02	0.01	< 0.02	0.37	< 0.5	< 0.005
PWI 7	CRR extract: 20 mg/L As	0.37	1200	26	72	0.08	0.09	0.1	0.46	0.8	0.007
SNM 7	CRR extract: 20 mg/L As	2.1	1200	39	40	< 0.02	0.01	0.07	0.3	0.7	< 0.005
SDH 7	CRR extract: 20 mg/L As	9.9	1100	11	9.1	< 0.02	0.02	0.02	0.04	< 0.5	< 0.005
PBC 7	CRR extract: 20 mg/L As	4.1	740	20	30	0.05	0.02	0.3	0.38	0.9	0.009
PMO6	20 mg/L As stock solution	1.4	35	1.0	< 0.05	< 0.02	0.02	0.03	< 0.01	< 0.5	< 0.005

Field No	Er ug/L	Fe ug/L	Gd ug/L	Ge ug/L	K ug/L	La ug/L	Li ug/L	Mg mg/L	Mn ug/L	Mo ug/L	Na mg/L	Nd ug/L
FLW 7	0.005	41	0.01	0.02	1200	0.03	4.2	0.19	1.6	0.58	-	0.03
ACT 7	< 0.005	180	< 0.005	0.02	2700	< 0.01	10	0.23	3.0	0.53	-	< 0.01
CHI 7	0.06	100	0.14	0.03	38000	0.50	1.5	0.54	7.6	0.81	-	0.52
CCO 7	< 0.005	190	< 0.005	0.05	6700	0.02	24	0.92	3.4	1.8	-	< 0.01
GCM 7	0.007	120	0.005	0.02	6100	0.01	1.9	2.1	7.7	0.58	-	< 0.01
FCWN 7	< 0.005	86	< 0.005	0.02	9500	0.02	12	1.4	1.6	0.65	-	< 0.01
ZEO 7	< 0.005	67	< 0.005	0.03	12000	< 0.01	4.5	1.1	13	0.60	-	< 0.01
PWI 7	< 0.005	220	0.009	0.02	18000	0.2	2.5	0.81	7.0	0.51	-	0.04
SNM 7	< 0.005	120	< 0.005	0.03	5100	0.01	1.2	3.0	10	0.4	-	< 0.01
SDH 7	< 0.005	42	< 0.005	0.02	6500	< 0.01	4.1	0.12	1.1	0.4	-	< 0.01
PBC 7	0.006	98	0.006	0.03	3000	0.01	11	0.92	43	0.60	-	< 0.01
PMO6	< 0.005	< 10	< 0.005	< 0.02	23	0.02	0.1	< 0.01	0.04	0.03	4.6	< 0.01

[a]Ag (< 0.01), Au (< 0.01), Be (< 0.05), Bi (< 0.01), Cr (< 0.5), Eu (< 0.005), Ga (< 0.02), Ge (< 0.02), Hf (< 0.05), Ho (< 0.005), In (< 0.01), Nb (< 0.02), Pr (< 0.01), Re (< 0.02), Sc (< 0.1), Sm (< 0.01), Ta (< 0.02), Tb (< 0.005),Te (< 0.1), Th (< 0.005), Tl (< 0.05), Tm (< 0.005), W (< 0.02), Yb (< 0.01), and Zr (< 0.05) have been omitted because the concentrations were less than the detection limits shown in parentheses.

[b]Average of 3; a 1:500 dilution.

Field No	Ni ug/L	P ug/L	Pb ug/L	Rb ug/L	Sb ug/L	Sc ug/L	Se ug/L	SiO2 mg/L	Sn ug/L	SO4 mg/L	Sr ug/L	Ti ug/L
FLW 7	0.4	42	0.1	3.2	0.55	< 0.1	0.6	2	0.06	630	26	2.7
ACT 7	1.4	21	0.06	10	0.4	0.4	0.4	4	0.05	610	140	2.6
CHI 7	1.0	22	0.2	87	0.2	0.2	0.5	3	< 0.05	600	75	2.6
CCO 7	1.7	98	0.2	35	0.55	< 0.1	0.6	3	0.05	610	350	2.7
GCM 7	1.0	33	0.07	16	0.51	< 0.1	0.5	2	< 0.05	620	240	2.7
FCWN 7	0.6	53	0.1	50	0.55	< 0.1	0.4	2	0.07	600	88	2.6
ZEO 7	0.5	15	< 0.05	26	0.88	0.1	0.4	3	0.06	620	260	2.6
PWI 7	1.8	74	0.3	40	0.4	< 0.1	0.4	3	< 0.05	600	69	2.6
SNM 7	1.0	36	0.1	11	0.4	< 0.1	0.5	2	< 0.05	630	1000	2.6
SDH 7	0.4	22	0.3	6.7	0.4	0.2	0.6	2	0.05	620	83	2.8
PBC 7	1.0	19	0.3	4.9	0.4	0.2	0.3	3	0.05	620	110	2.6
PMO6	0.2	5.7	0.5	0.02	< 0.02	< 0.1	0.2	< 0.5	0.1	9.4	0.1	0.1

Field No	Tl ug/L	U ug/L	V ug/L	Y ug/L	Zn ug/L
FLW 7	< 0.05	0.84	0.2	0.08	6
ACT 7	< 0.05	0.76	1	0.02	5
CHI 7	< 0.05	0.04	< 0.1	1.8	4
CCO 7	0.1	0.10	0.1	0.03	2
GCM 7	< 0.05	0.19	1	0.07	2
FCWN 7	0.1	0.55	2	0.03	3
ZEO 7	0.07	0.10	0.7	0.02	2
PWI 7	0.08	0.19	< 0.1	0.1	6
SNM 7	< 0.05	0.14	2	0.02	3
SDH 7	< 0.05	0.63	3	< 0.01	2
PBC 7	< 0.05	1.8	0.4	0.1	40
PMO6	< 0.05	0.01	< 0.1	0.2	2.7

Table A4. ICP - AES Results[a] for Pre- and Post- Exchange Calcium Stock Solution

Field No	Solution	Al mg/L	Ba mg/L	Ca mg/L	Ce mg/L	Cu mg/L	Fe mg/L	K mg/L	La mg/L	Li mg/L	Mg mg/L
ZEO18	CRR extract: 430 mg/L Ca	< 1	0.25	700	< 0.1	< 0.1	< 1	130	< 0.1	< 0.1	32
CHI18	CRR extract: 430 mg/L Ca	40	0.34	780	0.20	< 0.1	< 1	430	0.13	< 0.1	14
FLW18	CRR extract: 430 mg/L Ca	42	< 0.1	300	0.22	< 0.1	1.0	14	0.13	< 0.1	7.7
FCWN18	CRR extract: 430 mg/L Ca	23	0.13	620	< 0.1	< 0.1	< 1	100	< 0.1	0.18	39
PBC18	CRR extract: 430 mg/L Ca	39	0.18	730	< 0.1	< 0.1	7.7	29	< 0.1	0.20	33
ACT18	CRR extract: 430 mg/L Ca	< 1	0.26	1400	< 0.1	< 0.1	< 1	31	< 0.1	0.13	5.0
PWI18	CRR extract: 430 mg/L Ca	76	0.24	670	0.27	< 0.1	2.4	180	0.25	< 0.1	15
SNM18	CRR extract: 430 mg/L Ca	52	0.27	800	0.16	< 0.1	< 1	55	0.30	< 0.1	67
CCO18	CRR extract: 430 mg/L Ca	62	0.22	640	< 0.1	< 0.1	2.9	70	< 0.1	0.32	20
GCM18	CRR extract: 430 mg/L Ca	40	0.19	690	0.26	0.14	< 1	61	0.17	< 0.1	47
SDH18	CRR extract: 430 mg/L Ca	< 1	0.16	590	< 0.1	< 0.1	< 1	87	< 0.1	< 0.1	5.1
PMO15	Ca Stock Solution (average)	< 1	< 0.1	430	< 0.1	< 0.1	< 1	< 1	< 0.1	< 0.1	< 1

Field No	Mn mg/L	Na mg/L	Nd mg/L	P mg/L	Sr mg/L	Y mg/L	Zn mg/L
ZEO18	6.9	2400	< 0.1	< 1	4.6	< 0.1	< 0.1
CHI18	1.8	1900	0.29	60	1.5	1.2	< 0.1
FLW18	0.71	2900	0.16	1.6	0.55	0.36	0.26
FCWN18	0.56	2100	< 0.1	< 1	1.5	< 0.1	0.28
PBC18	15	2200	< 0.1	< 1	2.0	1.1	0.82
ACT18	0.11	1900	< 0.1	< 1	2.2	< 0.1	< 0.1
PWI18	0.19	1500	0.14	2.8	0.82	0.30	0.48
SNM18	1.2	1900	0.33	11	14	0.33	0.12
CCO18	0.21	1800	< 0.1	2.7	3.8	< 0.1	0.37
GCM18	1.5	2000	0.16	16	3.0	0.38	0.15
SDH18	2.6	2700	< 0.1	4.1	2.1	< 0.1	< 0.1
PMO15	< 0.1	2300	< 0.1	< 1	0.22	< 0.1	< 0.1

[a]Ag (< 0.1), As (< 0.2), Au (< 0.1), Be (< 0.1), Bi (< 0.2), Cd (< 0.1), Co (< 0.1), Cr (< 0.1), Eu (< 0.1), Ga (< 0.1), Ho (< 0.1), Mo (< 0.1), Nb (< 0.1), Pb (< 0.1), Sc (< 0.1), Sn (< 0.5), Ta (< 1), Th (< 0.1), Ti (< 1), U (< 1), V (< 0.1), and Yb (< 0.1) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Table A5. ICP - MS Results[a] for Pre- and Post- Exchange Cadmium Stock Solution

Field No	Solution	Al ug/L	As ug/L	Ba ug/L	Be ug/L	Ca mg/L	Cd ug/L	Ce ug/L	Co ug/L	Cs ug/L	Cu ug/L
FLW 6	CRR extract: 20 mg/L Cd	36	0.5	4	< 0.05	9.2	320	0.3	0.08	0.07	1
ACT 6	CRR extract: 20 mg/L Cd	< 0.01	0.3	23	< 0.05	50	140	0.02	0.03	1.5	< 0.5
CHI 6	CRR extract: 20 mg/L Cd	20	< 0.2	23	0.3	28	1100	0.97	0.1	1.2	< 0.5
CCO 6	CRR extract: 20 mg/L Cd	9.5	0.5	23	< 0.05	54	1200	0.3	0.2	12	2
GCM 6	CRR extract: 20 mg/L Cd	< 0.01	0.5	34	< 0.05	32	1200	0.1	0.04	0.1	4
FCWN 6	CRR extract: 20 mg/L Cd	4.7	0.7	13	< 0.05	24	430	0.06	0.06	1.0	2
ZEO 6	CRR extract: 20 mg/L Cd	28	0.2	15	< 0.05	18	180	0.08	< 0.02	0.43	< 0.5
PWI 6	CRR extract: 20 mg/L Cd	190	0.5	26	0.2	59	1500	2.0	0.2	0.46	0.7
SNM 6	CRR extract: 20 mg/L Cd	< 0.01	0.2	30	< 0.05	34	1400	0.66	0.1	0.30	0.6
SDH 6	CRR extract: 20 mg/L Cd	0.13	1	12	< 0.05	9.4	180	0.02	< 0.02	0.04	< 0.5
PBC 6	CRR extract: 20 mg/L Cd	< 0.01	< 0.2	12	< 0.05	28	290	0.02	0.09	0.41	< 0.5
PMO5	16 mg/L Cd stock solution	8.4	< 0.2	0.13	< 0.05	0.07	310	0.01	< 0.02	< 0.01	< 0.5

Field No	Dy ug/L	Er ug/L	Eu ug/L	Fe ug/L	Gd ug/L	Ge ug/L	Ho ug/L	K ug/L	La ug/L	Li ug/L	Mg mg/L	Mn ug/L
FLW 6	0.061	0.04	0.009	21	0.050	0.02	0.01	1100	0.2	4.2	0.20	7.0
ACT 6	< 0.005	< 0.005	< 0.005	130	< 0.005	< 0.02	< 0.005	2400	0.02	10	0.22	5.4
CHI 6	1.8	1.2	0.051	68	1.4	0.02	0.44	34000	0.80	1.6	0.53	22
CCO 6	0.062	0.071	0.009	140	0.056	0.07	0.02	6000	0.2	24	0.88	9.2
GCM 6	0.03	0.03	0.006	75	0.03	< 0.02	0.006	5500	0.1	2.1	1.9	25
FCWN 6	0.01	0.007	< 0.005	56	0.01	0.03	< 0.005	7800	0.04	13	1.4	5.8
ZEO 6	0.007	< 0.005	< 0.005	51	0.007	0.02	< 0.005	11000	0.06	4.8	1.1	46
PWI 6	0.44	0.32	0.04	150	0.36	< 0.02	0.11	15000	2.2	2.6	0.75	10
SNM 6	0.066	0.052	0.01	78	0.064	< 0.02	0.02	4700	0.50	1.1	2.8	42
SDH 6	< 0.005	< 0.005	< 0.005	16	0.005	< 0.02	< 0.005	6000	0.03	4.1	0.15	12
PBC 6	0.04	0.04	< 0.005	62	0.02	< 0.02	0.01	2600	0.03	12	0.98	200
PMO5	< 0.005	< 0.005	< 0.005	170	< 0.005	< 0.02	< 0.005	27	0.01	< 0.1	< 0.01	0.72

[a]Ag (< 0.01), Au (< 0.01), Bi (< 0.01), Cr (< 0.5), Ga (< 0.02), Hf (< 0.05), In (< 0.01), Nb (< 0.02), Re (< 0.02), Sc (< 0.1), Sn (< 0.05), Ta (< 0.02), Th (< 0.005), Te (< 0.1), and W (< 0.02) have been omitted because the concentrations were less than the detection limits shown in parentheses.
[b]Average of 3; a 1:50 dilution.

Field No	Mo ug/L	Na mg/L	Nd ug/L	Ni ug/L	P ug/L	Pb ug/L	Pr ug/L	Rb ug/L	Sb ug/L	Se ug/L	SiO2 mg/L	Sm ug/L
FLW 6	0.4	-	0.1	0.6	22	0.2	0.04	3.1	0.2	0.6	1	0.03
ACT 6	0.4	-	0.01	1.3	15	< 0.05	< 0.01	9.1	0.04	0.4	2	< 0.01
CHI 6	0.07	-	3.0	1.0	29	0.2	0.48	84	0.02	0.4	2	0.75
CCO 6	0.4	-	0.2	2.0	58	0.95	0.03	35	0.3	0.4	2	0.04
GCM 6	0.4	-	0.08	1.1	37	0.1	0.02	15	< 0.02	0.4	1	0.02
FCWN 6	0.72	-	0.03	0.9	26	0.2	< 0.01	45	0.08	0.5	1	< 0.01
ZEO 6	0.50	-	0.02	0.7	6	0.07	< 0.01	28	0.4	0.4	2	< 0.01
PWI 6	0.2	-	1.3	1.7	84	0.75	0.31	36	0.1	0.5	2	0.22
SNM 6	0.2	-	0.26	1.2	50	0.06	0.07	11	< 0.02	0.4	1	0.05
SDH 6	0.4	-	< 0.01	0.3	40	< 0.05	< 0.01	7.1	0.02	0.5	2	< 0.01
PBC 6	0.50	-	0.01	0.9	3	< 0.05	< 0.01	4.8	0.07	0.5	2	< 0.01
PMO5	0.23	42	< 0.01	0.89	14	0.43	< 0.01	0.05	< 0.02	0.27	< 0.5	< 0.01

Field No	SO4 mg/L	Sr ug/L	Tb ug/L	Ti ug/L	Tl ug/L	Tm ug/L	U ug/L	V ug/L	Y ug/L	Yb ug/L	Zn ug/L	Zr ug/L
FLW 6	290	28	0.008	2.2	< 0.05	0.006	0.66	0.1	0.5	0.04	4	0.2
ACT 6	280	130	< 0.005	2.1	< 0.05	< 0.005	0.63	0.6	0.04	< 0.01	< 0.5	< 0.05
CHI 6	280	81	0.25	2.2	< 0.05	0.17	1.0	< 0.1	18	0.86	2	< 0.05
CCO 6	280	330	0.007	2.2	0.09	0.01	0.28	< 0.1	0.60	0.1	5	< 0.05
GCM 6	280	220	< 0.005	2.1	< 0.05	< 0.005	0.05	0.6	0.3	0.02	3	< 0.05
FCWN 6	280	98	< 0.005	2.1	0.1	< 0.005	0.16	0.6	0.07	< 0.01	2	< 0.05
ZEO 6	290	240	< 0.005	2.3	0.07	< 0.005	0.10	0.3	0.07	< 0.01	< 0.5	< 0.05
PWI 6	260	71	0.063	2.0	0.07	0.050	0.88	< 0.1	6.6	0.28	20	< 0.05
SNM 6	280	950	0.01	2.1	< 0.05	0.008	0.01	0.5	0.50	0.05	2	< 0.05
SDH 6	280	98	< 0.005	2.1	< 0.05	< 0.005	0.31	1	0.02	< 0.01	1	< 0.05
PBC 6	280	120	< 0.005	1.9	< 0.05	< 0.005	0.28	< 0.1	0.61	0.03	3	< 0.05
PMO5	40	0.47	< 0.005	0.4	< 0.05	< 0.005	0.009	< 0.1	< 0.01	< 0.01	2.7	< 0.05

Table A6. ICP - MS Results[a] for Pre- and Post- Exchange Cesium and Rubidium Stock Solution

Field No	Solution	Al ug/L	As ug/L	Ba ug/L	Be ug/L	Ca mg/L	Cd ug/L	Ce ug/L	Co ug/L	Cs ug/L	Cu ug/L
FLW 10	CRR extract: Cs & Rb 1 mg/L ea.	540	10	5.4	0.2	16	0.1	9.4	0.4	1.4	0.9
ACT 10	CRR extract: Cs & Rb 1 mg/L ea.	0.80	7.3	32	< 0.05	76	< 0.02	0.04	0.08	3.8	0.8
CHI 10	CRR extract: Cs & Rb 1 mg/L ea.	710	5.9	28	2.1	39	0.1	3.9	0.08	3.8	0.7
CCO 10	CRR extract: Cs & Rb 1 mg/L ea.	1600	5.7	26	0.7	68	0.1	2.2	0.66	16	4
GCM 10	CRR extract: Cs & Rb 1 mg/L ea.	450	5.3	26	0.1	45	0.04	5.8	0.1	1.9	8
FCWN 10	CRR extract: Cs & Rb 1 mg/L ea.	9.8	4.6	19	0.08	37	0.05	0.2	0.2	4.3	2
ZEO 10	CRR extract: Cs & Rb 1 mg/L ea.	17	3.5	16	< 0.05	35	0.03	0.1	0.04	2.8	< 0.5
PWI 10	CRR extract: Cs & Rb 1 mg/L ea.	3100	4.1	22	0.4	50	0.2	6.8	0.4	2.0	2
SNM 10	CRR extract: Cs & Rb 1 mg/L ea.	1100	3.4	26	0.2	50	0.05	8.1	0.2	2.5	1
SDH 10	CRR extract: Cs & Rb 1 mg/L ea.	1.8	4.6	17	< 0.05	22	< 0.02	0.02	0.02	1.3	< 0.5
PBC 10	CRR extract: Cs & Rb 1 mg/L ea.	48	2.3	16	0.07	38	0.3	0.94	1.0	2.7	1
PMO9	1 ppm Cs & Rb stock solution[b]	3.5	2.0	0.3	< 0.05	< 0.05	< 0.02	0.02	0.04	160	< 0.5

Field No	Dy ug/L	Er ug/L	Eu ug/L	Fe ug/L	Gd ug/L	Ge ug/L	Ho ug/L	K ug/L	La ug/L	Li ug/L	Mg mg/L	Mn ug/L
FLW 10	1.8	0.98	0.23	64	1.8	0.04	0.38	1400	4.2	5.6	0.35	20
ACT 10	0.01	0.008	< 0.005	230	0.01	0.04	< 0.005	3300	0.04	11	0.28	4.1
CHI 10	6.3	4.1	0.18	130	4.8	0.04	1.5	44000	1.6	2.1	0.68	62
CCO 10	0.52	0.51	0.050	230	0.40	0.1	0.13	8200	1.2	25	1.1	24
GCM 10	1.6	0.88	0.28	140	1.1	0.06	0.31	7100	3.4	2.6	2.5	78
FCWN 10	0.04	0.02	0.005	120	0.04	0.03	0.008	11000	0.2	14	1.7	14
ZEO 10	0.01	0.01	< 0.005	110	0.01	0.02	< 0.005	14000	0.1	5.0	1.6	230
PWI 10	1.2	0.78	0.083	210	0.93	0.04	0.26	18000	5.7	2.9	0.87	14
SNM 10	2.4	1.1	0.31	150	3.0	0.04	0.43	5600	10	1.6	3.6	79
SDH 10	< 0.005	< 0.005	< 0.005	66	< 0.005	0.02	< 0.005	8600	0.02	4.3	0.22	63
PBC 10	4.4	3.6	< 0.005	120	1.6	0.03	1.1	3200	0.51	14	1.4	790
PMO9	< 0.005	< 0.005	< 0.005	< 10	< 0.005	0.03	< 0.005	50	< 0.01	0.2	< 0.01	0.23

[a]Ag (< 0.01), Au (< 0.01), Bi (< 0.01), Cr (< 0.5), Ga (< 0.02), Hf (< 0.05), In (< 0.01), Na (not determined), Nb (< 0.02), Re (< 0.02), Ta (< 0.02), Te (< 0.1), and W (< 0.02) have been omitted because the concentrations were less than the detection limits shown in parentheses.
[b]Average of 3; a 1:10 dilution.

Field No	Mo ug/L	Nd ug/L	Ni ug/L	P ug/L	Pb ug/L	Pr ug/L	Rb ug/L	Sb ug/L	Sc ug/L	Se ug/L	SiO2 mg/L	Sm ug/L	Sn ug/L
FLW 10	0.1	5.4	0.8	120	0.4	1.2	4.7	0.1	0.4	0.8	3	1.4	< 0.05
ACT 10	0.50	0.02	1.8	48	0.1	< 0.01	15	0.06	< 0.1	0.4	3	< 0.01	< 0.05
CHI 10	0.08	8.4	1.1	2500	0.4	1.2	110	0.04	0.3	0.8	4	2.4	< 0.05
CCO 10	0.1	1.5	2.6	120	2.2	0.31	47	0.2	0.6	0.5	4	0.34	0.06
GCM 10	0.06	3.6	1.4	320	0.51	0.88	21	0.04	0.1	0.6	2	0.83	< 0.05
FCWN 10	0.4	0.1	1.3	42	0.2	0.03	62	0.2	< 0.1	0.5	2	0.03	0.1
ZEO 10	0.4	0.04	0.8	17	0.06	0.02	38	0.5	< 0.1	0.5	2	0.01	0.09
PWI 10	0.09	3.6	1.3	560	0.82	0.90	40	0.04	0.1	0.4	2	0.65	0.05
SNM 10	0.04	12	1.6	530	0.3	2.7	17	0.02	< 0.1	0.6	2	2.8	0.05
SDH 10	0.4	< 0.01	0.6	300	0.1	< 0.01	11	0.04	< 0.1	0.9	2	< 0.01	< 0.05
PBC 10	0.07	1.0	2.1	16	0.4	0.2	7.5	0.06	0.2	0.7	3	0.50	0.08
PMO9	0.5	< 0.01	0.2	16	0.3	< 0.01	95	< 0.02	< 0.1	0.4	< 0.5	< 0.01	0.1

Field No	SO4 mg/L	Sr ug/L	Tb ug/L	Th ug/L	Ti ug/L	Tl ug/L	Tm ug/L	U ug/L	V ug/L	Y ug/L	Yb ug/L	Zn ug/L	Zr ug/L
FLW 10	720	40	0.30	0.23	3.2	< 0.05	0.14	5.7	< 0.1	14	0.79	10	0.69
ACT 10	730	190	< 0.005	0.03	3.0	< 0.05	< 0.005	1.6	0.9	0.1	< 0.01	3	< 0.05
CHI 10	710	96	0.87	0.03	2.9	< 0.05	0.57	4.5	< 0.1	56	3.2	5	0.1
CCO 10	710	450	0.076	0.17	3.2	0.1	0.10	3.1	< 0.1	4.6	0.82	10	0.2
GCM 10	710	290	0.22	0.45	3.0	< 0.05	0.12	0.56	0.1	11	0.75	8	0.2
FCWN 10	720	140	0.005	0.10	3.1	0.2	< 0.005	0.13	0.6	0.3	0.02	4	0.07
ZEO 10	740	370	< 0.005	0.04	3.0	0.09	< 0.005	0.68	0.4	0.2	0.01	4	< 0.05
PWI 10	570	67	0.16	0.12	2.4	0.08	0.12	3.8	< 0.1	17	0.69	24	0.1
SNM 10	710	1300	0.46	0.22	3.0	< 0.05	0.14	0.46	< 0.1	13	0.77	6	< 0.05
SDH 10	720	160	< 0.005	0.03	3.0	< 0.05	< 0.005	1.5	2	0.03	< 0.01	3	< 0.05
PBC 10	720	160	0.50	0.02	3.0	< 0.05	0.60	0.93	< 0.1	40	3.9	20	< 0.05
PMO9	730	2.3	< 0.005	< 0.005	3.0	< 0.05	< 0.005	< 0.005	< 0.1	< 0.01	< 0.01	1.7	< 0.05

Table A7. ICP - AES Results[a] for Pre- and Post- Exchange Copper Stock Solution

Field No	Solution	Al mg/L	As mg/L	Ba mg/L	Ca mg/L	Cu mg/L	Ga mg/L	K mg/L	Li mg/L	Mg mg/L
ZEO3	CRR extract: 357 mg/L Cu	< 1	< 0.2	< 0.1	600	8.8	< 0.1	160	< 0.1	35
CHI3	CRR extract: 357 mg/L Cu	12	0.20	< 0.1	560	320	< 0.1	520	< 0.1	19
FLW3	CRR extract: 357 mg/L Cu	6.6	< 0.2	< 0.1	220	180	< 0.1	19	< 0.1	8.0
FCWN3	CRR extract: 357 mg/L Cu	< 1	< 0.2	0.11	580	310	< 0.1	110	0.17	46
PBC3	CRR extract: 357 mg/L Cu	1.9	0.23	< 0.1	590	290	0.12	38	0.20	34
ACT3	CRR extract: 357 mg/L Cu	< 1	< 0.2	< 0.1	580	25	< 0.1	26	0.13	5.6
PWI3	CRR extract: 357 mg/L Cu	36	< 0.2	0.10	600	280	< 0.1	180	< 0.1	25
SNM3	CRR extract: 357 mg/L Cu	11	0.23	0.12	750	380	0.13	46	< 0.1	86
CCO3	CRR extract: 357 mg/L Cu	15	< 0.2	< 0.1	660	320	< 0.1	73	0.32	29
GCM3	CRR extract: 357 mg/L Cu	9.7	0.24	< 0.1	680	380	0.11	72	< 0.1	64
SDH3	CRR extract: 357 mg/L Cu	< 1	< 0.2	< 0.1	300	140	< 0.1	110	< 0.1	6.0
PMO2	Cu stock solution (average)	< 1	< 0.2	< 0.1	< 1	360	< 0.1	1.2	< 0.1	< 1

Field No	Mn mg/L	Na mg/L	Nd mg/L	P mg/L	Pb mg/L	Sr mg/L	Y mg/L	Zn mg/L
ZEO3	7.2	3200	< 0.1	< 1	< 0.1	5.4	< 0.1	0.19
CHI3	2.3	2800	0.12	3.5	0.64	1.3	0.85	0.23
FLW3	0.44	3600	< 0.1	< 1	0.36	0.60	0.15	0.27
FCWN3	0.46	3000	< 0.1	< 1	0.60	1.9	< 0.1	0.74
PBC3	13	3000	< 0.1	< 1	0.58	1.9	0.90	1.3
ACT3	0.48	2300	< 0.1	< 1	< 0.1	1.3	< 0.1	0.14
PWI3	0.21	2000	0.10	< 1	0.57	0.73	0.27	0.72
SNM3	1.3	2500	0.19	< 1	0.78	17	0.16	0.31
CCO3	0.29	2200	< 0.1	< 1	0.62	3.9	< 0.1	0.41
GCM3	1.5	2800	< 0.1	< 1	0.73	3.4	0.16	0.18
SDH3	2.2	3600	< 0.1	< 1	0.25	2.0	< 0.1	0.21
PMO2	< 0.1	2600	< 0.1	< 1	0.78	< 0.1	< 0.1	< 0.1

[a]Ag (< 0.1), Au (< 0.1), Be (< 0.1), Bi (< 0.2), Cd (< 0.1), Ce (< 0.1), Co (< 0.1), Cr (< 0.1), Eu (< 0.1), Fe (< 1), Ga (< 0.1), Ho (< 0.1), La (< 0.1), Mo (< 0.1), Nb (< 0.1), Ni (< 0.1), Sc (< 0.1), Sn (< 0.5), Ta (< 1), Th (< 0.1), Ti (< 1), U (< 1), V (< 0.1), and Yb (< 0.1) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Table A8. ICP - AES Results[a] for Pre- and Post- Exchange Ferrous Iron Stock Solution

Field No	Solution	Al mg/L	Ba mg/L	Ca mg/L	Ce mg/L	Cu mg/L	Fe mg/L	K mg/L	La mg/L	Li mg/L
ZEO4	CRR extract: 820 mg/L Fe (II)	< 1	< 0.1	550	< 0.1	< 0.1	23	130	< 0.1	< 0.1
CHI4	CRR extract: 820 mg/L Fe (II)	30	< 0.1	420	0.25	0.16	570	370	< 0.1	< 0.1
FLW4	CRR extract: 820 mg/L Fe (II)	25	< 0.1	140	0.15	< 0.1	280	15	< 0.1	< 0.1
FCWN4	CRR extract: 820 mg/L Fe (II)	10	< 0.1	460	< 0.1	0.31	700	87	< 0.1	0.13
PBC4	CRR extract: 820 mg/L Fe (II)	27	< 0.1	370	< 0.1	0.22	500	25	< 0.1	0.15
ACT4	CRR extract: 820 mg/L Fe (II)	< 1	< 0.1	460	< 0.1	< 0.1	31	20	< 0.1	0.10
PWI4	CRR extract: 820 mg/L Fe (II)	65	< 0.1	560	0.51	0.10	540	120	0.26	< 0.1
SNM4	CRR extract: 820 mg/L Fe (II)	32	0.13	580	0.58	0.31	640	38	0.15	< 0.1
CCO4	CRR extract: 820 mg/L Fe (II)	43	< 0.1	520	< 0.1	0.22	550	57	< 0.1	0.24
GCM4	CRR extract: 820 mg/L Fe (II)	38	0.12	500	< 0.1	0.63	720	53	< 0.1	< 0.1
SDH4	CRR extract: 820 mg/L Fe (II)	< 1	< 0.1	410	< 0.1	< 0.1	150	92	< 0.1	< 0.1
PMO3	Fe (II) stock solution (average)	< 1	< 0.1	< 1	< 0.1	0.12	820	< 1	< 0.1	< 0.1

Field No	Mg mg/L	Mn mg/L	Na mg/L	Nd mg/L	Ni mg/L	P mg/L	Pb mg/L	Sr mg/L	Ti mg/L	Y mg/L	Zn mg/L
ZEO4	30	13	940	< 0.1	< 0.1	< 1	< 0.1	4.8	< 1	< 0.1	< 0.1
CHI4	18	9.2	560	0.32	< 0.1	1.4	0.11	1.1	1.5	1.1	0.22
FLW4	9.4	1.2	1900	< 0.1	< 0.1	< 1	< 0.1	0.40	< 1	0.14	0.28
FCWN4	42	1.7	680	0.10	0.11	< 1	0.10	1.3	1.9	< 0.1	0.63
PBC4	31	14	750	0.10	0.22	< 1	< 0.1	1.2	1.4	0.97	1.2
ACT4	4.2	2.6	340	< 0.1	< 0.1	< 1	< 0.1	0.88	< 1	< 0.1	< 0.1
PWI4	21	0.53	280	0.30	< 0.1	< 1	< 0.1	0.60	1.5	0.43	0.52
SNM4	74	23	210	0.21	0.11	< 1	0.10	14	2.0	0.14	0.29
CCO4	24	0.83	340	< 0.1	0.10	< 1	0.10	3.0	1.4	< 0.1	0.37
GCM4	62	19	700	0.11	0.11	< 1	0.12	2.6	2.3	0.18	0.25
SDH4	6.1	7.3	1400	< 0.1	< 0.1	< 1	< 0.1	1.8	< 1	< 0.1	0.10
PMO3	< 1	0.39	170	< 0.1	< 0.1	< 1	0.13	< 0.1	1.8	< 0.1	< 0.1

[a]Ag (< 0.1), As (< 0.2), Au (< 0.1), Be (< 0.1), Bi (< 0.2), Cd (< 0.1), Co (< 0.1), Cr (< 0.1), Eu (< 0.1), Ga (< 0.1), Ho (< 0.1), Mo (< 0.1), Nb (< 0.1), Sc (< 0.1), Sn (< 0.5), Ta (< 1), Th (< 0.1), U (< 1), V (< 0.1), and Yb (< 0.1) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Table A9. ICP - AES Results[a] for Pre- and Post- Exchange Ferric Iron Stock Solution

Field No	Solution	Al mg/L	Ba mg/L	Ca mg/L	Ce mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L
ZEO8	CRR extract: 180 mg/L Fe (III)	< 1	0.11	470	< 0.1	< 0.1	< 0.1	< 1	110
CHI8	CRR extract: 180 mg/L Fe (III)	38	0.18	320	0.14	< 0.1	< 0.1	13	290
FLW8	CRR extract: 180 mg/L Fe (III)	55	< 0.1	63	0.16	< 0.1	< 0.1	36	7.5
FCWN8	CRR extract: 180 mg/L Fe (III)	36	< 0.1	330	< 0.1	0.11	0.18	80	55
PBC8	CRR extract: 180 mg/L Fe (III)	58	0.13	300	< 0.1	0.11	0.10	90	23
ACT8	CRR extract: 180 mg/L Fe (III)	< 1	< 0.1	560	< 0.1	< 0.1	< 0.1	< 1	19
PWI8	CRR extract: 180 mg/L Fe (III)	82	0.17	560	0.48	0.12	< 0.1	80	100
SNM8	CRR extract: 180 mg/L Fe (III)	52	0.13	390	0.13	< 0.1	< 0.1	70	34
CCO8	CRR extract: 180 mg/L Fe (III)	69	< 0.1	470	< 0.1	0.10	0.13	58	42
GCM8	CRR extract: 180 mg/L Fe (III)	51	0.10	320	0.24	< 0.1	0.21	69	40
SDH8	CRR extract: 180 mg/L Fe (III)	< 1	< 0.1	340	< 0.1	< 0.1	< 0.1	< 1	74
PMO7	Fe (III) stock solution (average)	< 1	< 0.1	< 1	< 0.1	0.16	< 0.1	180	< 1

Field No	La mg/L	Li mg/L	Mg mg/L	Mn mg/L	Na mg/L	Nd mg/L	P mg/L	Sr mg/L	Y mg/L	Zn mg/L
ZEO8	< 0.1	< 0.1	21	8.2	1200	< 0.1	< 1	2.8	< 0.1	< 0.1
CHI8	< 0.1	< 0.1	9.5	1.7	780	0.18	6.4	0.63	0.88	0.13
FLW8	< 0.1	< 0.1	3.9	0.11	1400	0.12	< 1	0.15	0.24	0.12
FCWN8	< 0.1	0.12	28	0.51	870	< 0.1	< 1	0.65	< 0.1	0.28
PBC8	< 0.1	0.16	28	13	1100	< 0.1	< 1	0.88	1.1	0.99
ACT8	< 0.1	< 0.1	3.0	0.19	690	< 0.1	< 1	0.80	< 0.1	< 0.1
PWI8	0.35	< 0.1	11	0.20	500	0.22	1.0	0.47	0.32	0.41
SNM8	0.17	< 0.1	50	0.98	620	0.22	1.2	8.1	0.19	0.14
CCO8	< 0.1	0.20	13	0.23	590	< 0.1	< 1	2.0	< 0.1	0.28
GCM8	0.13	< 0.1	37	1.8	880	0.14	2.0	1.5	0.29	0.17
SDH8	< 0.1	< 0.1	4.4	3.4	1600	< 0.1	< 1	1.1	< 0.1	0.10
PMO7	< 0.1	< 0.1	< 1	< 0.1	920	< 0.1	< 1	< 0.1	< 0.1	< 0.1

[a]Ag (< 0.1), As (< 0.2), Au (< 0.1), Be (< 0.1), Bi (< 0.2), Cd (< 0.1), Co (< 0.1), Eu (< 0.1), Ga (< 0.1), Ho (< 0.1), Mo (< 0.1), Nb (< 0.1), Ni (< 0.1), Pb (< 0.1), Sc (< 0.1), Sn (< 0.5), Ta (< 1), Th (< 0.1), Ti (< 1), U (< 1), V (< 0.1), and Yb (< 0.1) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Table A10. ICP - AES Results[a] for Pre- and Post- Exchange Potassium Stock Solution

Field No	Solution	Al mg/L	Ba mg/L	Bi mg/L	Ca mg/L	Fe mg/L	K mg/L	Li mg/L	Mg mg/L	Mn mg/L	Na mg/L
ZEO17	CRR extract: 22 mg/L K	3.4	0.33	< 0.2	560	< 1	190	< 0.1	36	2.3	3700
CHI17	CRR extract: 22 mg/L K	5.8	0.24	< 0.2	380	< 1	370	< 0.1	10	0.41	2000
FLW17	CRR extract: 22 mg/L K	2.6	< 0.1	< 0.2	130	< 1	9.6	< 0.1	4.1	0.20	2600
FCWN17	CRR extract: 22 mg/L K	1.0	0.11	< 0.2	350	< 1	84	0.16	27	< 0.1	2200
PBC17	CRR extract: 22 mg/L K	< 1	0.16	< 0.2	370	< 1	24	0.16	21	5.3	2200
ACT17	CRR extract: 22 mg/L K	< 1	0.20	< 0.2	710	< 1	26	0.12	3.8	< 0.1	2000
PWI17	CRR extract: 22 mg/L K	36	0.43	< 0.2	1500	1.2	280	< 0.1	24	0.24	2800
SNM17	CRR extract: 22 mg/L K	4.2	0.28	< 0.2	490	< 1	54	< 0.1	54	0.59	2000
CCO17	CRR extract: 22 mg/L K	14	0.45	< 0.2	1200	< 1	130	0.57	30	0.28	3400
GCM17	CRR extract: 22 mg/L K	2.9	0.29	< 0.2	580	< 1	76	< 0.1	53	0.90	2800
SDH17	CRR extract: 22 mg/L K	< 1	0.11	< 0.2	180	< 1	69	< 0.1	2.9	0.31	2500
PMO14	K stock solution (average	< 1	< 0.1	< 0.2	< 1	< 1	22	< 0.1	< 1	< 0.1	2200

Field No	P mg/L	Sr mg/L	Y mg/L	Zn mg/L
ZEO17	< 1	5.0	< 0.1	0.16
CHI17	7.5	0.95	0.42	0.10
FLW17	< 1	0.34	< 0.1	0.11
FCWN17	< 1	1.1	< 0.1	0.11
PBC17	< 1	1.4	0.18	0.16
ACT17	< 1	1.6	< 0.1	< 0.1
PWI17	2.3	1.6	0.28	0.55
SNM17	1.1	12	< 0.1	0.12
CCO17	< 1	7.6	< 0.1	0.32
GCM17	< 1	3.2	0.10	0.18
SDH17	< 1	1.2	< 0.1	< 0.1
PMO14	< 1	< 0.1	< 0.1	< 0.1

[a]Ag (< 0.1), As (< 0.2), Au (< 0.1), Be (< 0.1), Bi (< 0.2), Cd (< 0.1), Ce (< 0.1), Co (< 0.1), Cr (< 0.1), Cu (< 0.1), Eu (< 0.1), Ga (< 0.1), Ho (< 0.1), La (< 0.1), Mo (< 0.1), Nb (< 0.1), Nd (< 0. 1), Ni (< 0.1), Pb (< 0.1), Sc (< 0.1), Sn (< 0.5), Ta (< 1), Th (< 0.1), Ti (< 1), U (< 1), V (< 0.1), and Yb (< 0.1) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Table A11. ICP - AES Results[a] for Pre- and Post- Exchange Magnesium Stock Solution

Field No	Solution	Al mg/L	Ba mg/L	Bi mg/L	Ca mg/L	Ga mg/L	K mg/L	Li mg/L	Mg mg/L	Mn mg/L	Na mg/L
ZEO14	CRR extract: 280 mg/L Mg	< 1	0.15	< 0.2	300	0.14	150	< 0.1	120	0.91	2400
CHI14	CRR extract: 280 mg/L Mg	1.9	0.23	< 0.2	410	0.19	420	< 0.1	210	0.60	2100
FLW14	CRR extract: 280 mg/L Mg	< 1	< 0.1	< 0.2	130	0.15	12	< 0.1	160	0.22	2700
FCWN14	CRR extract: 280 mg/L Mg	< 1	0.11	0.20	290	0.23	91	0.14	250	< 0.1	2200
PBC14	CRR extract: 280 mg/L Mg	< 1	0.15	< 0.2	370	0.21	29	0.14	220	3.9	2300
ACT14	CRR extract: 280 mg/L Mg	< 1	0.24	< 0.2	710	0.16	32	0.12	170	< 0.1	2000
PWI14	CRR extract: 280 mg/L Mg	6.4	0.25	< 0.2	870	0.21	190	< 0.1	250	0.13	1500
SNM14	CRR extract: 280 mg/L Mg	< 1	0.27	0.24	450	0.23	62	< 0.1	280	0.44	2100
CCO14	CRR extract: 280 mg/L Mg	1.2	0.24	< 0.2	780	0.20	75	0.29	240	0.27	1900
GCM14	CRR extract: 280 mg/L Mg	< 1	0.37	0.21	430	0.23	65	< 0.1	280	0.42	2200
SDH14	CRR extract: 280 mg/L Mg	< 1	0.10	< 0.2	150	0.16	73	< 0.1	180	0.36	2700
PMO12	Mg stock solution (average	< 1	< 0.1	0.26	< 1	0.22	< 1	< 0.1	280	< 0.1	2600

Field No	Sr mg/L	Ti mg/L	Y mg/L	Zn mg/L
ZEO14	3.4	1.0	< 0.1	0.10
CHI14	1.1	1.5	0.32	0.14
FLW14	0.33	1.1	< 0.1	0.13
FCWN14	1.0	1.7	< 0.1	0.11
PBC14	1.4	1.5	< 0.1	0.13
ACT14	1.7	1.4	< 0.1	< 0.1
PWI14	0.88	1.7	0.10	0.39
SNM14	12	1.9	< 0.1	0.15
CCO14	4.4	1.6	< 0.1	0.24
GCM14	2.6	1.7	< 0.1	0.14
SDH14	1.1	1.3	< 0.1	< 0.1
PMO12	< 0.1	1.8	< 0.1	< 0.1

[a]Ag (< 0.1), As (< 0.2), Au (< 0.1), Be (< 0.1), Cd (< 0.1), Ce (< 0.1), Co (< 0.1), Cr (< 0.1), Cu (< 0.1), Eu (< 0.1), Fe (< 1), Ho (< 0.1), La (< 0.1), Mo (< 0.1), Nb (< 0.1), Nd (< 0. 1), Ni (< 0.1), P (< 1), Pb (< 0.1), Sc (< 0.1), Sn (< 0.5), Ta (< 1), Th (< 0.1), U (< 1), V (< 0.1), and Yb (< 0.1) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Table A12. ICP - AES Results[a] for Pre- and Post- Exchange Manganese Stock Solution

Field No	Solution	Al mg/L	Ca mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L	Na mg/L	P mg/L	Sr mg/L
ZEO19	CRR extract: 36 mg/L Mn	18	6.9	3.4	10	2.5	0.36	150	< 1	< 0.1
CHI19	CRR extract: 36 mg/L Mn	1.3	7.2	< 1	26	< 1	0.66	66	3.8	< 0.1
FLW19	CRR extract: 36 mg/L Mn	3.2	< 1	1.7	< 1	< 1	< 0.1	120	< 1	< 0.1
FCWN19	CRR extract: 36 mg/L Mn	< 1	11	< 1	7.0	3.0	2.2	100	< 1	< 0.1
PBC19	CRR extract: 36 mg/L Mn	3.7	6.7	5.0	1.2	1.5	0.66	88	< 1	< 0.1
ACT19	CRR extract: 36 mg/L Mn	< 1	65	< 1	2.1	< 1	2.2	64	< 1	< 0.1
PWI19	CRR extract: 36 mg/L Mn	3.0	41	< 1	14	1.2	2.0	41	< 1	< 0.1
SNM19	CRR extract: 36 mg/L Mn	< 1	52	< 1	2.6	9.9	7.9	22	< 1	0.46
CCO19	CRR extract: 36 mg/L Mn	< 1	39	< 1	5.1	1.3	2.5	54	< 1	< 0.1
GCM19	CRR extract: 36 mg/L Mn	< 1	13	< 1	2.4	2.6	2.3	72	< 1	< 0.1
SDH19	CRR extract: 36 mg/L Mn	38	3.1	34	12	17	1.2	150	< 1	< 0.1
PMO16	Mn stock solution (average)	< 1	< 1	< 1	< 1	< 1	36	< 1	< 1	< 0.1

[a]Ag (< 0.1), As (< 0.2), Au (< 0.1), Ba (< 0.1), Be (< 0.1), Bi (< 0.2), Cd (< 0.1), Ce (< 0.1), Co (< 0.1), Cr (< 0.1), Cu (< 0.1), Eu (< 0.1), Ga (< 0.1), Ho (< 0.1), La (< 0.1), Li (< 0.1), Mo (< 0.1), Nb (< 0.1), Nd (< 0. 1), Ni (< 0.1), Pb (< 0.1), Sc (< 0.1), Sn (< 0.5), Ta (< 1), Th (< 0.1), Ti (< 1), U (< 1), V (< 0.1), Y (< 0.1), Yb (< 0.1), and Zn (< 0.1) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Table A13. ICP - MS Results[a] for Pre- and Post- Exchange Ammonium Stock Solution

Field No	Solution	Al ug/L	As ug/L	Ba ug/L	Be ug/L	Ca mg/L	Cd ug/L	Ce ug/L	Co ug/L	Cs ug/L	Cu ug/L
FLW 20	CRR extract: 100 mg/L NH_4	290	2.7	4	0.1	12	0.08	5.8	0.2	0.1	0.6
ACT 20	CRR extract: 100 mg/L NH_4	1.2	2.0	23	< 0.05	72	< 0.02	0.04	0.08	1.5	0.5
CHI 20	CRR extract: 100 mg/L NH_4	640	2	16	2.2	37	0.2	3.4	0.06	0.94	< 0.5
CCO 20	CRR extract: 100 mg/L NH_4	1100	2.0	18	0.4	53	0.1	1.6	0.53	8.5	2
GCM 20	CRR extract: 100 mg/L NH_4	270	2.3	18	0.09	43	< 0.02	4.4	0.1	0.09	5
FCWN 20	CRR extract: 100 mg/L NH_4	5.7	2.2	14	< 0.05	38	< 0.02	0.2	0.1	0.89	2
ZEO 20	CRR extract: 100 mg/L NH_4	1.0	2	12	< 0.05	33	0.05	0.04	0.04	0.39	< 0.5
PWI 20	CRR extract: 100 mg/L NH_4	3000	2.2	18	0.5	50	0.1	7.0	0.3	0.33	1
SNM 20	CRR extract: 100 mg/L NH_4	680	2	17	0.2	51	0.04	6.8	0.2	0.36	0.8
SDH 20	CRR extract: 100 mg/L NH_4	1.9	3.3	11	< 0.05	18	0.4	0.01	0.03	0.04	< 0.5
PBC 20	CRR extract: 100 mg/L NH_4	11	1	13	< 0.05	37	0.2	0.64	2.4	0.30	0.6
PMO17	100 mg/L NH_4 stock solution[b]	1.5	0.7	0.3	< 0.05	< 0.05	< 0.02	0.04	0.05	< 0.01	< 0.5

Field No	Dy ug/L	Er ug/L	Eu ug/L	Fe ug/L	Gd ug/L	Ge ug/L	Ho ug/L	K ug/L	La ug/L	Li ug/L	Mg mg/L	Mn ug/L
FLW 20	1.2	0.66	0.15	52	1.2	0.03	0.25	1100	2.7	5.2	0.29	15
ACT 20	0.008	0.006	< 0.005	210	0.005	< 0.02	< 0.005	2400	0.04	11	0.28	3.6
CHI 20	5.5	3.7	0.15	110	4.0	0.03	1.3	34000	1.1	1.9	0.75	66
CCO 20	0.42	0.39	0.04	170	0.32	0.08	0.11	5400	0.92	25	1.1	20
GCM 20	1.2	0.68	0.22	140	0.90	0.04	0.25	5200	2.6	2.5	2.7	75
FCWN 20	0.03	0.02	0.007	110	0.03	< 0.02	0.006	8300	0.1	14	1.9	11
ZEO 20	0.007	0.01	< 0.005	100	0.006	0.02	< 0.005	9900	0.04	5.1	1.5	190
PWI 20	1.1	0.77	0.084	190	0.90	0.02	0.27	13000	5.9	2.8	0.96	11
SNM 20	2.2	0.97	0.29	150	2.8	0.04	0.39	4200	8.9	1.5	3.6	63
SDH 20	< 0.005	< 0.005	< 0.005	58	< 0.005	0.02	< 0.005	6600	0.01	4.3	0.20	37
PBC 20	2.7	2.2	< 0.005	110	1.1	0.02	0.68	2600	0.4	16	1.4	700
PMO17	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.02	< 0.005	22	0.02	< 0.1	< 0.01	0.03

[a]Ag (< 0.01), Au (< 0.01), Bi (< 0.01), Cr (< 0.5), Ga (< 0.02), Hf (< 0.05), In (< 0.01), Nb (< 0.02), Re (< 0.02), Ta (< 0.02), Te (< 0.1), Tl (< 0.05), and W (< 0.02) have been omitted because the concentrations were less than the detection limits shown in parentheses.
[b]Average of 3; a 1:1000 dilution.

Field No	Mo ug/L	Na mg/L	Nd ug/L	Ni ug/L	P ug/L	Pb ug/L	Pr ug/L	Rb ug/L	Sb ug/L	Sc ug/L	Se ug/L	SiO2 mg/L	Sm ug/L
FLW 20	0.07	-	3.5	0.8	91	0.2	0.75	2.3	0.1	0.4	0.7	3	0.90
ACT 20	0.09	-	0.02	1.7	41	0.08	< 0.01	8.2	0.03	0.1	0.4	3	< 0.01
CHI 20	0.03	-	6.8	1.2	3400	0.3	0.96	73	< 0.02	0.2	0.6	4	2.1
CCO 20	0.07	-	1.2	2.4	100	1.1	0.24	28	0.09	0.4	0.4	4	0.31
GCM 20	0.03	-	2.8	1.6	260	0.2	0.69	12	< 0.02	< 0.1	0.5	2	0.68
FCWN 20	0.2	-	0.08	1.3	45	0.09	0.02	42	0.1	< 0.1	0.5	2	0.02
ZEO 20	0.2	-	0.01	0.9	27	0.1	< 0.01	22	0.50	< 0.1	0.4	2	< 0.01
PWI 20	0.03	-	4.0	1.6	380	0.59	0.99	29	0.02	0.2	0.4	3	0.73
SNM 20	0.06	-	11	1.9	440	0.2	2.4	8.9	0.03	< 0.1	0.5	2	2.4
SDH 20	0.08	-	< 0.01	0.5	270	0.09	< 0.01	6.8	< 0.02	< 0.1	0.7	2	< 0.01
PBC 20	0.03	-	0.71	4.2	11	0.3	0.1	4.0	0.02	< 0.1	0.5	4	0.32
PMO17	0.03	2.1	< 0.01	0.2	13	0.2	< 0.01	0.02	< 0.02	< 0.1	0.2	< 0.5	< 0.01

Field No	Sn ug/L	SO4 mg/L	Sr ug/L	Tb ug/L	Th ug/L	Ti ug/L	Tm ug/L	U ug/L	V ug/L	Y ug/L	Yb ug/L	Zn ug/L	Zr ug/L
FLW 20	0.05	600	26	0.20	0.09	2.6	0.090	4.1	< 0.1	8.5	0.50	6	0.4
ACT 20	0.07	610	150	< 0.005	0.02	2.5	< 0.005	1.5	0.8	0.08	< 0.01	2	< 0.05
CHI 20	< 0.05	600	78	0.75	0.01	2.6	0.49	3.2	< 0.1	47	2.9	3	< 0.05
CCO 20	< 0.05	550	320	0.052	0.08	2.2	0.080	1.9	< 0.1	3.6	0.64	10	< 0.05
GCM 20	< 0.05	610	240	0.18	0.18	2.6	0.10	0.35	< 0.1	8.8	0.54	6	< 0.05
FCWN 20	< 0.05	630	100	0.006	0.06	2.7	< 0.005	0.26	0.5	0.2	0.03	3	< 0.05
ZEO 20	0.05	640	350	< 0.005	0.01	2.6	< 0.005	0.65	0.4	0.2	< 0.01	2	< 0.05
PWI 20	0.08	490	53	0.17	0.06	2.1	0.12	3.3	< 0.1	16	0.66	20	0.07
SNM 20	< 0.05	600	1200	0.41	0.11	2.5	0.13	0.35	< 0.1	12	0.73	5	< 0.05
SDH 20	0.06	630	100	< 0.005	0.02	2.6	< 0.005	1.5	2	0.02	< 0.01	1	< 0.05
PBC 20	0.06	620	110	0.32	< 0.005	2.6	0.36	0.40	< 0.1	27	2.3	10	< 0.05
PMO17	0.07	5.2	0.04	< 0.005	< 0.005	< 0.1	< 0.005	< 0.005	< 0.1	< 0.01	< 0.01	2.3	< 0.05

Table A14. ICP - MS Results[a] for Pre- and Post- Exchange Lead Stock Solution

Field No	Solution	Al ug/L	As ug/L	Ba ug/L	Be ug/L	Ca mg/L	Cd ug/L	Ce ug/L	Co ug/L	Cs ug/L	Cu ug/L
FLW 11	CRR extract: 10 mg/L Pb	140	1	4	0.07	12	0.05	3.2	0.1	0.06	0.7
ACT 11	CRR extract: 10 mg/L Pb	< 0.01	0.6	24	< 0.05	60	< 0.02	0.02	0.05	1.1	0.5
CHI 11	CRR extract: 10 mg/L Pb	370	0.5	26	1.3	31	0.1	2.6	0.05	1.0	0.6
CCO 11	CRR extract: 10 mg/L Pb	370	0.9	25	0.3	60	0.08	0.97	0.4	10	2
GCM 11	CRR extract: 10 mg/L Pb	47	0.9	25	< 0.05	36	< 0.02	1.1	0.07	0.08	4
FCWN 11	CRR extract: 10 mg/L Pb	7.4	1	14	< 0.05	29	< 0.02	0.1	0.09	0.86	2
ZEO 11	CRR extract: 10 mg/L Pb	60	0.6	15	< 0.05	24	< 0.02	0.2	0.02	0.33	0.6
PWI 11	CRR extract: 10 mg/L Pb	2100	1	25	0.3	70	0.1	4.4	0.4	0.35	1
SNM 11	CRR extract: 10 mg/L Pb	140	0.6	25	0.06	38	0.03	2.8	0.2	0.2	0.7
SDH 11	CRR extract: 10 mg/L Pb	4.1	2.1	12	< 0.05	14	< 0.02	0.02	< 0.02	0.02	< 0.5
PBC 11	CRR extract: 10 mg/L Pb	0.63	0.4	18	< 0.05	30	0.08	0.2	0.3	0.31	< 0.5
PMO10	10 mg/L Pb stock solution[b]	< 0.01	< 0.2	< 0.02	< 0.05	< 0.05	< 0.02	< 0.01	< 0.02	< 0.01	< 0.5

Field No	Dy ug/L	Er ug/L	Eu ug/L	Fe ug/L	Gd ug/L	Ge ug/L	Ho ug/L	K ug/L	La ug/L	Li ug/L	Mg mg/L	Mn ug/L
FLW 11	0.62	0.35	0.079	45	0.60	0.02	0.13	970	1.5	4.6	0.27	22
ACT 11	0.01	0.005	< 0.005	190	0.006	< 0.02	< 0.005	2500	0.03	11	0.24	2.8
CHI 11	3.7	2.4	0.10	99	2.8	0.03	0.86	35000	1.4	1.8	0.60	50
CCO 11	0.27	0.25	0.02	200	0.21	0.09	0.071	6400	0.59	24	0.94	17
GCM 11	0.33	0.24	0.054	110	0.23	0.03	0.075	5000	0.99	2.0	2.2	44
FCWN 11	0.02	0.02	< 0.005	92	0.02	< 0.02	0.005	7700	0.09	13	1.5	5.6
ZEO 11	0.01	0.009	< 0.005	84	0.008	< 0.02	< 0.005	12000	0.08	4.7	1.2	93
PWI 11	0.85	0.62	0.062	250	0.65	0.03	0.20	15000	4.3	2.6	0.76	14
SNM 11	0.50	0.28	0.060	120	0.57	< 0.02	0.10	4600	2.2	1.2	3.1	50
SDH 11	< 0.005	< 0.005	< 0.005	48	< 0.005	0.03	< 0.005	5800	0.02	3.9	0.17	24
PBC 11	0.63	0.56	< 0.005	96	0.26	< 0.02	0.17	2500	0.2	12	1.1	400
PMO10	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.02	< 0.005	5.2	< 0.01	< 0.1	< 0.01	< 0.01

[a]Ag (< 0.01), Au (< 0.01), Bi (< 0.01), Cr (< 0.5), Ga (< 0.02), Hf (< 0.05), In (< 0.01), Nb (< 0.02), Re (< 0.02), Sc (< 0.1), Sn (< 0.05), Ta (< 0.02), Te (< 0.1), Tl (< 0.05), and W (< 0.02) have been omitted because the concentrations were less than the detection limits shown in parentheses.

[b]Average of 3; a 1:100 dilution.

Field No	Mo ug/L	Na mg/L	Nd ug/L	Ni ug/L	P ug/L	Pb ug/L	Pr ug/L	Rb ug/L	Sb ug/L	Se ug/L	SiO2 mg/L	Sm ug/L
FLW 11	0.07	-	1.9	1.0	90	1.5	0.40	2.6	0.2	0.7	2	0.47
ACT 11	0.1	-	0.01	1.6	42	1.1	< 0.01	8.8	0.1	0.5	3	< 0.01
CHI 11	0.06	-	5.6	1.4	610	1.2	0.89	81	0.05	0.6	3	1.5
CCO 11	0.1	-	0.71	2.8	87	6.5	0.1	35	0.2	0.4	3	0.2
GCM 11	0.04	-	0.75	1.6	51	5.2	0.2	12	0.06	0.5	1	0.2
FCWN 11	0.2	-	0.06	1.2	55	2.5	0.02	41	0.2	0.3	1	0.01
ZEO 11	0.2	-	0.04	0.8	26	1.2	0.01	26	0.4	0.3	2	0.01
PWI 11	0.04	-	2.7	2.5	230	3.6	0.67	33	0.07	0.4	2	0.49
SNM 11	0.1	-	2.1	1.6	84	9.1	0.50	9.8	0.03	0.4	1	0.45
SDH 11	0.09	-	< 0.01	0.8	120	1.3	< 0.01	6.2	0.1	0.7	2	< 0.01
PBC 11	0.1	-	0.2	1.6	21	1.4	0.04	4.2	0.07	0.6	2	0.07
PMO10	< 0.02	21	< 0.01	0.15	5.7	25	< 0.01	< 0.01	< 0.02	0.27	< 0.5	< 0.01

Field No	SO4 mg/L	Sr ug/L	Tb ug/L	Th ug/L	Ti ug/L	Tm ug/L	U ug/L	V ug/L	Y ug/L	Yb ug/L	Zn ug/L	Zr ug/L
FLW 11	310	31	0.10	0.15	2.7	0.04	2.7	< 0.1	4.3	0.25	2	0.50
ACT 11	310	140	< 0.005	0.04	2.6	< 0.005	1.2	0.6	0.06	< 0.01	< 0.5	< 0.05
CHI 11	300	86	0.51	0.04	2.5	0.33	2.9	< 0.1	31	1.9	1	0.06
CCO 11	310	360	0.04	0.06	2.5	0.056	1.3	< 0.1	2.4	0.40	6	< 0.05
GCM 11	300	220	0.050	0.07	2.5	0.03	0.14	0.1	2.8	0.21	2	0.05
FCWN 11	300	100	< 0.005	0.03	2.5	< 0.005	0.19	0.4	0.2	0.02	1	< 0.05
ZEO 11	300	250	< 0.005	0.03	2.6	< 0.005	0.35	0.2	0.1	0.01	2	< 0.05
PWI 11	290	83	0.12	0.04	2.5	0.093	2.7	< 0.1	12	0.57	22	0.07
SNM 11	300	970	0.081	0.03	2.4	0.04	0.16	< 0.1	2.6	0.25	4	< 0.05
SDH 11	310	110	< 0.005	0.01	2.4	< 0.005	1.1	1	0.02	< 0.01	1	< 0.05
PBC 11	300	120	0.072	< 0.005	2.4	0.083	0.06	< 0.1	7.6	0.44	4	< 0.05
PMO10	21	0.05	< 0.005	< 0.005	0.23	< 0.005	0.02	< 0.1	< 0.01	< 0.01	< 0.5	< 0.05

Table A15. ICP - MS Results[a] for Pre- and Post- Exchange Sulfate Stock Solution

Field No	Solution	Al ug/L	As ug/L	Ba ug/L	Be ug/L	Ca mg/L	Cd ug/L	Ce ug/L	Co ug/L	Cs ug/L	Cu ug/L
FLW 2	CRR extract: 5,200 mg/L SO_4	710	2	4	0.2	11	0.09	8.2	0.2	0.06	0.8
ACT 2	CRR extract: 5,200 mg/L SO_4	2.9	0.5	17	< 0.05	77	< 0.02	0.03	0.1	0.76	0.5
CHI 2	CRR extract: 5,200 mg/L SO_4	1500	0.3	17	2.7	36	0.2	6.1	0.08	0.87	0.6
CCO 2	CRR extract: 5,200 mg/L SO_4	2400	0.8	6.0	0.7	42	0.1	2.0	0.55	4.7	4
GCM 2	CRR extract: 5,200 mg/L SO_4	1100	1	5.9	0.2	44	< 0.02	8.7	0.1	0.04	8
FCWN 2	CRR extract: 5,200 mg/L SO_4	29	0.7	11	0.2	37	0.02	0.58	0.2	0.54	2
ZEO 2	CRR extract: 5,200 mg/L SO_4	9.3	0.4	7.8	< 0.05	39	< 0.02	0.07	0.04	0.31	< 0.5
PWI 2	CRR extract: 5,200 mg/L SO_4	5100	1	4	0.7	38	0.1	10	0.4	0.2	1
SNM 2	CRR extract: 5,200 mg/L SO_4	440	0.6	7.8	0.08	51	0.06	5.3	0.3	0.09	1
SDH 2	CRR extract: 5,200 mg/L SO_4	20	2.6	12	< 0.05	20	0.02	0.05	0.03	0.03	< 0.5
PBC 2	CRR extract: 5,200 mg/L SO_4	320	< 0.2	3	0.3	37	0.4	1.4	2.0	0.2	2
PMO1	5,200 mg/L SO_4 stock solution	2.7	< 0.2	< 0.02	< 0.05	< 0.05	< 0.02	< 0.01	0.07	< 0.01	< 0.5

Field No	Dy ug/L	Er ug/L	Eu ug/L	Fe ug/L	Gd ug/L	Ge ug/L	Ho ug/L	K ug/L	La ug/L	Li ug/L	Mg mg/L	Mn ug/L
FLW 2	1.8	0.96	0.22	53	1.7	0.03	0.34	960	3.7	5.0	0.31	22
ACT 2	0.007	0.01	< 0.005	240	0.008	0.02	< 0.005	1600	0.05	12	0.33	3.5
CHI 2	6.9	4.5	0.20	120	5.1	0.06	1.6	34000	2.3	1.8	0.67	76
CCO 2	0.48	0.48	0.05	160	0.42	0.08	0.12	3400	1.2	25	1.3	17
GCM 2	2.1	1.2	0.42	140	1.6	0.05	0.44	3600	4.8	2.6	2.8	110
FCWN 2	0.091	0.060	0.009	130	0.083	0.03	0.02	5600	0.4	13	1.9	17
ZEO 2	0.009	0.02	< 0.005	120	0.01	0.03	< 0.005	8700	0.06	5.5	1.6	260
PWI 2	1.4	0.88	0.10	180	1.2	< 0.02	0.30	8200	7.3	2.8	1.0	16
SNM 2	1.4	0.64	0.20	160	1.8	0.04	0.27	2400	6.6	1.6	3.9	78
SDH 2	< 0.005	0.005	< 0.005	76	0.006	0.03	< 0.005	6200	0.04	4.4	0.22	81
PBC 2	6.0	4.7	0.01	150	2.3	0.03	1.5	1700	0.64	16	1.6	1000
PMO1	< 0.005	< 0.005	< 0.005	11	< 0.005	< 0.02	< 0.005	17	0.02	< 0.1	< 0.01	0.6

[a]Ag (< 0.01), Au (< 0.01), Bi (< 0.01), Cr (< 0.5), Ga (< 0.02), Hf (< 0.05), In (< 0.01), Nb (< 0.02), Re (< 0.02), Sn (< 0.05), Ta (< 0.02), Te (< 0.1), Tl (< 0.05), and W (< 0.02) have been omitted because the concentrations were less than the detection limits shown in parentheses.
[b]Average of 3; a 1:1000 dilution.

Field No	Mo ug/L	Na mg/L	Nd ug/L	Ni ug/L	P ug/L	Pb ug/L	Pr ug/L	Rb ug/L	Sb ug/L	Sc ug/L	Se ug/L	SiO2 mg/L	Sm ug/L
FLW 2	0.1	-	4.7	0.8	180	0.2	1.0	2.8	0.1	0.8	0.7	4	1.3
ACT 2	0.3	-	0.02	1.8	49	< 0.05	< 0.01	6.2	0.09	0.4	0.5	4	< 0.01
CHI 2	0.1	-	10	1.0	7300	0.4	1.6	79	0.03	0.7	0.7	4	2.9
CCO 2	0.07	-	1.5	2.5	170	0.81	0.31	17	0.08	1	0.4	6.2	0.34
GCM 2	0.08	-	5.0	1.4	1200	0.3	1.3	8.8	0.03	0.6	0.5	3	1.3
FCWN 2	0.3	-	0.30	1.4	31	0.2	0.07	29	0.1	0.4	0.4	2	0.06
ZEO 2	0.5	-	0.02	0.9	12	< 0.05	< 0.01	21	0.61	0.4	0.3	3	< 0.01
PWI 2	0.08	92	5.4	1.0	750	0.4	1.3	18	0.02	0.6	0.3	5.0	1.0
SNM 2	0.05	-	7.6	1.8	300	0.2	1.7	4.7	0.05	0.3	0.4	3	1.7
SDH 2	0.3	-	0.02	0.6	420	0.08	< 0.01	6.8	0.05	0.2	1	2	< 0.01
PBC 2	0.06	-	1.6	3.2	10	0.50	0.27	2.6	0.03	0.7	0.7	5.6	0.77
PMO1	0.03	1.9	< 0.01	< 0.1	5.0	0.14	< 0.01	0.02	< 0.02	< 0.1	0.27	< 0.5	< 0.01

Field No	Sn ug/L	SO4 mg/L	Sr ug/L	Tb ug/L	Th ug/L	Ti ug/L	Tm ug/L	U ug/L	V ug/L	Y ug/L	Yb ug/L	Zn ug/L	Zr ug/L
FLW 2	0.05	590	26	0.29	0.35	2.5	0.13	6.6	< 0.1	13	0.69	7	0.72
ACT 2	< 0.05	590	140	< 0.005	0.03	2.5	< 0.005	1.8	0.8	0.1	< 0.01	4	< 0.05
CHI 2	0.3	580	82	0.98	0.04	2.5	0.60	5.1	< 0.1	59	3.5	4	0.09
CCO 2	< 0.05	480	240	0.072	0.13	2.1	0.096	2.4	< 0.1	4.4	0.77	20	0.1
GCM 2	< 0.05	590	210	0.31	0.70	2.5	0.16	0.78	< 0.1	15	1.0	6	0.2
FCWN 2	< 0.05	570	91	0.01	0.13	2.4	0.009	0.64	0.3	0.72	0.07	3	< 0.05
ZEO 2	< 0.05	610	370	< 0.005	0.02	2.6	< 0.005	0.92	0.6	0.3	0.02	< 0.5	< 0.05
PWI 2	< 0.05	400	41	0.21	0.12	1.7	0.13	3.7	< 0.1	19	0.76	23	0.2
SNM 2	0.05	550	1000	0.29	0.05	2.4	0.083	0.20	< 0.1	8.8	0.49	10	< 0.05
SDH 2	< 0.05	610	100	< 0.005	0.04	2.8	< 0.005	1.6	2	0.05	< 0.01	2	< 0.05
PBC 2	0.06	600	100	0.69	0.07	2.5	0.83	1.6	< 0.1	53	5.5	25	< 0.05
PMO1	< 0.05	5.2	0.05	< 0.005	< 0.005	0.1	< 0.005	< 0.005	< 0.1	0.01	< 0.01	4.0	< 0.05

Table A16. ICP - MS Results[a] for Pre- and Post- Exchange Uranium Stock Solution

Field No	Solution	Al ug/L	As ug/L	Ba ug/L	Be ug/L	Ca mg/L	Cd ug/L	Ce ug/L	Co ug/L	Cs ug/L	Cu ug/L
FLW 16	CRR extract: 2 mg/L U (VI)	240	2.0	2	0.1	8.6	0.07	3.8	0.2	0.04	0.6
ACT 16	CRR extract: 2 mg/L U (VI)	14	1	17	< 0.05	56	< 0.02	0.03	0.08	0.76	0.6
CHI 16	CRR extract: 2 mg/L U (VI)	550	1	21	1.6	28	0.1	3.0	0.09	0.67	< 0.5
CCO 16	CRR extract: 2 mg/L U (VI)	1000	2	19	0.5	54	0.08	1.2	0.5	5.9	2
GCM 16	CRR extract: 2 mg/L U (VI)	97	2	22	< 0.05	33	0.02	2.5	0.1	0.04	3
FCWN 16	CRR extract: 2 mg/L U (VI)	12	2	9.6	0.07	27	0.02	0.2	0.1	0.63	2
ZEO 16	CRR extract: 2 mg/L U (VI)	24	0.9	17	< 0.05	24	0.03	0.09	0.05	0.2	0.8
PWI 16	CRR extract: 2 mg/L U (VI)	2500	2	22	0.3	64	0.2	6.3	0.86	0.2	1
SNM 16	CRR extract: 2 mg/L U (VI)	490	1	26	0.06	34	0.04	3.9	0.2	0.1	0.7
SDH 16	CRR extract: 2 mg/L U (VI)	18	2.8	8.3	< 0.05	13	< 0.02	0.3	0.08	0.02	0.7
PBC 16	CRR extract: 2 mg/L U (VI)	21	0.8	14	< 0.05	27	0.1	0.4	2.0	0.2	0.5
PMO13	2 mg/L U (VI) stock solution	15	0.7	3.1	< 0.05	0.1	< 0.02	0.1	0.2	0.03	0.6

Field No	Dy ug/L	Er ug/L	Eu ug/L	Fe ug/L	Gd ug/L	Ge ug/L	Ho ug/L	K ug/L	La ug/L	Li ug/L	Mg mg/L	Mn ug/L
FLW 16	0.77	0.42	0.091	40	0.74	0.02	0.16	770	1.8	4.6	0.23	12
ACT 16	0.01	0.005	< 0.005	160	0.01	< 0.02	< 0.005	2000	0.03	10	0.22	2.5
CHI 16	4.0	2.5	0.12	86	3.0	0.05	0.91	28000	1.4	1.8	0.60	48
CCO 16	0.37	0.35	0.03	180	0.29	0.07	0.088	4400	0.79	24	0.93	14
GCM 16	0.66	0.40	0.12	100	0.48	< 0.02	0.14	3900	1.7	2.2	2.1	48
FCWN 16	0.04	0.03	< 0.005	88	0.03	< 0.02	0.009	6200	0.2	13	1.5	8.2
ZEO 16	0.009	0.009	< 0.005	79	0.01	< 0.02	< 0.005	8200	0.06	4.6	1.1	120
PWI 16	0.96	0.60	0.076	220	0.73	< 0.02	0.21	11000	5.6	2.8	0.74	18
SNM 16	1.2	0.53	0.16	97	1.5	0.02	0.22	3500	5.2	1.4	2.8	50
SDH 16	0.007	< 0.005	< 0.005	47	0.02	0.02	< 0.005	4600	0.2	4.2	0.16	34
PBC 16	1.7	1.3	< 0.005	79	0.64	< 0.02	0.42	1700	0.3	13	1.1	540
PMO13	< 0.005	< 0.005	< 0.005	37	< 0.005	< 0.02	< 0.005	32	0.1	< 0.1	< 0.01	0.3

[a]Ag (< 0.01), Au (< 0.01), Bi (< 0.01), Cr (< 0.5), Ga (< 0.02), Hf (< 0.05), In (< 0.01), Na (not determined), Nb (< 0.02), Re (< 0.02), Sc (< 0.1), Sn (< 0.05), Ta (< 0.02), Te (< 0.1), Tl (< 0.05), and W (< 0.02) have been omitted because the concentrations were less than the detection limits shown in parentheses.

[b]Average of 3; a 1:10 dilution.

Field No	Mo ug/L	Nd ug/L	Ni ug/L	P ug/L	Pb ug/L	Pr ug/L	Rb ug/L	Sb ug/L	Se ug/L	SiO2 mg/L	Sm ug/L	Sn ug/L
FLW 16	0.05	2.3	0.6	120	0.1	0.48	1.9	0.1	0.7	3	0.60	0.06
ACT 16	0.1	0.02	1.5	39	0.1	< 0.01	6.5	0.05	0.4	3	< 0.01	0.1
CHI 16	0.04	5.9	1.0	2600	0.3	0.93	59	< 0.02	0.5	4	1.6	0.07
CCO 16	0.08	0.99	2.3	130	1.0	0.20	21	0.1	0.5	3	0.22	< 0.05
GCM 16	0.04	1.6	1.2	150	0.2	0.38	8.7	0.03	0.4	1	0.35	< 0.05
FCWN 16	0.2	0.1	1.1	49	0.90	0.02	30	0.1	0.4	1	0.02	0.2
ZEO 16	0.2	0.03	0.7	30	0.2	< 0.01	18	0.4	0.4	2	< 0.01	0.1
PWI 16	0.08	3.1	2.0	280	0.84	0.79	23	0.03	0.4	2	0.54	0.05
SNM 16	0.05	5.9	1.4	320	0.4	1.4	6.6	0.03	0.4	2	1.4	0.2
SDH 16	0.1	0.2	0.4	230	0.96	0.04	4.4	0.06	0.8	2	0.02	0.05
PBC 16	0.1	0.43	4.2	19	0.3	0.07	2.5	0.04	0.5	3	0.2	0.09
PMO13	0.5	0.1	2.2	110	1.0	< 0.01	0.05	< 0.02	0.4	< 0.5	< 0.01	0.3

Field No	SO4 mg/L	Sr ug/L	Tb ug/L	Th ug/L	Ti ug/L	Tm ug/L	U ug/L	V ug/L	Y ug/L	Yb ug/L	Zn ug/L	Zr ug/L
FLW 16	540	18	0.13	0.11	2.2	0.060	180	< 0.1	5.3	0.32	5	0.61
ACT 16	520	99	< 0.005	0.02	2.3	< 0.005	250	0.7	0.08	< 0.01	5	< 0.05
CHI 16	510	67	0.57	0.02	2.2	0.35	170	< 0.1	33	1.9	3	0.07
CCO 16	520	290	0.050	0.07	2.2	0.074	120	< 0.1	3.1	0.54	10	0.05
GCM 16	540	190	0.095	0.16	2.2	0.060	65	0.1	4.9	0.36	4	< 0.05
FCWN 16	530	73	0.006	0.06	2.2	0.007	31	0.4	0.3	0.03	3	< 0.05
ZEO 16	520	240	< 0.005	0.03	2.2	< 0.005	240	0.3	0.1	< 0.01	6	< 0.05
PWI 16	500	59	0.13	0.07	2.0	0.096	270	< 0.1	12	0.54	21	0.07
SNM 16	510	840	0.23	0.10	2.0	0.072	230	< 0.1	6.1	0.41	4	< 0.05
SDH 16	530	71	< 0.005	0.11	2.3	< 0.005	240	1	0.06	< 0.01	2	< 0.05
PBC 16	510	88	0.19	0.02	2.0	0.22	48	< 0.1	16	1.4	8	< 0.05
PMO13	500	0.5	< 0.005	0.03	2.3	< 0.005	260	< 0.1	< 0.01	< 0.01	3.7	< 0.05

Table A17. ICP - AES Results[a] for Pre- and Post- Exchange Zinc Stock Solution

Field No	Solution	Al mg/L	Au mg/L	Ba mg/L	Ca mg/L	Ce mg/L	Cu mg/L	Fe mg/L	K mg/L	La mg/L	Li mg/L
ZEO5	CRR extract: 430 mg/L Zn	< 1	< 0.1	0.14	480	< 0.1	< 0.1	< 1	190	< 0.1	< 0.1
CHI5	CRR extract: 430 mg/L Zn	19	< 0.1	0.24	450	< 0.1	< 0.1	< 1	490	< 0.1	< 0.1
FLW5	CRR extract: 430 mg/L Zn	13	< 0.1	< 0.1	150	0.16	< 0.1	< 1	18	< 0.1	< 0.1
FCWN5	CRR extract: 430 mg/L Zn	2.0	0.13	0.10	470	< 0.1	0.21	< 1	130	< 0.1	0.16
PBC5	CRR extract: 430 mg/L Zn	13	< 0.1	< 0.1	420	< 0.1	0.12	2.5	41	< 0.1	0.19
ACT5	CRR extract: 430 mg/L Zn	< 1	< 0.1	0.24	950	< 0.1	< 0.1	< 1	43	< 0.1	0.13
PWI5	CRR extract: 430 mg/L Zn	45	0.10	0.10	840	0.16	< 0.1	2.0	230	0.20	< 0.1
SNM5	CRR extract: 430 mg/L Zn	20	0.11	0.23	520	0.10	0.16	< 1	68	0.22	< 0.1
CCO5	CRR extract: 430 mg/L Zn	32	0.10	0.10	720	< 0.1	0.16	1.2	85	< 0.1	0.29
GCM5	CRR extract: 430 mg/L Zn	20	0.11	0.17	470	0.17	0.44	< 1	83	0.14	< 0.1
SDH5	CRR extract: 430 mg/L Zn	< 1	< 0.1	0.13	250	< 0.1	< 0.1	< 1	110	< 0.1	< 0.1
PMO4	Zn stock solution (average)	< 1	0.18	< 0.1	1	< 0.1	< 0.1	< 1	1.2	< 0.1	< 0.1

Field No	Mg mg/L	Mn mg/L	Na mg/L	Nd mg/L	P mg/L	Sr mg/L	Y mg/L	Zn mg/L
ZEO5	29	5.4	2600	< 0.1	< 1	4.2	< 0.1	150
CHI5	13	1.5	2100	0.18	32	1.1	0.94	250
FLW5	6.6	0.47	2900	0.11	< 1	0.41	0.21	95
FCWN5	36	0.53	2400	< 0.1	< 1	1.3	< 0.1	340
PBC5	30	14	2500	< 0.1	< 1	1.7	0.94	290
ACT5	5.1	0.36	2100	< 0.1	< 1	1.9	< 0.1	210
PWI5	15	0.19	1700	0.11	1.2	0.84	0.26	280
SNM5	66	1.1	2200	0.28	4.5	13	0.25	330
CCO5	19	0.65	1900	< 0.1	< 1	4.4	< 0.1	280
GCM5	49	1.5	2200	0.13	9.5	2.7	0.30	330
SDH5	4.6	2.3	2800	< 0.1	< 1	1.6	< 0.1	160
PMO4	< 1	< 0.1	2700	< 0.1	< 1	< 0.1	< 0.1	430

[a]Ag (< 0.1), As (< 0.2), Be (< 0.1), Bi (< 0.2), Cd (< 0.1), Co (< 0.1), Cr (< 0.1), Eu (< 0.1), Ga (< 0.1), Ho (< 0.1), Mo (< 0.1), Nb (< 0.1), Ni (< 0.1), Pb (< 0.1), Sc (< 0.1), Sn (< 0.5), Ta (< 1), Th (< 0.1), Ti (< 1), U (< 1), V (< 0.1), and Yb (< 0.1) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Table A18. ICP - MS Results[a] for Pre- and Post- Exchange De-ionized Water Control Solution

Field No	Solution	Al ug/L	As ug/L	Ba ug/L	Be ug/L	Ca mg/L	Ce ug/L	Co ug/L	Cs ug/L	Cu ug/L	Dy ug/L
FLW 1	CRR extract: De-ionized water	1300	2.2	5.4	0.05	0.1	3.2	0.1	0.1	2	0.13
ACT 1	CRR extract: De-ionized water	1200	0.7	0.8	< 0.05	0.89	2.1	0.2	1.2	< 0.5	0.15
CHI 1	CRR extract: De-ionized water	2800	< 0.2	5.0	0.2	0.63	3.6	0.05	0.47	2	0.31
CCO 1	CRR extract: De-ionized water	510	2.4	0.8	< 0.05	0.2	0.4	< 0.02	1.1	3	0.02
GCM 1	CRR extract: De-ionized water	410	0.9	3	< 0.05	0.2	0.3	< 0.02	0.03	5	0.03
FCWN 1	CRR extract: De-ionized water	180	3.0	0.3	< 0.05	0.2	0.4	< 0.02	0.2	3	0.03
ZEO 1	CRR extract: De-ionized water	3600	1	7.8	0.6	1.2	0.69	0.06	0.2	0.9	0.064
PWI 1	CRR extract: De-ionized water	230	0.7	1	< 0.05	0.08	1.5	< 0.02	0.04	0.5	0.051
SNM 1	CRR extract: De-ionized water	140	0.3	1	< 0.05	0.3	0.4	< 0.02	0.03	< 0.5	0.01
SDH 1	CRR extract: De-ionized water	3600	3.2	2	0.1	0.4	1.8	0.81	0.34	2	0.13
PBC 1	CRR extract: De-ionized water	1200	2	4	< 0.05	0.3	0.79	0.3	0.2	0.9	0.28
X	De-ionized water control	6.6	< 0.2	0.05	< 0.05	< 0.05	< 0.01	< 0.02	< 0.01	< 0.5	< 0.005

Field No	Er ug/L	Eu ug/L	Fe ug/L	Ga ug/L	Gd ug/L	Ho ug/L	K ug/L	La ug/L	Li ug/L	Mg mg/L	Mn ug/L	Mo ug/L
FLW 1	0.061	0.02	520	0.5	0.15	0.02	48	1.7	1.0	0.21	3.2	0.4
ACT 1	0.067	0.02	650	0.4	0.18	0.03	280	0.92	3.2	0.19	9.2	0.3
CHI 1	0.14	0.02	1500	1.2	0.31	0.060	600	2.0	0.6	0.11	6.6	0.4
CCO 1	0.01	< 0.005	250	0.1	0.02	0.005	130	0.2	2.7	0.04	0.89	1.6
GCM 1	0.02	0.007	200	0.2	0.03	0.009	130	0.2	0.3	0.08	6.7	0.2
FCWN 1	0.02	< 0.005	93	0.06	0.03	0.007	310	0.2	3.3	0.04	0.61	0.4
ZEO 1	0.066	0.008	1000	0.54	0.050	0.02	1000	0.4	1.5	0.38	25	0.09
PWI 1	0.03	0.006	120	0.08	0.090	0.01	300	0.80	0.5	0.01	0.50	0.1
SNM 1	0.005	< 0.005	53	0.04	0.02	< 0.005	130	0.1	0.2	0.06	1.1	0.09
SDH 1	0.079	0.02	2800	0.68	0.15	0.03	1300	0.95	7.1	1.1	86	0.06
PBC 1	0.25	< 0.005	1200	0.56	0.14	0.075	140	0.4	1.9	0.26	50	0.2
X	< 0.005	< 0.005	< 10	< 0.02	< 0.005	< 0.005	19	< 0.01	< 0.1	< 0.01	0.08	0.50

[a]Ag (< 0.01), Au (< 0.01), Bi (< 0.01), Cr (< 0.5), Ge (< 0.02), Hf (< 0.05), In (< 0.01), Nb (< 0.02), Re (< 0.02), Ta (< 0.02), Te (< 0.1), Tl (< 0.05), and W (< 0.02) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Field No	Na mg/L	Nb ug/L	Nd ug/L	Ni ug/L	P ug/L	Pb ug/L	Pr ug/L	Rb ug/L	Sb ug/L	Sc ug/L	Se ug/L	SiO2 mg/L	Sm ug/L
FLW 1	4.8	0.1	1.2	0.3	140	1.4	0.31	1.6	0.3	2	0.6	8.7	0.2
ACT 1	2.8	0.03	0.94	0.4	49	0.66	0.24	3.5	0.1	1	0.4	10	0.20
CHI 1	0.71	0.2	1.6	0.2	220	1.2	0.42	5.8	0.1	2	0.2	14	0.34
CCO 1	1.2	0.2	0.1	0.2	330	0.92	0.04	1.8	0.56	0.7	0.3	5.2	0.02
GCM 1	3.0	< 0.02	0.1	0.2	53	0.4	0.04	1.0	0.07	0.5	0.4	5.3	0.03
FCWN 1	4.4	0.02	0.2	0.2	90	0.3	0.04	2.3	0.1	0.4	0.3	4	0.03
ZEO 1	9.0	0.03	0.27	0.2	32	1.4	0.08	4.7	0.3	2	0.4	18	0.05
PWI 1	0.44	0.3	0.53	0.1	210	0.57	0.1	1.1	0.1	0.4	< 0.2	4	0.09
SNM 1	1.3	0.03	0.1	0.2	34	0.3	0.02	0.64	0.05	0.3	0.2	3	< 0.01
SDH 1	11	0.2	0.75	1.4	90	2.5	0.20	8.0	0.08	4	0.5	28	0.2
PBC 1	4.0	0.1	0.39	0.6	14	1.4	0.1	1.3	0.1	2	0.4	11	0.1
X	0.05	< 0.02	< 0.01	0.1	11	0.79	< 0.01	0.02	0.2	< 0.1	0.3	< 0.5	< 0.01

Field No	Sn ug/L	SO4 mg/L	Sr ug/L	Tb ug/L	Th ug/L	Ti ug/L	Tm ug/L	U ug/L	V ug/L	Y ug/L	Yb ug/L	Zn ug/L	Zr ug/L
FLW 1	0.4	5.9	1.1	0.02	0.65	9.8	0.01	0.44	2	0.76	0.05	9	0.5
ACT 1	< 0.05	1.1	1.0	0.03	0.46	6.8	0.01	0.13	5.4	0.86	0.08	6	0.3
CHI 1	< 0.05	0.3	1.8	0.05	0.60	14	0.02	0.27	0.6	1.9	0.1	20	< 0.05
CCO 1	< 0.05	1.1	1.1	< 0.005	0.27	6.5	< 0.005	0.29	0.7	0.2	0.03	3	0.4
GCM 1	< 0.05	1.0	1.1	0.007	0.08	0.7	< 0.005	0.05	2	0.3	0.02	4	0.1
FCWN 1	0.2	1.4	0.4	0.006	0.1	1.7	< 0.005	0.23	5.0	0.2	0.02	4	0.2
ZEO 1	< 0.05	0.6	14	0.008	0.28	2.0	0.01	0.15	5.0	0.73	0.1	10	< 0.05
PWI 1	0.2	0.5	0.2	0.01	0.26	5.5	< 0.005	0.14	< 0.1	0.4	0.02	4	0.3
SNM 1	< 0.05	0.9	4.7	< 0.005	0.10	1.8	< 0.005	0.02	2	0.06	< 0.01	6	0.08
SDH 1	0.1	0.7	2.8	0.02	0.58	58	0.01	0.66	11	0.93	0.1	20	0.2
PBC 1	0.06	0.6	1.3	0.03	0.70	13	0.050	0.65	3	2.5	0.36	10	0.2
X	0.08	0.4	0.03	< 0.005	< 0.005	< 0.1	< 0.005	< 0.005	< 0.1	< 0.01	< 0.01	2	< 0.05

Table A19. ICP - MS Results[a] for Pre- and Post- Exchange Burleigh Mine Drainage Solution

Field No	Solution	Al ug/L	As ug/L	Ba ug/L	Ca mg/L	Cd ug/L	Ce ug/L	Co ug/L	Cs ug/L	Cu ug/L
FLW 21	CRR extract: Burleigh tunnel water 1:10	150	0.7	2	0.52	0.09	0.3	0.02	0.01	1
FLW 21	CRR extract: Burleigh tunnel water 1:100	6.1	< 0.2	< 0.02	< 0.05	< 0.02	0.02	< 0.02	< 0.01	< 0.5
ACT 21	CRR extract: Burleigh tunnel water 1:10	2.1	< 0.2	1	11	0.4	< 0.01	0.1	0.2	< 0.5
ACT 21	CRR extract: Burleigh tunnel water 1:100	0.04	< 0.2	0.1	1.1	0.02	< 0.01	< 0.02	0.02	< 0.5
CHI 21	CRR extract: Burleigh tunnel water 1:10	3.2	< 0.2	8.0	3.3	0.90	0.02	0.07	0.1	< 0.5
CHI 21	CRR extract: Burleigh tunnel water 1:100	< 0.01	< 0.2	0.7	0.3	0.07	< 0.01	< 0.02	0.01	< 0.5
CCO 21	CRR extract: Burleigh tunnel water 1:10	< 0.01	< 0.2	1	9.8	1.6	0.01	0.2	1.1	0.6
CCO 21	CRR extract: Burleigh tunnel water 1:100	< 0.01	< 0.2	0.06	0.93	0.2	< 0.01	< 0.02	0.1	2
GCM 21	CRR extract: Burleigh tunnel water 1:10	0.12	< 0.2	2	5.4	1.9	0.01	0.2	< 0.01	2
GCM 21	CRR extract: Burleigh tunnel water 1:100	< 0.01	< 0.2	0.2	0.51	0.2	< 0.01	< 0.02	< 0.01	< 0.5
FCWN 21	CRR extract: Burleigh tunnel water 1:10	0.14	< 0.2	0.3	3.9	1.1	0.01	0.3	0.09	0.6
FCWN 21	CRR extract: Burleigh tunnel water 1:100	< 0.01	< 0.2	< 0.02	0.4	0.09	< 0.01	< 0.02	< 0.01	< 0.5
ZEO 21	CRR extract: Burleigh tunnel water 1:10	1.2	< 0.2	4	1.6	0.2	< 0.01	< 0.02	0.06	< 0.5
ZEO 21	CRR extract: Burleigh tunnel water 1:100	< 0.01	< 0.2	0.3	0.2	< 0.02	< 0.01	< 0.02	< 0.01	< 0.5
PWI 21	CRR extract: Burleigh tunnel water 1:10	2.8	< 0.2	2	10	2.1	0.02	0.3	0.04	< 0.5
PWI 21	CRR extract: Burleigh tunnel water 1:100	< 0.01	< 0.2	0.3	1.0	0.2	< 0.01	< 0.02	< 0.01	< 0.5
SNM 21	CRR extract: Burleigh tunnel water 1:10	0.02	< 0.2	3	11	3.9	0.01	0.4	0.04	< 0.5
SNM 21	CRR extract: Burleigh tunnel water 1:100	0.34	< 0.2	0.3	1.0	0.4	< 0.01	< 0.02	< 0.01	< 0.5
SDH 21	CRR extract: Burleigh tunnel water 1:10	160	0.6	0.7	0.4	0.05	0.2	< 0.02	0.02	< 0.5
SDH 21	CRR extract: Burleigh tunnel water 1:100	15	< 0.2	< 0.02	< 0.05	< 0.02	0.01	< 0.02	< 0.01	< 0.5
PBC 21	CRR extract: Burleigh tunnel water 1:10	< 0.01	< 0.2	2	3.4	0.3	< 0.01	0.06	0.05	< 0.5
PBC 21	CRR extract: Burleigh tunnel water 1:100	< 0.01	< 0.2	0.2	0.3	< 0.02	0.02	< 0.02	< 0.01	< 0.5
1PMO18	Burleigh tunnel water (1:10)	1.5	< 0.2	2	8.3	16	0.1	0.98	0.03	0.6
1PMO18	Burleigh tunnel water (1:100)	< 0.01	< 0.2	0.1	0.80	1.5	0.02	0.08	< 0.01	< 0.5
2PMO18	Burleigh tunnel water (1:10)	1.1	< 0.2	2	8.2	15	0.1	0.97	0.03	< 0.5
2PMO18	Burleigh tunnel water (1:100)	< 0.01	< 0.2	0.1	0.77	1.5	0.01	0.06	< 0.01	< 0.5
3PMO18	Burleigh tunnel water (1:10)	7.0	< 0.2	2	8.4	16	0.1	1.0	0.04	< 0.5
3PMO18	Burleigh tunnel water (1:100)	0.74	< 0.2	0.2	0.83	1.6	0.01	0.1	< 0.01	< 0.5

[a]Ag (< 0.01), Au (< 0.01), Be (< 0.05), Bi (< 0.01), Cr (< 0.5), Er (< 0.005), Eu (< 0.005), Ga (< 0.02), Gd (< 0.02), Hf (< 0.05), Ho (< 0.005), In (< 0.01), Nb (< 0.02), Pr (< 0.01), Re (< 0.02), Sc (< 0.1), Sm (< 0.01), Sn (< 0.05), Ta (< 0.02), Tb (< 0.005), Te (< 0.1), Th (< 0.005), Tl (< 0.05), Tm (< 0.005), W (< 0.02), Yb (< 0.01), and Zr (< 0.05) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Field No	Dy ug/L	Fe ug/L	Gd ug/L	K ug/L	La ug/L	Li ug/L	Mg mg/L	Mn ug/L	Mo ug/L	Na mg/L	Nd ug/L	Ni ug/L	P ug/L
FLW 21	0.02	< 10	0.02	82	0.2	1.6	0.13	7.2	0.4	29	0.1	0.3	39
FLW 21	< 0.005	< 10	< 0.005	< 0.3	0.01	< 0.1	0.01	0.34	0.2	2.8	< 0.01	< 0.1	7
ACT 21	< 0.005	11	< 0.005	500	< 0.01	5.6	0.76	53	0.2	11	< 0.01	1.1	7
ACT 21	< 0.005	< 10	< 0.005	< 0.3	< 0.01	0.4	0.08	5.6	0.1	1.1	< 0.01	< 0.1	5
CHI 21	0.01	< 10	0.009	6800	0.06	1.3	0.54	36	0.4	15	0.02	0.6	11
CHI 21	< 0.005	< 10	< 0.005	660	< 0.01	< 0.1	0.06	3.7	0.1	1.5	< 0.01	< 0.1	11
CCO 21	< 0.005	< 10	< 0.005	1200	< 0.01	12	1.3	79	1.1	9.4	< 0.01	1.6	19
CCO 21	< 0.005	< 10	< 0.005	64	< 0.01	1.1	0.13	8.1	0.2	0.96	< 0.01	< 0.1	10
GCM 21	0.005	< 10	0.006	850	0.01	1.5	1.8	99	0.1	15	< 0.01	1.5	15
GCM 21	< 0.005	< 10	< 0.005	42	0.2	0.2	0.19	10	0.06	1.5	< 0.01	0.1	5
FCWN 21	< 0.005	< 10	< 0.005	1100	< 0.01	6.6	2.4	100	0.4	16	< 0.01	2.0	13
FCWN 21	< 0.005	< 10	< 0.005	58	< 0.01	0.6	0.24	11	0.09	1.6	< 0.01	0.1	9
ZEO 21	< 0.005	< 10	< 0.005	2100	< 0.01	3.1	0.20	12	0.2	26	< 0.01	0.2	8
ZEO 21	< 0.005	< 10	< 0.005	120	< 0.01	0.3	0.02	1.4	0.04	2.6	< 0.01	< 0.1	19
PWI 21	< 0.005	10	< 0.005	2900	0.03	1.6	1.5	80	0.1	7.3	< 0.01	2.0	17
PWI 21	< 0.005	< 10	< 0.005	160	< 0.01	< 0.1	0.16	8.8	0.04	0.76	< 0.01	0.3	10
SNM 21	< 0.005	9.9	< 0.005	640	< 0.01	1.1	2.8	140	0.1	4.4	< 0.01	2.1	4
SNM 21	< 0.005	< 10	< 0.005	32	< 0.01	< 0.1	0.28	16	< 0.02	0.27	< 0.01	0.2	10
SDH 21	0.006	80	0.008	940	0.07	2.2	0.16	7.3	0.1	29	0.05	0.1	13
SDH 21	< 0.005	< 10	< 0.005	48	< 0.01	< 0.1	0.02	0.68	0.02	2.8	< 0.01	< 0.1	13
PBC 21	< 0.005	< 10	< 0.005	450	< 0.01	5.6	0.84	92	0.3	21	< 0.01	0.5	< 1
PBC 21	< 0.005	< 10	< 0.005	31	< 0.01	0.6	0.09	10	0.04	2.1	< 0.01	< 0.1	8
1PMO18	0.008	31	0.009	140	0.1	0.9	3.7	340	0.06	1.1	0.03	4.9	1
1PMO18	< 0.005	< 10	< 0.005	12	0.01	0.1	0.37	39	< 0.02	0.10	< 0.01	0.5	10
2PMO18	0.006	22	0.009	140	0.1	1.0	3.7	330	0.07	1.1	0.04	4.8	2
2PMO18	< 0.005	< 10	< 0.005	11	0.01	< 0.1	0.36	37	< 0.02	0.09	< 0.01	0.5	14
3PMO18	0.007	24	0.01	140	0.1	1.2	3.7	340	0.1	1.1	0.03	5.0	6
3PMO18	< 0.005	< 10	< 0.005	12	0.02	0.2	0.38	39	< 0.02	0.09	< 0.01	0.4	9

Field No	Pb ug/L	Rb ug/L	Sb ug/L	Se ug/L	SiO2 mg/L	Sn ug/L	SO4 mg/L	Sr ug/L	Ti ug/L	U ug/L	V ug/L	Y ug/L	Zn ug/L
FLW 21	0.4	0.4	0.2	0.7	2	0.06	33	1.3	2.3	1.6	0.3	0.2	38
FLW 21	0.08	0.04	0.08	0.4	< 0.5	< 0.05	2.8	0.09	0.1	0.16	< 0.1	< 0.01	3
ACT 21	0.07	2.2	0.1	0.4	3	0.06	29	20	0.4	1.4	0.8	0.01	440
ACT 21	< 0.05	0.2	0.05	0.3	< 0.5	< 0.05	2.4	2.0	< 0.1	0.14	< 0.1	< 0.01	44
CHI 21	0.08	15	0.09	0.3	2	0.06	29	9.5	0.2	0.20	< 0.1	0.1	390
CHI 21	< 0.05	1.4	0.03	0.3	< 0.5	0.06	2.3	1	< 0.1	0.02	< 0.1	0.01	38
CCO 21	0.1	5.9	0.3	0.5	3	0.06	29	29	0.2	0.50	< 0.1	0.01	790
CCO 21	0.98	0.53	0.05	0.2	< 0.5	0.1	2.4	2.8	< 0.1	0.06	< 0.1	< 0.01	79
GCM 21	0.2	2.1	0.05	0.4	2	< 0.05	30	22	0.2	1.1	0.4	0.06	1100
GCM 21	0.1	0.2	0.02	0.4	< 0.5	< 0.05	4.5	2.2	< 0.1	0.11	< 0.1	< 0.01	110
FCWN 21	< 0.05	5.6	0.1	0.5	2	0.08	30	11	0.2	1.3	0.8	0.02	870
FCWN 21	0.08	0.56	0.02	0.4	< 0.5	< 0.05	4.5	1.1	< 0.1	0.12	< 0.1	< 0.01	89
ZEO 21	0.2	4.9	0.51	0.3	2	0.06	30	17	0.2	0.91	0.7	0.02	58
ZEO 21	0.1	0.50	0.05	0.4	< 0.5	< 0.05	4.5	1.7	< 0.1	0.09	< 0.1	< 0.01	6
PWI 21	0.09	6.0	0.08	0.2	2	0.07	29	8.4	0.2	1.3	< 0.1	0.04	790
PWI 21	0.05	0.60	< 0.02	0.3	< 0.5	< 0.05	4.4	0.9	< 0.1	0.13	< 0.1	< 0.01	85
SNM 21	< 0.05	1.9	0.04	0.4	2	< 0.05	29	130	0.3	0.99	0.5	0.01	1800
SNM 21	0.1	0.2	< 0.02	0.2	< 0.5	< 0.05	4.3	13	< 0.1	0.10	< 0.1	< 0.01	180
SDH 21	0.2	1.3	0.05	0.5	3	0.1	30	2.6	2.8	1.7	4	0.06	34
SDH 21	< 0.05	0.1	< 0.02	0.4	< 0.5	< 0.05	4.3	0.3	0.3	0.18	0.2	< 0.01	3
PBC 21	0.1	0.77	0.09	0.5	2	< 0.05	29	8.9	0.2	2.2	0.1	0.07	140
PBC 21	< 0.05	0.08	< 0.02	0.2	< 0.5	< 0.05	4.3	1.0	< 0.1	0.21	< 0.1	< 0.01	10
1PMO18	2.9	0.84	0.04	0.3	< 0.5	< 0.05	28	160	0.2	1.6	< 0.1	0.09	6800
1PMO18	0.3	0.08	< 0.02	0.4	< 0.5	< 0.05	4.1	17	< 0.1	0.16	< 0.1	< 0.01	720
2PMO18	2.1	0.84	0.04	0.5	< 0.5	< 0.05	27	160	0.2	1.6	< 0.1	0.09	6800
2PMO18	0.2	0.09	< 0.02	0.3	< 0.5	< 0.05	4.0	17	< 0.1	0.14	< 0.1	< 0.01	700
3PMO18	2.1	0.88	0.04	0.4	< 0.5	< 0.05	28	160	0.2	1.6	< 0.1	0.1	7000
3PMO18	0.2	0.1	< 0.02	0.2	< 0.5	< 0.05	4.3	18	< 0.1	0.16	< 0.1	< 0.01	720

Table A20. ICP - MS Results[a] for Pre- and Post- Exchange McClelland Mine Drainage Solution

Field No	Solution	Al ug/L	As ug/L	Ba ug/L	Be ug/L	Ca mg/L	Cd ug/L	Ce ug/L	Co ug/L	Cs ug/L
FLW 23	CRR extract: McClelland tunnel water 1:10	39	0.3	0.5	< 0.05	0.3	0.04	0.2	0.1	< 0.01
FLW 23	CRR extract: McClelland tunnel water 1:10	8.1	< 0.2	0.05	< 0.05	< 0.05	< 0.02	0.02	< 0.02	< 0.01
ACT 23	CRR extract: McClelland tunnel water 1:10	3.5	< 0.2	2	< 0.05	15	0.1	0.02	0.60	0.30
ACT 23	CRR extract: McClelland tunnel water 1:10	1.8	< 0.2	0.2	< 0.05	1.5	< 0.02	< 0.01	0.1	0.02
CHI 23	CRR extract: McClelland tunnel water 1:10	1.7	< 0.2	11	< 0.05	5.4	0.4	0.1	0.83	0.2
CHI 23	CRR extract: McClelland tunnel water 1:10	< 0.01	< 0.2	1	< 0.05	0.55	0.03	0.02	0.05	0.02
CCO 23	CRR extract: McClelland tunnel water 1:10	1.2	0.2	2	< 0.05	13	0.66	0.05	1.6	1.4
CCO 23	CRR extract: McClelland tunnel water 1:10	16	< 0.2	0.2	< 0.05	1.3	0.05	0.01	0.1	0.1
GCM 23	CRR extract: McClelland tunnel water 1:10	5.4	< 0.2	4	< 0.05	8.3	0.66	0.1	1.7	0.01
GCM 23	CRR extract: McClelland tunnel water 1:10	0.51	< 0.2	0.3	< 0.05	0.80	0.05	0.02	0.2	< 0.01
FCWN 23	CRR extract: McClelland tunnel water 1:10	2.8	0.3	0.5	< 0.05	6.0	0.3	0.08	1.4	0.1
FCWN 23	CRR extract: McClelland tunnel water 1:10	1.3	< 0.2	0.1	< 0.05	0.60	0.02	0.01	0.2	0.06
ZEO 23	CRR extract: McClelland tunnel water 1:10	8.6	0.2	5.7	< 0.05	2.7	0.05	< 0.01	0.1	0.07
ZEO 23	CRR extract: McClelland tunnel water 1:10	2.2	< 0.2	0.6	< 0.05	0.3	< 0.02	< 0.01	< 0.02	< 0.01
PWI 23	CRR extract: McClelland tunnel water 1:10	10	< 0.2	3	< 0.05	13	0.83	0.2	2.0	0.05
PWI 23	CRR extract: McClelland tunnel water 1:10	2.1	< 0.2	0.4	< 0.05	1.3	0.1	0.03	0.2	< 0.01
SNM 23	CRR extract: McClelland tunnel water 1:10	1.5	< 0.2	4	< 0.05	15	1.3	0.07	2.4	0.05
SNM 23	CRR extract: McClelland tunnel water 1:10	1.9	< 0.2	0.4	< 0.05	1.5	0.1	0.02	0.2	< 0.01
SDH 23	CRR extract: McClelland tunnel water 1:10	24	1	0.4	< 0.05	0.51	< 0.02	0.01	0.06	0.02
SDH 23	CRR extract: McClelland tunnel water 1:10	1.3	< 0.2	< 0.02	< 0.05	< 0.05	< 0.02	< 0.01	< 0.02	< 0.01
PBC 23	CRR extract: McClelland tunnel water 1:10	1.5	< 0.2	3	< 0.05	5.4	0.1	< 0.01	0.2	0.04
PBC 23	CRR extract: McClelland tunnel water 1:10	0.41	< 0.2	0.3	< 0.05	0.54	< 0.02	< 0.01	< 0.02	< 0.01
1PMO19	McClelland tunnel water (1:10)	490	< 0.2	2	0.2	12	4.6	4.4	6.0	0.1
1PMO19	McClelland tunnel water (1:100)	50	< 0.2	0.2	< 0.05	1.2	0.4	0.4	0.60	< 0.01
2PMO19	McClelland tunnel water (1:10)	520	< 0.2	2	0.2	13	4.9	4.6	6.3	0.1
2PMO19	McClelland tunnel water (1:100)	50	< 0.2	0.1	< 0.05	1.2	0.4	0.4	0.62	< 0.01
3PMO19	McClelland tunnel water (1:10)	500	< 0.2	2	0.09	12	4.7	4.4	6.2	0.1
3PMO19	McClelland tunnel water (1:100)	50	< 0.2	0.2	< 0.05	1.2	0.4	0.4	0.61	< 0.01

[a]Ag (< 0.01), Au (< 0.01), Bi (< 0.01), Cr (< 0.5), Ga (< 0.02), Ge (< 0.02), Hf (< 0.05), In (< 0.01), Nb (< 0.02), Re (< 0.02), Sc (< 0.1), Ta (< 0.02), Te (< 0.1), Tl (< 0.05), W (< 0.02), Yb (< 0.01), and Zr (< 0.05) have been omitted because the concentrations were less than the detection limits shown in parentheses.

Field No	Cu ug/L	Dy ug/L	Er ug/L	Eu ug/L	Fe ug/L	Gd ug/L	Ho ug/L	K ug/L	La ug/L	Li ug/L	Mg mg/L	Mn ug/L	Mo ug/L
FLW 23	7	0.02	0.02	0.006	< 10	0.03	0.006	90	0.08	1.8	0.16	16	0.2
FLW 23	0.6	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	7.0	< 0.01	< 0.1	0.02	1.8	< 0.02
ACT 23	2	< 0.005	< 0.005	< 0.005	22	< 0.005	< 0.005	630	< 0.01	6.3	1.2	270	0.09
ACT 23	< 0.5	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	35	< 0.01	0.6	0.12	32	< 0.02
CHI 23	2	0.053	0.03	< 0.005	< 10	0.04	0.01	8200	0.3	1.6	0.97	240	0.1
CHI 23	< 0.5	< 0.005	< 0.005	< 0.005	< 10	0.005	< 0.005	810	0.03	0.1	0.10	28	< 0.02
CCO 23	6	< 0.005	0.006	< 0.005	15	0.006	< 0.005	1400	0.02	13	1.9	480	0.62
CCO 23	0.5	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	92	< 0.01	1.1	0.19	56	0.07
GCM 23	9	0.02	0.01	0.005	< 10	0.02	< 0.005	900	0.06	1.8	2.6	580	0.08
GCM 23	0.7	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	51	< 0.01	0.1	0.27	66	< 0.02
FCWN 23	7	0.01	0.006	< 0.005	< 10	0.01	< 0.005	1300	0.03	6.8	3.2	530	0.2
FCWN 23	0.6	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	80	< 0.01	0.8	0.33	63	0.03
ZEO 23	< 0.5	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	2300	< 0.01	3.4	0.35	65	0.1
ZEO 23	< 0.5	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	140	< 0.01	0.4	0.04	7.2	< 0.02
PWI 23	8	0.02	0.02	0.005	16	0.02	< 0.005	3300	0.2	1.9	2.2	470	0.06
PWI 23	0.7	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	350	0.02	< 0.1	0.22	53	< 0.02
SNM 23	4	< 0.005	< 0.005	< 0.005	25	0.005	< 0.005	720	0.05	1.2	3.7	810	0.07
SNM 23	0.6	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	67	0.01	< 0.1	0.38	93	< 0.02
SDH 23	< 0.5	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	1000	< 0.01	2.1	0.23	26	0.04
SDH 23	< 0.5	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	60	< 0.01	0.2	0.02	2.8	< 0.02
PBC 23	< 0.5	< 0.005	0.005	< 0.005	< 10	< 0.005	< 0.005	500	< 0.01	5.9	1.3	210	0.2
PBC 23	< 0.5	< 0.005	< 0.005	< 0.005	< 10	< 0.005	< 0.005	27	< 0.01	0.6	0.14	25	0.02
1PMO19	120	0.33	0.14	0.12	140	0.48	0.062	130	1.6	1.0	4.4	1700	0.07
1PMO19	12	0.04	0.01	0.01	< 10	0.04	0.006	12	0.2	< 0.1	0.46	180	< 0.02
2PMO19	130	0.36	0.15	0.14	150	0.48	0.063	140	1.6	0.9	4.5	1800	0.05
2PMO19	13	0.04	0.01	0.01	< 10	0.03	0.006	9.4	0.2	< 0.1	0.47	180	< 0.02
3PMO19	120	0.34	0.16	0.14	150	0.46	0.065	130	1.6	0.9	4.4	1700	0.07
3PMO19	13	0.04	0.02	0.01	< 10	0.050	< 0.005	18	0.2	< 0.1	0.47	180	< 0.02

Field No	Na mg/L	Nd ug/L	Ni ug/L	P ug/L	Pb ug/L	Pr ug/L	Rb ug/L	Sb ug/L	Se ug/L	SiO2 mg/L	Sm ug/L
FLW 23	34	0.1	0.9	23	0.08	0.02	0.5	0.1	0.5	3	0.02
FLW 23	3.3	< 0.01	< 0.1	14	0.1	< 0.01	0.05	< 0.02	0.4	< 0.5	< 0.01
ACT 23	11	< 0.01	2.5	6	0.1	< 0.01	2.5	0.02	0.4	3	< 0.01
ACT 23	1.1	< 0.01	0.2	15	0.07	< 0.01	0.2	< 0.02	0.2	< 0.5	< 0.01
CHI 23	17	0.2	2.9	4	0.1	0.04	19	< 0.02	0.5	4	0.02
CHI 23	1.7	< 0.01	0.2	15	0.07	< 0.01	1.9	< 0.02	0.4	< 0.5	< 0.01
CCO 23	10	0.02	4.8	29	0.1	< 0.01	6.9	0.3	0.3	3	< 0.01
CCO 23	1.1	< 0.01	0.5	19	0.09	< 0.01	0.75	< 0.02	0.2	< 0.5	< 0.01
GCM 23	16	0.07	5.3	11	0.09	0.01	2.3	< 0.02	0.3	2	< 0.01
GCM 23	1.6	< 0.01	0.5	11	0.1	< 0.01	0.2	< 0.02	0.3	< 0.5	< 0.01
FCWN 23	18	0.05	5.1	15	0.1	0.01	7.0	0.05	0.5	2	< 0.01
FCWN 23	1.8	< 0.01	0.5	14	0.3	< 0.01	0.69	< 0.02	0.4	< 0.5	< 0.01
ZEO 23	28	< 0.01	0.5	4	0.06	< 0.01	5.7	0.4	0.3	2	< 0.01
ZEO 23	2.8	< 0.01	< 0.1	9	0.2	< 0.01	0.56	0.03	0.3	< 0.5	< 0.01
PWI 23	8.1	0.1	7.5	29	0.2	0.03	7.7	0.06	0.3	3	0.02
PWI 23	0.87	< 0.01	0.8	14	0.2	< 0.01	0.71	< 0.02	0.3	< 0.5	< 0.01
SNM 23	4.7	0.03	7.2	150	0.1	< 0.01	2.0	< 0.02	0.4	3	< 0.01
SNM 23	0.61	< 0.01	1.6	34	0.2	< 0.01	0.2	< 0.02	0.3	< 0.5	< 0.01
SDH 23	32	< 0.01	0.3	12	0.1	< 0.01	1.3	< 0.02	0.6	3	< 0.01
SDH 23	3.2	< 0.01	< 0.1	10	0.05	< 0.01	0.1	< 0.02	0.4	< 0.5	< 0.01
PBC 23	22	< 0.01	1.0	< 1	< 0.05	< 0.01	0.87	0.05	0.4	2	< 0.01
PBC 23	2.3	< 0.01	< 0.1	12	0.06	< 0.01	0.1	< 0.02	0.2	< 0.5	< 0.01
1PMO19	1.2	2.6	16	2	2.1	0.59	1.0	< 0.02	0.4	2	0.47
1PMO19	0.09	0.27	1.7	9	0.2	0.05	0.1	< 0.02	0.4	< 0.5	0.05
2PMO19	1.2	2.7	16	< 1	2.8	0.60	1.1	< 0.02	0.3	2	0.46
2PMO19	0.09	0.26	1.6	10	0.3	0.06	0.09	< 0.02	0.3	< 0.5	0.03
3PMO19	1.2	2.5	16	< 1	2.2	0.58	1.0	< 0.02	0.3	2	0.44
3PMO19	0.10	0.23	1.7	6	0.3	0.06	0.1	< 0.02	0.4	< 0.5	0.04

Sn ug/L	SO4 mg/L	Field No	Sr ug/L	Tb ug/L	Th ug/L	Ti ug/L	Tm ug/L	U ug/L	V ug/L	Y ug/L	Yb ug/L	Zn ug/L	Zr ug/L
< 0.05	44	FLW 23	1.0	< 0.005	0.01	0.9	< 0.005	0.68	0.1	0.2	0.03	6	1.1
< 0.05	5.9	FLW 23	0.1	< 0.005	< 0.005	0.3	< 0.005	0.07	< 0.1	0.02	< 0.01	0.8	< 0.05
< 0.05	40	ACT 23	25	< 0.005	< 0.005	0.4	< 0.005	1.5	0.6	0.02	< 0.01	20	< 0.05
< 0.05	5.5	ACT 23	2.5	< 0.005	< 0.005	0.2	< 0.005	0.15	< 0.1	< 0.01	< 0.01	3	< 0.05
< 0.05	41	CHI 23	13	0.007	< 0.005	0.3	< 0.005	0.06	< 0.1	0.5	0.02	49	< 0.05
< 0.05	5.5	CHI 23	1.4	< 0.005	< 0.005	< 0.1	< 0.005	0.005	< 0.1	0.05	< 0.01	5	< 0.05
< 0.05	41	CCO 23	36	< 0.005	< 0.005	0.3	< 0.005	0.08	< 0.1	0.05	0.01	92	< 0.05
0.08	5.6	CCO 23	3.6	< 0.005	< 0.005	< 0.1	< 0.005	0.008	< 0.1	< 0.01	< 0.01	10	< 0.05
< 0.05	42	GCM 23	28	< 0.005	< 0.005	0.3	< 0.005	1.2	0.4	0.1	0.01	73	< 0.05
< 0.05	5.5	GCM 23	2.8	< 0.005	< 0.005	< 0.1	< 0.005	0.12	< 0.1	0.01	< 0.01	7	< 0.05
< 0.05	40	FCWN 23	13	< 0.005	< 0.005	0.4	< 0.005	1.1	0.7	0.07	< 0.01	41	< 0.05
< 0.05	5.6	FCWN 23	1.4	< 0.005	< 0.005	< 0.1	< 0.005	0.11	< 0.1	< 0.01	< 0.01	5	< 0.05
< 0.05	40	ZEO 23	28	< 0.005	< 0.005	0.4	< 0.005	0.93	0.5	< 0.01	< 0.01	4	< 0.05
< 0.05	5.5	ZEO 23	2.7	< 0.005	< 0.005	< 0.1	< 0.005	0.09	< 0.1	< 0.01	< 0.01	0.9	< 0.05
< 0.05	40	PWI 23	9.8	< 0.005	< 0.005	0.4	< 0.005	0.10	< 0.1	0.2	< 0.01	100	< 0.05
< 0.05	5.4	PWI 23	1.0	< 0.005	< 0.005	< 0.1	< 0.005	0.01	< 0.1	0.02	< 0.01	10	< 0.05
< 0.05	41	SNM 23	150	< 0.005	< 0.005	0.3	< 0.005	0.46	0.3	0.04	< 0.01	160	< 0.05
< 0.05	5.5	SNM 23	17	< 0.005	< 0.005	< 0.1	< 0.005	0.05	< 0.1	< 0.01	< 0.01	20	< 0.05
< 0.05	40	SDH 23	3.1	< 0.005	< 0.005	0.6	< 0.005	1.6	3	< 0.01	< 0.01	0.6	< 0.05
< 0.05	5.4	SDH 23	0.3	< 0.005	< 0.005	< 0.1	< 0.005	0.16	0.2	< 0.01	< 0.01	1	< 0.05
< 0.05	40	PBC 23	13	< 0.005	< 0.005	0.3	< 0.005	1.6	< 0.1	0.06	< 0.01	6	< 0.05
< 0.05	5.5	PBC 23	1.4	< 0.005	< 0.005	< 0.1	< 0.005	0.15	< 0.1	< 0.01	< 0.01	3	< 0.05
< 0.05	37	1PMO19	140	0.068	0.11	0.3	0.02	3.2	< 0.1	1.8	0.1	710	< 0.05
0.3	5.1	1PMO19	15	0.006	< 0.005	< 0.1	< 0.005	0.31	< 0.1	0.2	< 0.01	74	< 0.05
< 0.05	38	2PMO19	150	0.080	0.14	0.3	0.02	3.4	< 0.1	1.8	0.1	730	< 0.05
< 0.05	5.2	2PMO19	15	0.006	< 0.005	< 0.1	< 0.005	0.33	< 0.1	0.2	< 0.01	75	< 0.05
0.8	38	3PMO19	140	0.065	0.19	0.3	0.02	3.2	< 0.1	1.8	0.1	720	< 0.05
0.07	5.2	3PMO19	15	0.006	< 0.005	< 0.1	< 0.005	0.31	< 0.1	0.2	0.01	76	< 0.05

Table A 21. ICP - AES Results[a] for CRR Composition

Field No	Ag mg/L	Al %	As mg/L	Au mg/L	Ba mg/L	Be mg/L	Bi mg/L	Ca %	Cd mg/L	Ce mg/L	Co mg/L
FLW	< 2	6.6	< 10	< 8	1000	2	< 10	1.0	< 2	85	< 1
ACT	< 2	6.5	< 10	< 8	730	4	< 10	2.9	< 2	81	4
CHI	< 2	5.5	< 10	< 8	1700	4	< 10	0.82	< 2	150	< 1
CCO	< 2	6.1	< 10	< 8	630	2	< 10	1.6	< 2	67	< 1
GCM	< 2	6.2	< 10	< 8	1400	2	< 10	1.6	< 2	26	< 1
FCWN	< 2	6.8	< 10	< 8	660	5	< 10	1.4	< 2	71	< 1
ZEO	< 2	6.1	< 10	< 8	820	2	< 10	3.0	< 2	71	< 1
PWI	< 2	5.3	< 10	< 8	930	3	< 10	1.5	< 2	140	< 1
SNM	< 2	6.3	< 10	< 8	1100	3	< 10	2.2	< 2	88	< 1
SDH	< 2	6.2	12	< 8	750	3	< 10	1.5	< 2	69	3
PBC	< 2	6.1	< 10	< 8	1800	2	< 10	1.5	< 2	63	2

Field No	Cr mg/L	Cu mg/L	Eu mg/L	Fe %	Ga mg/L	Ho mg/L	K %	La mg/L	Li mg/L	Mg %	Mn mg/L
FLW	2	9	< 2	0.80	12	< 4	1.3	51	8	0.33	59
ACT	9	4	< 2	1.9	15	< 4	2.0	41	39	0.53	370
CHI	2	5	< 2	1.6	16	< 4	3.7	84	4	0.12	250
CCO	3	7	< 2	0.91	12	< 4	3.0	39	26	0.40	100
GCM	2	4	< 2	0.51	11	< 4	2.5	15	2	0.46	280
FCWN	5	5	< 2	0.46	15	< 4	3.1	41	32	0.26	71
ZEO	< 1	< 1	< 2	0.73	11	< 4	0.94	40	8	0.54	770
PWI	< 1	3	< 2	1.1	14	< 4	3.3	82	23	0.26	49
SNM	3	6	< 2	0.88	15	< 4	1.9	48	9	0.79	470
SDH	8	9	< 2	1.4	13	< 4	3.3	37	22	0.49	430
PBC	10	10	< 2	1.6	18	< 4	2.0	33	13	0.44	300

[a]Ag (< 2), Au (< 8), Bi (< 10), Cd (< 2), Eu (< 2), Ho (< 4), Mo (< 2), Sn (< 5), Ta (< 40), and U (< 100) have been omitted because the concentrations were less than the detection limites shown in parentheses.

Field No	Mo mg/L	Na %	Nb mg/L	Nd mg/L	Ni mg/L	P %	Pb mg/L	Sc mg/L	Sn mg/L	Sr mg/L	Ta mg/L
FLW	< 2	3.2	31	32	< 2	0.02	15	5	< 5	370	< 40
ACT	< 2	1.3	32	35	4	0.03	16	6	< 5	380	< 40
CHI	< 2	0.64	50	65	< 2	0.08	17	3	< 5	140	< 40
CCO	< 2	0.81	21	26	< 2	0.03	19	4	< 5	520	< 40
GCM	< 2	1.1	23	10	< 2	0.02	8	< 2	< 5	530	< 40
FCWN	< 2	2.1	28	29	< 2	0.008	20	4	< 5	260	< 40
ZEO	< 2	0.79	17	28	< 2	0.01	< 4	3	< 5	510	< 40
PWI	< 2	0.41	50	54	< 2	0.01	15	3	< 5	120	< 40
SNM	< 2	0.45	32	31	3	0.02	24	3	< 5	1800	< 40
SDH	< 2	2.1	22	25	4	0.06	18	4	< 5	480	< 40
PBC	< 2	1.8	16	33	4	0.02	14	4	< 5	440	< 40

Field No	Th mg/L	Ti %	U mg/L	V mg/L	Y mg/L	Yb mg/L	Zn mg/L
FLW	20	0.12	< 100	9	27	2	53
ACT	22	0.21	< 100	25	44	4	80
CHI	23	0.16	< 100	3	81	8	110
CCO	23	0.14	< 100	19	20	2	34
GCM	5	0.06	< 100	4	16	1	44
FCWN	17	0.14	< 100	19	33	3	45
ZEO	25	0.12	< 100	8	29	3	38
PWI	30	0.17	< 100	< 2	52	5	42
SNM	25	0.14	< 100	9	32	3	53
SDH	16	0.18	< 100	23	24	2	58
PBC	7	0.14	< 100	20	46	5	120