Evaluation of Mozley C800 Laboratory Mineral Separator for Heavy Mineral Concentration of Stream Sediments in Exploration for Carbonatite-Hosted Specialty Metal Deposits: Case Study at the Aley Carbonatite, Northeastern British Columbia (NTS 094B)

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Introduction

Finding tools to explore for overburden-covered or poorly exposed ore deposits is one objective of Natural Resources Canada's Targeted Geoscience Initiative 4 (TGI-4). Indicator minerals and geochemical studies are particularly effective tools. General principles about stream sediment surveys are given by Levinson (1974), Hawkes (1976), Rose et al. (1979) and Fletcher (1997). Lett (2007), Friske (2005) and McCurdy et al. (2006, 2009) provided guidelines for regional geochemical surveys. Methods for regional indicator mineral studies at the regional scale are also well established (McCurdy et al., 2006, 2009; McClenaghan, 2011). Indicator mineral studies generally require large samples that need to be treated by heavy liquid separation, isodynamic magnetic separation, optical identification and hand picking. The limited budgets of exploration companies targeting specific deposit types or commodities, or following up on regional geochemical or indicator mineral surveys, necessitate a more focused, customized approach. One of the objectives of the specialty metal component of the TGI-4 is to develop simpler, more inexpensive methods to explore for rare earth element (REE), niobium (Nb) and, potentially, tantalum (Ta) deposits. This research comprises three stages.

Stage one involved stream sediment sample collection, characterization of the carbonatite-related deposits and chemical analyses of the sediments from the Aley carbonatite (large, high-grade Nb deposit; Mackay and Simandl, 2014a), Wicheeda Lake carbonatite (high-grade REE deposit; Mackay and Simandl, 2014b) and Lonnie carbonatite (modest-grade Nb and REE deposit; Luck and Simandl, 2014). Geochemical stream sediment surveys commonly rely on the <177 µm (–80 mesh) size fraction (Fletcher, 1997). In contrast, the size fractions commonly used for hand picking and indicator mineral studies vary from 0.25 to 2.0 mm (McClenaghan, 2011). The stage one orientation surveys examined the optimal grain-size fraction for indicator mineral studies. Stage two comprises evaluation of rapid, low-cost methods to produce heavy-mineral concentrates for specialty metal exploration, using indicator minerals containing Nb, Ta and light rare earth elements (LREE [La, Ce, Pr, Nd]). Processing results for synthetic standards (prepared for this purpose) and Aley carbonatite stream sediments using the Mozley C800 laboratory mineral separator (MMS) are presented here. Stage three considers the use of custom microscope, scanning electron microscope (SEM), QEMSCAN®, mineral liberation analyzer (MLA) and electron microprobe analyses to reduce the need for hand picking of minerals and will be presented elsewhere.

Deposit Characterization, Geological Setting

The Aley carbonatite is 290 km north of Prince George, British Columbia (Figure 1 inset), and outcrops over a 3 to 3.5 km diameter area (Figure 1; Mäder, 1986; McLeish,

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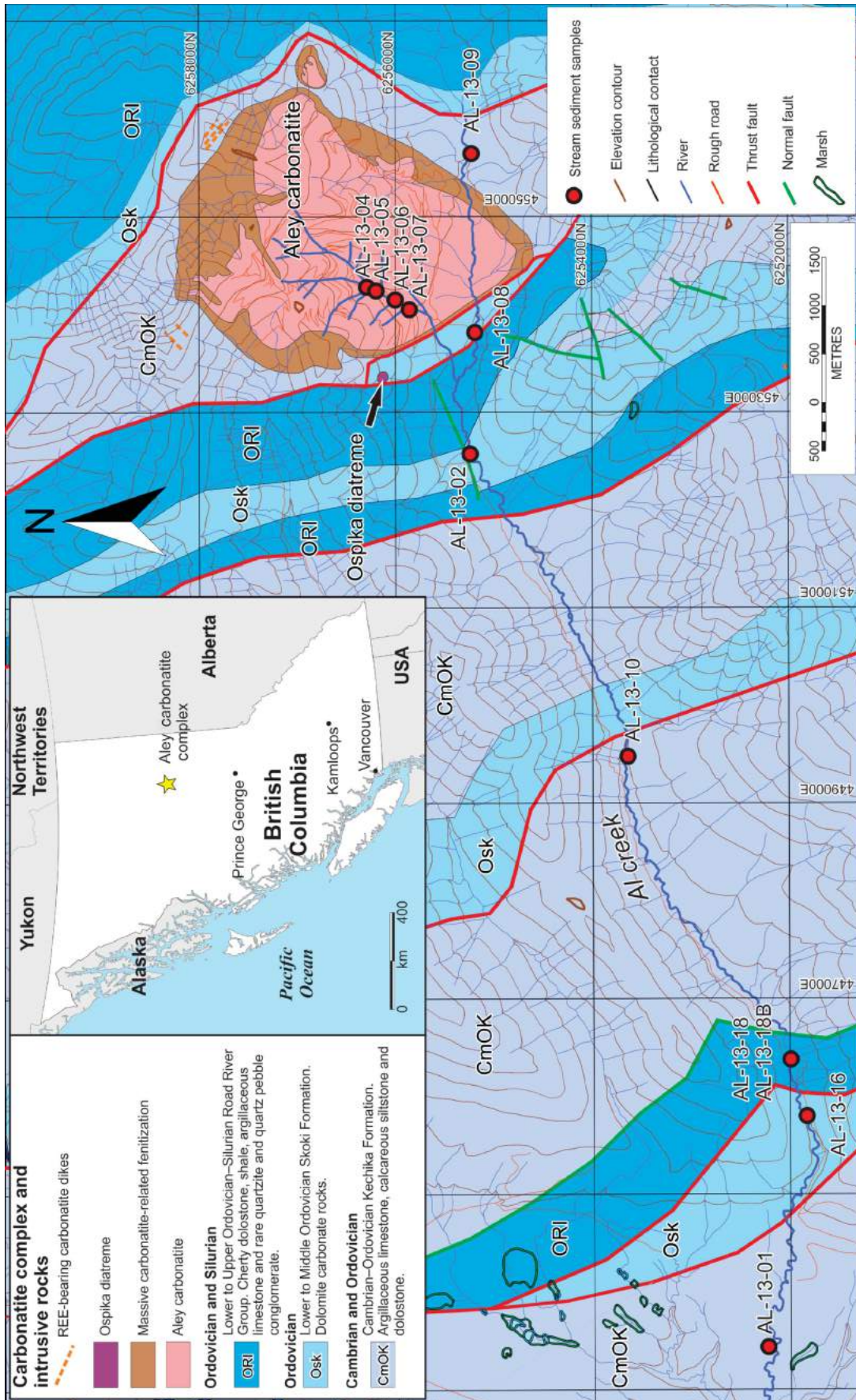
Figure 1. Location and geology of the Aley carbonatite, northeastern British Columbia. Stream sediment sample locations are denoted by red circles. Modified after Pride (1983), Mäder (1986), Massey et al. (2005), McLeish (2013) and Mackay and Simandl (2014a). Abbreviation: REE, rare earth element.

2013). Measured and indicated resources are 113 million tonnes at 0.41% Nb_2O_5 and 173 million tonnes at 0.35% Nb_2O_5, respectively, with a cutoff grade of 0.20% Nb_2O_5 (Simpson, 2012). The main phase of the carbonatite is predominantly dolomite surrounded by a minor calcite carbonatite phase. The dolomite carbonatite contains apatite, pyrite, calcite, fersmite, columbite-(Fe) and pyrochlore (Kressell et al., 2010). Magnetite pods tens of centimetres to metres in size are found throughout. These pods also contain apatite, phlogopite, pyrochlore, columbite-(Fe), fersmite, zircon and carbonate minerals (Mäder, 1986; Kressall et al., 2010). The carbonatite is surrounded by a zone of fenitized (Na and K hydrothermally altered) country rock containing richterite, arfvedsonite, aegirine and albite. Fenitization intensity varies from pervasive massive alteration (near the carbonatite contact) to millimetre- to centimetre-scale veins containing Na-amphiboles and feldspars (distal to the carbonatite contact).

The Aley carbonatite intruded into platformal carbonate and siliciclastic rocks of the Cambrian–Ordovician Kechika Formation, Lower to Middle Ordovician Skoki Formation and Lower to Upper Ordovician–Silurian Road River Group (Figure 1; Irish, 1970; Mäder, 1986; Pyle and Barnes, 2001). The carbonatite is older than 365.9 ±2.1 m.y.

(McLeish, 2013) and younger than the Lower to Upper Ordovician–Silurian Road River Group (Mäder, 1986; Pyle and Barnes, 2001). Regional lower-greenschist–facies metamorphism coincided with compressional deformation at ca. 155 and 50 m.y. (Read et al., 1991; Pell, 1994) and overprints the rocks in the area, including the carbonatite (Mäder, 1986; McLeish, 2013).

Summary of Previous Work

Twelve stream sediment samples were collected from the stream draining the Aley carbonatite (Mackay and Simandl, 2014a). Eleven samples were collected directly over and downstream (up to 11.5 km) of the carbonatite; one was collected upstream (Figure 1). Samples were prescreened in the field; material that passed through an 8 mm sieve was kept in permeable canvas bags. Samples were dry sieved into eight size fractions (>4 mm, 2–4 mm, 1–2 mm, 500 µm–1 mm, 250–500 µm, 125–250 µm, 63–125 µm and <63 µm). The follow-up laboratory sample preparation, dry sieving procedure and analytical methods leading to the selection of the ideal size fraction for the follow-up study are described by Luck and Simandl (2014) and Mackay and Simandl (2014a). Dry sieved but otherwise unprocessed stream sediment samples will be referred to here on as raw samples.
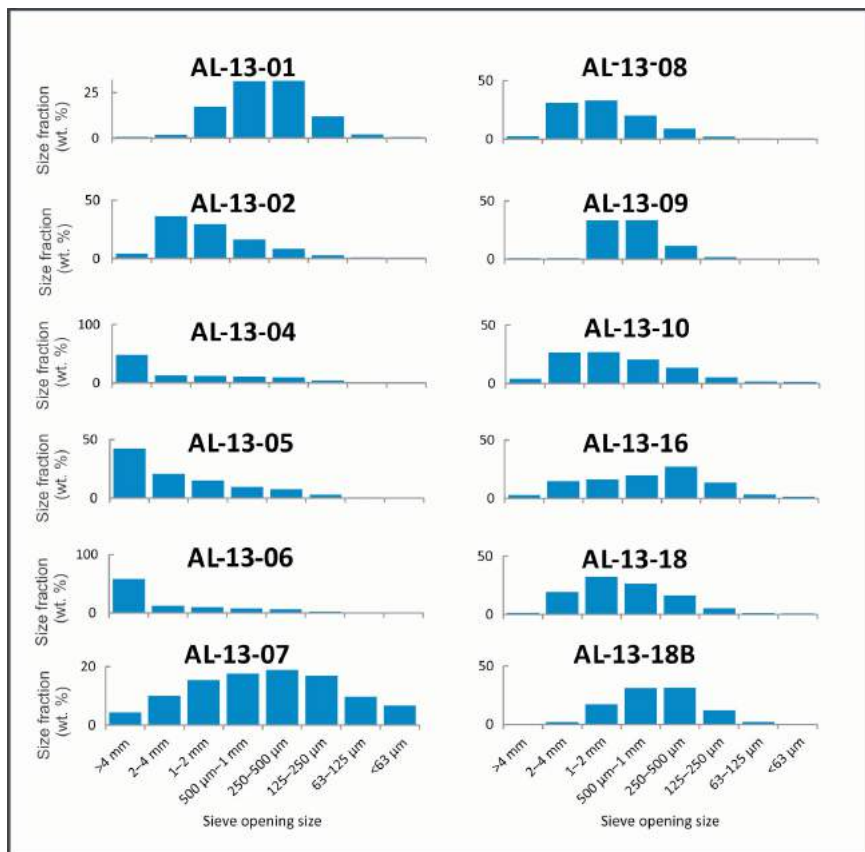
The distribution of size fractions in stream sediments from the Aley carbonatite vary in different reaches of the creek (Figure 2). Samples downstream of the deposit (AL-13-01, AL-13-02, AL-13-08, AL-13-10, AL-13-16, AL-13-18, AL-13-18B) show a more balanced size-fraction distribution (either slightly skewed toward a coarser fraction or approaching a normal bell-shape distribution) than those from over the deposit (AL-13-04, AL-13-05, AL-13-06). The latter samples show distribution patterns skewed toward the coarsest fractions. Sample AL-13-07 was also collected over the deposit but where the stream gully cuts through >5 m of overburden (downslope of a major scree slope) and shows a normal distribution of material between size fractions. Sample Al-13-09 collected upstream of the deposit (in a meandering reach of the creek) is somewhat unique, with very little material coarser than 2 mm.

Figure 2. Weight percent distribution of material for different size fractions in dry sieved stream sediment samples from the Aley carbonatite drainage area, northeastern British Columbia (Mackay and Simandl, 2014a)

Approximately 10 g of each raw sample was split using a riffle-style split-

ter, milled, prepared in standard X-ray diffraction sample cups and analyzed using a Thermo Scientific Niton® FXL-950 as described by Luck and Simandl (2014). The 125–250 μm fraction (Figure 3) shows elevated levels of elements associated with carbonatite-hosted Nb deposits (Nb, Ta and LREE [La, Ce, Pr, Nd]) relative to other size fractions. This, and equivalent studies at the Wicheeda Lake (Mackay and Simandl, 2014b) and Lonnie carbonatites (Luck and Simandl, 2014), indicates that the 125–250 μm fraction is the most appropriate to explore for specialty metal deposits in the Canadian Cordillera. Based on the distribution of material in the different size fractions of each sample and the concentration of potential pathfinder elements associated with carbonatite-hosted Nb deposits, the
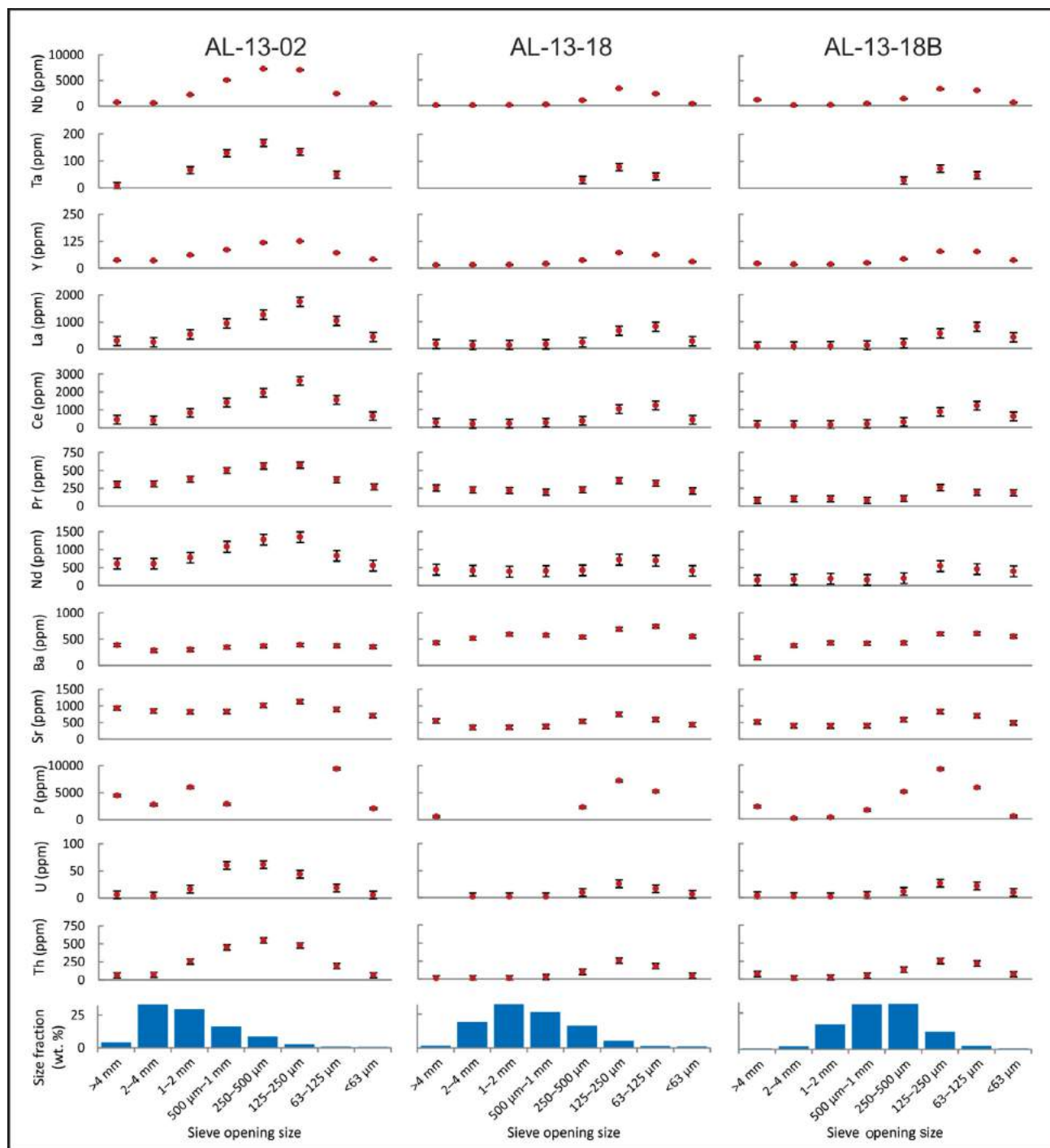

Figure 3. Concentration of selected elements associated with carbonatites for each size fraction of stream sediment samples from the Aley carbonatite drainage area, northeastern British Columbia. Modified after Mackay and Simandl (2014a).

125–250 µm size fraction was selected for geochemical and indicator mineral studies. The 63–125 µm and 250–500 µm size fractions could have also been used.

Assessment of the Mozley C800 Laboratory Mineral Separator Procedure

The Mozley C800 laboratory mineral separator (MMS) is a light and compact alternative to the shaker tables and gravity concentrators that are commonly used by metallurgists. The v-profile tray, best suited for coarse grain sizes (100 µm–2 mm), was used for this study instead of a flat tray, traditionally used for finer grain sizes (~100 µm or less). The MMS set up parameters were: 1.75° longitudinal slope; 70 rpm table speed; 6.35 cm amplitude (throw or stroke); and 1.6 L/min water flow rate. Specifications and detailed operating procedures for the MMS are described in the instrument manual (Mozley Inc., undated). Optimal operating conditions are determined by running synthetic standards.

Processing Procedure

The operating procedure is relatively simple once optimal conditions for sample processing are identified. Dry sieved (125–250 µm size fraction) samples weighing ~75 g are

Figure 4. A sample being poured onto a Mozley C800 laboratory mineral separator. Water is supplied to the v-profile tray by the wash water pipe (copper tube) and the irrigation pipes (two white plastic tubes with water outlets at regular intervals). The direction of water flow is denoted by black arrows.

gradually poured from a beaker onto the table and thoroughly wetted at the wash water pipe (Figure 4). A spray bottle is used to remove all material from the beaker. Tailings (low density material) separate first, moving longitudinally down the trough in the direction of water flow. The tailings are collected at the end of the table. Once the selected time interval is reached, the table and water are turned off. Tailings, middlings and concentrate are separated and carefully washed into separate containers. The concentrate consists of the highest density material in the sample. The middlings are a transition zone between the tailings and concentrate. They contain medium-density material and a mixture of low- and high-density minerals. The division of sediment into concentrate, middlings and tailings is visually discernable by shape and, to a lesser extent, colour (which in this study reflects the proportion of heavy minerals; Figure 5).

Following a sample run, suspended particles are allowed to settle, excess water is decanted from the concentrate, middlings and tailings containers and the fractions are dried overnight at 90°C then weighed for quality control and bagged separately. This procedure allows for samples to be reconstituted and reprocessed if needed. The same procedure was used to process all synthetic samples (standards) and multiple splits of a natural stream sediment sample collected in the field to determine optimal operating conditions and run time. Once the optimal operating conditions were determined, table speed, slope, water flow rate, throw amplitude and size of the samples were kept constant. A portion (~75 g) of the 125–250 µm fraction of each stream sediment sample was split and processed on the MMS. After processing, concentrate, middlings and tailings were analyzed by portable X-ray fluorescence (pXRF) spectrometer.

Optimizing Operating Conditions Based on Synthetic Samples

Testing and optimizing operating conditions for the MMS were performed using synthetic standards and a quintet of subsamples split from the natural sample AL-13-16. Synthetic standards contained 75 g of material made up of magnetite (0.33–10 wt. %), garnet (0.33–10 wt. %), fluorite (0.33–10 wt. %) and quartz (remaining portion of the stan-

Figure 5. View of the surface of the Mozley C800 laboratory mineral separator table and sample material after a completed run. Concentrate, middlings and tailings are separated based on pattern and colour of the material stream.

dard sample). All constituents of the synthetic standards were milled and sieved to the 125–250 µm size fraction (compatible with the size fraction identified previously for testing). Magnetite in MMS concentrates increased by 5.5 to 228.2 times relative to unprocessed synthetic standards. The strong correlation (R^2=0.98) between magnetite contained in unprocessed standard samples and MMS concentrates indicates consistent and predictable concentration of standards (Figure 6).

Optimizing Operating Conditions Using Natural Samples

One of the larger natural samples (AL-13-16) was split using a riffle splitter into five identical subsamples (~75 g)
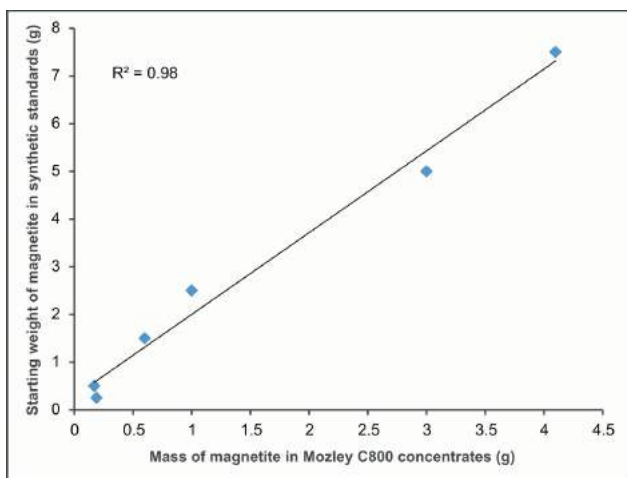

Figure 6. Comparison of the weight of magnetite contained in unprocessed synthetic standards with corresponding weight of magnetite in Mozley C800 laboratory mineral separator concentrates (from Aley carbonatite drainage area, northeastern British Columbia).
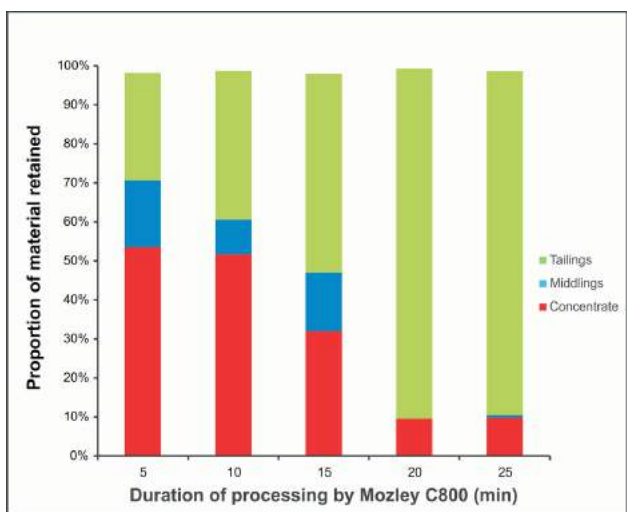
and these subsamples were processed for 5, 10, 15, 20 and 25 minutes (Figure 7). The proportion of retained concentrate decreases with increasing processing time when all other parameters are kept constant (Figure 7). Reproducibility of the MMS was tested on three subsamples (~77 g each) of AL-13-16 processed for 25 minutes. The retained concentrate fraction varied only slightly with observed weights representing 12, 9.4 and 9.9% of the initial sample weights. Based on these tests, a processing time of 15 minutes was selected for processing stream samples from the Aley carbonatite. The 15-minute run time is a compromise that ensures adequate concentration of heavy minerals (magnetite) and minimal loss to tailings.

Results

Mozley C800 Laboratory Mineral Separator and Geochemical Analyses

Separation by MMS of the 125–250 µm fraction of stream sediment samples from the Aley carbonatite drainage area produced a range in proportions of concentrate (3.8–32.0%), middlings (0–17.1%) and tailings (51.0–94.1%). Ten out of twelve samples show 24.7 to 32.0% of material retained in concentrate, consistent with the desired proportion of material retained in concentrate for the sample (AL-13-16) used to test the separation procedure (Figure 8). Only sample AL-13-09 shows noticeably lower proportions of retained concentrate (3.8%).

Raw samples (Table 1) and MMS concentrates (Table 2) from the Aley carbonatite drainage area were analyzed by pXRF following the procedure described by Luck and Simandl (2014) and Mackay and Simandl (2014a). Abundances of Nb in MMS concentrates increased by a factor of 2.7 to 17.2 (average of 4.3) relative to the raw samples (Figure 9a). For samples with available analyses, concentration

Figure 7. Proportions of concentrate, middlings and tailings in five subsamples of AL-13-16 (Aley carbonatite drainage area, northeastern British Columbia) after processing on the Mozley C800 laboratory mineral separator for 5, 10, 15, 20 and 25 minutes.
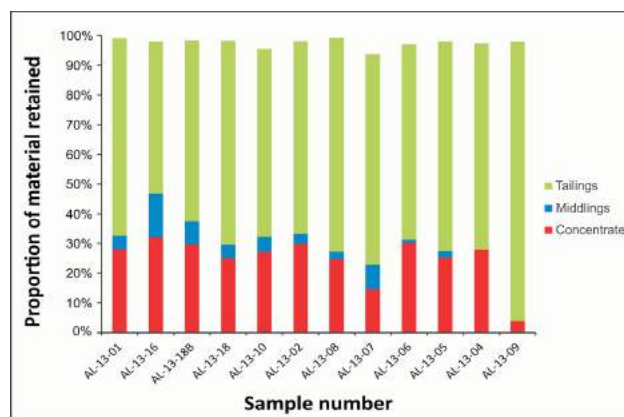

Figure 8. Proportions of Mozley C800 laboratory mineral separator concentrates, middlings and tailings for stream sediment samples from the Aley carbonatite drainage area, northeastern British Columbia. Samples were processed for 15 minutes. Samples appear in order of their geographic location from west to east (see Figure 1 for sample locations).

of Nb is 2.4 to 9.9 times higher in concentrates relative to middlings (Table 2). The MMS concentrates also show large increases in the concentration of Ta (factor of 1.5 to 11.7; average of 3.1) and LREE (factor of 2.6 to 12.6; average of 3.9) relative to raw samples (Figure 9b, c).

Discussion

Processing samples using a MMS permits separation of dense indicator minerals. Pyrochlore (4.2–6.4 g/cm^3), columbite-(Fe) (5.3–7.3 g/cm^3), fersmite (4.69–4.79 g/cm^3), monazite (4.8–5.5 g/cm^3) and REE-fluorocarbonates, such as bastnaesite (4.95–5.00 g/cm^3) and synchysite (3.90–4.15 g/cm^3), have been identified in mineralogical studies of the Aley carbonatite (Mäder, 1986; Kressall et al., 2010; Chakhmouradian et al., 2014) and targeted as indicator minerals for carbonatite-hosted specialty metal deposits in this study. These minerals have similar or greater densities than magnetite (5.1–5.2 g/cm^3) in the synthetic standards used herein. Based on the consistent and effective concentration of magnetite from the synthetic standards, the targeted heavy mineral fraction should be retained effectively in MMS concentrates.

Comparison of the results of the pXRF analyses of raw samples and MMS concentrates, middlings and tailings shows that the concentration of Nb-, Ta- and LREE-bearing heavy minerals was successful. High concentrations of Nb (average increase by a factor of 4.3) in MMS concentrates relative to tailings and corresponding raw samples (Figure 9a) indicate that most of the Nb-bearing minerals (pyrochlore, columbite-(Fe) and fersmite) were successfully concentrated by the MMS. The correlation (R^2=0.94) between Nb in raw samples and MMS concentrates (Figure 10a) indicates that the procedure consistently and efficiently concentrates pyrochlore, columbite-(Fe) and fersmite in all samples in the range of 2000 to 30 000 ppm Nb. The correlation (R^2=0.86) between Fe in raw samples and

concentrates indicates magnetite was successfully concentrated.

High Ta contents (average increase by a factor of 3.1) in MMS concentrates relative to tailings and raw samples (Figure 9b) are likely due to pyrochlore and columbite-(Fe); however the Ta/Nb ratio for these minerals in carbonatites is typically very low. The lack of correlation between Ta concentrations in raw samples and concentrate (R^2=0.23; Figure 10b) is likely due to low (near detection limit) contents. Also, the elemental concentration for two concentrates (AL-13-09 and AL-13-05) had to be calculated because the amount of material retained following Mozley separation was insufficient for chemical analyses (Table 2). In these cases, elemental concentration can be calculated based on initial concentrations measured in raw samples and analyses of tailings and middlings (normalized to wt. % of retained material). Error propagation from analyses near detection limits combined with error in weights of raw samples, concentrates, middlings and tailings makes calculated concentrations unreliable. Despite this, the calculated elemental concentrations for AL-13-05 do not appear to dramatically affect the results. Sample AL-13-09 was collected upstream of the Aley carbonatite and is unique in the sample set (Figure 1). It shows a different grain size distribution relative to the other samples (Figure 2), and lower proportions of retained concentrate (3.8%; Figure 8). Elemental concentrations of Nb, Ta and LREE in raw samples are also much lower than in other samples (Figure 9). This may reflect background levels of heavy minerals in the Aley carbonatite area, and the different flow characteristics of the creek (meandering reach) upstream of the deposit.

Concentrations of LREE are also high (average increase by a factor of 3.9) in MMS concentrates relative to tailings and raw samples (Figure 9c). Combined with correlations for

Table 1. Relative concentrations (in ppm) of major and minor elements associated with carbonatite from raw stream sediment samples, analyzed by portable X-ray fluorescence spectrometer. Samples are listed from upstream of, to directly over, and with increasing distance downstream of the Aley carbonatite, northeastern British Columbia. See Figure 1 for sample locations. From Mackay and Simandl (2014a).

Sample no.	Nb	Ta	La	Ce	Pr	Nd	Y	Ba	Sr	P	U	Th	Fe	Ca
AL-13-09	444	28	184	288	188	351	29	324	177	1885	9	53	15968	78201
AL-13-04	9971	131	1592	2647	660	1585	170	355	2013	n.d.	31	589	90204	209044
AL-13-05	8647	120	1521	2466	614	1453	156	379	1655	n.d.	32	534	87093	198956
AL-13-06	7977	123	1536	2447	623	1443	155	380	1591	n.d.	36	497	90654	193408
AL-13-07	615	23	316	505	289	580	34	244	688	4215	6	68	22375	186264
AL-13-08	6695	135	2010	2977	599	1421	124	421	1054	n.d.	40	461	79669	160338
AL-13-02	7036	134	1746	2599	565	1326	125	379	1126	n.d.	43	474	77903	169329
AL-13-10	5543	110	1280	1918	520	1161	104	505	944	n.d.	40	376	65852	165451
AL-13-18	3311	78	662	1025	355	721	71	688	747	7221	26	255	42845	154081
AL-13-18B	3361	73	561	866	259	542	77	598	827	9203	27	251	39801	166097
AL-13-16	5246	101	1083	1648	470	1028	93	910	745	n.d.	36	355	59782	149924
AL-13-01	3495	79	596	936	346	724	72	670	711	7117	26	266	40852	156997

Abbreviation: n.d., not detected

Table 2. Relative concentrations (in ppm) of major and minor elements associated with carbonatite from Mozley C800 laboratory mineral separator concentrates, middlings and tailings from stream sediment samples, analyzed by portable X-ray fluorescence spectrometer. Samples are listed from upstream of, to directly over, and with increasing distance downstream of the Aley carbonatite, northeastern British Columbia. See Figure 1 for sample locations. Error propagation and elemental concentrations near the limit of detection greatly reduce the reliability of calculated values.

Sample no.	Nb	Ta	La	Ce	Pr	Nd	Y	Ba	Sr	P	U	Th	Fe	Ca
Concentrate														
AL-13-09[1]	7635	327	1725	2688	1222	2210	223	976	842	34659	109	791	80156	162926
AL-13-04	26514	193	3857	6347	1061	2853	343	364	2076	n.d.	73	788	194756	193214
AL-13-05[1]	26389	325	4130	6593	1295	3235	365	664	2030	n.d.	87	1516	213404	222021
AL-13-06	21571	217	3785	6031	1029	2730	319	407	1779	n.d.	76	785	185251	190196
AL-13-07	2262	48	694	1076	354	762	72	218	987	10791	14	164	37475	223300
AL-13-08	23076	292	7325	11001	1373	3832	339	501	1275	n.d.	120	987	233457	150235
AL-13-02	21400	335	5541	8420	1153	3198	327	459	1464	n.d.	133	961	210258	175782
AL-13-10	17271	279	4047	6154	963	2611	277	773	1383	n.d.	111	942	169748	185713
AL-13-18	11923	176	2341	3600	734	1804	203	1225	1184	n.d.	84	573	114173	191843
AL-13-18B	10227	182	1869	2906	640	1534	184	1084	1204	n.d.	80	591	88135	194940
AL-13-16	14603	290	3023	4605	798	2006	229	1595	1059	n.d.	95	874	139688	172378
AL-13-01	11481	183	1795	2808	616	1486	189	1018	1112	n.d.	78	700	95421	189733
Middlings														
AL-13-07	939	27	325	502	184	359	46	158	874	6941	7	87	23952	213935
AL-13-18B	1547	23	327	529	163	362	60	335	996	11701	13	126	25994	190527
AL-13-16	1483	27	413	672	280	553	57	410	957	10436	13	124	26276	188037
Tailings														
AL-13-09	163	17	126	197	150	283	22	305	154	597	5	24	13718	76492
AL-13-04	3704	55	792	1356	476	1026	110	298	2027	21556	15	273	52382	215621
AL-13-05	2804	54	676	1134	406	901	91	299	1619	15708	14	214	47007	202470
AL-13-06	2487	47	689	1133	425	904	86	310	1524	13871	15	196	48808	194605
AL-13-07	279	n.d.	231	370	257	500	25	244	640	1686	6	39	18900	178263
AL-13-08	612	33	275	450	243	489	34	296	948	3624	10	62	21832	156680
AL-13-02	741	38	307	478	257	516	37	296	947	3959	11	74	22482	157974
AL-13-10	298	n.d.	190	330	220	426	27	318	744	2388	7	41	19832	151534
AL-13-18	320	17	164	282	192	354	26	501	590	1865	6	36	18935	140844
AL-13-18B	239	n.d.	180	294	211	412	25	473	625	2255	5	37	17959	149069
AL-13-16	242	22	171	265	199	352	23	552	529	<90	6	35	19601	124735
AL-13-01	284	28	157	271	190	347	24	496	528	1845	7	34	17322	137060

[1] Calculated values
Abbreviation: n.d., not detected
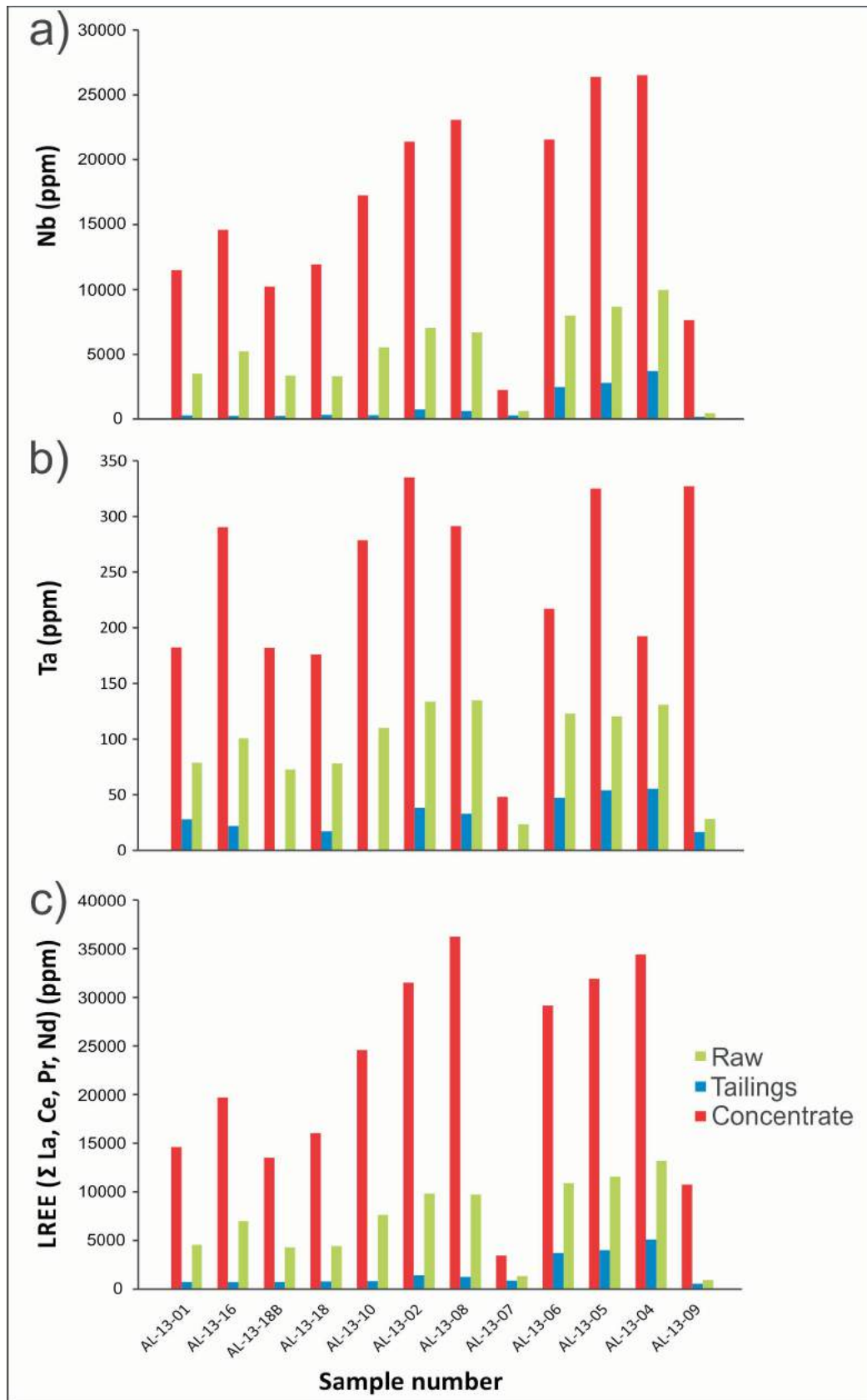
Figure 9. Comparison of **a)** Nb, **b)** Ta and **c)** LREE (ΣLa, Ce, Nd, Pr) concentrations in Mozley C800 laboratory mineral separator concentrates, tailings and corresponding raw samples. Samples appear in order of their geographic location from west to east (see Figure 1 for sample locations).
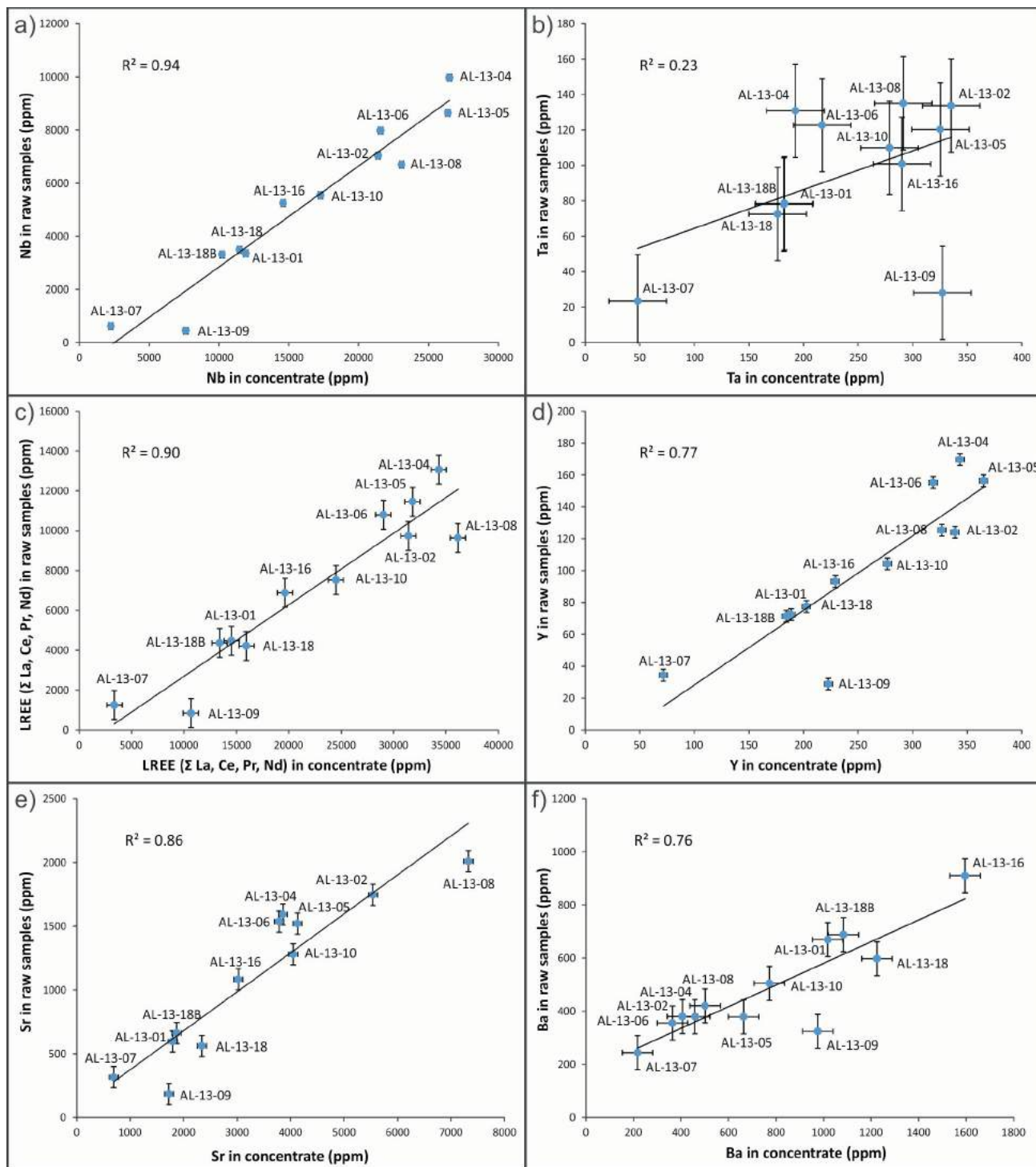
Figure 10. Comparison of the concentrations of **a)** Nb, **b)** Ta, **c)** light rare earth elements (LREE), **d)** Y, **e)** Sr and **f)** Ba in Mozley C800 laboratory mineral separator concentrates versus raw samples (from Aley carbonatite drainage area, northeastern British Columbia). Error bars (2σ) are based on repeated portable X-ray fluorescence analyses of standards.

LREE (R^2=0.90; Figure 10c) and Y (R^2=0.77; Figure 10d), this indicates that heavy minerals, such as monazite and REE-bearing fluorocarbonates (e.g., bastnaesite and synchysite), were concentrated during Mozley separation in the range of 3000–40 000 ppm LREE. Correlation for Sr (R^2=0.86; Figure 10e) and Ba (R^2=0.76; Figure 10f) in raw samples and MMS concentrate indicate that the carbonatite signature in stream sediments is preserved following MMS concentration. The low coefficients of determination for Th (R^2=0.44) and U (R^2=0.43) are due to low concentrations (near detection limits) in samples AL-13-09 and AL-13-07 and the error propagation issue described for Ta.

The MMS is lighter and easier to transport than other density separator equipment, such as shaker tables. The method presented by this study is able to effectively detect and amplify a weak carbonatite signature up to 11.5 km from its source. The small sample size required for Mozley separation also allows for increased sampling efficiency during exploration programs.

Conclusions

The Mozley C800 laboratory mineral separator is a compact, simple to operate instrument that can be transported and optimized for specific drainages, deposits or commodities. After selecting the most favourable size fraction (125–250 μm, dry sieved, in this study), the MSS was used to increase the heavy mineral content of the stream sediment samples from the drainage area surrounding the Aley carbonatite-hosted specialty metal deposit. This is substantiated by increased concentrations of Nb (average factor of 4.3), Ta (average factor of 3.1) and LREE (average factor of 3.9) in MMS concentrates relative to corresponding raw samples. Correlations between Nb, LREE and Y concentrations in the raw stream sediment samples and corresponding concentrates indicate that Nb- and LREE-bearing minerals (such as pyrochlore, columbite-(Fe) and REE-bearing fluorocarbonates) were consistently concentrated, and that a predictable relationship between indicator mineral counts in raw stream sediments samples and concentrates should be expected. Extending this study, the plan is to examine microscope, SEM, QEMSCAN, MLA and electron microprobe methods to eliminate the need to hand pick indicator minerals.

Acknowledgments

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