CANADIAN MINING INDUSTRY RESEARCH ORGANIZATION (CAMIRO) EXPLORATION DIVISION

Project 08E01

Multi-media Techniques for Direct Detection of Covered Unconformity Uranium Deposits in the Athabasca Basin

FINAL REPORT

Biogeochemical Surveys at Cigar West, and McClean South: Athabasca Basin, Saskatchewan

Open Jack Pine Forest with Scattered Black Spruce – Cigar Lake West

Colin E. Dunn, PhD, P.Geo
Consulting Geochemist
Sidney, BC

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Executive Summary

Spruce twigs were collected at Cigar Lake from 112 sample stations in 2008 and 86 stations in 2009. The collection from McClean Lake comprised samples from 103 stations in 2008 and 61 in 2009.

From a modified aqua regia digestion (AR) of dry twig tissue, determinations of 64 elements in all samples were made by ICP-MS. In addition, all samples from Cigar Lake collected in 2008 and selected samples from McClean Lake were analyzed by high resolution ICP-MS following two separate digestion procedures: 1) Bioleach and 2) Sodium pyrophosphate (NaPyr).

Each of the three leaches yielded differing concentrations of elements, but plots showing the spatial distributions were remarkably similar for many elements attesting to the robustness of the biogeochemical signature. Furthermore, the Bioleach provided data for several elements not readily determined from the aqua regia leach – notably Br which was enriched by an order of magnitude in trees growing over mineralization occurring beneath 440 of sandstone. The NaPyr data were of less use, largely because of the poor precision for many elements.

Compared to the Cigar Lake data, the AR leach shows that there is at McClean Lake relative enrichment in Al, As, Bi, Cd, Co, Fe, Hf, Li, Mo, Nb, Ni, Pb, REE, Th, Ti, U and Zr. Cigar Lake has higher concentrations of Ba, Cs and Tl. It is noteworthy that, compared to usual background values, U is markedly enriched in both areas and especially at McClean Lake – up to almost 100 times normal background values. However, within each area U concentrations are only 2 to 5 times local background. The absolute U concentrations compare favourably with those recorded 30 years ago when samples were collected within a few weeks of the initial drill-hole discovery at McClean Lake.

At Cigar Lake, plots of the spatial distributions of several elements showed patterns that appear related to the Cigar West zone of U mineralization, present beneath approximately 440 m of Athabasca Sandstone and several metres of glacial overburden. Of note are Ba, Sr, Br, Co, Ni, Pb, REE and U.

At McClean Lake, above mineralization located beneath 160 m of Athabasca Sandstone and a few metres of glacial overburden, a similar suite of elements (plus Bi, Mo, As, and Cd) have higher concentrations than at Cigar Lake and exhibit enrichments extending westward over the McClean South mineralization.

Follow up sampling in 2009 was to more firmly establish 'background' levels of elements; to determine the reproducibility of the data by resampling; and to undertake some 'infill' sampling between lines sampled in 2008 to assess the continuity of some anomalous trends in the data.

By extending sampling farther to the north and south at both Cigar and McClean the background was established with samples yielding element concentrations close to the median levels (a geochemical estimate of background) of the complete dataset. The new data confirm that anomalous signatures of elements in the vicinities of the zones of mineralization are, with rare exceptions, confined to those areas.

Reproducibility of values by resampling some sites in 2009 showed the expected variance because of seasonal changes in plant chemistry (2008 survey was in June; the 2009 survey in August). However, in the dominant boggy conditions at McClean Lake the reproducibility of analytical data from twig samples was quite good and extremely good for some elements (e.g. Mo and Pb). At Cigar Lake element concentrations were lower with concomitant poorer reproducibility (poor precision close to detection limits). Most elements yielded higher concentrations in the June survey (a period of vigorous plant growth), with U showing some of the greatest differences (2.6 times higher in June). Over all it appeared that seasonal differences were greater in well-drained areas (Cigar) than those of slow growth in bogs (McClean). Seasonal variations can be allowed for by levelling the data to a common time datum. For many elements differences are so small that this is not necessary.

Among the highlights of the biogeochemical survey the following element distribution patterns and associations are:

1. Cigar Lake: Anomalous concentrations of Sr and Ba over the zone of mineralization provide some of the most distinct signatures. They suggest a carbonate or calc-silicate source. Additionally, there is a good relationship of Ni and Br, and weaker associations (moving outward from mineralization) of Co, U, Pb and REE. Near the eastern shore of Cat Lake several elements are enriched at the junction of several faults interpreted by Cogema from geophysical data (U, Co, Sr, Ba, Pb, REE, Cd, P, Fe, Mn, Mo, Ag, Sn, Zn, In). This area could be another locus of mineralization.
2. McClean Lake: Signatures of element concentrations in plants from over McClean South are much stronger in the commodity metals (and pathfinders) than at Cigar Lake, probably because of the shallower depth to mineralization. Elements giving the strongest indications include U, Mo, Bi, Pb, Co, Ni, Cd, As, Fe, and REE.

It is concluded that the spruce twigs reflect mineralization at both Cigar Lake West and McClean South. At McClean Lake South, where mineralization occurs beneath about 160 m of Athabasca Sandstone covered by several metres of glacial overburden, the signatures of many commodity-related elements are robust and stand out clearly from the surrounding area. At Cigar West, where mineralization lies mostly beneath 440 m of Athabasca Sandstone, covered with a few metres of glacial overburden, the geochemical signature is less pronounced, although there are strong signatures of several elements – notably Sr, Ba, Ni and Br. The evidence is compelling that elements migrate to the surface from deeply buried mineralization.

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1 Physical Environment and Geological Summary

Vegetation throughout much of the Athabasca Basin, including the survey areas, is typical of the boreal forest that covers large tracts of northern latitudes. It is dominated by jack pine (*Pinus banksiana*) and black spruce (*Picea mariana*). Occasional small stands of white birch occur in well-drained areas, whereas lowlands commonly contain muskeg varying from wet, non-treed areas to stands of variable tree density dominated by stunted black spruce with some tamarack (*Larix laricina*). Under-story shrubs are dominated by Labrador tea (*Ledum groenlandicum*) and alder (*Alnus spp.*).

Soils are dominated by podsols developed on a sandy substrate that has developed on a veneer of glacial deposits. Rarely, in wet areas, a gleysol is developed. At Cigar West the ground is mostly well-drained and the dominant tree is jack pine. At McClean Lake, especially over the mineralized zones, the ground is much wetter and peat is quite common.

1.1 Cigar West

At the Cigar West zone of mineralization (the portion west of Cigar Lake) a panel of 23 drill-holes spanning a N/S distance of 200m over the area that was drilled to define the mineralization shows that the glacial till cover is mostly 5-10 m in thickness, with a single local pocket 23 m thick. Another dozen holes drilled beneath Cigar Lake reveal a till thickness of 10-15 m. It appears safe to assume that for much of the survey area the thickness is likely to be 5-10 m.

These same drill holes provide the only information on the nature of the underlying bedrock. The cores show that the Athabasca Group is represented entirely by the Manitou Falls Formation (medium to coarse grained sandstone with clay 'pebbles', locally brecciated and/or conglomeratic at the base) which increases in thickness from about 420 m beneath Cigar Lake to 480 m at the western end of the mineralized zone. On average it is ~440 m in this area. Since the elevation of the area is about 450 m, the unconformity with the underlying basement rocks is close to sea level.

At the unconformity the Wollaston Group rocks are described as mostly graphitic metapelites with some calc-silicate banding and pegmatitic gneisses. Uranium mineralization (pitchblende) straddles the unconformity. In one hole, just west of Cigar Lake, perched mineralization (>1% U over 12 m) is recorded at a depth of 293 m.

A structural interpretation by Cogema geologists in the 1980s based on geophysical signatures indicates a number of interpreted faults trending in several directions. The trends are dominated by a conjugate set trending NE/SW and NW/SE, with the addition of some N/S striking faults.

1.2 McClean South

More drilling has taken place in the McClean Lake area than at Cigar West such that a more comprehensive database of information on the substrate is available. In general, the sandy glacial overburden (till) is less than 5 m thick. The Athabasca Group rocks are

Manitou Falls Formation, similar in nature to Cigar West that range in thickness from 140-180 m, and are in the 160-170 m range over McClean South. There is a major lithological divide in the basement rocks 100 m south of McClean South. To the south of that line (shown on many of the McClean plots in this report) the rock is Achaean gneiss. North of that contact there are predominantly pelitic gneisses with zones of graphitic pelite gneiss and some pegmatites of the Wollaston Group. No down-hole lithological logs are available for more detailed comment. A series of northeasterly trending faults are interpreted to transect the area. Unlike Cigar Lake, calc-silicates are not reported which is likely to account for some differing elemental signatures in the overlying soils and trees.

2 Sample Collection and Laboratory Procedures

Vegetation suitable for biogeochemical sampling in the survey areas consists of scattered black spruce in the bogs, and jack pine interspersed with some black spruce in the freely drained areas. Black spruce was selected as the vegetation sample medium due to its widespread availability in both freely drained and poorly drained areas. Twigs with attached needles were collected from around the circumference of an individual tree at each soil sampling site. Approximately 7-10 twigs (~25 cm lengths, each representing 7-10 years of growth) were obtained from a single tree within 2-3 m of each soil or drainage sample station, and placed in 5.5” x 8.5” cloth bags.

At Cigar Lake, spruce twig samples were collected in June 2008 at 112 sample stations in June 2008: of these, 89 were at 50 m spacing along 4 survey lines spaced 200 m apart, and the remaining 23 from sites scattered across the survey area where waters and no soils were obtained. In August 2009, of the 86 samples collected, 44 were from the same sample stations as in 2008, and the remaining 42 from stations between two of the original lines, and farther into background areas to the north and south (Fig. 1).

At McClean Lake the 2008 spruce twig collection comprised samples from 103 stations on the same grid spacing as at Cigar West. Of these, 73 were along four lines and the remaining 30 from sites scattered across the survey area where waters and no soils were obtained. In 2009 a total of 61 samples were collected. Of these, 19 were from the same sample stations along a single line, and another 42 samples were from stations between two of the 2008 lines, and from farther into background areas to the north and south (Fig. 2).

Samples were sent to Victoria, BC, where they were dried in an oven for 24 hours at 80^{o}C. Once dry, the spruce twigs were separated from the needles and the twigs were milled to a fine powder prior to being forwarded to Acme Laboratories in Vancouver, BC, together with inserted standards (Control Reference Materials – CRM). Analysis involved digestion of the dry tissue in nitric acid then aqua regia with an ICP-MS finish for determinations of 64 elements (method 1VE-MS [plus all REE] at Acme Laboratories). For U, Th, Se, Te and Bi extra sensitivity (lower detection levels) was obtained by applying Acme’s ultra-low methodology.

In addition, selected samples from the 2008 collection were analyzed at ActLabs by high resolution ICP-MS following a Bioleach digestion (proprietary method developed by ActLabs) and a separate split by sodium pyrophosphate leaching. No previous data on vegetation analysis following a Bioleach digestion had previously been published, and the sodium pyrophosphate method is seldom used. The methods provided data for a wide range of elements at the low ppb or even parts per trillion (ppt) levels for some elements, including several for which analysis by the quadrapole ICP-MS instrumentation consistently yielded values below detection (e.g. many of the REE and In). In addition, data were provided for some elements that could not be readily determined following an aqua regia digestion (e.g. Br and I).

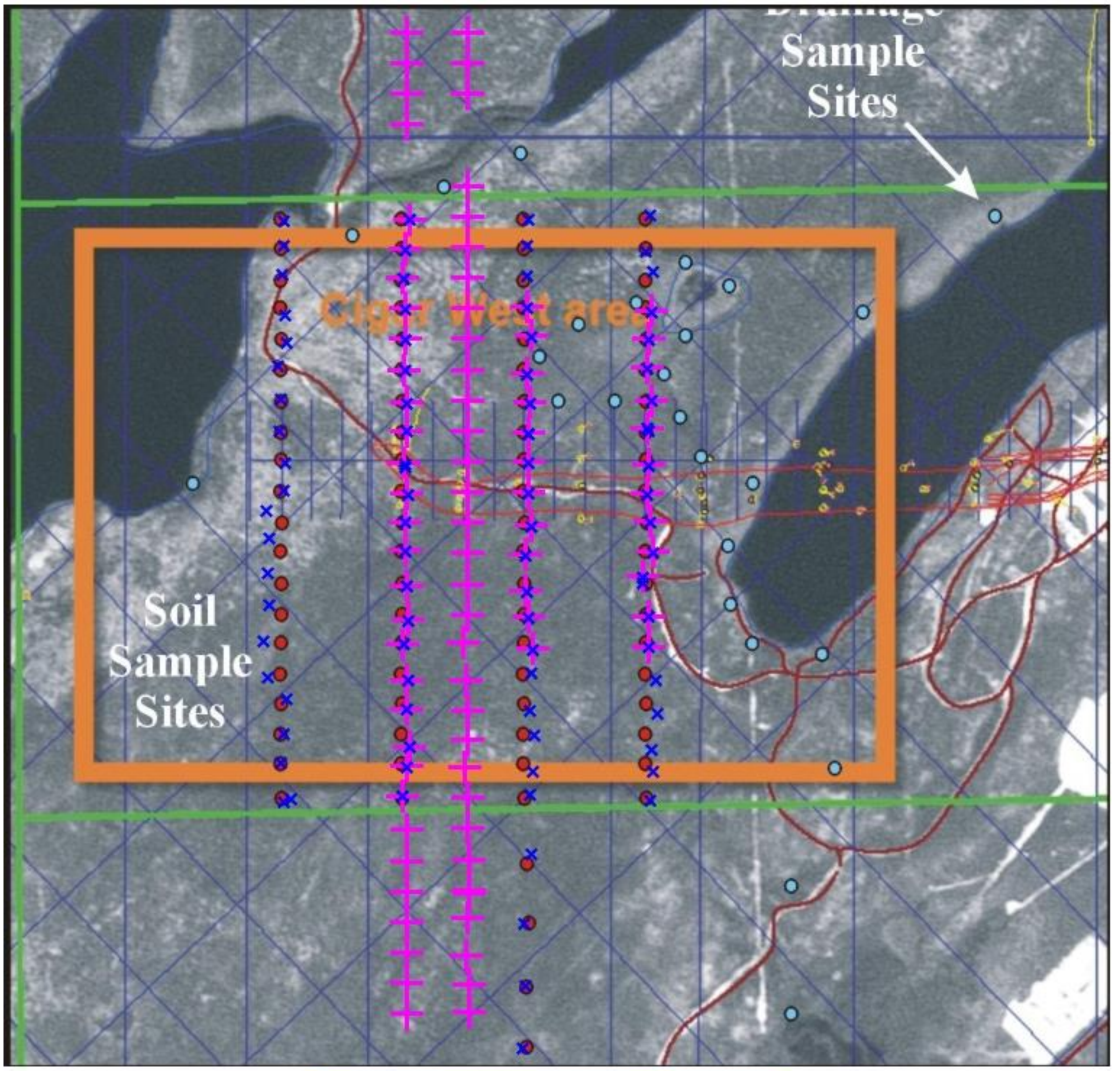
3. Quality Assurance/Quality Control Program

The quality assurance/quality control program (QA/QC) was designed to establish the levels of analytical and sample site variance and to identify relative accuracy shifts or instrumental drift should this occur within or between batches of samples.

Duplicate vegetation samples were collected at a frequency of 1 per 20 sites. Analytical variance was assessed based on duplicate analyses of pulps determined routinely as part of the laboratory's QA/QC program. Standards were available for vegetation samples (control V6 – established at the GSC in 1990) and were inserted into the numerical sequence at a frequency of 1 per 20 samples.

Within each survey area, duplicate samples were collected at 1 in 20 sites, and Certified Reference Materials (CRMs) were inserted at 1 in 20 samples. In addition, Acme provided duplicate analyses and inserted CRMs and blanks. This generated a grand total of 327 samples (including Dawn Lake and Tamarack area sites) in 2008 and 147 in 2009. Determinations were made for 64 elements. The resulting database comprised more than 30,000 analytical determinations. Full details of all the analytical data, including synopses of control samples, are provided in Appendix 1.

CIGAR LAKE 2009
PINK CROSSES - 2009 SAMPLE SITES



2008 SURVEY
Red dots - proposed soil sites for 2008
Blue dots - proposed water sites for 2008
Blue crosses - Actual soil sites for 2008

Figure 1: Cigar West - Sample sites, 2008 (blue crosses) and 2009 (pink crosses).

McClean Lake Sample Sites

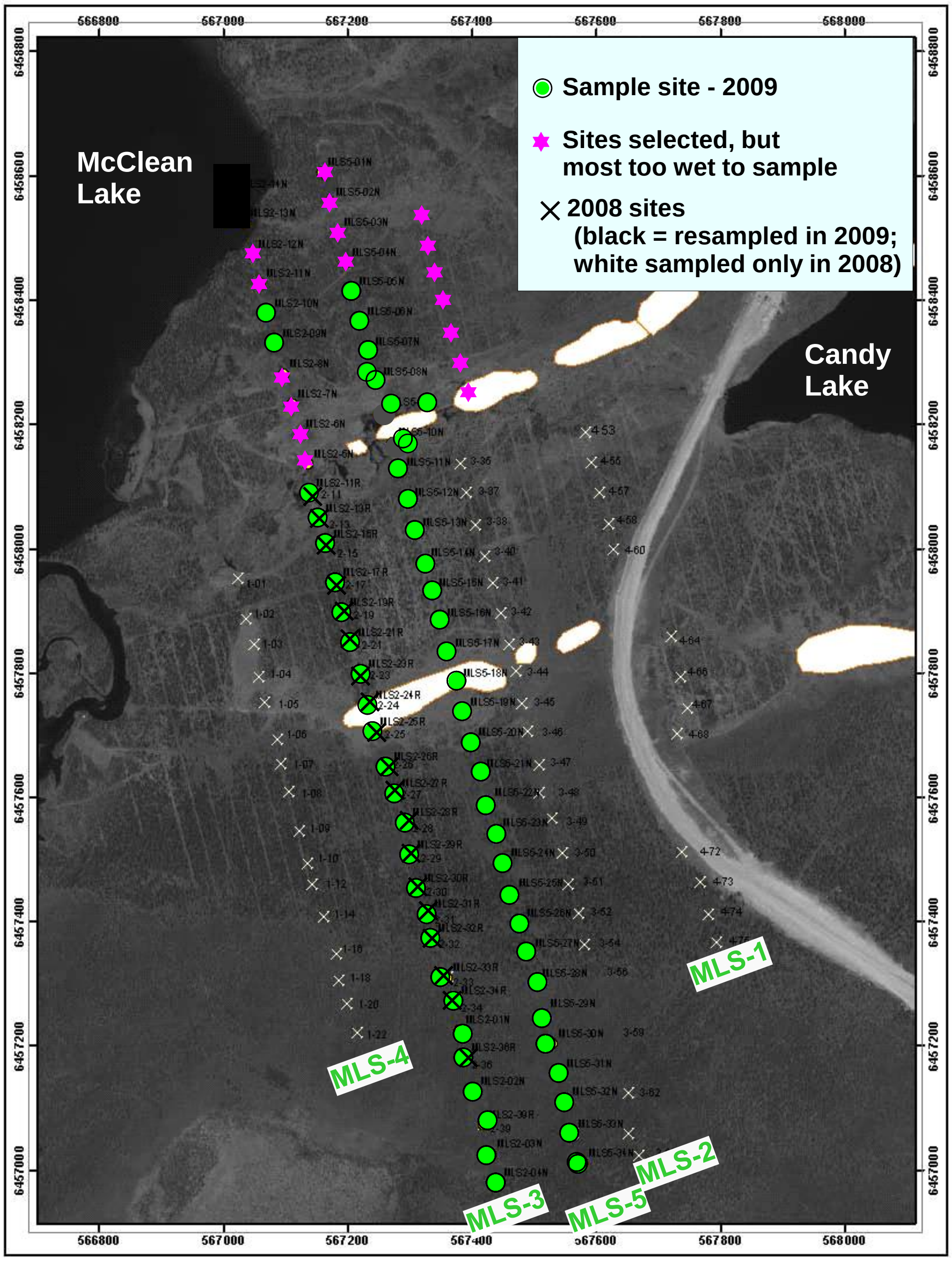


Figure 2: McClean Lake sample sites. All crosses (white and black) are 2008 sample sites. Green circles are 2009 sites.

4 Results

Results of the 2008 survey were presented as a separate report in October 2008. These plots have been refined, but remain essentially the same. The data from 2008 and 2009 have been combined into single plots by Graeme Bonham-Carter and are presented in Appendix 4 (Cigar Lake) and Appendix 5 (McClean Lake). In the following there is discussion of seasonal variation and this is a factor to be taken into account when fine-tuning the plots. However, these plots serve as a good broad-brush approach to visualize the element distribution patterns. Some refinements of the data are discussed and plotted.

4.1 Bioleach and Sodium Pyrophosphate Leach

Selected spruce twig samples collected in 2008 were submitted for some experimental analysis using the new Bioleach method developed at Actlabs. This involves a weak digestion of the plant tissues and analysis by high resolution ICP-MS. The latter provides data for 61 elements, mostly to the low ppb range with detection limits for some elements (e.g. some REE) as low as 1 part per trillion. The method has the advantages of:

1. Generating data at ultra-low detection levels for many elements that commonly return values below the level of detection.
2. Generating data above detection for all the REE.
3. Providing data for Br and I – elements of potential use in exploration geochemistry
4. Since it is a weak selective leach, it is anticipated that any silicate dust that might adhere to the samples would not be dissolved by this digestion. Consequently, the method would eliminate (or, at least, minimize) any anthropogenic contamination and the signature should be very largely from the plant tissue.

In addition, another portion of each sample was leached in 0.1M sodium pyrophosphate ($Na_4P_2O_7$ – abbreviated here to NaPyr) as another approach to releasing loosely bound elements.

The precision of the analytical data was very good for most elements determined by the Bioleach method (Table 1). The RSD% was less than 10% for most elements, but considerably worse for Ag, Au, Be, several of the REE, Li, Mo, Sc, Se, Sn, Te and Zr. Precision obtained on samples digested using the NaPyr leach was far inferior for many elements (Table 2); there were substantial variations such that data for many elements were not usable. Elements highlighted in Tables 1 and 2 are those for which precision was particularly poor. However, it appears to be a ‘batch’ problem at the laboratory, because controls interspersed among the batch of samples from Cigar Lake yielded much greater variation than the same controls among the samples from McClean Lake. Full details are given in Appendix 1 – Table A7 for Bioleach, and Table A8 for NaPyro.

	LOD (ppb)	CLV-1	CLV-2	V6
		RSD %	RSD %	RSD %
		n=10	*n=4*	*n=4*
Ag	0.3	**75.2**		43
As	6	**5.3**	**21.1**	15
Au	1	**16.6**		
B	36	**5.4**	**5.8**	15
Ba	1	**5.4**	**6.6**	50
Be	0.1	**19.7**	**44.7**	29
Bi	0.04	**17.9**	**13.4**	39
Br	75	**6.6**	**1.8**	6
Ca	1	**5.2**	**3.2**	8
Cd	0.04	**10.2**	**13.7**	17
Ce	0.3	**7.3**	**26.6**	73
Co	0.1	**3.7**	**3.2**	9
Cr	1	**6.3**	**1.4**	14
Cs	0.1	**4.5**	**2.0**	15
Cu	1	**4.6**	**1.9**	5
Dy	0.004	**6.6**	**3.5**	24
Er	0.003	**6.1**	**3.7**	22
Eu	0.004	**5.6**	**8.0**	26
Fe	15	**10.5**	**15.0**	14
Ga	0.1	**10.8**	**9.6**	17
Gd	0.004	**10.9**	**4.2**	32
Ge	0.1	**40.0**		
Hf	0.01	**9.9**	**14.1**	8
Hg	6	**22.5**		
Ho	0.001	**6.9**	**8.4**	23
I	3	**15.8**		22
In	0.01	**11.8**	**43.3**	39
K	149	**7.3**	**8.8**	10
La	0.3	**9.0**	**48.2**	96
Li	4	**78.2**	**81.0**	139
Lu	0.001	**7.2**	**77.0**	30

	LOD (ppb)	CLV-1	CLV-2	V6
		RSD %	RSD %	RSD %
		n=10	*n=4*	*n=4*
Mg	30	**2.7**	**2.7**	6
Mn	15	**6.8**	**5.6**	10
Mo	0.6	**15.5**	**26.4**	37
Nb	0.01	**13.2**	**42.2**	11
Nd	0.01	**5.2**	**6.5**	29
Ni	7	**7.4**	**17.3**	11
Pb	0.4	**6.3**	**5.2**	12
Pr	0.004	**5.8**	**4.2**	40
Rb	0.7	**2.7**	**1.3**	4
Re	0.01	**3.5**	**1.8**	6
Sb	0.1	**12.4**	**16.0**	12
Sc	1	**51.2**		67
Se	22	**51.5**	**47.1**	63
Sm	0.04	**8.0**	**9.2**	28
Sn	1	**29.1**	**30.3**	44
Sr	1	**3.7**	**5.6**	8
Ta	0.1			
Tb	0.003	**7.2**	**18.4**	28
Te	0.1	**22.7**	**64.7**	
Th	0.003	**13.0**	**8.4**	29
Ti	1	**9.4**	**20.7**	6
Tl	0.01	**4.2**	**2.6**	5
Tm	0.01	**5.8**	**14.3**	21
U	0.01	**3.3**	**2.1**	15
V	0.06	**4.6**	**2.5**	15
W	0.1	**10.8**	**14.9**	32
Y	0.04	**7.0**	**4.4**	21
Yb	0.007	**7.4**	**8.2**	20
Zn	60	**3.9**	**8.9**	14
Zr	0.1	**14.9**	**37.5**	8

The high RSD% values for elements highlighted were from controls interspersed among all samples from Cigar Lake and McClean Lake. For controls within the suite of samples from McClean, the precision was considerably better for several elements - e.g. Ag 26%, Li 16%, Se 20% and Sc 5.6%

Table 1 Analytical Precision on control samples – Bioleach method

	LOD	**V6**	**CLV-1**
	ppb	***RSD%***	***RSD%***
		n=9	**n=10**
Ag	8	**501**	**292**
As	160	**86**	**90**
Au	28	**nd**	**nd**
B	970	**248**	**47**
Ba	16	**18**	**19**
Be	4	**663**	**nd**
Bi	1	**nd**	**47**
Br	2009	**nd**	**nd**
Ca	20	**12**	**13**
Cd	1	**4**	**23**
Ce	8	**9**	**29**
Co	4	**32**	**20**
Cr	24	**41**	**29**
Cs	4	**55**	**30**
Cu	40	**86**	**26**
Dy	0.1	**4**	**17**
Er	0.1	**6**	**16**
Eu	0.1	**9**	**18**
Fe	400	**21**	**21**
Ga	4	**172**	**151**
Gd	0.1	**11**	**19**
Ge	4	**329**	**nd**
Hf	0.4	**61**	**45**
Hg	160	**nd**	**nd**
Ho	0.04	**3**	**18**
I	80	**nd**	**nd**
In	0.4	**133**	**102**
K	4000	**4**	**17**
La	8	**13**	**42**
Li	120	**258**	**84**
Lu	0.04	**21**	**32**

	LOD	**V6**	**CLV-1**
	ppb	***RSD%***	***RSD%***
		n=9	**n=10**
Mg	800	**5**	**17**
Mn	400	**2**	**16**
Mo	16	**262**	**27**
Nb	0.4	**292**	**237**
Nd	0.4	**3**	**17**
Ni	200	**47**	**27**
Pb	12	**6**	**20**
Pr	0.1	**5**	**18**
Rb	20	**4**	**15**
Re	0.4	**nd**	**16**
Sb	4	**120**	**76**
Sc	40	**0**	**0**
Se	600	**87**	**59**
Sm	1	**5**	**18**
Sn	24	**73**	**131**
Sr	40	**7**	**18**
Ta	2	**nd**	**nd**
Tb	0.1	**12**	**19**
Te	4	**nd**	**nd**
Th	0.1	**14**	**25**
Ti	40	**11**	**21**
Tl	0.4	**60**	**56**
Tm	0.4	**6**	**17**
U	0.4	**6**	**18**
V	2	**12**	**24**
W	4	**85**	**45**
Y	1	**4**	**17**
Yb	0.2	**5**	**18**
Zn	1600	**106**	**34**
Zr	4	**53**	**37**

Very poor precision - data not usable, although some valid for individual areas

Table 2 Analytical precision on control samples – Na Pyrophosphate

Table 3 summarizes the percentages of each element extracted by the Bioleach method compared to the strong (near total) digestion by the conventional nitric acid/aqua regia method. Clearly there is only a very small portion of many elements that was extracted; <2% of most of the high field strength elements (HFSE) and low yields of the REE. There is an apparent *gain* of Li and B extracted by Bioleach, but the analytical precision was very poor and no doubt fully accounts for this anomalous situation.

	Aqua Regia (AR)			Bioleach (BL)			AR vs. BL
		Ave_AR	Ave. in ppb			Ave	% leached
Ag	AR-ppb		37	Ag	BL-ppb	1	2.8
Al	AR-%		16765				
As	AR-ppm	0.80	800	As	BL-ppb	162	20.3
Au	AR-ppb			Au	BL-ppb		
B	AR-ppm	6.88	6882	B	BL-ppb	9343	135.8
Ba	AR-ppm	42.89	42888	Ba	BL-ppb	3772	8.8
Be	AR-ppm	0.05	50	Be	BL-ppb	3	7.0
Bi	AR-ppm	0.04	42	Bi	BL-ppb	0.4	1.0
				Br	BL-ppb	4288	
Ca	AR-%	0.37	3705882	Ca	BL-ppb	396515	10.7
Cd	AR-ppm	0.05	49	Cd	BL-ppb	4	7.6
Ce	AR-ppm	0.93	926	Ce	BL-ppb	24	2.6
Co	AR-ppm	0.13	128	Co	BL-ppb	31	24.0
Cr	AR-ppm	1.71	1706	Cr	BL-ppb	24	1.4
Cs	AR-ppm	0.12	116	Cs	BL-ppb	46	39.8
Cu	AR-ppm	3.62	3615	Cu	BL-ppb	413	11.4
Dy	AR-ppm	0.04	35	Dy	BL-ppb	2	6.2
Er	AR-ppm			Er	BL-ppb	1	
Eu	AR-ppm			Eu	BL-ppb	1	
Fe	AR-%	0.25	249412	Fe	BL-ppb	6905	2.8
Ga	AR-ppm	0.06	62	Ga	BL-ppb	1	1.8
Gd	AR-ppm	0.05	49	Gd	BL-ppb	2	4.3
Ge	AR-ppm	0.01	10	Ge	BL-ppb	0	1.6
Hf	AR-ppm	0.01	11	Hf	BL-ppb	0	2.6
Hg	AR-ppb		28	Hg	BL-ppb	3	10.8
Ho	AR-ppm			Ho	BL-ppb	0.4	
				I	BL-ppb	3	
In	AR-ppm			In	BL-ppb	0.1	
K	AR-%	0.29	2923529	K	BL-ppb	1965699	67.2
La	AR-ppm	0.42	420	La	BL-ppb	11	2.6
Li	AR-ppm	0.21	210	Li	BL-ppb	568	270.4
Lu	AR-ppm	0.01	10	Lu	BL-ppb	0	1.0
Mg	AR-%	0.75	7517650	Mg	BL-ppb	287939	3.8
Mn	AR-ppm	441.82	441824	Mn	BL-ppb	52867	12.0
Mo	AR-ppm	0.09	93	Mo	BL-ppb	6	7.0
Na	AR-ppm	0.00	4				
Nb	AR-ppm	0.04	38	Nb	BL-ppb	0.2	0.5
Nd	AR-ppm	0.44	443	Nd	BL-ppb	12	2.7
Ni	AR-ppm	1.79	1788	Ni	BL-ppb	798	44.6
P	AR-%		67059				
Pb	AR-ppm	4.54	4541	Pb	BL-ppb	65	1.4
Pr	AR-ppm	0.11	115	Pr	BL-ppb	3	2.4
Rb	AR-ppm	7.67	7671	Rb	BL-ppb	5313	69.3
Re	AR-ppb			Re	BL-ppb	0.02	
S	AR-%		36176				
Sb	AR-ppm	0.09	89	Sb	BL-ppb	10	10.7
Sc	AR-ppm	0.21	206	Sc	BL-ppb	1	0.2
Se	AR-ppm	0.16	159	Se	BL-ppb	99	62.2
Sm	AR-ppm	0.06	60	Sm	BL-ppb	3	4.3
Sn	AR-ppm	0.18	175	Sn	BL-ppb	3	1.8
Sr	AR-ppm	19.22	19224	Sr	BL-ppb	1758	9.1
Ta	AR-ppm	0.00	2	Ta	BL-ppb	0.1	3.3
Tb	AR-ppm	0.01	10	Tb	BL-ppb	0.4	4.3
Te	AR-ppm	0.00	4	Te	BL-ppb	0.2	4.4
Th	AR-ppm	0.15	147	Th	BL-ppb	2	1.4
Ti	AR-ppm	10.65	10647	Ti	BL-ppb	52	0.5
Tl	AR-ppm	0.04	43	Tl	BL-ppb	11	26.5
Tm	AR-ppm			Tm	BL-ppb	0.1	
U	AR-ppm	1.19	1191	U	BL-ppb	481	40.4
V	AR-ppm	1.00	1000	V	BL-ppb	9	0.9
W	AR-ppm	0.05	50	W	BL-ppb	4	8.6
Y	AR-ppm	0.15	153	Y	BL-ppb	13	8.6
Yb	AR-ppm	0.01	14	Yb	BL-ppb	1	5.9
Zn	AR-ppm	50.18	50182	Zn	BL-ppb	10226	20.4
Zr	AR-ppm	0.39	385	Zr	BL-ppb	8	2.0

Table 3 Percentage extraction of elements from Bioleach compared to aqua regia.

4.1.1 McClean Lake

At McClean Lake, the samples selected for Bioleach and NaPyr analysis were from line MLS-2 (Fig 3) and, as noted above, the precision of the NaPyr data for these samples was considerably better for most elements than for Cigar Lake, and so meaningful comparisons of the 3 leaches can be made for the McClean profile.

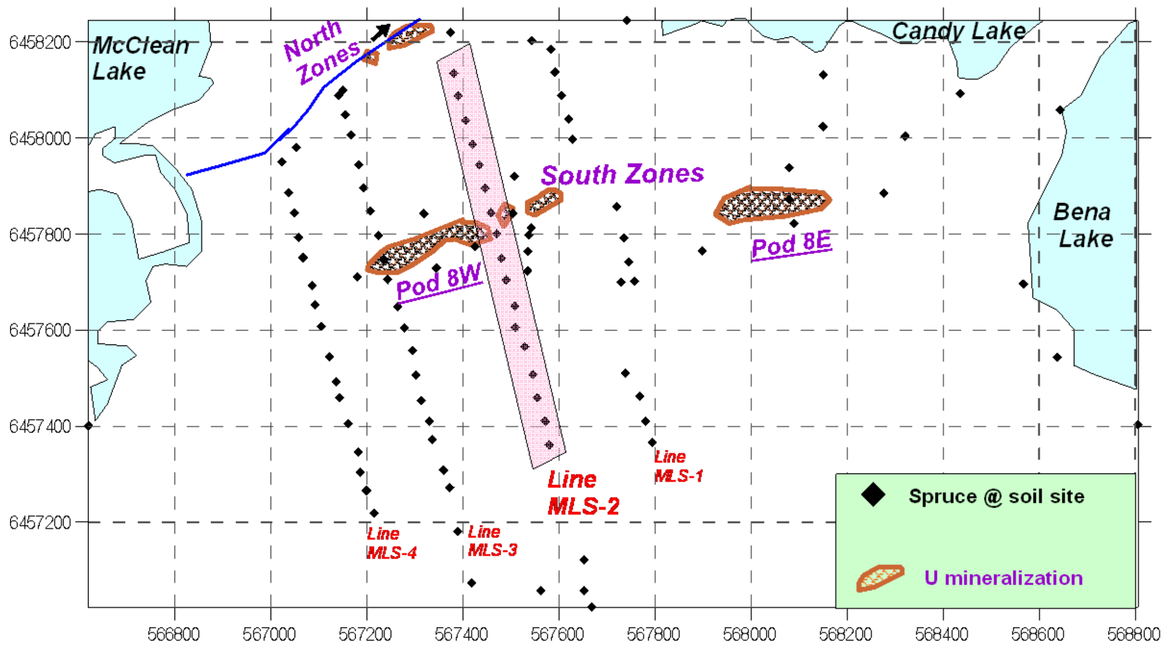


Fig. 3 Samples in shaded area (MLS-2) selected for Bioleach and Na Pyrophosphate digestions.

Examples of element profiles along line MLS-2 are shown for the aqua regia digestion compared with the Bioleach and the NaPyr. Note that the right-hand axis (showing data for the Bioleach and NaPyr) is at a different scale from the left axis (AR).

Although the Bioleach extracts only a small percentage of the total element content compared to the aqua regia leach (<10% for many elements – Table 3), the similarities in most of the element distribution profiles are striking.

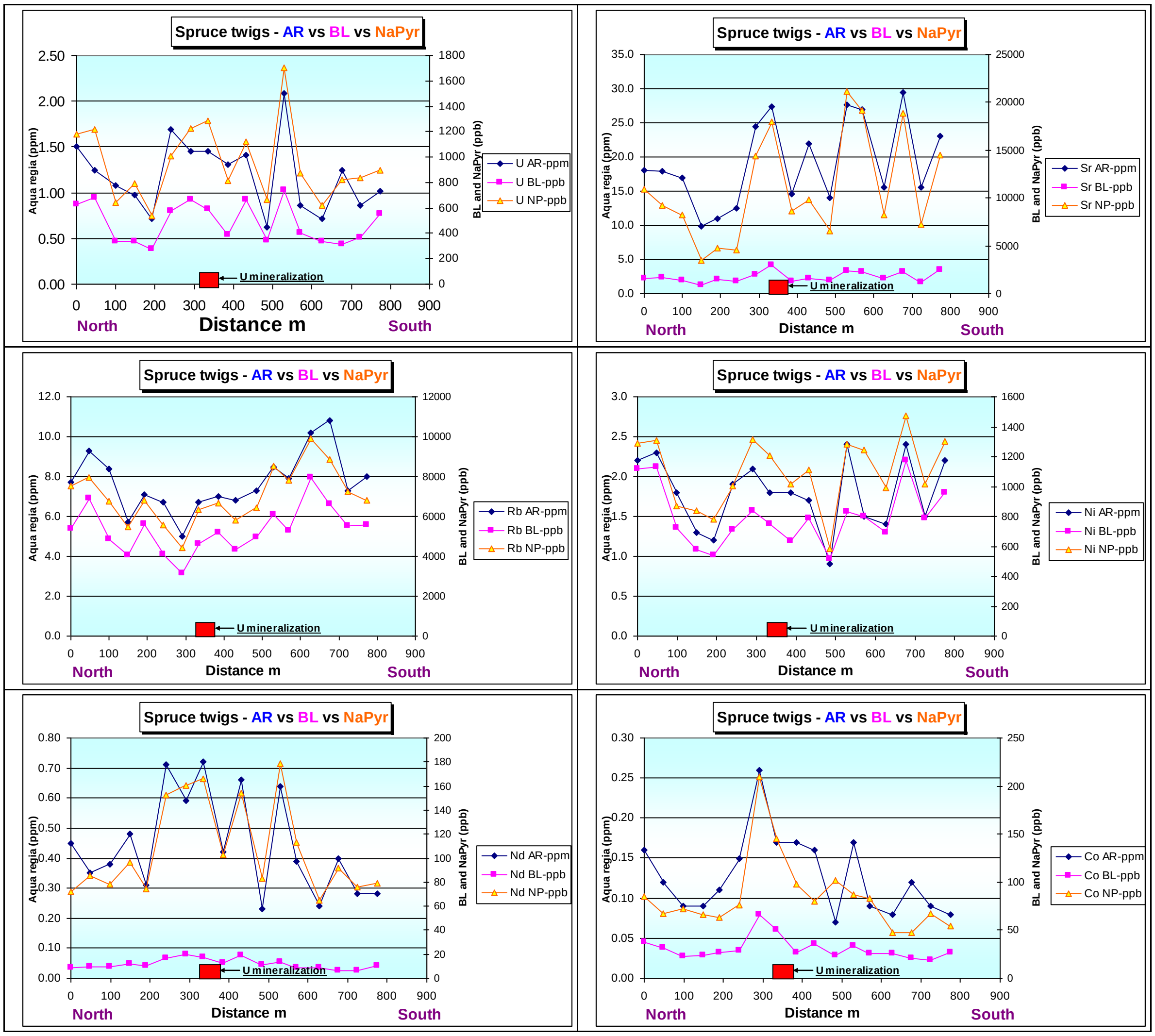


Fig. 4 Comparison of profiles (Line MLS-2) of concentrations obtained by aqua regia (AR), Bioleach (BL) and sodium pyrophosphate (NaPyr).

The NaPyr leach is stronger than the Bioleach, extracting a greater percentage of the elements. For the elements shown in Fig. 4 (all with good precision), each method generates very similar relative concentration profiles along the line. Because the Bioleach values are so much lower, this is not apparent in all the plots in Fig. 4. For example, the Bioleach profile for Nd (typical of the REE) appears almost flat, because the leach released less than 3% of the total Nd. However, when values for the AR leach are plotted against the Bioleach it is evident that there is a strong relationship (Fig. 5).

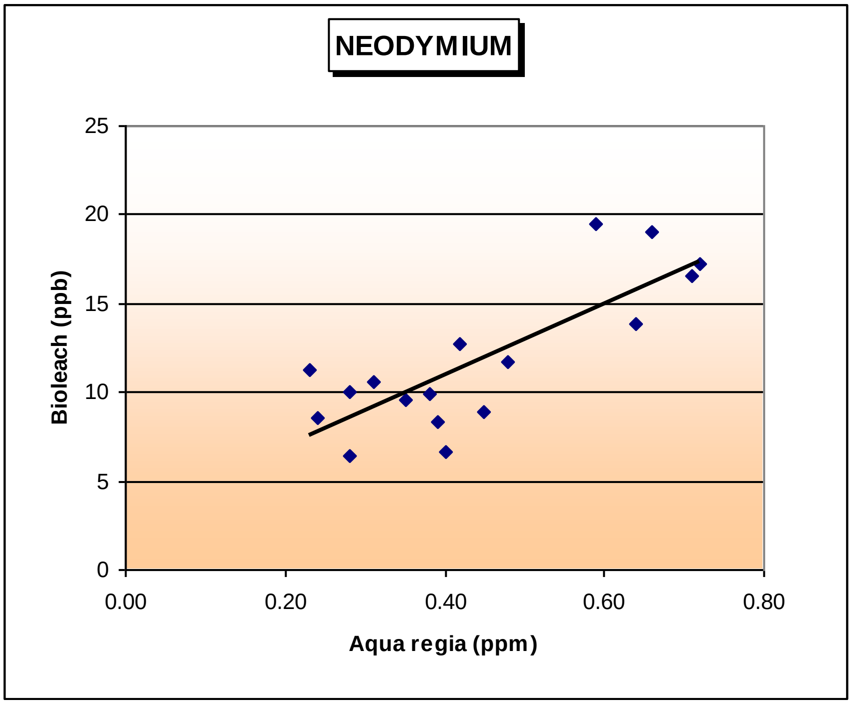


Fig. 5 Neodymium extracted by Bioleach (ppb) vs Nd extracted by Aqua regia (ppm).

Figure 6 shows plots of U and Mo along the transect, with data by the 3 methods. The signature is broad, but it should be noted that the transect did not pass directly over known buried mineralization.

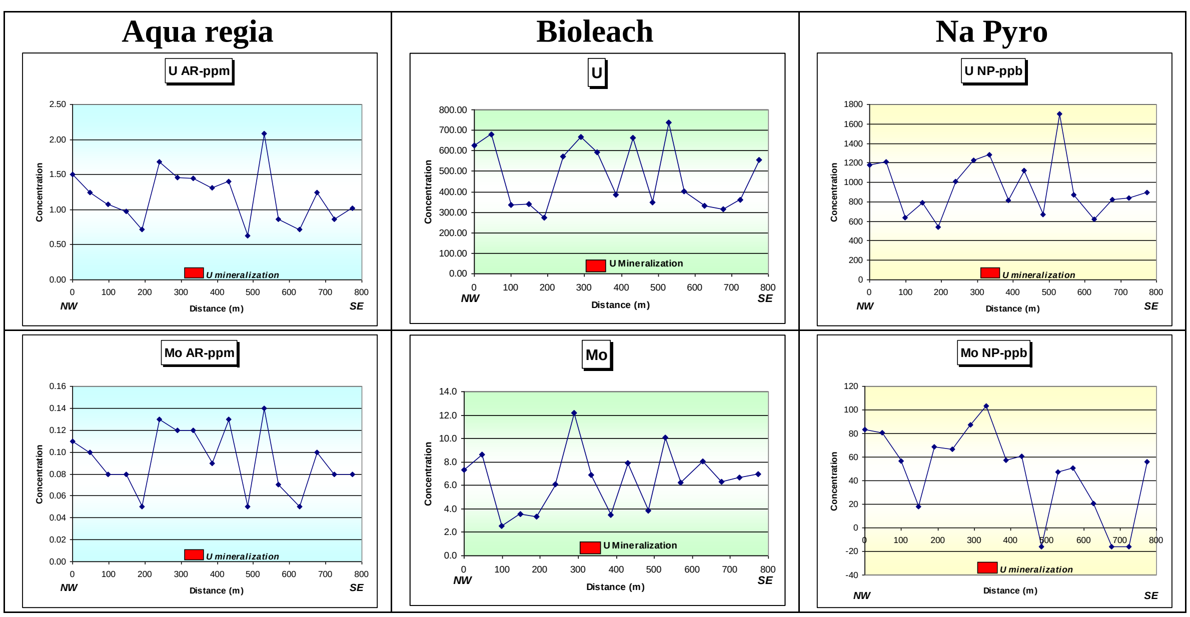


Fig. 6 Comparison of U and Mo along the transect at McClean Lake – analysis by 3 techniques

Figure 7 shows comparative profiles of elements that show anomalous concentrations in the vicinity of buried mineralization.

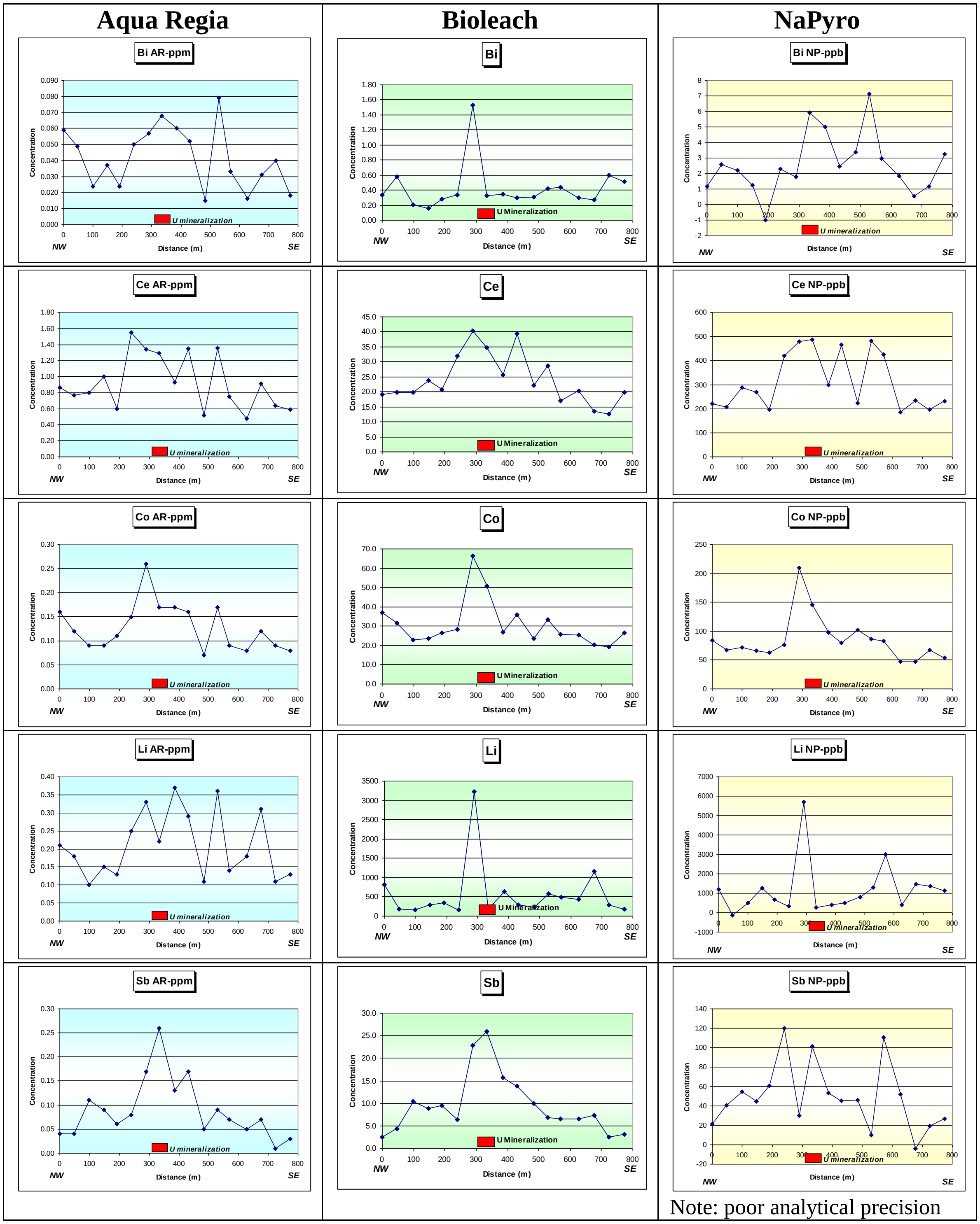


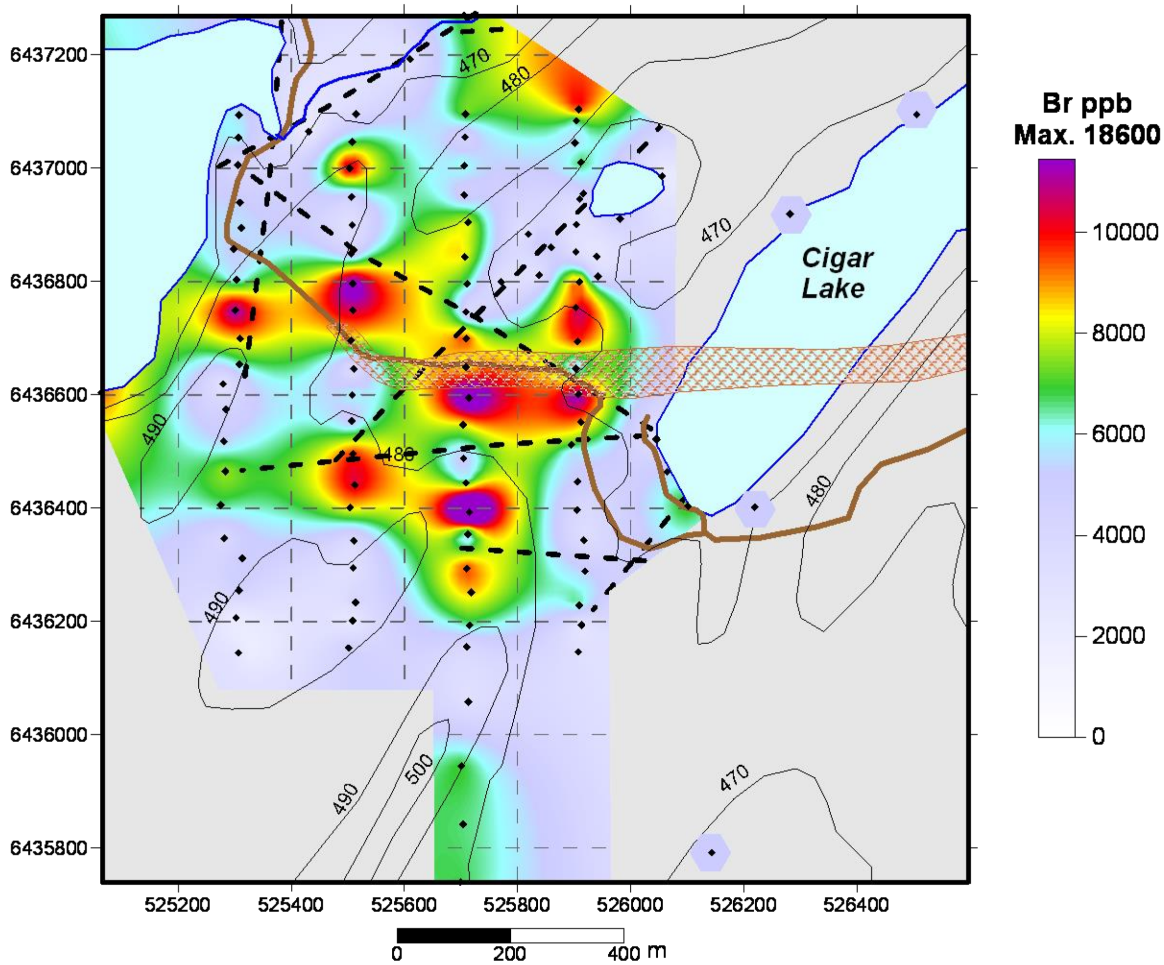
Fig. 7 Comparisons of profiles of selected elements along MLS-2 at McClean Lake by the three analytical methods.

In summary, this comparison of leaches from samples along a single traverse at McClean Lake has shown that:

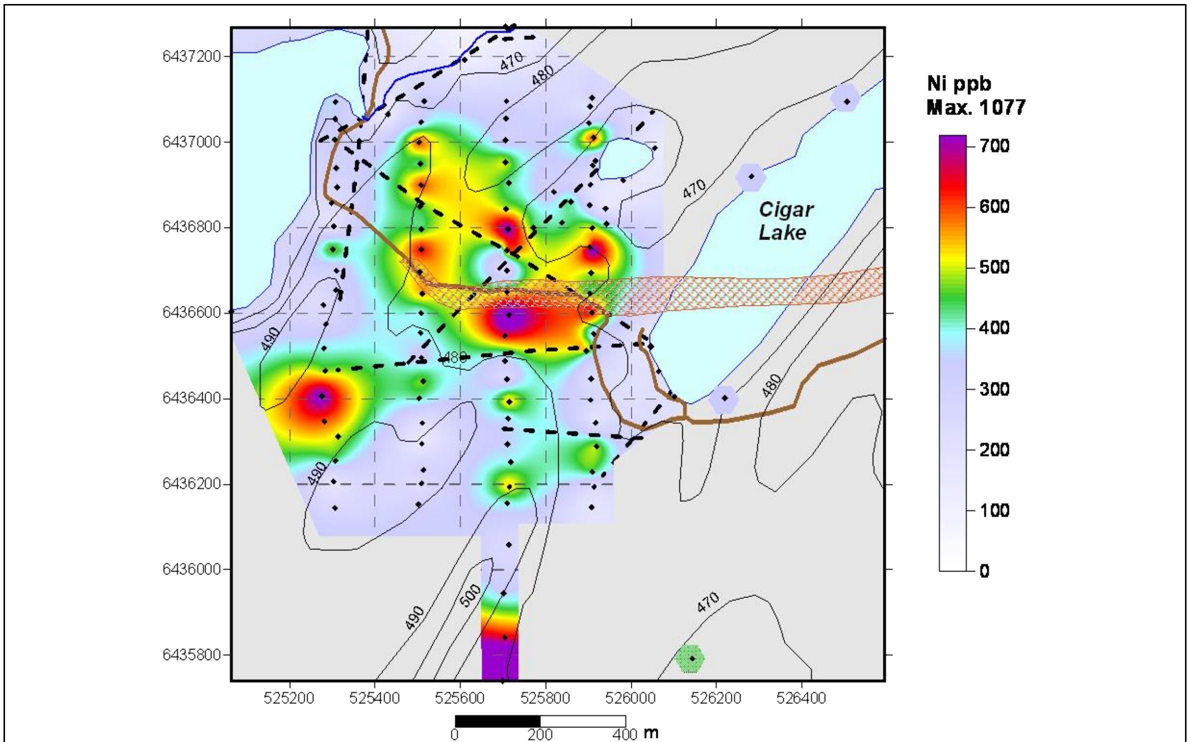
1. Most elements have very similar *relative* concentrations extracted by the three leaches even though the absolute amounts vary considerably. This is demonstrated from a comparison of the element concentration profiles along line MLS-2. Therefore, the signatures are robust.
2. Aqua regia liberates more of most elements than the NaPyr leach, and both leaches liberate far more than the Bioleach. The data indicate that *more* B and Li are extracted by the Bioleach than by the aqua regia digestion (AR). The NaPyr digestion also shows more Li generated than by AR and a little more than by Bioleach. However, this is probably a function of the poor precision obtained for these elements by Bioleach and NaPyr rather than their not being fully extracted from the AR.
3. The data indicate that there is no discernible dust contamination on the spruce twigs that is likely to be contributing to the AR signature, because the *relative* concentrations of elements by the three methods are consistent, generating similar concentration profiles. The typical 'dust' elements (e.g. Ti and the high field strength elements Hf, Nb, REE, Th, and Zr) generate remarkably similar concentration profiles.

4.1.2 Cigar Lake

All 112 samples collected at Cigar Lake in 2008 were analyzed by both Bioleach and NaPyr. The over all data quality is described in the previous section. Plots of all elements with adequate analytical precision have been prepared and are presented in Appendices 2 (Bioleach) and 3 (NaPyr). Of particular interest is the pattern for bromine (Fig. 8) because of its strong relationship to the location of the Cigar Lake West zone of U mineralization. Note that the anomalous sites are enriched by an order of magnitude above those of the background sites. The interpreted faults plotted on these maps were taken from a Saskatchewan Geological Survey assessment file geophysical compilation map submitted by Cogema in the mid-1980s.



Nickel has many of its highest concentrations in samples marginal to Cigar West, whereas Co is more strongly enriched toward the east, but north of the zone of mineralization (Fig. 9).


Ni ppb
Max. 1077
700
600
500
400
300
200
100
0
Cigar
Lake
6437200
6437000
6436800
6436600
6436400
6436200
6436000
6435800
525200
525400
525600
525800
526000
526200
526400
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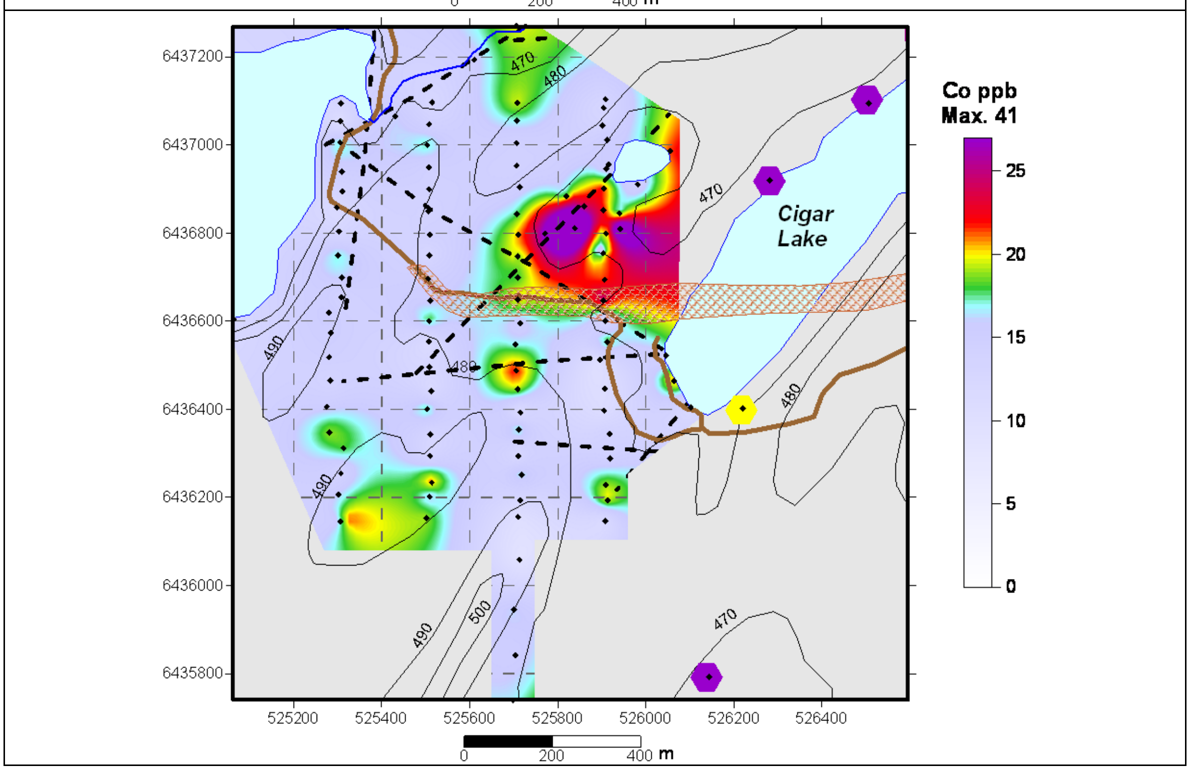
200
400 m
470
480
490
500


Co ppb
Max. 41
25
20
15
10
5
0
Cigar
Lake
6437200
6437000
6436800
6436600
6436400
6436200
6436000
6435800
525200
525400
525600
525800
526000
526200
526400
0
200
400 m
470
480
490
500

Strontium and Ba are relatively enriched in the vicinity of the Cigar West mineralization, and also along a northeasterly trend through a boggy area at the northern limit of the map where a fault was interpreted by Cogema (Fig. 10).

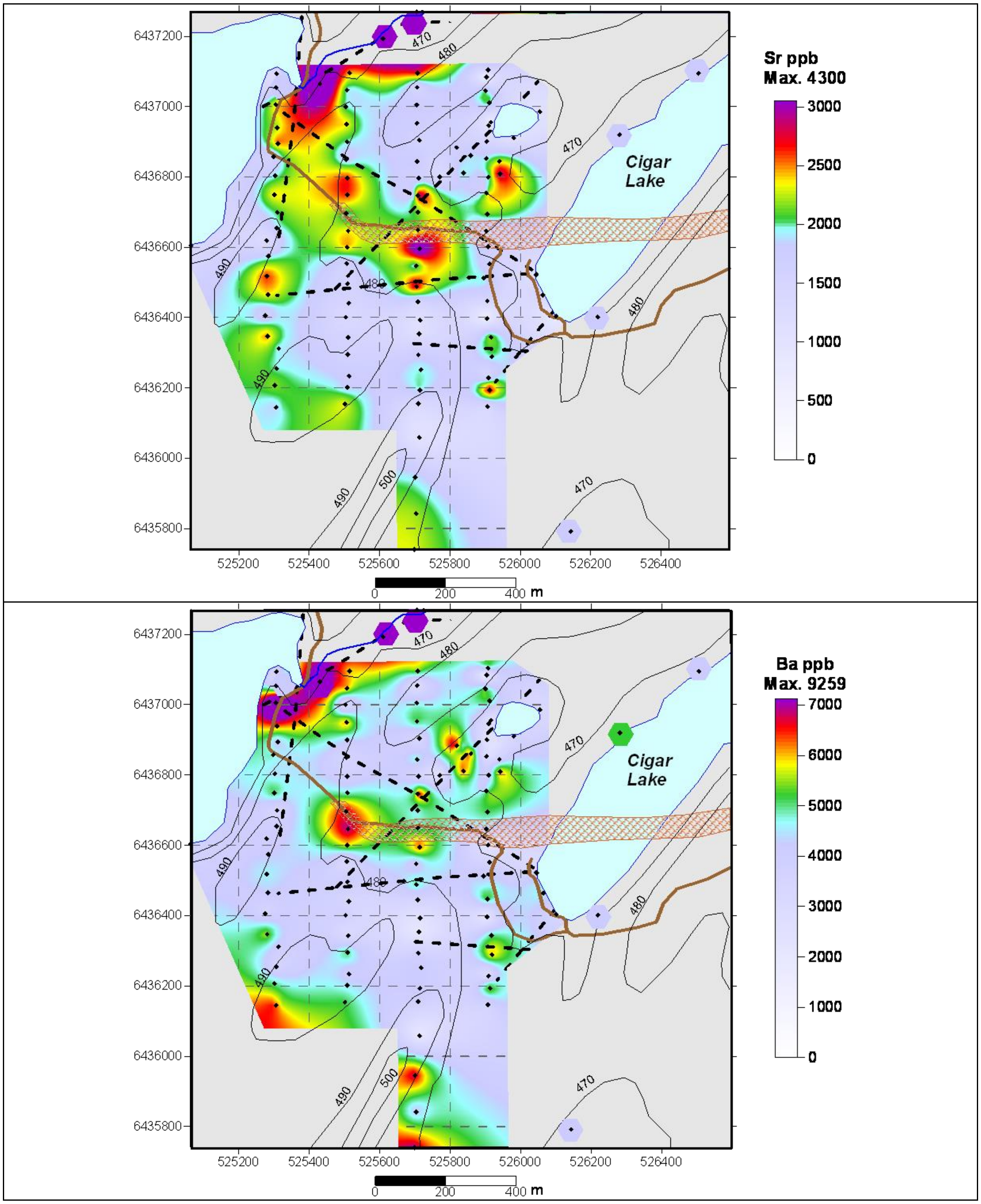


Fig. 10 Strontium and barium in dry spruce twigs at Cigar Lake - Bioleach

Although somewhat offset, there is a partially coincident trend of elevated values shown by Sb and Ag trending southwestward from Cigar Lake (Fig. 11).

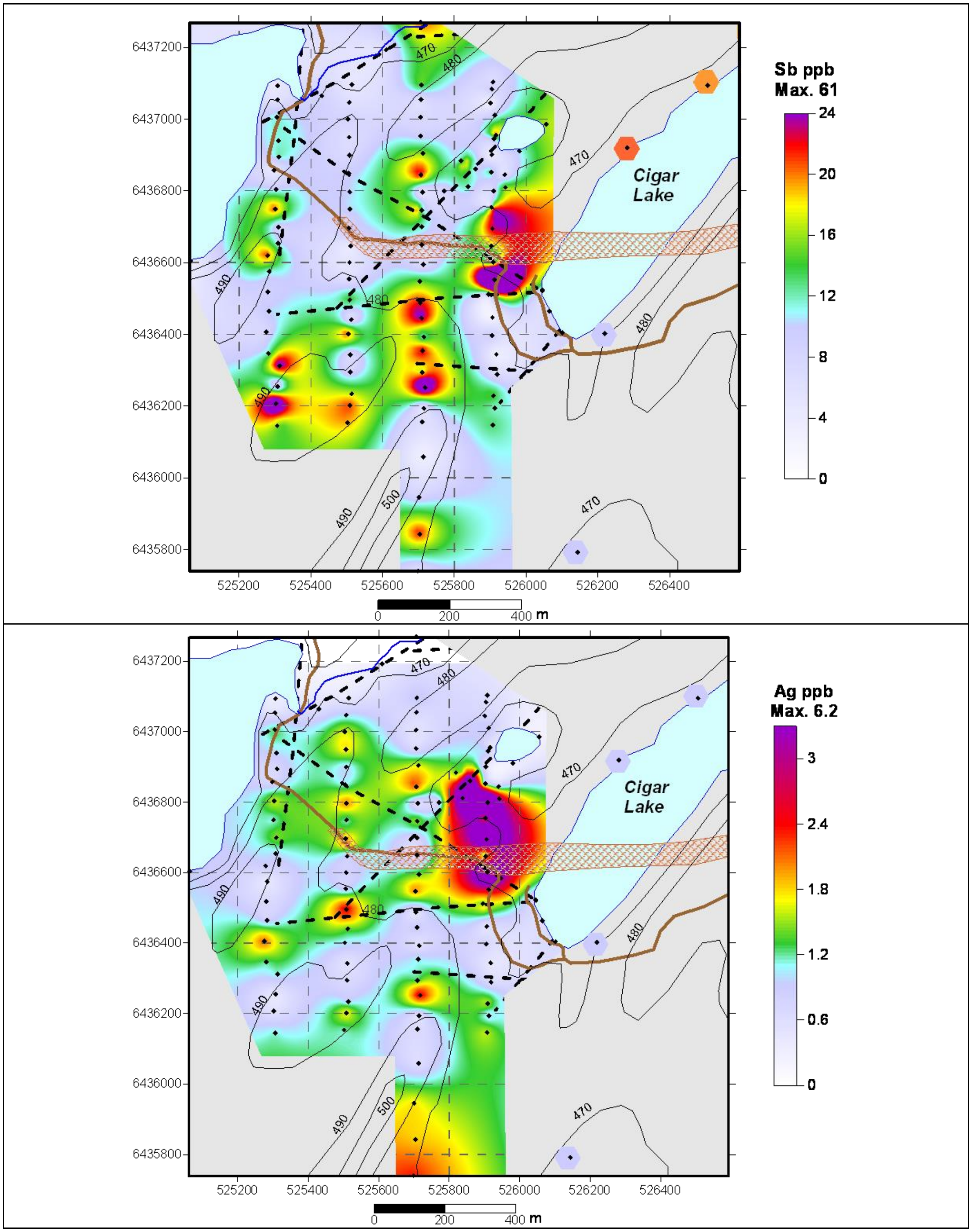


Fig. 11 Antimony and silver in dry spruce twigs at Cigar Lake – Bioleach.

Similar patterns of enrichment of Fe, As, REE (with examples of Nd and Dy) Pb, Th, V and Zr (Fig. 12) occur near Cigar Lake, and to the north and west of Cigar West.

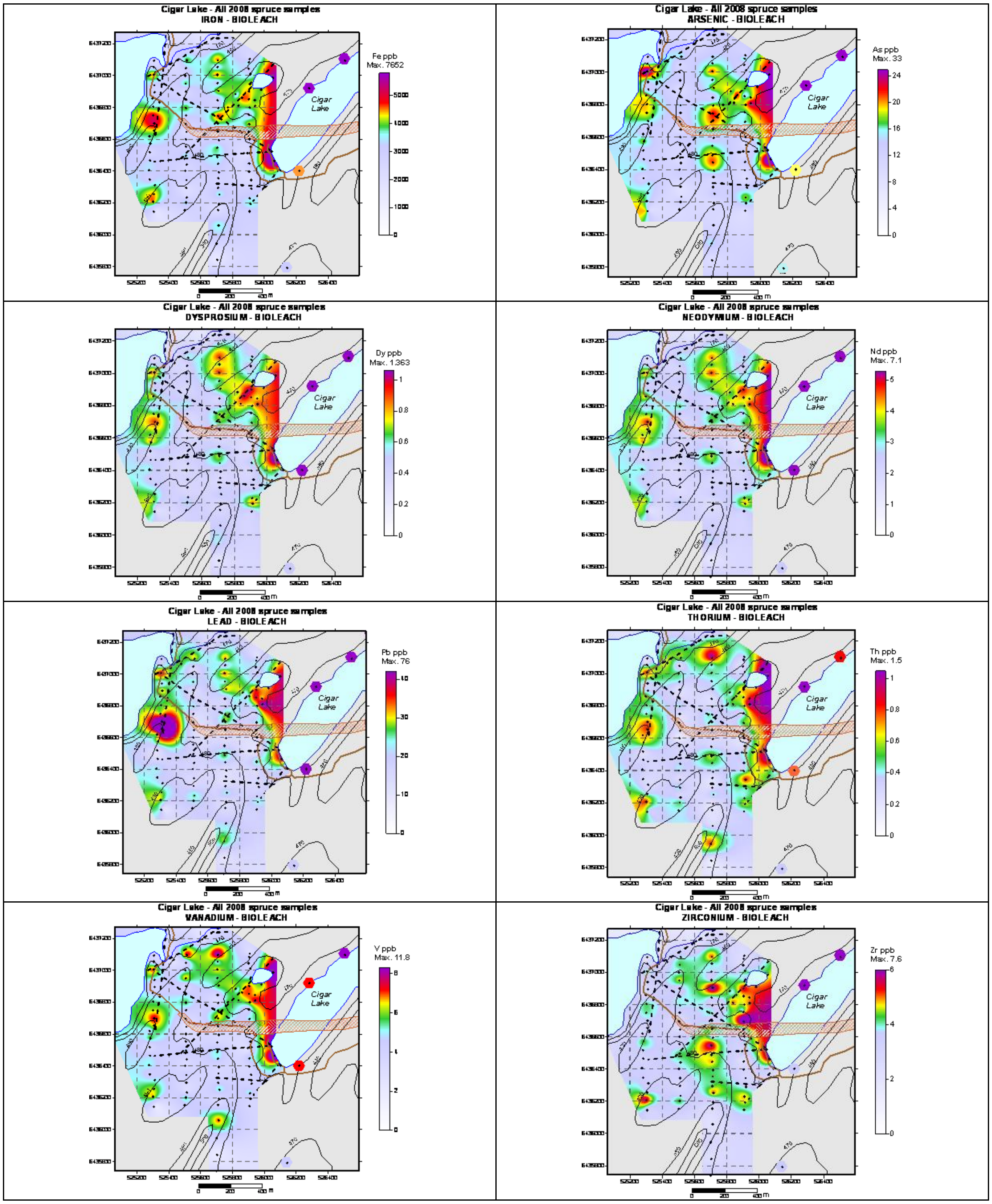


Fig. 12 Cigar Lake – elements showing similar patterns of enrichment.

4.1.3 Comparisons of Element Distribution Patterns: AR, Bioleach and NaPyr**.**

As noted above, analytical precision of data from the NaPyr leach was very poor for many elements. Consequently, comparisons with NaPyr are made only for a few elements yielding good precision. One such element is U for which RSD values were mostly better than 10% by all three extractions. Figure 13 shows that the distribution patterns are very similar for the three extractions. Note that the AR digestion was undertaken in the summer of 2008 by Acme Labs; the other two digestions were from splits of the same samples that were run in 2009 by ActLabs. The patterns are clearly robust, with none yielding anomalous concentrations of any apparent significance over Cigar West, but all showing anomalous sites along two lines that would suggest a classic 'Rabbit's Ears' type of anomaly. Also noteworthy are the concentrations near Cigar Lake and in the west of the survey area (Cat Lake) – particularly at interpreted fault intersections.

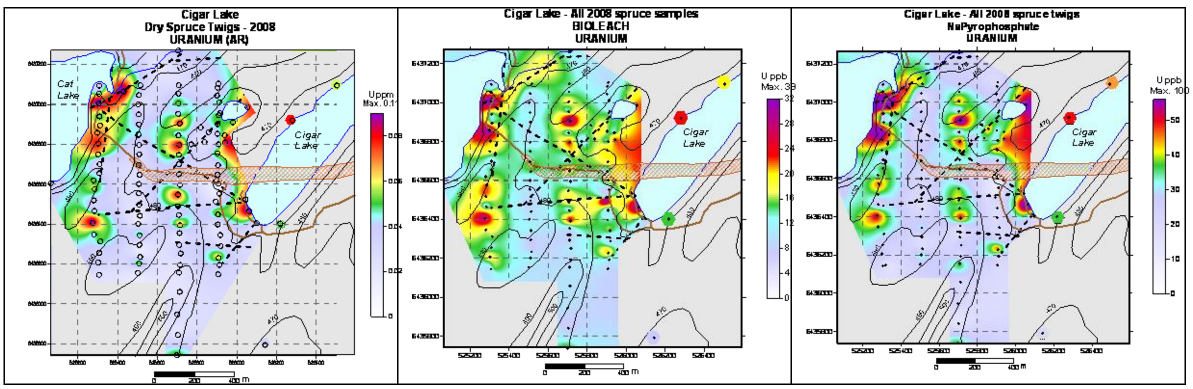


Fig. 13 Uranium in spruce twigs by AR, Bioleach and NaPyr – 2008 samples

Comparisons of the distribution patterns for strontium are shown in Fig. 14, with each exhibiting elevated concentrations over Cigar West mineralization and trending northeastward from Cat Lake.

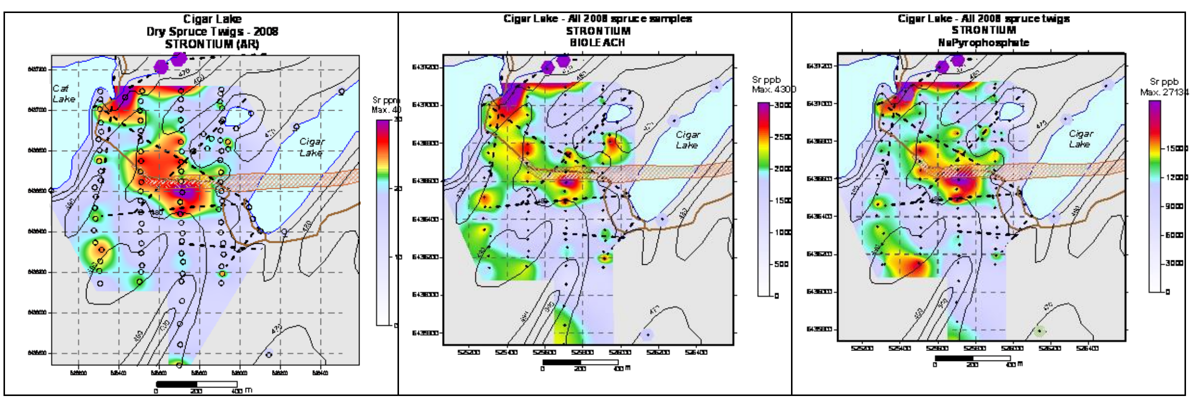


Fig. 14 Strontium in spruce twigs by AR, Bioleach and NaPyr – 2008 samples

Almost all other elements showed similar distribution patterns from analysis by the three leaches. The only notable exception was Pb. The analytical precision was similar for each leach and patterns by AR and Bioleach were very similar (even though only 1.4% of the total Pb was extracted by the Bioleach), yet considerably different by the NaPyr (20% of total Pb extracted).

4.1.4 Summary

The nitric/aqua regia digestion almost totally dissolves all elements contained within plant tissues. The NaPyr digestion releases lesser amounts of the elements, and the Bioleach releases a substantially lower proportion extracting <2% of the total amount of some elements (e.g. REE and HFSE). Even for the most soluble of elements (e.g. K, Rb) the extraction is less than 70%. For a few elements (B, Li) there appeared to be *more* extracted by Bioleach than AR, suggesting an analytical problem.

It is particularly encouraging that each leach method provided similar levels of analytical precision for many elements (except for analytical problems with NaPyr), and that plots of element distributions by the 3 methods for which data were sufficiently precise generated distribution patterns that were very similar, thereby attesting to the robustness of the biogeochemical signatures. This was despite the fact that the analyses were conducted on different instruments by two laboratories.

The analytical finish for the Bioleach is by HR-ICP-MS which has the advantage that it provides data for a number of elements that typically yield concentrations below detection in vegetation, yet may be of use to exploration (e.g. Br, I, REE, In). Furthermore, since Bioleach is a weak extraction, it is reasonable to assume that it leaches little, if any, of elements from any silicate dust particulates that might be adhering to plant surfaces, thereby confirming that the geochemical signature is locally derived from the substrate and is not exotic. This is particularly relevant for elements of low solubility (HFSE, such as Zr, Nb, Hf) for which there is often doubt as to whether or not their presence is a result of airborne contamination.

Whereas the AR leach results in good quality data for a wide range of elements, the Bioleach has the advantage of providing data of similar quality and, since the HR-ICP-MS is used for determinations, it generates data for some elements (e.g. HREE) that are commonly below the detection level of the quadrapole instrumentation and for others (e.g. notably the halogens) that are not determined from the AR digestion. Finally, in situations where there is some doubt as to vegetation contamination by airborne particulates, the Bioleach would be the preferred method since the geochemical signature is more likely to be derived very largely from the plant tissues themselves.

4.2 Repeat Sampling: 2008 vs 2009

An objective of the Athabasca Camiro geochemical sampling program was to determine the robustness of the geochemical signatures. One such test was to see if samples collected one year would generate similar element concentrations when the same sites were sampled the next year. For soils it is to be expected that this would be the case, provided samples are collected and processed in exactly the same manner. For vegetation, however, unless samples are collected at the same time of the year, it is to be expected that there will be differences for some elements because of seasonal variations in plant chemistry – as a plant evolves through a growing season its requirements for elements changes. Highest concentrations are commonly found in the spring during the dynamic and vigorous growth stage of a plant. As the summer wears on the chemistry becomes more stable and element levels in plant tissues tend to decrease.

For the present surveys, the first sampling period was in late June (i.e. late spring to early summer in the Athabasca environment). The repeat sampling was undertaken the following year in August – the height of summer. As a result, the concentrations of many elements were lower during the August sampling period. It is of note, though, that the concentrations proved to be quite similar at sites where growth is slow (boggy conditions – especially at McClean Lake), but greater variations were found at dry sites (most sites at Cigar Lake, and the southern part of the McClean survey area) where plant growth is more vigorous.

4.2.1 McClean Lake

In the dominant boggy conditions of the McClean Lake area, the reproducibility of analytical data from twig samples collected in 2008 and resampled in 2009 (same sample station, but not necessarily the same tree) was quite good (Fig. 15) and extremely good for some elements (e.g. Mo and Pb). For unknown reasons, some elements indicate higher concentrations in 2009 at the southern end of the traverse (line 3) where the terrain is well-drained. For elements with concentrations close to the detection limit there is generally only fair to poor reproducibility.

A comparison of all elements from both years of sampling can be made by examination of the data shown in Table A9 (Appendix 1). The embedded chart can be dragged across each paired column of data for each element.

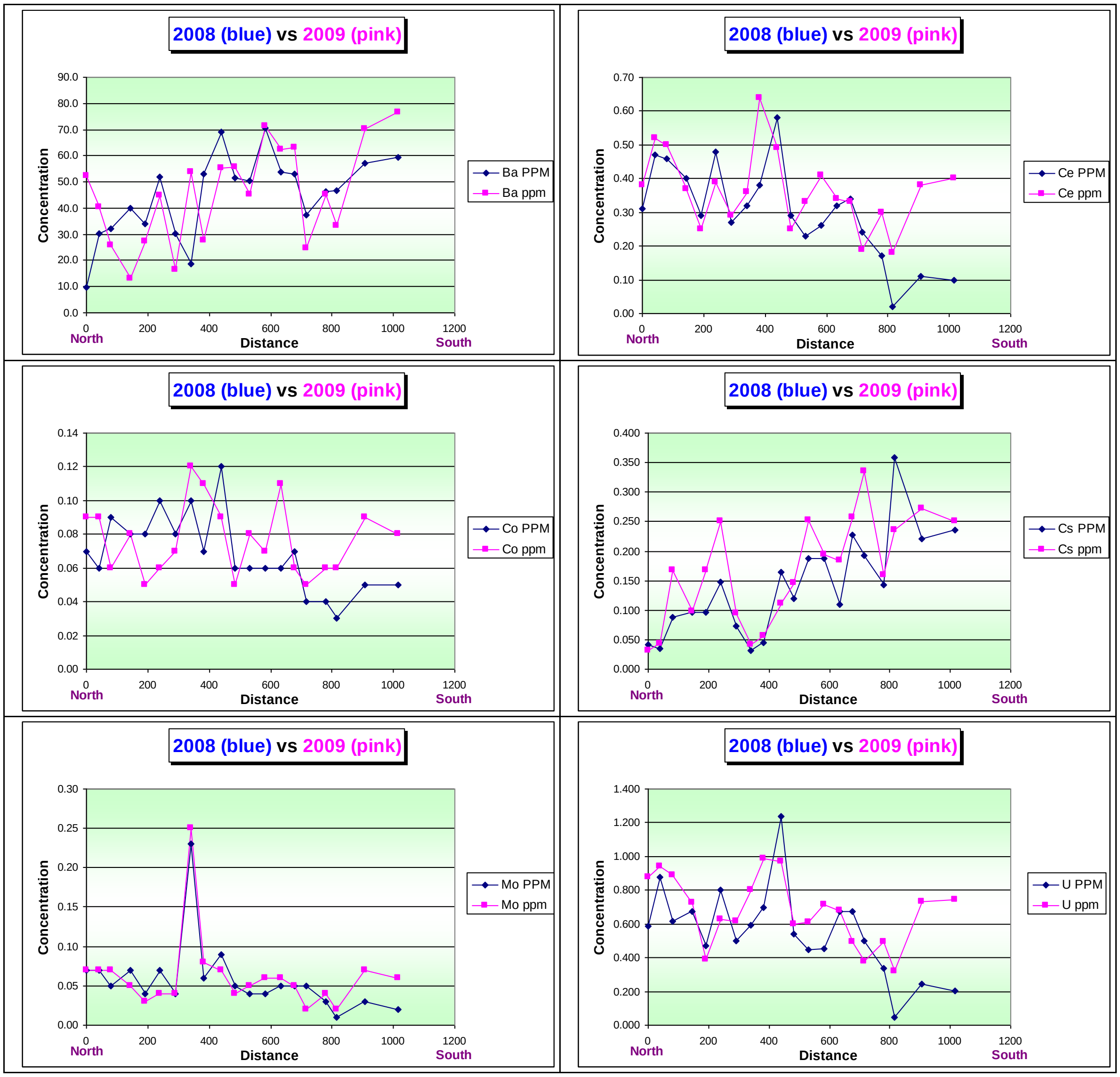


Fig. 15 McClean - Comparisons of trees collected in 2008 vs. 2009.

4.2.2 Cigar Lake

At Cigar West, spruce at 44 sample sites along lines 1, 2 and 3 (numbered from east to west) were resampled in 2009. Element concentrations in spruce twigs collected at Cigar Lake were lower than those at McClean with the result that the reproducibility of some elements with levels close to detection limits was inferior to that at McClean. Table A10 in Appendix 1 has an embedded chart that can be scrolled across the data to view the relationships of all elements from the 2008 samples versus the 2009 samples. In general, although values were quite similar, the reproducibility was inferior. As noted above, this is to be expected because of seasonal variations in element uptake – the 2008 survey was conducted in June when concentrations are relatively high during the active uptake of elements, whereas that in 2009 was in mid August at a time when plants were more stable and concentrations in the plant tissues were slightly lower. Table 4 summarizes these relationships by showing the average values obtained for trees from these 44 sites in 2008 versus 2009. As can be seen, most elements were slightly more enriched in samples from the 2008 late spring/early summer collection when compared to the mid/late summer sampling in 2009.

		2008 Averages	2009 Averages	Ratio 2008 vs 2009
Ag	ppb	41	39	1.1
As	ppm	0.11	0.09	1.2
B	ppm	6.5	6.2	1.1
Ba	ppm	55	49	1.1
Ca	%	0.357	0.287	1.2
Cd	ppm	0.03	0.02	1.5
Ce	ppm	0.14	0.09	1.6
Co	ppm	0.058	0.039	1.5
Cr	ppm	1.38	0.89	1.6
Cs	ppm	0.266	0.287	0.9
Cu	ppm	3.7	3.9	0.9
Fe	%	0.009	0.004	2.0
Gd	ppm	0.012	0.011	1.1
Hf	ppm	0.002	0.001	1.7
Hg	ppb	22	16	1.4
K	%	0.27	0.32	0.8
La	ppm	0.056	0.045	1.2
Li	ppm	0.098	0.075	1.3
Mg	%	0.081	0.087	0.9
Mn	ppm	358	431	0.8
Mo	ppm	0.017	0.011	1.4
Nb	ppm	0.007	0.005	1.3
Nd	ppm	0.078	0.042	1.9
Ni	ppm	0.68	0.63	1.1
P	%	0.065	0.072	0.9
Pb	ppm	0.269	0.216	1.2
Rb	ppm	10	13	0.8
S	%	0.04	0.06	0.7
Sb	ppm	0.067	0.010	6.7
Sc	ppm	0.19	0.11	1.7
Se	ppm	0.145	0.135	1.1
Sm	ppm	0.011	0.011	1.0
Sn	ppm	0.129	0.066	1.9
Sr	ppm	20	16	1.3
Th	ppm	0.010	0.011	0.9
Ti	ppm	4.6	4.5	1.0
Tl	ppm	0.104	0.091	1.1
U	ppm	0.038	0.014	2.6
Y	ppm	0.033	0.018	1.8
Zn	ppm	43	45	1.0
Zr	ppm	0.063	0.034	1.8

Table 4: Cigar Lake – Average concentrations in dry spruce twigs collected at 44 sites (elements all or mostly below d.l. omitted)

Of note is that U concentrations were, on average 2.6 times higher in June than in August. Similarly, Fe, REE and HFSE are mostly almost double the concentrations in samples collected in August. A fundamental rule in biogeochemical exploration is to collect samples within a short period of time (usually less than 3 weeks for the latitude of the Athabasca) because of seasonal variations in plant chemistry brought about by the metabolic requirements of a plant. If samples are collected at different times of the year then they need to be levelled to a common datum – preferably by resampling a particular site on a weekly basis. This is not always a simple linear relationship, especially when concentrations are low and close to detection limits.

4.3 Infill Lines

4.3.1 McClean Lake

The samples collected in 2008 were from lines spaced 200 m apart with samples along the lines at 50 m intervals. This resulted in some anisotropy in contoured plots and extrapolation of contours into area with no sample control. In order to test how robust these signatures might be, a line of samples between lines MLS-2 and MLS-3 was collected in 2009, and designated the number MLS-5 (Fig. 16). This line crossed directly over the known mineralization of McClean South.

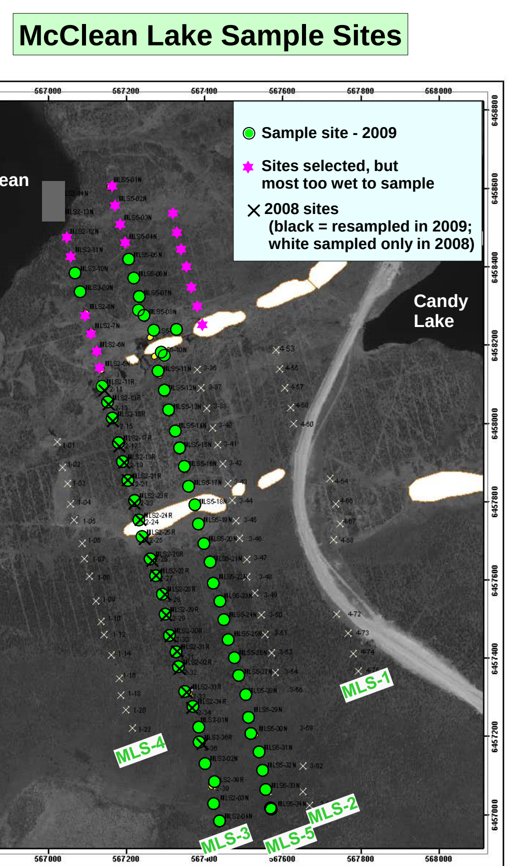


Fig. 16 Location of resampled sites (MLS-3 – green circles with black crosses) and sites from the 'infill' line MLS-5 with respect to samples collected in 2008 (crosses – black and white).

For those elements that did not exhibit significant seasonal variations, the 2009 data from the new sites could be integrated into the 2008 dataset. Molybdenum is a prime example for McClean Lake; Fig. 17 shows plots of 2008 data and the 2008+2009.

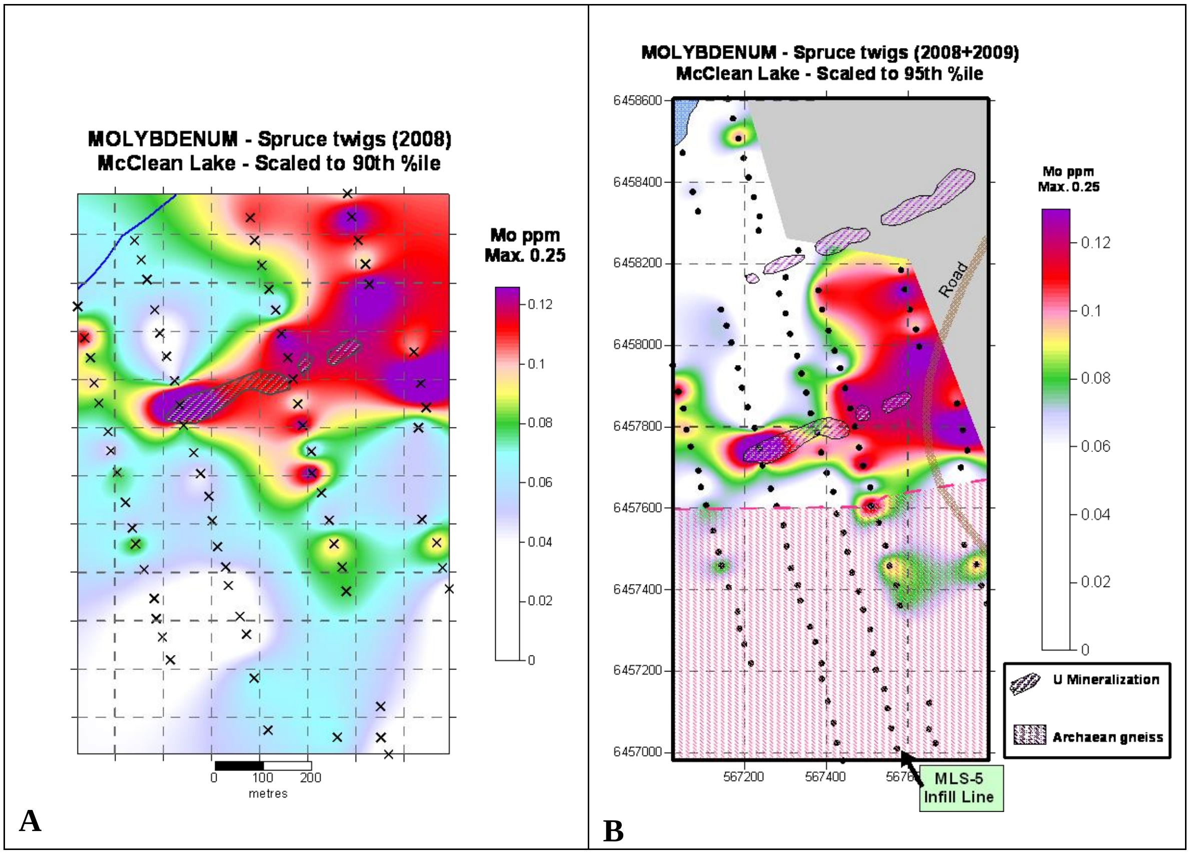


Fig. 17 Molybdenum: a) 2008 sample sites; b) 2008 plus new 2009 sites

By integrating the 2009 samples with those from 2008, the linear patterns remained and were refined by the addition of data from the new line of samples. Much the same picture was presented by adopting the same procedure for U (Fig. 18). Note, too, that the addition of samples into areas to the north and south that were presumed to be 'background' sites has shown that they are, indeed, at background levels and have further served to enhance the intensity of the anomalous patterns in the vicinity of McClean South.

The same procedure for Co, Ni, Bi and Nd (representative of the REE) have further enhanced and refined the extent of the zones of relative enrichments (Figs. 19 to 22).

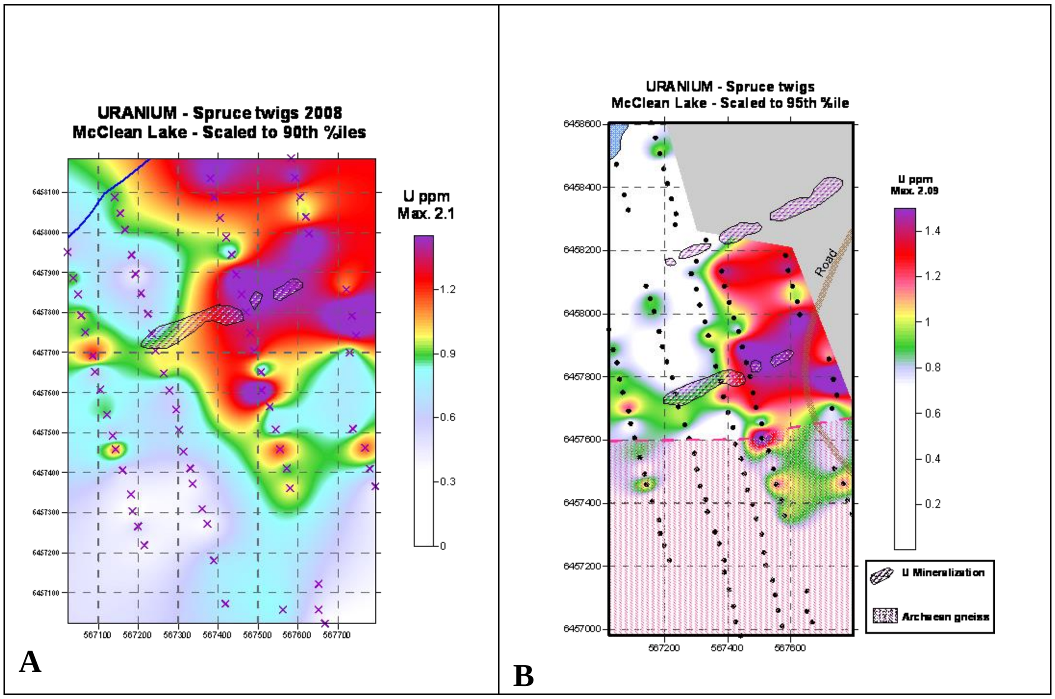


Fig. 18 Uranium: a) 2008 sample sites; b) 2008 plus new 2009 sites

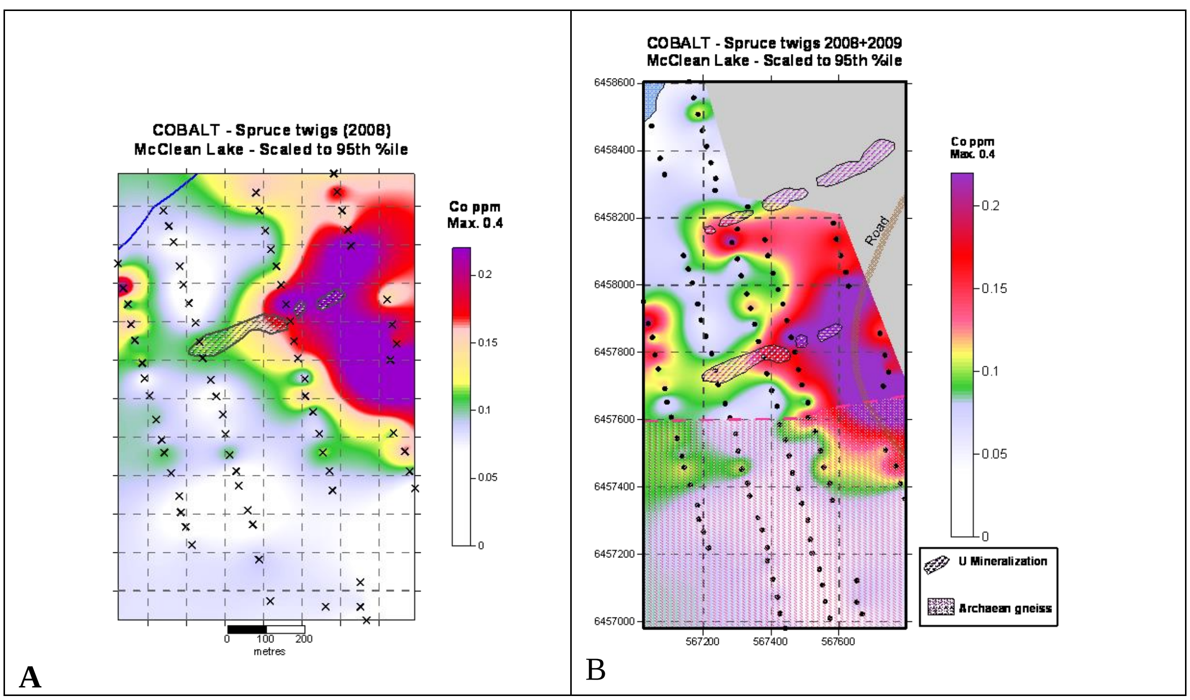


Fig. 19 Cobalt: a) 2008 sample sites; b) 2008 plus new 2009 sites

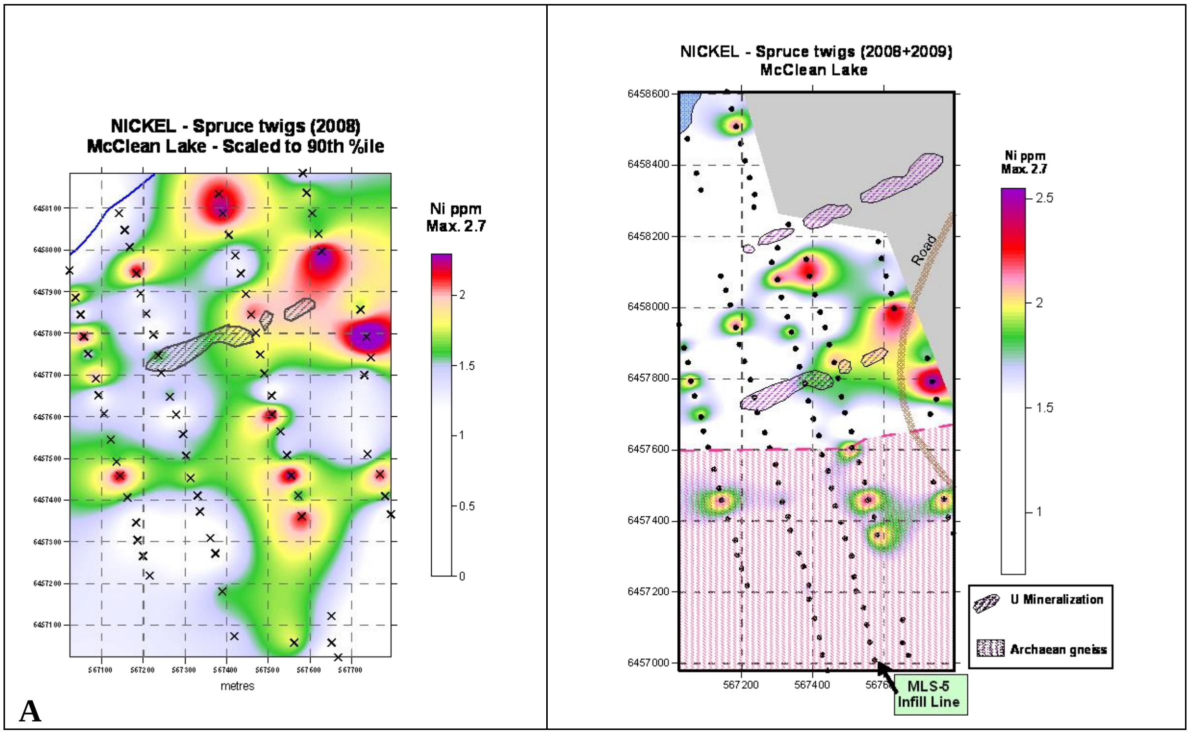


Fig. 20 Nickel: a) 2008 sample sites; b) 2008 plus new 2009 sites

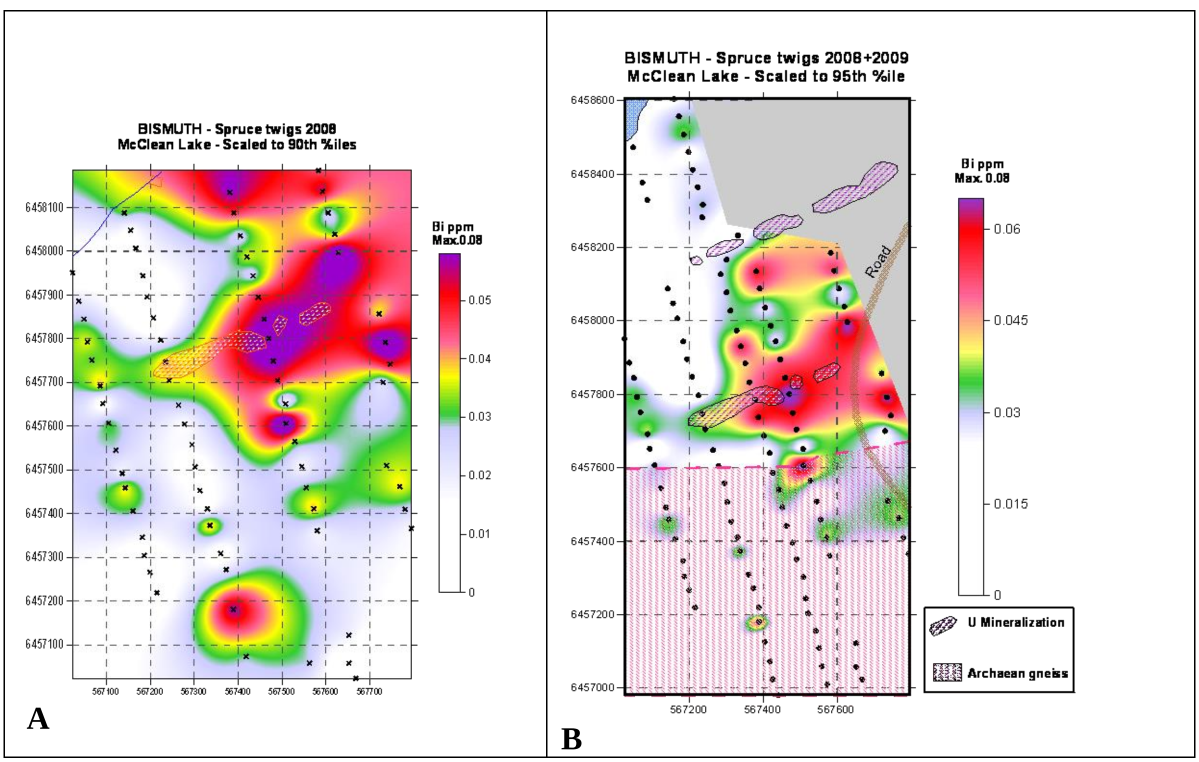


Fig. 21: Bismuth: a) 2008 sample sites; b) 2008 plus new 2009 sites

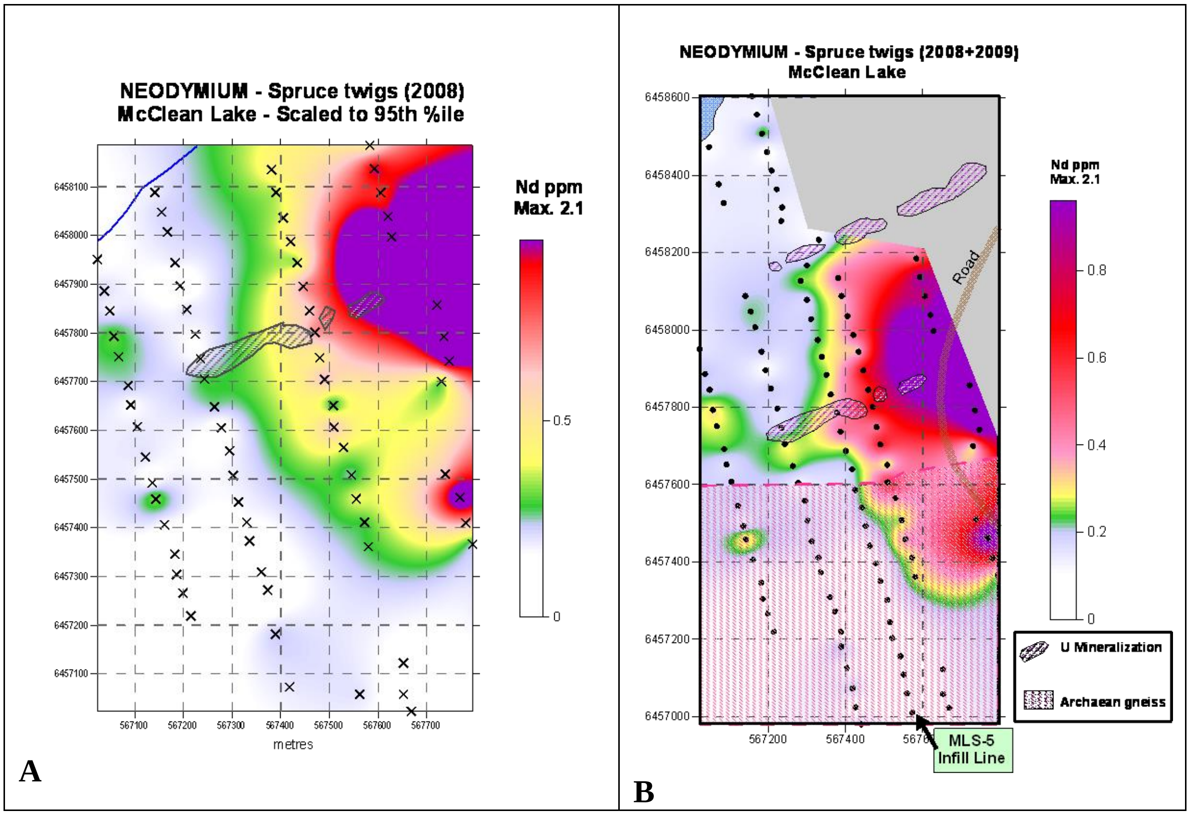


Fig. 22: Neodymium: a) 2008 sample sites; b) 2008 plus new 2009 sites

4.3.3 Cigar Lake

It was shown in Table 4 that concentrations of most elements were slightly higher in the 2008 samples than those from 2009. The data can be roughly levelled to a single year basis, but examination of the data shows that in essence, the element distribution patterns remain much the same. Figures 23 and 24 show the contoured data for Ba and Sr, respectively. Sampling that was extended into presumed background area to the north and south mostly helps to refine the extent of the principal anomalies which, in the case of these two elements are centred directly over the Cigar West zone of mineralization.

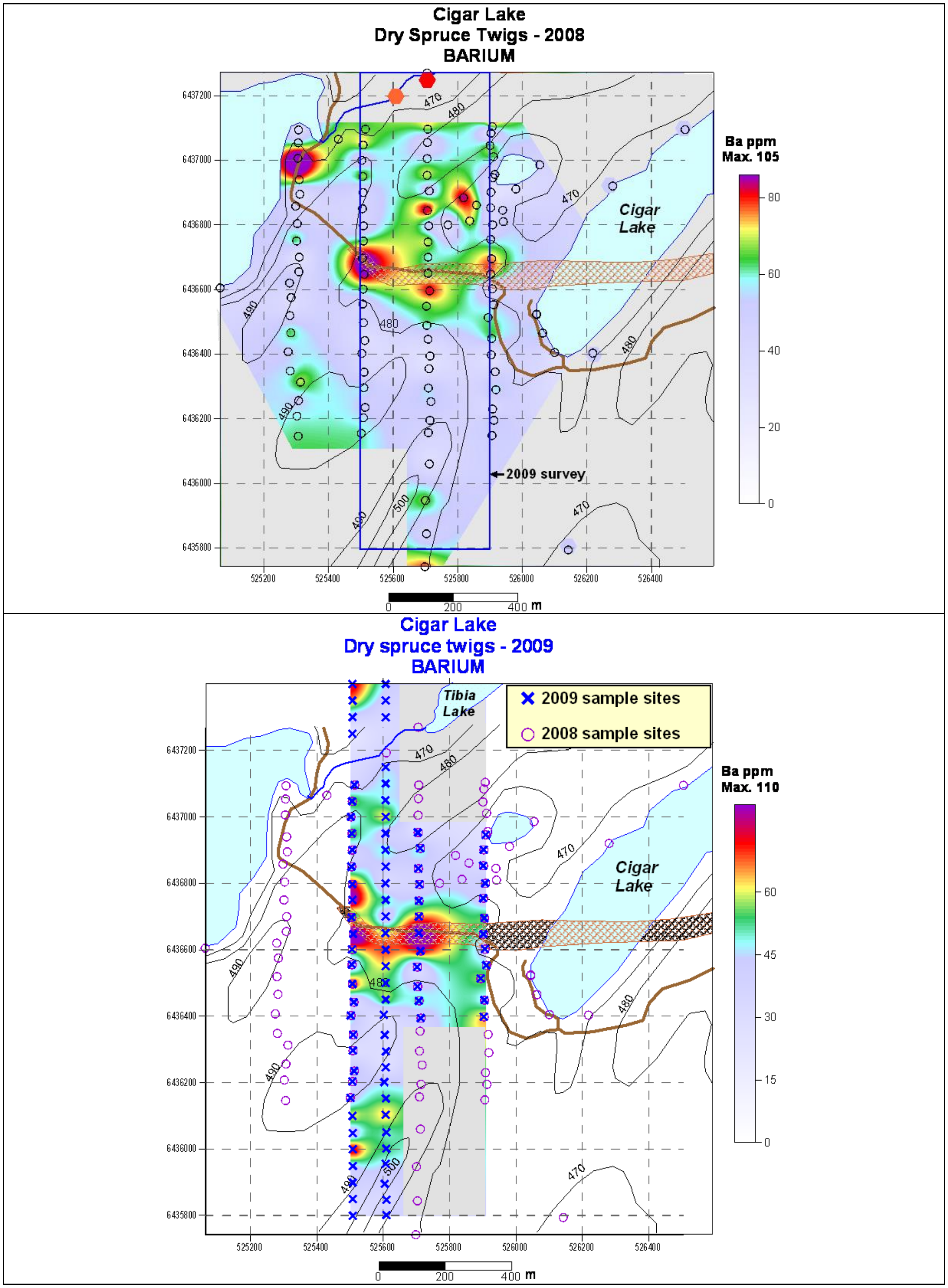


Fig. 23 Barium – Plots of data from 2008 samples and 2009 samples

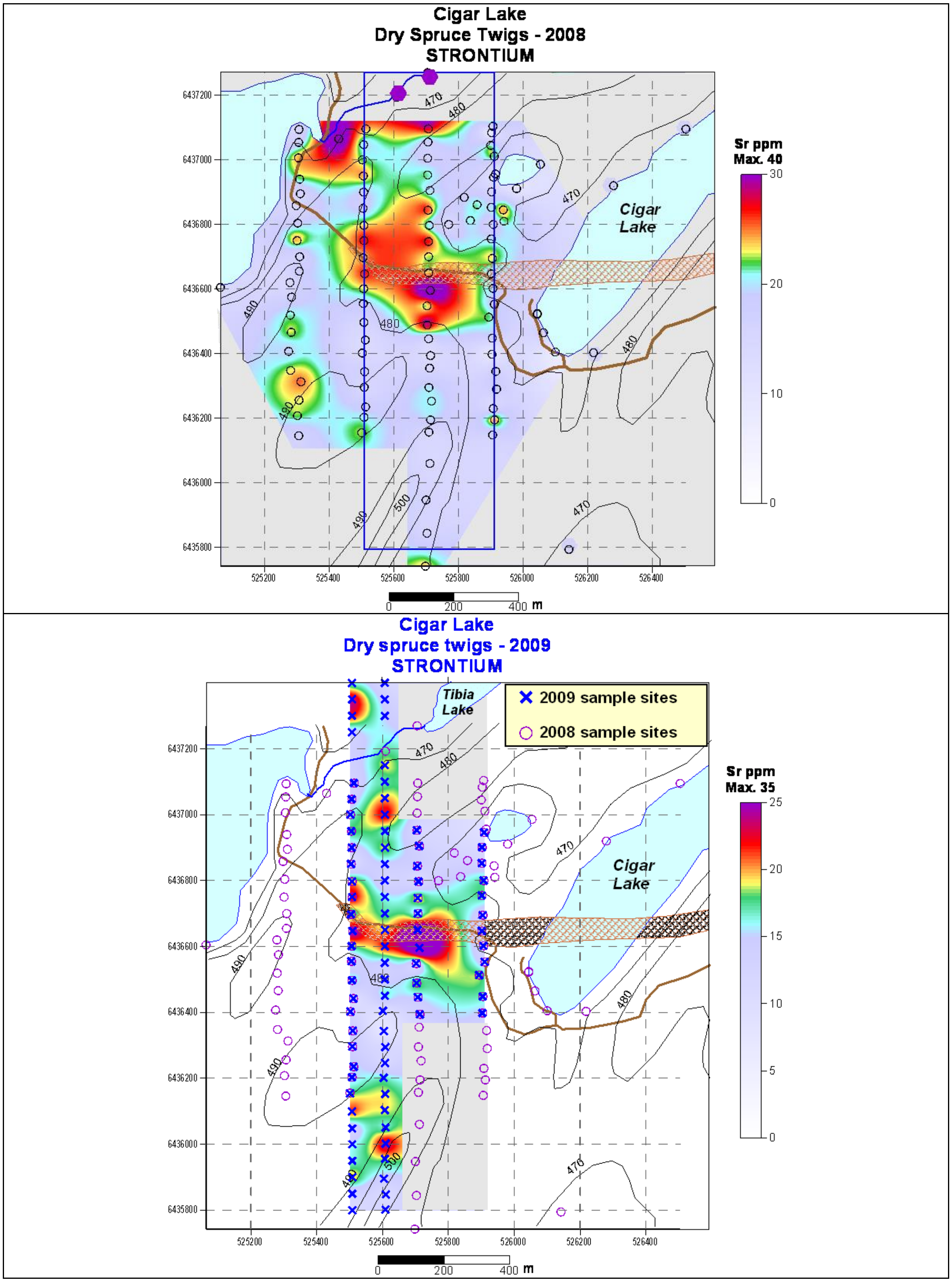


Fig. 24 Strontium – Plots of data from 2008 samples and 2009 samples

Graeme Bonham-Carter has applied his approach of plotting all the data from both surveys to the Cigar Lake spruce samples. All plots are shown in Appendix 4, and they give a broad indication of element distribution patterns. It appears that for most elements the signatures are quite robust. Examples of the more detailed interpolation approach that he has applied are shown in Fig. 25. Details of the calculations are given in the report on soil chemistry by Graeme and Gwendy.

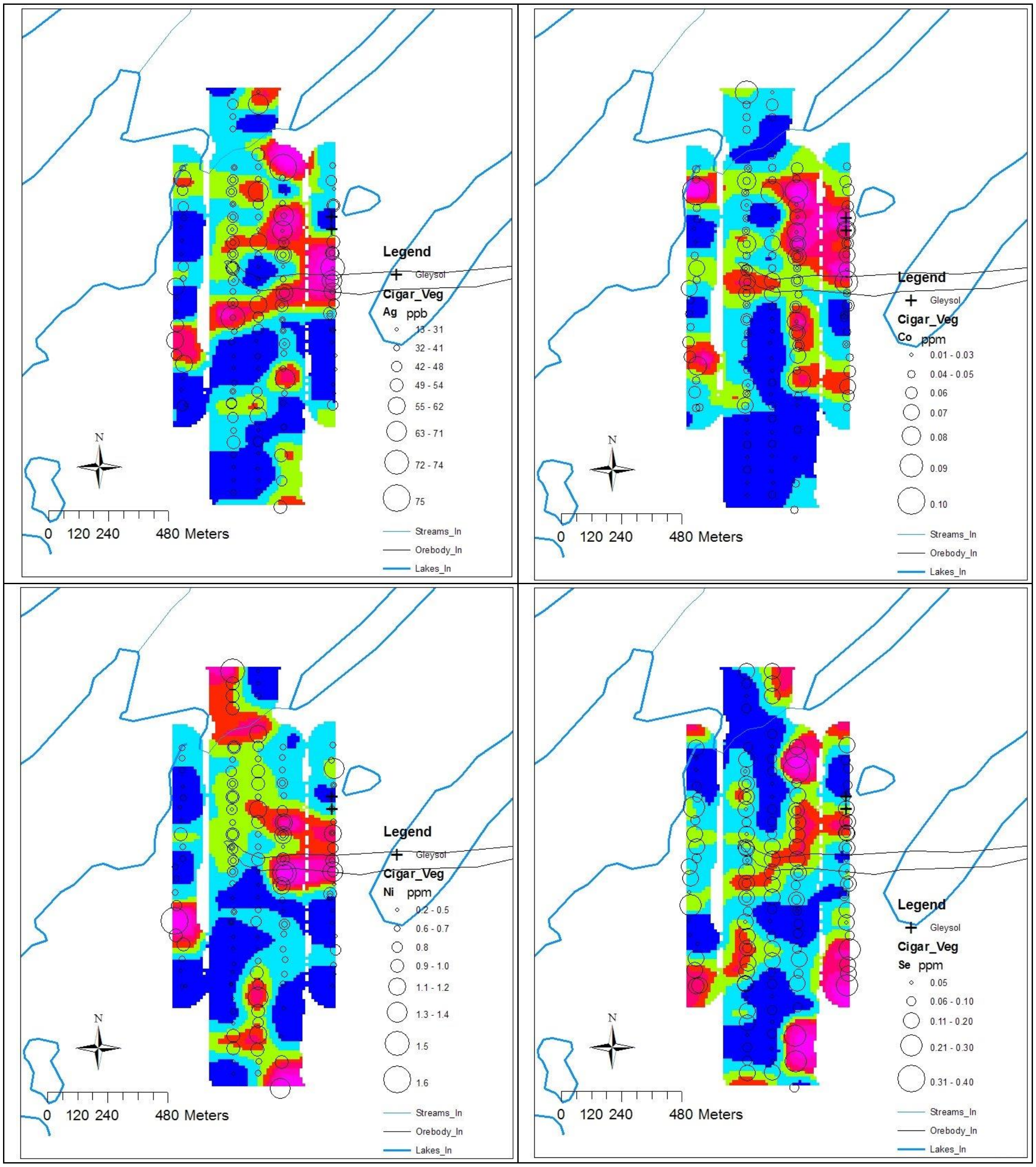


Fig. 25 Plots of Ag, Co, Ni and Se by the method designed by Graeme Bonham-Carter for the soil data.

Care should be taken when interpreting the plots to ensure that elements showing high variations from year to year (see Table 4) are not given overdue significance. For example, the median value for U from the 2008 samples was 2.6 times higher than for the 2009 samples. Similarly, the median for Y was 1.8 times higher in the 2008 samples. Plots of these elements (Fig. 26) show a linear zone of relatively low values (dark blue) down the centre of the plot. These lower values are from the 2009 infill line and distort the distribution patterns. The data should be levelled for these elements to generate a proper representation of the distribution patterns from the two surveys.

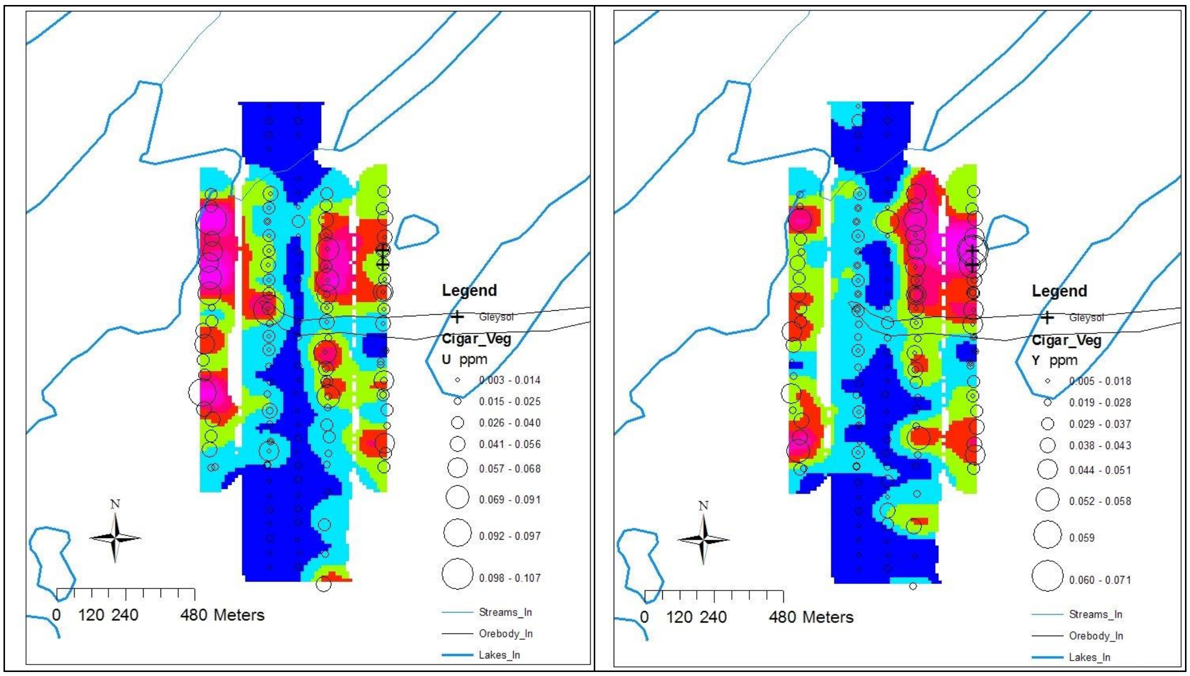


Fig. 26: U and Y from the integrated datasets obtained in 2008 and 2009.

Figure 27 shows plots of U with the 2009 data levelled to a 2008 basis. The linear feature of low values shown in Fig. 26 (plot on left) has now gone. The faulting interpreted by Cogema in the 1980s is now superimposed on the map on the right and a clear picture emerges of the relationships of the areas of relative enrichments to faulting and the Cigar West zone of mineralization. The plot on the left was prepared by Graeme using his standard method, whereas that on the right was plotted in Surfer using the same methodology as shown elsewhere in this report. Both methods capture the essential features of the data.

Several features are of note in these figures:

- The easternmost two lines appear to have 'Rabbit's Ear' anomalies – i.e. elevated levels to the north and south of a 'low' located over Cigar West mineralization.
- A cluster of relatively high values occurs to the east of Cat Lake at the intersection of several faults. The data would imply that the mineralization might extend as far as Cat Lake and the western line is, too, exhibiting a Rabbit's ear set of twin anomalies.
- 'Anomalies' are subtle and are only 3-4 times the background concentrations of 30 ppb U.

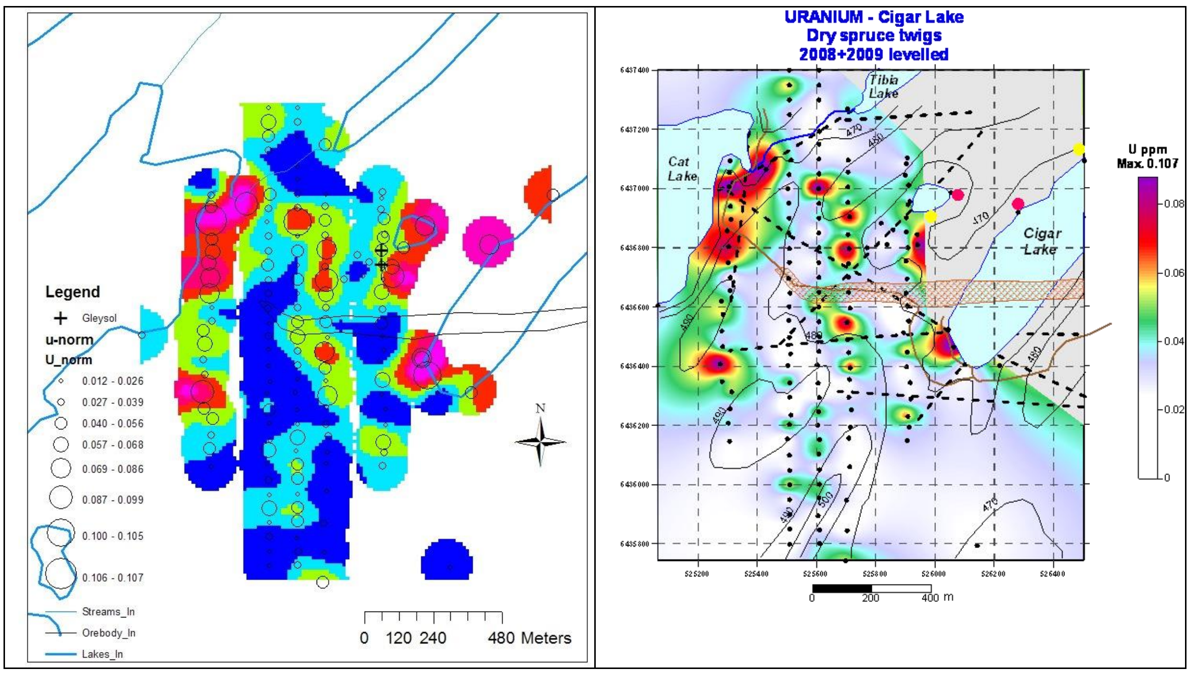


Fig. 27 Compilation maps of U data levelled to a common datum (plotted using two approaches – Graeme Bonham-Carter's method (used for the soils) and the Surfer percentile method used in this report.

5 Summary Observations and Interpretations

5.1 'Background'

An objective of the 2009 survey was to more firmly establish the background values. This was achieved by sampling farther to the north and south than the 2008 surveys, both at Cigar and McClean Lakes. The new data confirm that anomalous signatures of elements in the vicinities of the zones of mineralization are, with rare exceptions, confined to those areas. This more firmly establishes that there occurs a suite of elements above or laterally displaced from deeply buried mineralization that outline the general location of the mineralization to varying degrees, depending on the element concerned.

5.2 Infill samples

Sampling in 2009 along new lines, located between lines samples in 2008 confirms that the 2008 signatures are robust.

5.3 Resampling

Repeat sampling in 2009 of some 2008 sites has shown that similar patterns of element profiles are retained along transects. However, the plants exhibit the classic seasonal variations in chemistry that have long been recognized. Samples collected in June (early summer) have slightly higher concentrations of many elements than the same sites collected in August 2009 (late summer). For U, REE and HFSE these differences are sufficiently large to warrant levelling of the data to a common base in order to obtain accurate spatial plots of element distributions. The seasonal difference appears to be greater in the well-drained areas than in the bogs (where growth is much slower); consequently these differences are greater in the generally dry environment of Cigar West than the boggy terrain of McClean South.

5.4 Highlights of the Vegetation Study

5.4.1 Cigar Lake

Plots of all elements (combined 2008+2009 samples) from the AR leach have been prepared by Graeme and are presented in Appendix 4. Plots of the 2008 data, only, that are considered of greatest relevance because of their relationship to the Cigar West zone of mineralization are shown as a series of plots below (Fig. 28). The presence of Sr and Ba suggests a carbonate/calc-silicate source.

The coincident enrichments of several elements at the junction of 3 faults just east of Cat Lake could be worthy of closer investigation

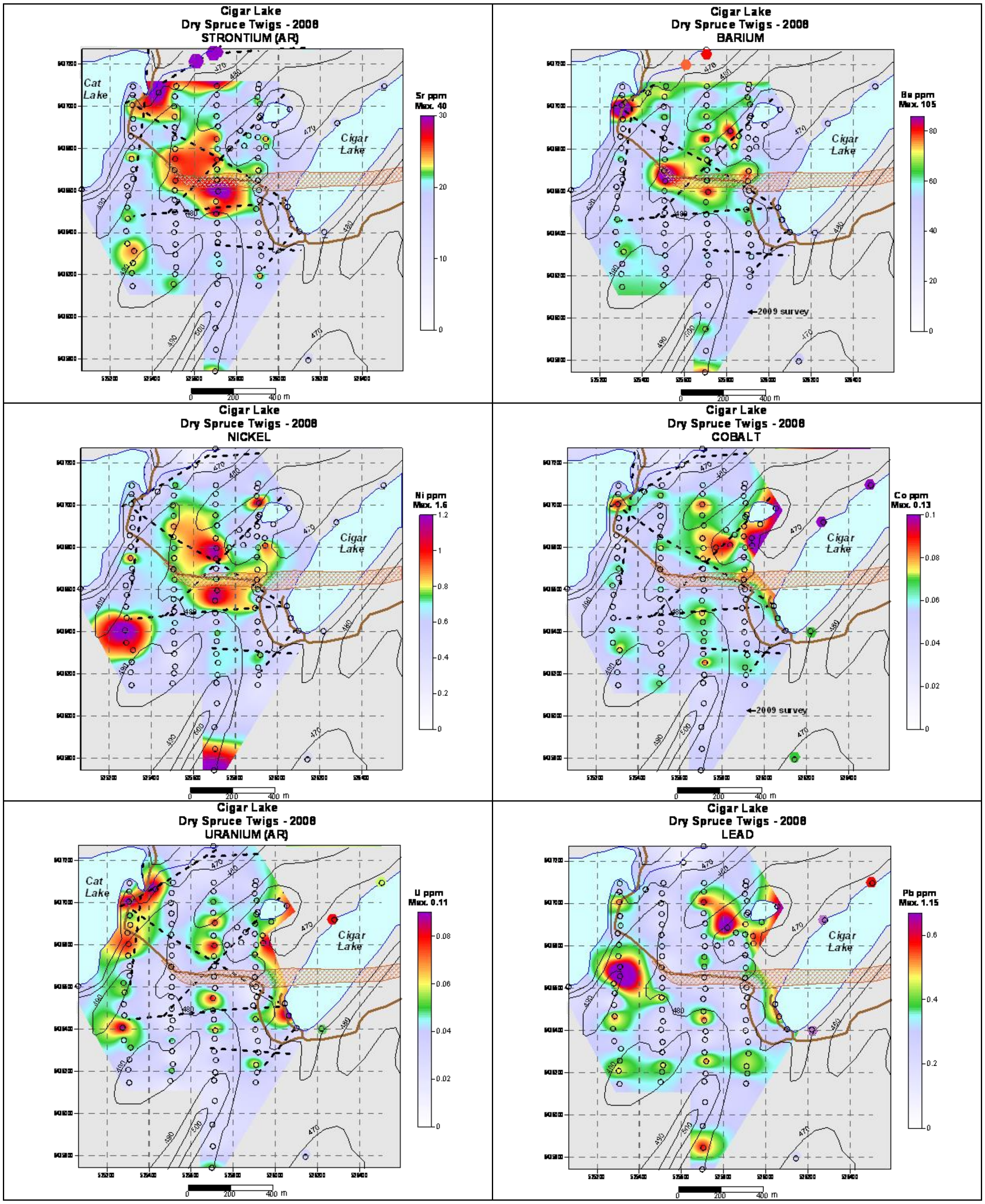


Fig. 28 Cigar West – plots of Sr, Ba, Ni, Co, U and Pb determined by aqua regia (all 2008 samples)

Plots of the element distribution patterns obtained from the Bioleach of the 2008 samples are shown in Appendix 2. Highlights of these are presented in Fig. 29.

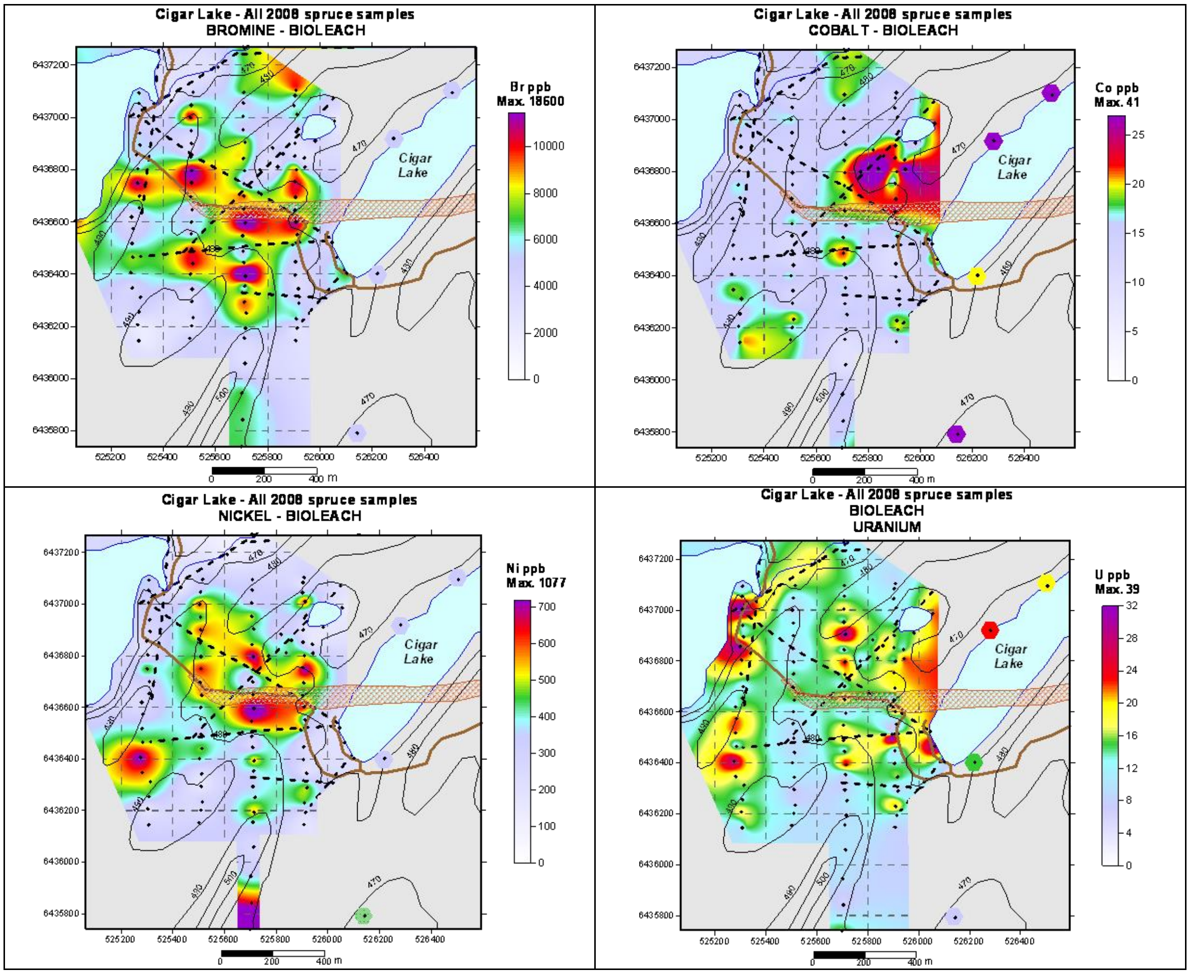


Fig. 29 Cigar West – plots of Br, Ni, Co, and U determined by Bioleach (all 2008 samples)

Plots of those elements determined by NaPyr that yielded adequate precision are presented in Appendix 3.

5.4.2 McClean Lake

Plots of all elements (combined 2008+2009 samples) from the AR leach have been prepared by Graeme and are presented in Appendix 5. Additional plots of the same data (2008+2009) for those elements that did not exhibit significant seasonal variations are shown in Fig. 30. Elements showing the strongest relationship to the McClean South zone of mineralization are presented.

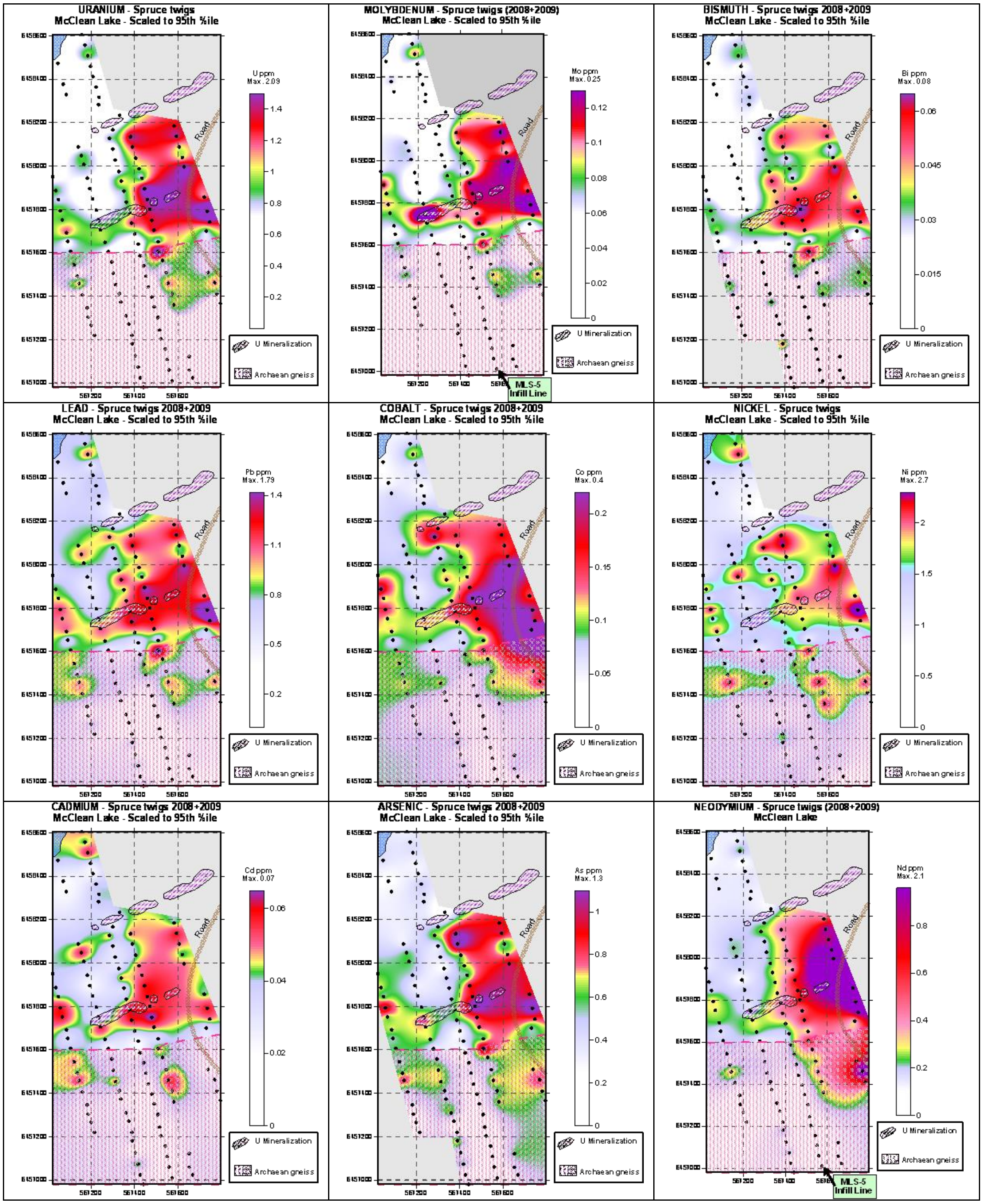


Fig. 30 McClean Lake – U, Mo, Bi, Pb, Co, Ni, Cd, As and Nd determined by AR (2008 data merged with 2009)

It is concluded that the spruce twigs reflect mineralization at both Cigar Lake West and McClean South. At McClean Lake South, where mineralization occurs beneath about 160 m of Athabasca Sandstone that is covered by several metres of glacial overburden, the signature of many commodity-related elements is robust and stands out clearly from the surrounding area. At Cigar West, where mineralization lies mostly beneath 440 m of Athabasca Sandstone, covered with a few metres of glacial overburden, the geochemical signature is less pronounced, although there are strong signatures of several elements – notably Sr, Ba, Ni and Br. The evidence is compelling that elements migrate to the surface from deeply buried mineralization, perhaps aided by bacterial activity.