Albert Creek
880035

FALCONBRIDGE

Sam 946-8785 (from: Shamus Young)

VGL → ACE

Tom Schroeter Dec-17/90

Memorandum

Date: 10 February 1983

To: FILE

Copies to: I.L. Elliott / J.B. Gammon
J.J. McDougall

From: R.L. Daykin

Subject: JOHN A.C. FORTESCUE PAPER

We approve the attached paper, "The Use of Mimulus Guttatus DC as an Aid to Prospecting at Springs in Northern British Columbia", to be delivered at -- Organic Matter, Biological Systems and Mineral Exploration Workshop/Colloquium, University of California, Los Angeles, February 14th to 18th, 1983.

W.D. Harrison
Director of Administration
and Management
Exploration and Development

J.D. Krane
Vice-President
Corporate Affairs

ORIGINAL SIGNED BY
R. L. DAYKIN

R.L. Daykin

RLD:mc

* Don't lose. My only copy JJMcD

J. J. McDougall & Associates Ltd.
7720 Sunnydene Rd.
Richmond, B.C.
V6Y 1H1

FALCONBRIDGE

Falconbridge Limited
Box 40, Commerce Court West
Toronto, Canada M5L 1B4
Telephone 416/863-7000
Telex 065-24211 Rapifax 364-8986

11 February 1983

Dr. John A. Fortescue
Research Geochemist
Ontario Geological Survey
712 - 77 Grenville Street
TORONTO, Ontario
M5S 1B3

Dear Dr. Fortescue:

This will confirm our telephone conversation whereby you were advised that this Company approved your paper, "The Use of Mimulus Guttatus DC as an Aid to Prospecting at Springs in Northern British Columbia", in respect of data which relates to this Company.

Please accept our very best wishes and sincerely trust your presentation of this paper will be well received.

Yours very truly,

FALCONBRIDGE LIMITED
ORIGINAL SIGNED
R. L. DAYKIN
R.L. Daykin
Manager, Administrative Service
Exploration and Development

RLD:mc

cc: J.B. Gammon/I.L. Elliott
J.J. McDougall

FALCONBRIDGE

RUSH

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THE USE OF MIMULUS GUTTATUS DC AS AN AID TO PROSPECTING AT SPRINGS IN NORTHERN BRITISH COLUMBIA

by

John A.C. Fortescue and Jim McDougall

Research Geochemist.

Ontario Geological Survey

742-77 Grenville St.

Toronto, Ontario.

Preprint of a paper to be delivered at :-

Organic Matter, Biological Systems and
Mineral Exploration Workshop/Colloquium
University of California Los Angeles
February 14th to 18th 1983

PREFACE

This paper is based directly on a small report[1] prepared for a consulting job for Falconbridge Nickel Mines in Vancouver and dated December 7th 1983. The work was done at the request of Dr J.F.Gammon under the direction of Dr I.Elliott. In my opinion this work was suitable for publication from the viewpoint of a conceptual approach to a very small scale study. This possibility was mentioned at the time but no decision was made. In the fall of 1982 I received a brochure for the Workshop/Colloquim in Los Angeles and wrote to ask the organiser Dr D.Carlisle to see if any of three titles which were suggested would be acceptable for inclusion in the proceedings of the meetings. A delayed reply reached me in mid December 1982 saying that the Mimulus guttatus DC study would be accepted provided that the abstract was submitted within a few days. A then called Dr Elliott and got verbal permission to go ahead with the abstract on the understanding that the paper would be submitted to him and Dr Gammon for comments as soon as completed. I phoned Dr Carlisle at this point and during the conversation happened to mention that I could not attend the meeting owing to lack of funds for travel. He replied that if travel funds could be found he would wave the entry fee of some $550.00 (Canadian). I then decided to attend the meetings at my own expense. Unfortunately, due to circumstances beyond my control, (the preparation of two reports at short notice and attendence at the Geoscience Appraisal meetings)work on the Mimulus guttatus paper did not commence until February 4th and was completed yesterday. When the paper preprint was completed I phoned Dr Gammon to ask how I should proceed with permission to publish from Falconbridge. He suggested that Dr Ray Daykin and Dr Chris Jennings should be contacted today in Toronto regarding this matter. Consequently two copies of the preprint with this preface have been prepared for the Company assessment.

J.A.C.Fortescue

John A.C.Fortescue
Until May 1982
Consultant,Enviroquest,
Vancouver.
10/2/83

1
John A.C.Fortescue

The use of Mimulus guttatus as an indicator plant in Northern British Columbia

A report compiled under contract to Falconbridge Nickel Mines : December 7th 1981 32pp.

ORGANIC MATTER, BIOLOGICAL SYSTEMS AND MINERAL EXPLORATION

A Workshop and Colloquium for Mineral Explorationists and Research Scientists

UCLA, February 14-18, 1983

Conveners: W. L. Berry, D. Carlisle (Chair), P. J. Coleman Jr., I. R. Kaplan, J. R. Watterson

This is an interdisciplinary workshop and colloquium bringing together industry, academic and government researchers interested in innovative exploration techniques for metallic deposits. We will focus on approaches that may have great potential because of recent developments in technology and concepts. Classical biogeochemical exploration has emphasized higher plants and perhaps has suffered from too little input from plant physiologists. The colloquium will address this. Of particular interest are new data and techniques from microbiology and research on natural organic substances.

The program incorporates two days of short course on state-of-the-art biogeochemical exploration, intended primarily for explorationists, followed by a critical evaluation of some case histories and followed in turn by the colloquium proper with papers by internationally known research scientists. The papers will be conceptual in nature. Limited space is available for additional shorter contributions, discussions and a poster session. An all-participant forum will conclude the meeting. Proceedings will be published as *Rubey Volume V*.

PROGRAM

February 14-15

BASIC PRICIPLES OF BIOLOGICAL METHODS OF EXPLORATION

A short course (Geology Building, Room 3656)

Intended primarily for mineral explorationists. Well-established metal-organic relationships and biogeochemical exploration methods. Some new microbiological techniques.

Instructors:
R. R. Brooks (Massey University, N.Z.)
P. J. Peterson (Imperial College, London)
J. R. Watterson (USGS)

THE COLLOQUIUM
Second Floor Lounge, Ackerman Union

February 16 AM

CASE HISTORIES FROM BIOGEOCHEMICAL EXPLORATION, SUCCESSES AND FAILURES

An overlap session between the short course and the colloquium. Emphasis on precious, ferro alloy, rare and base metals.

LUNCHEON: Speaker—H. V. Warren (University of British Columbia)

METALS, BIOLOGICAL SYSTEMS AND MINERAL EXPLORATION

February 16 PM - 17 AM

(A) PLANTS AND MINERAL EXPLORATION

Topics include:
Relationship of elemental content of plant tissue to environmental metal concentrations.
Effect of soil chemistry on metal transformations in the soil.
Availability of elements to plants as determined by the soil-plant interaction.
Ecology of root development and distribution within the soil.
Influence of plants on the movement and distribution of metals within the soil.
Tolerance: a plant's response to metal stress.
Impact of metal stress on plant communities.
Spectral radiometry of forest canopy.
Present status of biogeochemical exploration using higher plants.

Speakers include:
W. L. Berry (UCLA)
G. Sposito (UC Riverside)
I. Thornton (Imperial College, London)
J. H. Richards (Utah State University)
P. J. Peterson (Imperial College, London)
L. P. Gough (USGS)
W. E. Collins (Columbia University)
R. R. Brooks (Massey University, N. Z.)

POSTER SESSION

February 17 AM - PM

(B) MICROBIOLOGY IN MINERAL EXPLORATION—A NEW APPROACH

Topics include:
Geomicrobiological prospecting, past and future.
Interactions of heavy metals and microorganisms.
Genetic mechanisms of metal and antibiotic resistance.
Physiochemical constraints on microbial metal resistance.
Heavy metal resistance in relation to the metal content of soils.
Antibiotic and heavy metal resistance in natural ecosystems.
Penicillin resistance associated with known heavy metal mineralization.
Fungal bacterial ratios associated with mineralization.

Speakers include:
D. M. Updegraff (Colorado School of Mines)
H. L. Ehrlich (Rensselaer Polytechnic Institute)
A. O. Summers (University of Georgia)
G. Stotzky (New York University)
B. H. Olson (University of California, Irvine)
R. R. Colwell (University of Maryland)
J. R. Watterson (USGS)

BANQUET: Speaker—S. L. Bolivar (Institute of Geophysics and Planetary Physics, Los Alamos)
Redwood Room, Faculty Center

February 18 AM

(C) ORGANIC MATTER AND MINERAL EXPLORATION

Topics include:
Forest mull in geochemical exploration.
Humic substances and their role in the solubilization and transport of gold and other metals.
Sorption of metals on humic substances.
Volatile metal-organic compounds and atmospheric involvement in biogeochemical cycling.

Speakers include:
G. Curtis (USGS)
W. E. Baker (Tasmania Department of Mines)
M. Schnitzer (Chemical and Biological Research Institute of Canada)

ALL PARTICIPANTS FORUM: CURRENT PROBLEMS AND FUTURE DIRECTIONS

ABSTRACT

Mimulus guttatus DC (the monkey flower) is common in moist places over a range which extends from the Aleutian Islands to Mexico. It is less common in Northeastern British Columbia where it has been observed growing in the vicinity of mineralized springs. In August 1981, a small scale study was carried out in the One Ace Mountain area of British Columbia in order to examine the possible use of the plant as a geobotanical or biogeochemical indicator. A further object of the study was to discover the most effective medium for geochemical prospecting in the area based on springs. In order to do this, four plots were laid out and sampled according to a prearranged plan. Three plots were located at known mineralized springs and a fourth some distance away as a control. Waters, Mimulus guttatus material and stream sediments were systemically sampled at each plot. All samples were analyzed for 24 elements simultaneously using an ICP method. It was found that foliage (or roots) of Mimulus guttatus could be used as a successful biogeochemical indicator for Ag, Pb, Zn and Cu at the mineralized springs. However, chemical data obtained from five samples of sediment collected at 2m intervals from springs was found to be considerably more effective for prospecting purposes. It is concluded that, because of its bright colour, Mimulus guttatus can be used to spot springs from a helicopter during the flowering season from May to September. Such springs may be cold or warm with a near neutral pH. Once spotted, the springs provide convenient sites for the collection of stream sediment samples.

THE USE OF MIMULUS GUTTATUS DC AS AN AID TO PROSPECTING AT SPRINGS IN NORTHERN BRITISH COLUMBIA

John A.C. Fortescue[1] and Jim McDougall[2]

Introduction

During the past hundred years, scientists have begun to study systematically the use of plants as guides to mineral deposits. Pioneer studies along these lines were completed by Professor H.V. Warren, Dr. R.E. Delavault and their numerous co-workers at the University of British Columbia during the 1940's and thereafter. Both of us were students of Professor Warren and we are happy to make this presentation as a token of our appreciation of his contribution to our education.

In the fall of 1980, one of us (Jim McDougall) was claim staking in the vicinity of One Ace Mountain in northern British Columbia close to the Yukon border (Figure 1). Silver anomalies in stream sediments and water led to this activity and during the investigations, a lush growth of a bright yellow flower was observed at springs which were associated with the high silver values. Samples of the plants and pictures of the springs were used to identify the plant as Mimulus guttatus DC, the monkey flower, which is found in

[1]Research Geochemist, Ontario Geological Survey, 77 Grenville Street, Toronto, Ontario, Canada M5S 1B3.
[2]Falconbridge Nickel Mines Ltd., 6415-64th Street, Delta, British Columbia, Canada V4K 3N3.

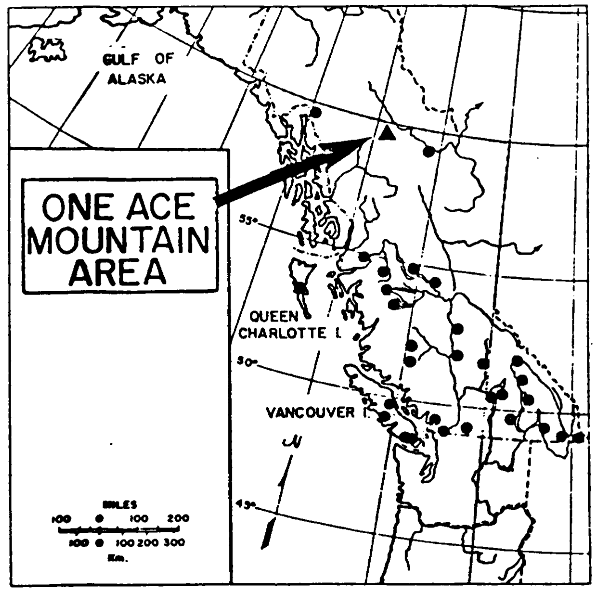

Figure 1 Map showing the range of Mimulus guttatus in British Columbia. [From Taylor (1974)].

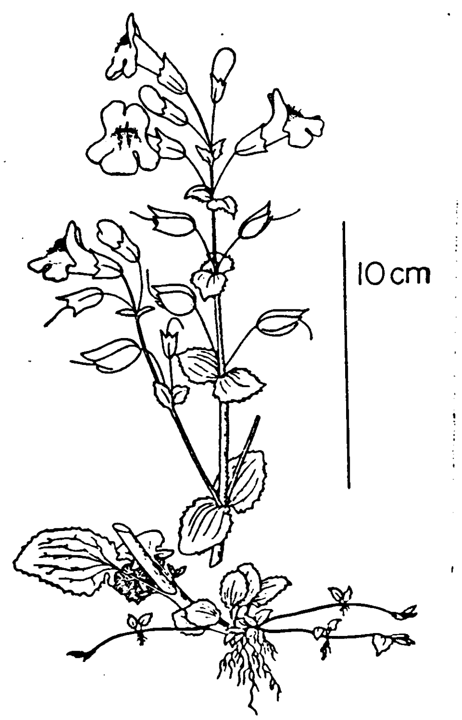

Figure 2 Yellow monkey-flower (Mimulus guttatus). [From Taylor (1974)].

moist places over a large range from the Aleution Islands to Mexico (Vickery 1959). As a result of these observations the second writer (John Fortescue) was hired by Falconbridge Nickel Mines Ltd. to complete a small scale study designed to discover if Mimulus guttatus could be used as a geobotanical, or biogeochemical, indicator of mineralized springs in the One Ace Mountain area. The writers are most grateful to Dr. J.F. Gammon, Dr. I. Elliott and Falconbridge Nickel Mines Ltd. for permission and encouragement to publish this paper.

Mimulus guttatus DC

Taylor (1974) in his description of the Figwort family in British Columbia described the plant as follows:-

"Annual, or perennial by stems rooting at the nodes, by creeping rootstocks or by stolons. Stems stout and erect or weak and more or less reclining, up to 55 cm tall, mostly simple, commonly glabrous and puberulent of pubescent above. Leaves variable, mostly rounded-ovate or ovate-oblong, up to 15 cm long, many-nerved, coarsely and irregularly dentate, often with small projections at the base of the blade; petioles usually much longer than the blades, upper leaves sessile; internnodes generally longer than the leaves. Inflorescence mostly racemose, sometimes solitary or few-flowered; pedicels less than twice as long as the calyx, rarely slender and elongated. Calyx glabrous or pubescent, campanulate, often dotted or tinged with red, 8-17 mm long, longer and much inflated in fruit, teeth short, upper tooth longer. Corolla up to 4 cm long, yellow, the throat usually spotted with red, ridges densely hairy, nearly closing the throat, strongly 2-lipped. Capsule broadly oblong, constricted at or short stipitate.

Common in wet places from sea-level to moderate altitudes; in mountainous regions of western North America from Alaska and Yukon, south to New Mexico. Common throughout the Province." (p.96-6)

Taylor's map for the distribution of Mimulus guttatus appears as Figure 1 and his line drawing of the plant appears as Figure 2. Abrams (1951) lists three subspecies and one variety for the plant and Clark (1976) notes that it is '...a very plastic species ... impoverished plants-dwarfed by the relatively huge flowers - may be only a few inches high ... but in wet fertile soil robust plants may approach 3 feet, with succulent, hollow, squarish stems as thick as ones thumb.'

In summary, from the viewpoint of geobotanical prospecting the plant has the advantage of growing naturally in damp places and springs where it is easily recognized from a helicopter by its yellow flowers during its long blooming season. A potential disadvantage is that it is not likely to be specific to mineralized springs and its variable growth habits appear not to be related to mineralization. Consequently, the One Ace Mountain study was planned as a biogeochemical rather than a geobotanical investigation.

EXPERIMENTAL DESIGN

The study of landscape for descriptive and comparative purposes associated with mineral exploration is facilitated by using a generalized conceptual model as a guide for sampling procedures. The model is designed prior to collection of samples and applied systematically at each of several sites. Then the interpretation of the data, within site, and from site to site, is relatively rigorous even though the sampling plan does not include sufficient numbers of samples of each type to perform formal statistical analysis. The model must be rigid enough to provide comparable sets of analytical data but flexible enough to cope with variations in local site conditions.

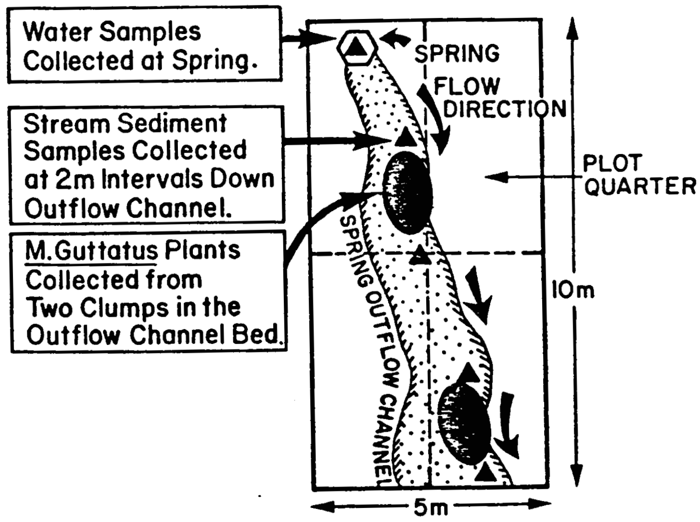

Figure 3 Pre-planned conceptual model used in the One Ace Mountain study.

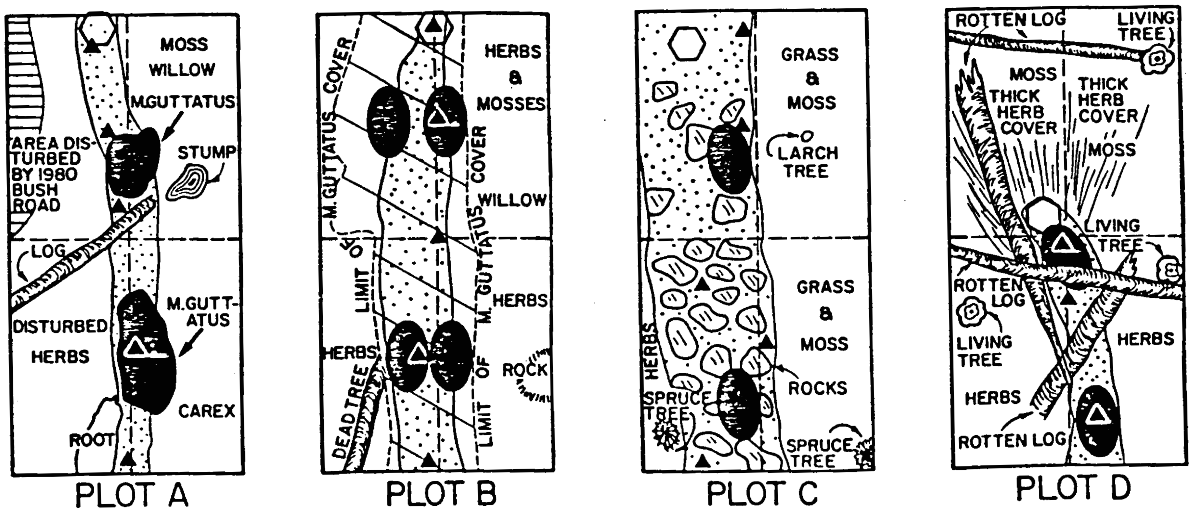

Figure 4 Application of the conceptual model to the four plots included in the One Ace Mountain study

The conceptual model drawn up for the One Ace Mountain project is illustrated in Figure 3. It is a rectangular plot divided into four quarters positioned so that the spring being investigated is at the centre of one short side of the plot. Water samples are collected at the spring and sediment samples are taken at regular intervals across the plot to make a total of five altogether. Plant samples are collected from each plot quarter making a total of four, or less if the plot is not entirely covered with the plant of interest. At the field site the plot is marked out using rods, then photographs are taken, followed by water, plant and sediment sampling. In the One Ace Mountain area, four plots, each 5m x 10m, were sampled.

SAMPLING AND CHEMICAL ANALYSIS

Two plots (A and B) were located at the springs where growth of *Mimulus guttatus* was originally observed. A third plot (C) was sited 60m down the stream from plot B where clumps of *Mimulus guttatus* were growing along the stream bed. This plot was located to study the geochemistry of an environment with *Mimulus guttatus* in a stream some distance from a mineral spring. Plot D was sited in a control area several km to the west of the others. No mineral indications were known in the control area. The field project was completed by three people during August 14th and 15th, 1981.

Two 1 litre water samples were collected from each plot. Both were filtered at the site and one was acidified with nitric acid. Plot maps and photographs were used to prepare the stylized diagrams of the four plots (Figure 4). At each

Element	ACME REFERENCE Standard			Water Replicates			*M. guttatus* Foliage Replicates			Stream Sediment Replicates		
Ag	0.30[1]	0.26[2]	0.31[2]	-	-	-	0.62	0.64	0.64	0.22	0.23	0.19
Pb	38.0	39.0	40.0	-	-	-	0.87	2.00	0.93	1.80	2.20	2.20
Zn	180.0	189.0	184.0	0.011	0.012	0.012	55.0	55.0	55.0	130.0	130.0	130.0
As	8.0	12.0	15.0	-	-	-	-	-	-	12.0	12.0	11.0
Cu	28.0	30.0	30.0	0.005	0.005	0.002	8.2	8.4	8.5	17.0	17.0	17.0
Mo	2.0	1.1	1.1	-	-	-	0.36	0.45	0.52	-	-	-
Bi	2.0	1.0	0.74	-	-	-	1.0	0.94	1.1	9.0	9.5	9.2
Sb	3.0	-	-	0.044	0.053	0.040	-	-	-	0.32	0.55	0.87
W	1.0	1.0	-	-	-	-	-	-	-	3.4	4.0	3.6
B	12.0	6.8	7.0	-	-	-	34.0	34.0	34.0	4.4	4.5	4.6
Ca	6200.0	5600.0	5600.0	32.0	32.0	32.0	1.2%	1.2%	1.2%	39.0%	39.0%	40.0%
Mg	6700.0	5800.0	5800.0	19.0	19.0	19.0	0.31%	0.31%	0.31%	0.28%	0.28%	0.28%
Fe	2.5%	2.46%	2.46%	-	-	-	0.021%	0.021%	0.019%	0.020%	0.021%	0.020%
Mn	800.0	820.0	806.0	0.004	0.004	0.004	1.2	1.1	1.0	9.4	9.4	9.4
Ni	32.0	38.0	37.0	-	-	-	0.89	1.1	1.1	2.6	2.7	2.2
Co	12.0	17.0	16.0	-	-	-	0.07	0.10	0.16	0.49	0.40	0.51

Table 1 The performance of the ICP analytical method (all values in ppm except where otherwise indicated).

[1]Published value

[2]Values for duplicate solutions included in the One Ace Mountain sample batch.

plot, samples of Mimulus guttatus were washed and separated into foliage and roots prior to bagging for transport to the laboratory. Sediment samples were collected in standard geochemical sampling bags and later air dried prior to being sieved. The -80 mesh material was used for chemical analysis. The plant samples were first air dried, and, later, oven dried at 80°C prior to being subsampled for chemical analysis. The pH and temperature of the spring waters was measured at the time of sampling.

Because the purpose of the study was to examine Mimulus guttatus as a biogeochemical indicator plant for silver and associated elements a single multielement spectrochemical method was selected for the chemical analysis of the waters, plants and sediments from the One Ace Mountain Area. Chemical analyses were carried out by ACME Industries (852 E. Hastings Street, Vancouver, British Columbia) using a Jarrell Ash ATOMCOMP ICP emission spectrographic system. The method involves the extraction of the plant (or sediment) material using a HCl/HNO_3/water mixture for 1 hour at 90°C in a water bath. The resulting solutions, together with water samples (which are untreated) are then analysed for 24 elements during a 2 minute burn time. The company realized that the extraction of Ca, P, Mg, Al, Ti, La, and W from sediment samples is partial but claim that data for Ag, Mo, Cu, Pb, Zn, Ni, Co, Mn, Fe, As, U, Th, Cd, Sb, Bi, V and B are reliable for geochemical exploration purposes. Two types of quality control were used on the One Ace Mountain samples. ACME Industries publish data for a reference standard solution which is included with unknowns for routine quality control purposes. This was analysed in duplicated with the batch of 54 One Ace Mountain samples. In addition, unknown to ACME, a water sample, a Mimulus guttatus foliage sample, and a sediment sample were replicated three times within the batch of unknowns. The performance of the anlytical method for selected elements is indicated on Table 1. It was concluded that for comparative purposes Zn, Cu, Sb, Ca, Mg and Mn data for waters might be used; for Mimulus guttatus Ag, Pb, Zn, Cu, Mo(?), Bi, B, Ca, Mg, Fe, Mn, Ni and Co could be utilized and for stream sediments As, Sb, W could be added to the plant list (with Mo removed). Table 1. The data on Table 1 are considered adequate for comparative purposes although they may be subject to bias and should not be considered as quantitative. Even so, the data were considered quite suitable for the small scale One Ace Mountain study.

Results

DESCRIPTION OF THE PLOTS

Generalized plot maps appear as Figure 4. Briefly, the whole area in which the springs occur is covered with glacial material which is highly calcarious. Although there is relief of up to 50m in the vicinity of the springs, outcrops are few: and the mineralized zones are not exposed.

PLOT A

The spring flows from the bottom of a drift covered slope, which forms the limit of Northern of the floodplain of Albert Creek in which the original sediment geochemical anomalies were found. In the floodplain there is a healthy growth of black spruce Picea mariana and a Sphagnum moss covers the forest floor. Downstream from the plot the spring outflow passes through a grassy area with no trees. On site measurement of the pH was 6.4 at the spring with a temperature of 16°C. No iron or manganese staining was observed at the spring. Herbarium specimens of plants within all the plots were collected for reference purposes.

PLOT B

Within the plot a spring (1.5m bed width) issues from a drift covered slope situation similar to that in Plot A. A large clump of Mimulus guttatus covers almost the entire plot. The cover of the floodplain is similar to that in the vicinity of plot A except that some willow occurs near plots B. The Mimulus guttatus plants grew well at this site and were some 50cm high. The temperature of the springwater was 8°C with a pH of 6.3.

PLOT C

Situated 60m downstream form Plot B, Plot C was located to include two patches of Mimulus guttatus. The small creek bed within plot C was full of boulders with the water flowing between them. The temperature of the water was 8°C with a pH of 6.1. The growth of Mimulus guttatus in plot C was poor compared with that in plot B.

PLOT D

This plot was situated on a slope which supported many springs with tufa associated with them. The spring sampled

		PLOT 3 BFBA	BFBB	BFBC	BFBD
FOLIAGE					
	Ag	3.7	1.1	0.64	0.66
	Pb	2.8	1.5	0.87	0.35
	Zn	90.0	66.0	55.0	55.0
	Cu	9.9	8.9	8.2	10.0
	B	35.0	34.0	34.0	38.0
	Mg	4,200.0	2,500.0	3,100.0	2,800.0
	Ca	13,000.0	13,000.0	12,000.0	11,000.0
	Al	100.0	100.0	100.0	100.0
	Fe	190.0	240.0	210.0	180.0
	Mn	6.7	3.5	1.2	1.7
	P	3,800.0	3,600.0	2,900.0	2,900.0
	Ni	1.1	0.5	0.9	0.7
	Bi	1.6	1.4	1.0	1.0
	Ba	200.0	100.0	100.0	100.0
ROOTS					
	Ag	29.7	25.7	21.7	21.0
	Pb	131.0	152.0	183.0	101.0
	Zn	484.0	491.0	915.0	700.0
	Cu	33.0	29.0	30.0	16.0
	B	9.6	1.3	12.0	19.0
	Mg	13,000.0	9,400.0	7,100.0	5,700.0
	Ca	31,000.0	26,000.0	24,000.0	16,000.0
	Al	2,500.0	2,300.0	1,800.0	800.0
	Fe	5,100.0	5,100.0	3,700.0	1,900.0
	Mn	133.0	136.0	123.0	65.0
	P	1,400.0	1,600.0	2,000.0	1,900.0
	Ni	7.1	9.9	7.1	3.2
	Bi	2.6	2.7	1.9	1.4
	Ba	200.0	200.0	200.0	200.0

Table 2 Chemical data for foliage and roots of *Mimulus guttatus* collected from Plot B (ppm oven dry weight).

was in woodland with relatively lush understory vegetation under a mature black spruce forest with trees several tens of metres high. The temperature of the spring was 13°C with a pH of 7.2. No marl or iron staining was observed within the plot area although it was quite common at other springs nearby.

The growth of Mimulus guttatus varied considerably form plot to plot and the form of individual plants within plots also varied considerably. These variations were apparently not associated with the presence of mineralization in the springs.

DESCRIPTION OF THE RESULTS OF CHEMICAL ANALYSIS

The relationship between the levels of 14 elements in roots and foliage of Mimulus guttatus collected from the four quarters of Plot B are shown on Table 2. Briefly, samples BFBA and BFBB are taken from the proximity of the spring and BFBC and BFBD from 5-10m down channel from the spring. In the case of the foliage the values for the principal elements of interest, silver, lead and zinc, the precision is good and there is a decrease in level away from the spring. This relationship holds for silver in the roots but not for lead and zinc. In general, the data for the four quarters of the plot is quite consistant. The low manganese in both foliage and roots may be a significant factor and so may the relatively high aluminium content of the roots. Although care was taken to wash the roots well at the time of sampling, some mineral matter may have got through; for example resulting in high calcium, magnesium in BFBA. It was concluded that the

		PLOT A AFBA	PLOT B BFBA	PLOT C CFBA	PLOT D DFBA
FOLIAGE					
	Ag	2.1	3.7	0.22	0.04
	Pb	17.0	2.8	1.00	0.29
	Zn	136.0	90.0	68.0	67.0
	Cu	26.0	9.9	6.2	15.0
	B	46.0	35.0	45.0	38.0
	Mg	3,800.0	4,200.0	3,100.0	2,800.0
	Ca	15,900.0	13,000.0	12,000.0	21,000.0
	Al	100.0	100.0	100.0	100.0
	Fe	300.0	190.0	200.0	200.0
	Mn	56.0	6.7	23.0	1.9
	P	2,500.0	3,800.0	2,900.0	2,100.0
	Ni	1.8	1.1	0.5	1.2
	Bi	1.1	1.6	1.1	1.5
	Ba	400.0	200.0	100.0	300.0
ROOTS					
	Ag	28.7	29.7	20.7	2.7
	Pb	600.0	131.0	63.0	5.2
	Zn	1,026.0	484.0	381.0	312.0
	Cu	48.0	33.0	6.2	13.0
	B	15.0	9.6	16.0	13.0
	Mg	160,000.0	13,000.0	3,200.0	3,400.0
	Ca	400,000.0	31,000.0	7,800.0	58,000.0
	Al	1,400.0	2,500.0	300.0	100.0
	Fe	4,900.0	5,100.0	900.0	200.0
	Mn	751.0	133.0	47.0	3.0
	P	1,400.0	1,400.0	1,800.0	2,000.0
	Ni	4.5	7.1	1.4	2.3
	Bi	3.5	2.6	1.3	2.0
	Ba	300.0	200.0	100.0	100.0

Table 3 Chemical data for foliage and roots of *Mimulus guttatus* collected from the near spring sample points in all four plots (ppm oven dry weight).

highest amount of the elements of interest tend to be in the samples collected nearest the spring.

On Table 3 are listed the data for the chemical composition of the foliage and root samples of Mimulus guttatus collected nearest to the springs in all four plots. A 10 fold increase in silver occurs in the spring foliage material compared with that taken downstream (i.e. Plot C) while the values narly 40 times lower occur in the control (Plot D). In roots the silver is high at the mineralized springs (Plots A and B) and in the downstream channel (Plot C). Silver is ten fold lower than in the other plots in the control plot (Plot D). The other elements of interest tend to mimic the pattern found for silver with more contrast in the roots than in the foliage. In general, mineral spring in Plot A carried higher levels of the elements of interest than plot B. It is concluded that either roots, or foliage, of Mimulus guttatus might be used to identify silver rich springs in the area of One Ace Mountain and that it is likely lead, zinc and possibly copper may also be used to identify mineralized springs.

HYDROGEOCHEMISTRY/BIOGEOCHEMISTRY

The geochemical data for the water samples is listed on Table 4. Briefly, silver was not detected in the water samples and little significance is placed on the zinc or copper content of acidified (or non-acidified) waters as guides to the mineralized springs. Clearly the use of Mimulus guttatus is superior to hydrogeochemistry based on spectrographic technique used for this study.

	PLOT A		PLOT B		PLOT C		PLOT D	
	AFWA	AFWB	BFWA	BFWB	CFWA	CFWB	DFWA	DFWB
Ca	25.9	32.2	27.9	32.0	27.7	32.0	34.4	39.2
Mg	18.2	19.9	17.5	19.4	17.3	19.6	12.9	14.2
Ba	0.193	0.201	0.151	0.152	0.154	0.140	0.103	0.092
Mn	0.004	0.003	0.004	0.004	0.004	0.003	0.002	0.003
Zn	0.042	0.008	0.022	0.011	0.012	0.008	0.012	0.003
Cu	0.011	0.005	0.014	0.005	0.005	0.005	0.005	0.003
Sb	0.042	0.037	0.096	0.044	0.059	0.042	0.047	0.064

Table 4 Geochemical data for water samples collected from One Ace Mountain area (All samples filtered in the field WA samples acidified WB samples not acidified. All elements determined directly by the ICP method levels in ppm).

Sample		Ag ppm	Pb ppm	Zn ppm	As ppm	Cu ppm	Mo ppm	Cd ppm	Bi ppm	W ppm	Co ppm	Ni ppm	B ppm	Mn ppm
	AACA	52.5	565	589	54	28	0.18	2.0	12.0	-	1.5	5.2	2.7	602
	ABCA	55.2	835	795	92	33	0.25	2.5	11.0	-	2.8	7.2	3.4	1,099
Plot A	ACCC	55.9	924	779	84	38	0.06	2.3	12.0	-	1.8	5.8	3.5	1,003
	ADCD	3.0	34	115	20	17	0.33	2.1	5.0	0.28	8.3	29.0	6.2	179
	AECE	22.8	181	307	29	14	0.61	1.6	5.0	-	8.2	29.0	6.2	168
	BACA	156.0	210	266	24	23	0.84	2.1	5.0	0.25	10.0	32.0	4.8	335
	BBCB	142.0	290	364	29	38	0.90	2.3	6.0	-	9.5	30.0	7.1	331
Plot B	BCCC	119.0	216	355	25	20	1.10	1.8	4.0	-	9.2	33.0	3.5	216
	BDCD	95.0	204	310	23	15	1.10	1.4	4.0	-	9.3	34.0	3.6	207
	BECE	94.0	200	310	24	15	1.30	1.7	3.0	-	9.5	34.0	3.5	207
	CACA	27.5	105	304	35	6	-	0.50	2.0	-	3.9	15.0	1.5	110
	CBCB	32.8	142	278	23	5	-	0.58	2.0	-	4.2	15.0	1.4	142
Plot C	CCCC	24.7	143	258	27	5	0.26	0.33	2.0	-	4.3	15.0	1.2	144
	CDCD	30.8	195	268	26	5	-	0.58	2.0	-	4.4	15.0	1.1	167
	CECE	37.6	165	288	20	6	0.12	0.87	2.0	0.02	4.5	17.0	1.8	120
	DACA	3.43	12	130	13	10	0.04	0.14	9.7	3.8	1.0	2.6	1.2	27
	DBCB	0.22	4	126	11	21	0.13	0.14	8.9	3.7	0.7	2.6	3.7	13
Plot D	DCCC	0.21	2	114	11	14	-	0.01	8.4	3.3	0.6	2.1	9.7	85
	DDCD	0.19	1	123	10	21	0.10	0.13	7.8	3.4	0.5	2.2	2.6	10
	DECE	0.22	2	130	12	17	-	0.12	9.0	3.4	0.5	2.6	4.4	9

Table 5 Geochemical data for stream sediment samples collected in quintuplicate (parts per million oven dry weight ICP determination).

roots from plots A and B and in the sediments from the same plots. Boron was variable in both the plants and the sediments. Nickel and cobalt were low in the control and variable in the mineralized plot samples of sediment (Table 5). Dilution effects for several elements were seen in the sediment data for plot C (e.g. for silver, cadmium and lead).

It is concluded that Mimulus guttatus roots and/or foliage may be used for biogeochemical prospecting for silver in the vicinity of One Ace Mountain. Lead, copper, and zinc may also be used as guides to mineralized springs using biogeochemical data from this plant species. However, if stream sediments are used, the mineralized springs may be identified on the basis of silver, lead, (zinc), (arsenic), cadmium, cobalt, nickel and manganese. Using the methods described hydrogeochemical prospecting yielded negative results at One Ace Mountain.

General Conclusions

1) The use of a simple conceptual model facilitated rapid field appraisal of the possible significance of Mimulus guttatus as a geobotanical or biogeochemical indicator plant for silver at mineralized springs in Northern British Columbia. The model also facilitated sampling plants, waters and stream sediments to investigate the relative effectiveness of different geochemical prospecting techniques in the area. It also allowed for the completion of the field work in two days.

2) The use of a rapid Scan ICP spectrochemical technique allowed for the simultanious determination of 22 elements in the plant and sediment material. Fifteen of these were useful for comparative purposes based on Mimulus guttatus. In stream sediments, thirteen trace elements were useful for comparative purposes.

3) It was found that Mimulus guttatus foliage, or roots, could be used as a basis for biogeochemical surveys to determine silver rich springs in the One Ace Mountain. The use of the plant as a geobotanical indicator of silver mineralization was not proven.

4) Comparative studies indicated that, for practical geochemical prospecting, the multielement stream sediment approach was superior to the multielement biogeochemical approach. A possible exception was surveys aimed at silver only when Mimulus guttatus might be used as a basis for biogeochemical prospecting.

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