

Preliminary Results of a Geochemical Investigation of Halogen and Other Volatile Compounds Related to Mineralization, Part 2: Mount Washington Epithermal Gold Prospect, Vancouver Island (NTS 092F/14)

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Introduction

The halogens (F, Cl, Br and I) are common constituents of igneous, metamorphic and sedimentary rocks (Billings and Williams, 1967). Heberlein and Dunn (2017) provide a discussion of the rationale behind determining the concentrations of the halogens and other volatile compounds in the exploration for concealed mineral deposits. At the Mount Washington (epithermal) Au prospect on Vancouver Island, sample media and methods are used that are similar to those employed in the Lara VMS study (Heberlein and Dunn, 2017). However, to assist in understanding natural processes, a key component of this study is the use of ion-collection devices (traps). Activated charcoal and alkaline ion-exchange resin packages were buried in the soil profile for three months to capture volatile anions and cations emanating from the ground. In addition, the flux of these components through vegetation will be measured through the analysis of transpired fluids exuded from mountain hemlock (*Tsuga mertensiana*) twigs, and in snow.

Study Area

The Mount Washington epithermal Au prospect is located near the city of Courtenay on Vancouver Island. A biogeochemical study of the area, conducted by the Geological Survey of Canada in 1990, revealed strong geochemical signals of the commodity and pathfinder elements related to the underlying mineralization (Dunn, 1995, 2007). This indicated that Mount Washington would be a suitable area for testing the volatile components sought in this study. Furthermore, archived samples from the 1990 survey were available for additional analysis.

Keywords: British Columbia, deep-penetrating geochemistry, Mount Washington, biogeochemistry, halogens, ion traps, mountain hemlock, transpired fluids, Ah horizon, snow, ammonium, halogens, multi-element analysis

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At Mount Washington, the sampling approach was somewhat different from that at Lara. In addition to collecting plants and soils to assess their volatile-compound concentrations and spatial patterns around the mineralized zone, artificial media were placed in the ground to collect ions that may be migrating to the surface from the underlying rocks. By using this novel approach, the aim is to establish if there is, indeed, a vertical flux of volatile compounds emanating from the bedrock. Activated carbon and alkaline ion-exchange resin are used as collectors for these mobile cations and anions. Results from the artificial media will be compared to patterns in natural media, including Ah horizon soil, vegetation (mountain hemlock and yellow-cedar) and transpired fluids collected from the dominant species (mountain hemlock).

Location and Access

The study area lies immediately north of the Mount Washington Alpine Resort (Figure 1). Access from the nearest logistical centre at Courtenay is via Highway 19 north to the Strathcona Parkway and then west for 10 km to the alpine resort, all on well-maintained paved roads. From the alpine lodge, the sampling area is accessible on foot via mountain biking trails and ski runs to the Boomerang chairlift and then by a network of old drilling and mining roads to the northwest. Alternative access can be gained by four-wheel-drive vehicle from the Raven Lodge parking area via a network of variably maintained logging roads (Figure 1).

Surficial Environment

The sampling area is at midslope (approximately 1360 m elevation) on the western flank of Mount Washington, just above the transition between steeper colluvial slopes above and more gentle, poorly drained slopes below. Drainage development at the elevation of the sampling area is poor.

Much of the area has been previously logged. Present-day vegetation consists of fairly open subalpine woodland containing a variety of tree species, including yellow-cedar (*Chamaecyparis nootkatensis*), mountain hemlock (*Tsuga*

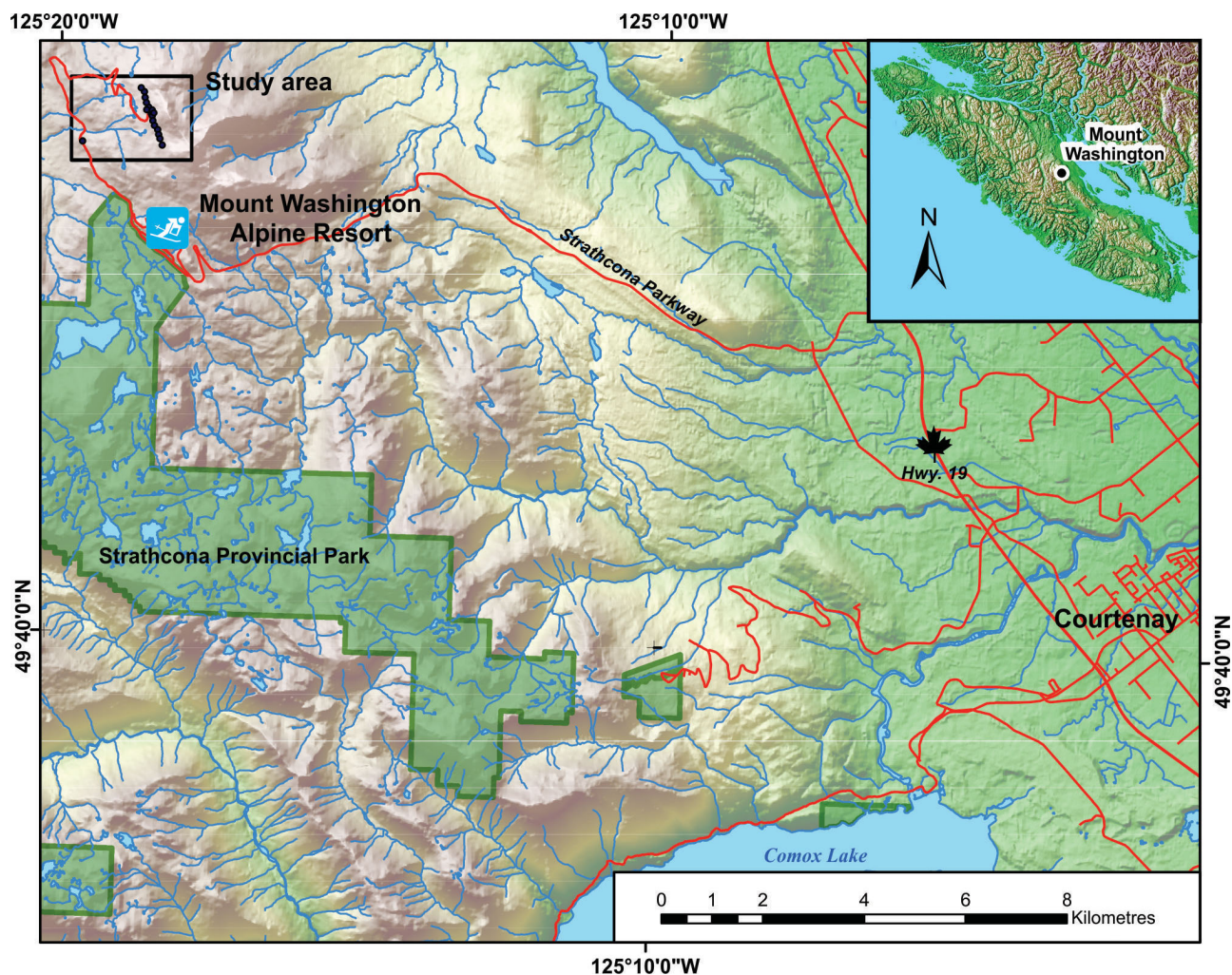


Figure 1. Location of the Mount Washington study area (black box), east-central Vancouver Island. Sample locations indicated by black dots. Contains information licensed under the Open Government Licence – Canada.

mertensiana), Pacific silver fir (or Amabilis fir; *Abies amabilis*) and subalpine fir (*Abies lasiocarpa*). The dominant understorey species is white-flowered rhododendron (*Rhododendron albiflorum*).

Surficial geology is relatively simple. Above about 1320 m, the hillsides are covered with a veneer of colluvium. Exposures in roadcuts show that this material rarely exceeds 2 m in thickness and, over much of the sampled area, it is less than 0.5 m thick. A thin soil profile is developed on this sandy matrix material. Observations from sample holes and roadcuts show that the most common profile consists of poorly developed dystic Brunisol, typified by a surface LFH layer and a thin Ah horizon (<2 cm) overlying a uniform, brown, undifferentiated Bm horizon. Incipient podzolization, marked by the presence of an intermittent eluvial Aej horizon and Fe-enriched Bf horizon, is present at about 10% of the sample locations.

Below the 1320 m contour, particularly in the northwest corner of the survey area, there is an abrupt transition from

well-drained colluvium to water-saturated ground. This elevation is marked by an almost continuous line of meltwater-fed springs and seeps that form a series of small raised bogs, which feed downslope into a number of ponds and lakes. These water bodies define the headwaters of several streams that drain the slope westward into the northwest-flowing Goss Creek.

Geology

This study was carried out over the western part of the Lakeview-Domineer resource area (Houle, 2013), which is defined by a number of shallow-dipping, Au-Ag-Cu-bearing quartz-sulphide veins (Figure 2).

The Lakeview-Domineer zones have been exploited in two small open pits and explored by extensive diamond-drilling, trenching, bulk sampling and underground drifts. Production by Mount Washington Copper Co. Ltd. between 1964 and 1967 was 381 733 tonnes grading 0.34 g/t Au, 19 g/t Ag and 0.93% Cu (Houle, 2013).

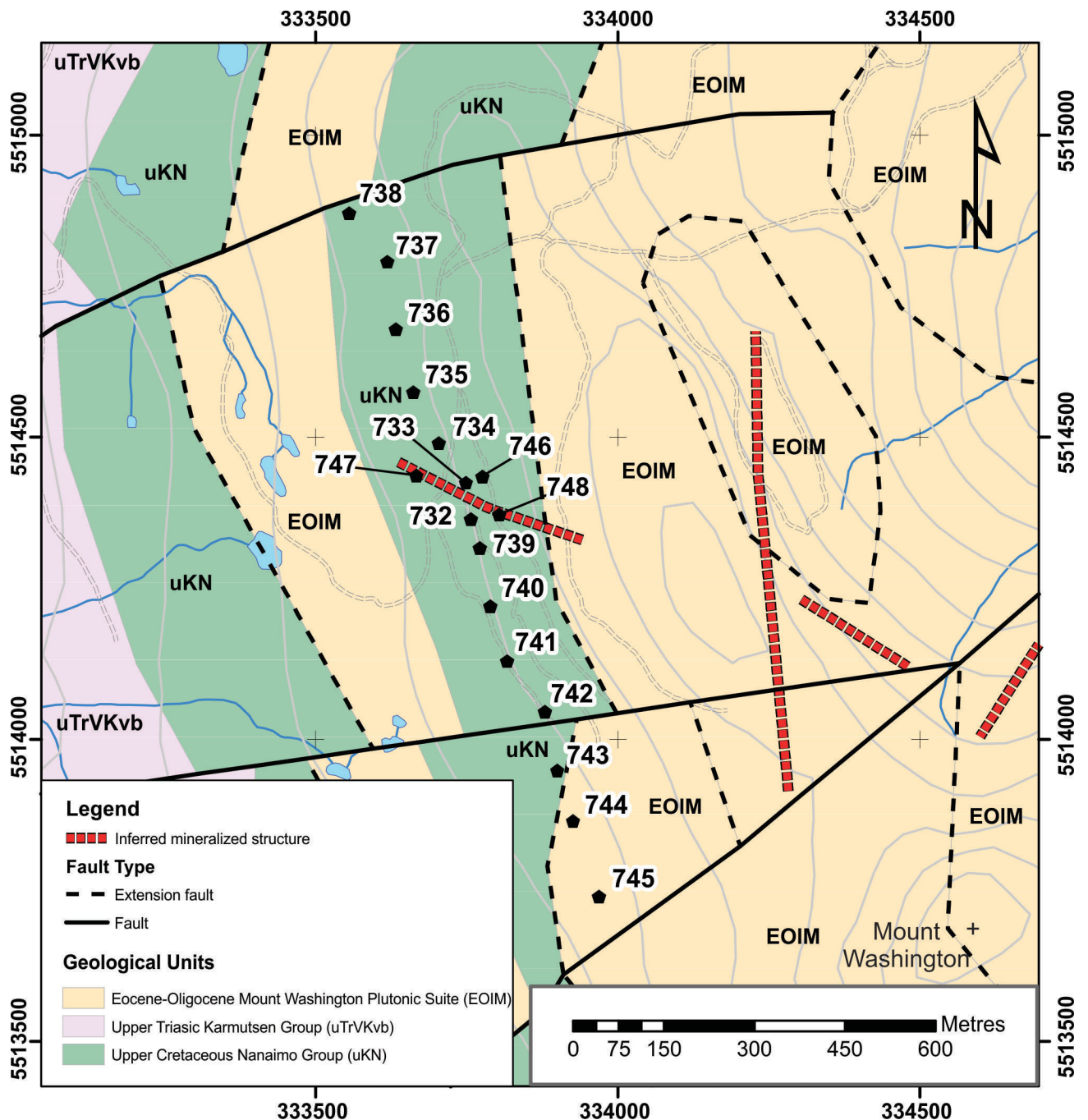


Figure 2. Geology of the Mount Washington study area (after Massey et al., 2005), east-central Vancouver Island, showing sample locations (black pentagons).

From the most up-to-date geological mapping of the Mount Washington area, it is apparent that most of the area to the west of Mount Washington is underlain by pillow basalts of the Triassic Karmutsen Formation. Close to Mount Washington itself, the basalts are unconformably overlain by a gently east-dipping sequence of sandstone, siltstone and conglomerate of the Upper Cretaceous Nanaimo Group. This is the main unit underlying the sampled area. The ridges and upper elevations of the mountain are defined by intrusive rocks, consisting of quartz diorite and feldspar-

hornblende dacite porphyry that together make up the Eocene–Oligocene (41–35.5 Ma; Madsen et al., 2006) Mount Washington Plutonic Suite. The intrusions occur as stocks, sills and dike-like bodies that intrude the Nanaimo Group.

At least seven different breccia bodies, some pipe like and others more flat lying, have been recognized in the Domineer-Lakeview resource area (Houle, 2013). Zones of brecciation are localized along the intrusive contacts and

on north- and northwest-trending structures. They vary widely in texture and composition, and appear to be the principal controls for polymetallic sulphide mineralization. Mineralization also occurs in veins and stringers. The style of mineralization is considered to be high-sulphidation epithermal Au-Ag-Cu (BC Mineral Deposit Profile L04; Panteleyev, 1995) or 'subvolcanic' Cu-Au-Ag (Houle, 2013).

Sampling

The Mount Washington sampling campaign is divided into three parts. **Part 1**, carried out between June 27 and 30, involved the installation of 18 passive ion collectors along a south-southeast-trending traverse over the Domineer Au zone (Figure 3) and the collection of foliage and transpired fluids from mountain hemlock at the same sample stations.

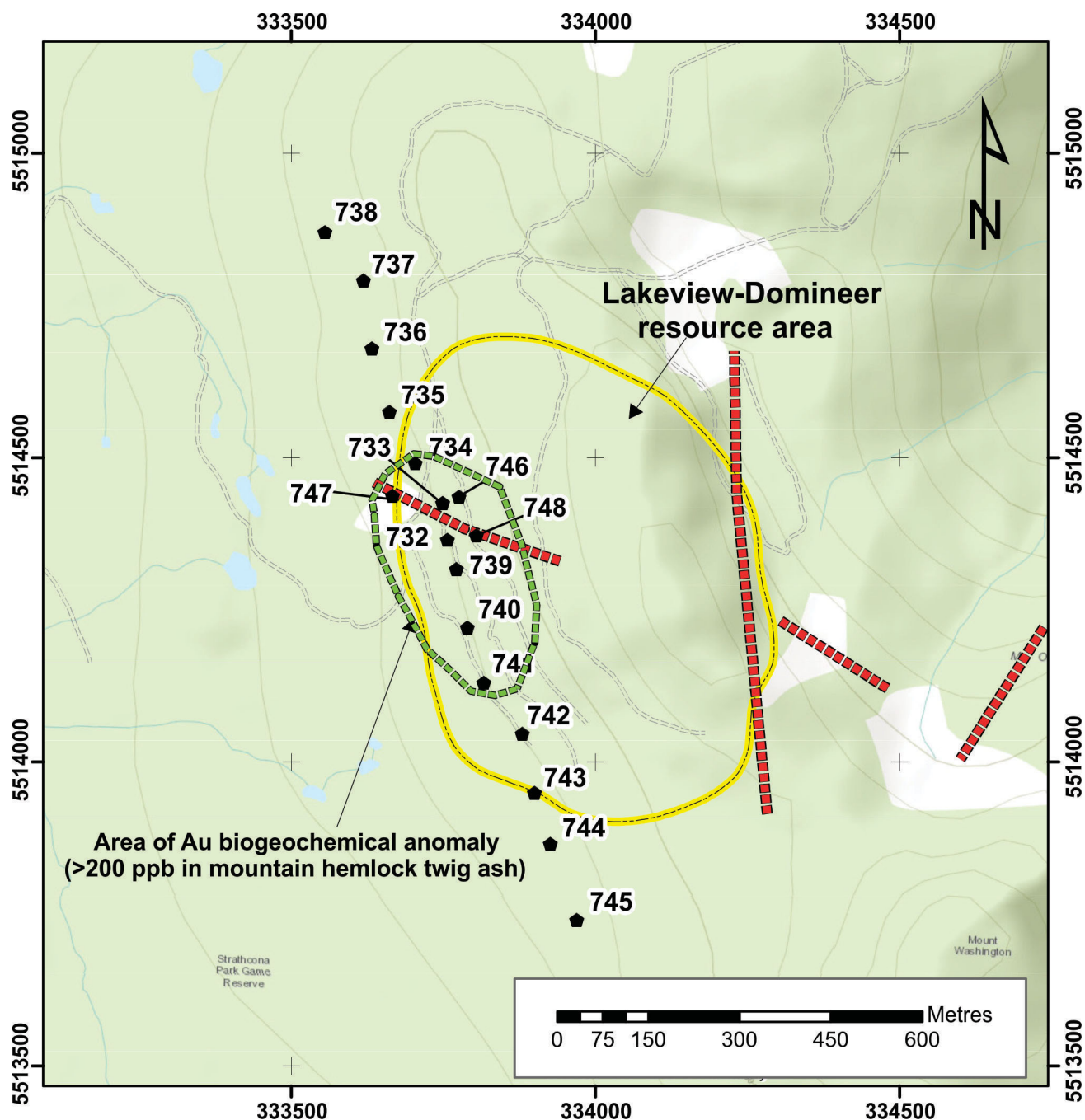


Figure 3. Location of passive ion-collector sites, showing also the locations of the Lakeview-Domineer resource area (yellow outline), the 1990 biogeochemical anomaly (green outline) and the approximate positions of mineralized structures (red). White areas are devoid of trees. Contains information licensed under the Open Government Licence – Canada.

Collectors were installed at nominal 100 m intervals. A single collector was also installed in a presumed unmineralized area located 1500 m to the west, to act as a background/control site. A summary of samples collected to date is presented in Table 1.

The ion collectors contain two different collection media: activated charcoal for cations and alkali ion-exchange resin for anions (Sigma Aldrich Amberlite IRA743®). The media were accurately weighed into 10 by 7 cm porous nylon sachets (15 and 20 g, respectively) and the bags were heat sealed. In the field, they were placed on a 2 cm thick bed of pure silica sand housed in an 18 cm diameter by 15 cm deep cardboard tube that was buried to 20 cm in the ground. The silica sand serves to isolate the collectors from the soil, so as to avoid capture of endogenic ions: a filter paper was used to isolate the collectors from the silica sand. A ceramic tile was placed between the collectors in order to avoid the possibility of cross-contamination between the charcoal and resin sachets. The apparatus was capped with an overlapping plastic plate to prevent entry of rain water and surface debris, and shallowly buried. Each site was sprayed with animal repellent to discourage disturbance by curious bears. One of the collectors is illustrated in Figure 4.

Duplicate collectors were planted at two of the sites: one over mineralization and the other in a background location.

In addition to installing the passive collectors, mountain hemlock (*Tsuga mertensiana*) foliage (MHF; 16) and transpired-fluid samples (16) were collected at each location. Transpired fluids (from mountain hemlock) were obtained



Figure 4. Partly installed ion collector showing sachets of activated carbon (right) and ion-exchange resin (left) separated by a ceramic partition. Cardboard tube is 18 cm in diameter.

Table 1. Numbers and types of samples collected for the Mount Washington study.

Sample medium	No. of samples	No. of duplicates	Comment
Mountain hemlock foliage (MHF)	22	2	Collected June 2016
Ion collectors (IC)	18	2	Put in place June 2016
Transpired fluids (TFMH)	18	2	Collected August 2016
Ah soils			To be collected October 2016
Additional MHF			To be collected October 2016
Snow	18	2	To be collected January 2017
Archived MHF	~50		Collected August 1990
Archived yellow-cedar bark ash (YCB)	17		Collected August 1990

by enclosing several 25 cm lengths of twig with needles in plastic bags and leaving them for a minimum of 24 hours during a period of sunny weather (Figure 5). After that time, the transpired fluid was recovered by removing the bag and taking up the fluid in a 100 ml syringe. A 0.45 µm filter was then attached to the end of the syringe and the liquid filtered into 25 ml glass vials. The glass vials were placed in a cooler with ice packs for transportation to Vancouver.

The ion collectors were left in the ground for three months. **Part 2** of the program, carried out in early October, involved recovery of the ion collectors and collection of Ah horizon soil samples. Ion collectors were carefully exposed and each medium placed in individual Ziploc® bags. Both bags were then placed in a third bag to isolate the samples from the atmosphere. All of the used materials were removed from the sample sites and disposed of.

Collection of additional vegetation samples included repeats of the Part 1 sites to permit an evaluation of temporal changes in foliage chemistry, and collection of samples from parallel sample lines 100 m to the east and west of the ion-collector line.



Figure 5. Collection of transpired fluid (left) and filtration of fluid into glass vial (right).

The final part of the Mount Washington sampling program (**Part 3**) is planned for January, 2017, when base-of-snow samples will be collected from selected collector sites. This part of the program is contingent on snow conditions at that time.

Sample Preparation and Analysis

Mountain hemlock samples will be oven dried at 80°C and the foliage will be separated from the twigs and milled to a fine powder. Aliquots of the powdered samples (0.5 g) will be leached in warm water and analyzed, initially, for ammonium (NH₄); additional anions will be determined if a suitable methodology can be successfully developed. In addition, all samples will be microwave-digested in HNO₃ and analyzed at the ALS Geochemistry Laboratories (North Vancouver, BC) by ICP-ES/MS for all of the same elements and compounds listed in the accompanying paper (Heberlein and Dunn, 2017), as well as F⁻ by ion chromatography (IC) using a newly developed method. Tests comparing element concentrations in dry and ashed vegetation will be made to determine if ashing provides a similar halogen signature to analysis of the dry tissue, even though a portion of the halogens will volatilize during ashing. If signatures are similar, ashing might be the preferred method because it eliminates many of the analytical interferences encountered during analysis of organic-rich media by IC. Transpired fluids are to be analyzed by ICP-MS and IC at ALS Geochemistry Laboratories.

Ah horizon samples will be oven dried at 80°C and sieved to -80 mesh (177 µm). A 0.5 g aliquot of the fine fraction will be digested by a 1:1 nitric:hydrochloric acid mixture and analyzed for multiple elements by ICP-ES/MS. Halogens will be determined by IC (F and Cl) and ICP-MS (Cl, Br and I) on a warm-water leach. Other tests to be conducted will depend on results obtained from the ongoing analytical research component of this study.

All vegetation and Ah horizon samples will be analyzed by Bioleach at Activation Laboratories Ltd. ('Actlabs'; Ancaster, ON). Analytical methods for the ion collectors had yet to be determined at the time of writing. Snow samples will be analyzed as water samples following the protocols used for the transpired fluids.

All field components of the study will have been completed by early October 2016, except for the snow collection, which will be undertaken in mid- to late winter when snow-pack conditions are suitable and it is considered that there has been sufficient time for a signature to have developed for elements fluxing from mineralization into the snow profile. In the meantime, all other analytical components will be completed and results will be prepared for preliminary presentation at the Mineral Exploration Roundup in January 2017. A final report is expected to be completed by the end of April 2017.

Quality Control

Quality-control measures employed at Mount Washington include the collection of field duplicates (2) and the use of reference materials for biogeochemistry (control V14) and Ah horizon soils (LIM-2011).

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