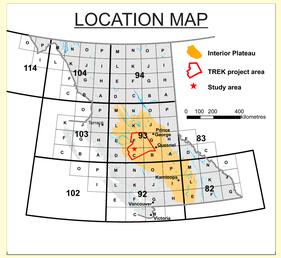
Halogens in Tree Tops: Guides to Geology, Structure and Mineralization

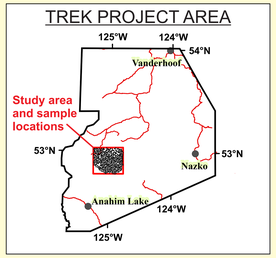
C. E. Dunn[1],and D. R. Heberlein[2] (Email: colindunn@biogeochemistry.ca)

[1] *Colin Dunn Consulting Inc., Sidney, BC,* [2] *Heberlein Geoconsulting, North Vancouver*

Introduction

In June 2015, side-branch samples, each comprising 1 kg of twigs, needles and cones, were systematically collected by helicopter from near the tops of 399 healthy Interior spruce trees. The survey followed a 1500 m offset grid pattern comprising a 1000 km^2 area of the Blackwater/TREK regions of central British Columbia. Samples were analyzed for 65 elements by ICP-MS and results published by Jackaman and Sacco (2016). There remained a surplus portion of ashed needles from each site. In the current study, these samples were analyzed for the four halogens (F, Cl, Br and I) after some further analytical method development at ALS-Geochemistry, North Vancouver.





Helicopter sampling of lateral branches of an Interior Spruce tree.

Analytical Methods and Quality Control

Experimentation determined that the optimum procedure is to leach 0.5 g of ash in hot de-ionized water for several hours and the leachate analyzed by a combination of ion chromatography (IC) and inductively-coupled mass spectrometry (ICP-MS). Data with good precision were obtained on repeat analysis of two control ash samples All field samples yielded concentrations of all four halogens that were well above the DL (Table 1) and with a precision of about 20% relative standard deviation (RSD) for field duplicate pairs. Precision for blind ash control samples was considerably better at around 5% RSD (Table 1).

Table 1. Halogen Summary Statistics (concentrations in ash)

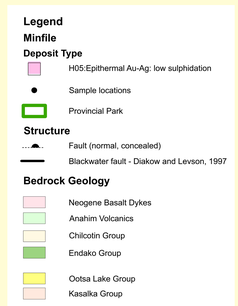
				Percentiles									
	n	Mean	Std. Dev.	Minimum	25	50	75	87	93	96	98	99	Maximum
I_ppm	399	0.034	0.029	<0.005	0.014	0.023	0.043	0.067	0.081	0.099	0.126	0.146	0.212
Br_ppm	399	2.9	6.1	<0.02	0.43	1.17	2.27	5.46	10.85	16.75	20.1	29.7	71
F_ppm	399	62	38	<0.05	36.4	52.6	75	96.5	115	153	179	193.5	324
Cl_ppm	399	926	1144	0.1	100	507	1330	2060	2700	3300	4170	5400	>10000

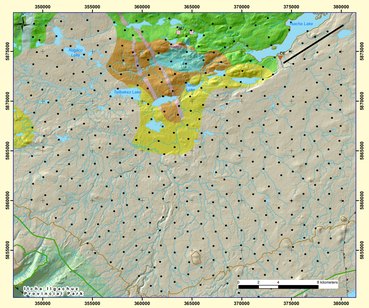
Table 2. Halogen %RSDs for 20 Field Duplicate pairs

	Average RSD% (n=20 pairs)			
Analyte	Br	Cl	F	I
Average RSD	19.8%	20.3%	16.8%	17.9%

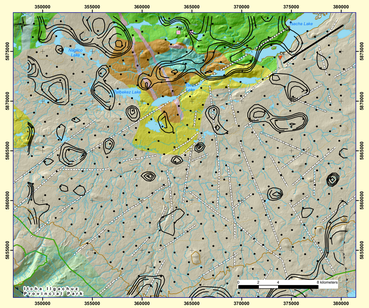
Data Analysis

After verification of some of the original trace element data, a reduced data set of 17 of the original 65 elements was combined with the halogens and the correlations determined. Two distinct populations emerged: 1) Cl-Br-I; and 2) Ag-Br-Cl-Cs-Cu-Na-Pb-Rb. Fluorine had no statistically significant correlation with any other element. However, when plotted spatially, its distribution revealed some distinct trends of which some were coincident with magnetic lineaments and known faults: 1) linear F anomalies with a north-easterly trend for about 30 km following the trend of the Blackwater fault and, in conjunction with the trend of analytic signal aeromagnetic and past geological mapping, suggests leakage from a fault zone; 2) Br, Cl and I tend to cluster and, since they are also statistically related, an index of their concentrations could be developed.

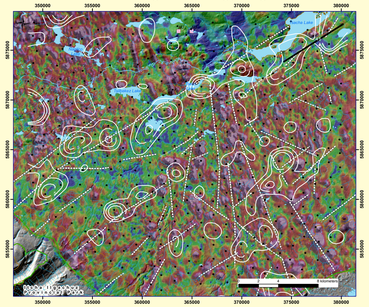




Sample locations over regional geology (Angen et al., 2017).



Contours of a Cl-Br-I summative index on geology. Structures interpreted from the aeromag Analytic Signal are shown as white dashed lines.



Fluorine contours (white solid lines) superimposed on Analytic Signal of aeromag. Interpreted structures are indicated by white dashed lines. The position of the mapped Blackwater fault (Diakow and Levson, 1997) is indicated as a solid black line.

Results

The statistical association of Br, Cl and I with the Ag-Cs-Cu-Fe-Na-Pb-Rb assemblage provides a guideline toward zones of potential mineralization and/or hitherto un-mapped windows through the Chilcotin Group. All three halogens are important ligands for the transport of metals in hydrothermal fluids. Therefore, coincident anomalies of these elements may be showing areas where there has been hydrothermal activity involving magmatically derived fluids.

A principal components (PC) analysis using ioGAS on the same element suite minus the halogens, revealed 4 (PCs) with Eigenvalues >1 (Table 3).

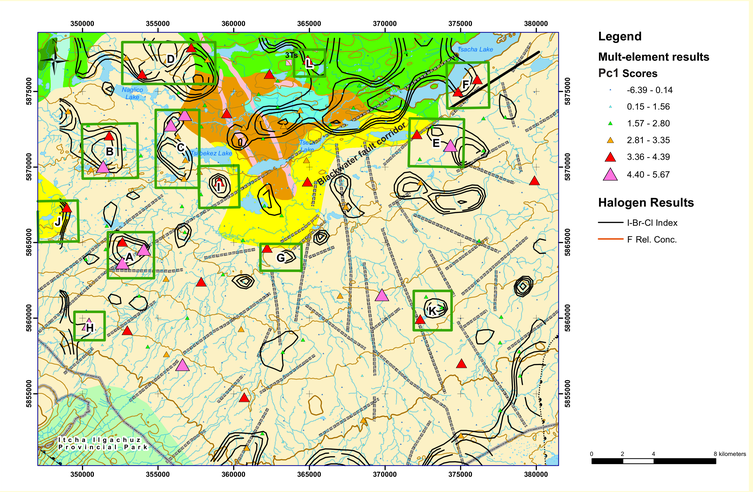
Table 3. PCA Loadings for the first four principal components.

Scaled Coordinates	PC1	PC2	PC3	PC4
Ag_ppb	0.294	0.099	0.211	0.190
B_ppm	0.484	-0.341	0.212	-0.011
Be_ppm	-0.282	0.752	0.150	0.133
Cd_ppm	0.459	0.314	0.019	0.382
Cs_ppm	0.387	0.506	-0.035	-0.413
Cu_ppm	0.667	0.269	-0.277	0.048
Cu_ppm	0.868	0.173	0.094	0.012
Fe_pct	0.577	-0.394	0.006	0.095
I_ppm	0.401	-0.605	0.156	-0.145
Mo_ppm	0.383	-0.581	0.437	-0.120
Na_pct	0.792	-0.145	-0.029	-0.134
Ni_ppm	0.374	0.562	-0.030	-0.484
Pb_ppm	0.662	0.074	-0.069	0.477
Rb_ppm	0.780	0.392	-0.089	-0.157
S_pct	0.477	-0.046	0.457	0.296
Sr_ppm	0.480	0.395	0.400	0.347
Zn_ppm	0.273	0.331	0.689	0.001

PCA Loadings for PC1 (31.8%).

Discussion

To investigate the relationship between the halogens and the pathfinder elements, a scaled symbol plot of PC1 scores is superimposed on the halogen index contours and reveals 12 areas where PC1 and the halogen index coincide (green rectangles labelled A to L). Coincidence of pathfinder element and halogen anomalies is compelling evidence for metal bearing hydrothermal systems. Ten of the features highlighted occur in areas mapped as Chilcotin Group basalt. Feature L in the north is on Hazelton Group and coincides with the 3Ts epithermal Au-Ag occurrence; the only known metal occurrence in the map area. Features A, E, H and I all lie within the NE-SW Blackwater fault corridor defined by the aeromagnetic survey. The most compelling coincident halogen and pathfinder element anomalies are A, B, C and D. Each represents an area of at least 10 km2 – each is considered as a potential target for epithermal and/or porphyry mineralization beneath the Quaternary and Chilcotin Group cover; further investigation of their significance is justified.



Areas with coincident Cl-Br-I anomalies and PC1 pathfinder elements responses (green boxes).

Conclusions

1. Halogens in the spruce needle ash produce geologically meaningful patterns.
2. Fluorine identifies a NE striking structural corridor that aligns with the Blackwater fault defined by aeromagnetic results (Analytic Signal).
3. Bromine, Cl and I show sympathetic patterns. Elevated concentrations in the northern part, sub-parallel with the Blackwater fault corridor, may indicate background differences between the Hazelton, Bowser Lake and Ootsa Lake Groups in the north, and Chilcotin basalts to the south.
4. The one coincident halogen index and PC1 anomaly on Hazelton Group rocks coincides with the 3Ts epithermal Au-Ag prospect; the only known mineral occurrence in the survey area. This confirms that the halogens, in concert with the multi-element geochemistry, can detect mineralization.
5. Coincident halogen and PC1 anomalies over Chilcotin basalt may indicate windows through the basalt cover exposing prospective Ootsa Lake and Hazelton Group rocks.

Acknowledgements

We thank staff and management at ALS-Geochemistry for discussions and further method development – in particular Alemayehu Asfaw, Amanda Stoltze and Iyad Al Khatib, as well as earlier discussions with Sarah Rice and Emma Armstrong, and for discounting the analytical work. We are grateful to Wayne Jackaman for discussions on the original sampling program and supplying the ash samples on which this study is based. Finally, we gratefully acknowledge the financial support of Geoscience BC and the province of British Columbia.

References

Angen, J.J., Rahimi, M., Hart, C.J.R., Westberg, E., Logan, J.M. and Kim, R. (2017): Bedrock geology, TREK project area, northern Interior Plateau, central British Columbia; Geoscience BC Map 2017-06-01 and MDRU Map 12-2017.

Diakow, L. J. and Levson V.M. (1997): Bedrock and Surficial Geology of the Southern Nechako Plateau, Central British Columbia, Ministry of Employment and Investment, Geoscience Map, 1997-2, 1:100,000 Scale.

Jackaman, W. and Sacco, D.A. (2016): Reconnaissance biogeochemical survey using spruce-tops in the West Road (Blackwater) River area, Fraser Plateau, British Columbia; Geoscience BC, Report 2016-05, 8pp. + 3 appendices.