AN OVERVIEW OF GEOCHEMICAL METHODS

CIM Short Course
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INTRODUCTION

Geochemistry has a direct connection to the commodity that is sought. Only direct prospecting can make the same claim – geophysics, though indisputably useful, can not.

A geochemical response is often larger than the target itself, which makes it easier (and cheaper) to detect (Figure 1).

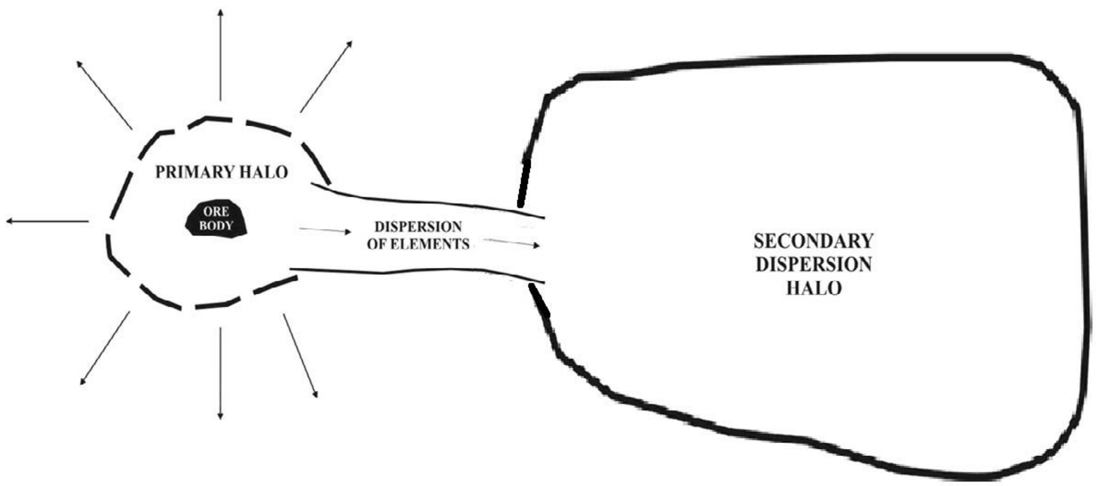


Figure 1: Schematic diagram of primary and secondary dispersion

We sample material derived from the rocks on the assumption that if the rocks are enriched in metals of interest, the derived material will be too. We may sample solid material derived directly from the rock as soil, or sediment created by the mass-wasting of soil into streams, or sediment on which metals transported in solution (ground-, creek- or lake-water) are precipitated, or the waters themselves (Figure 2). In Newfoundland, we also may be sampling material that has been transported by glaciers, or stream or lake sediment derived from it (Figure 3).

In general, the fundamental principle involves testing naturally occurring sample media for enrichment in certain elements, and tracing those elements back to their source

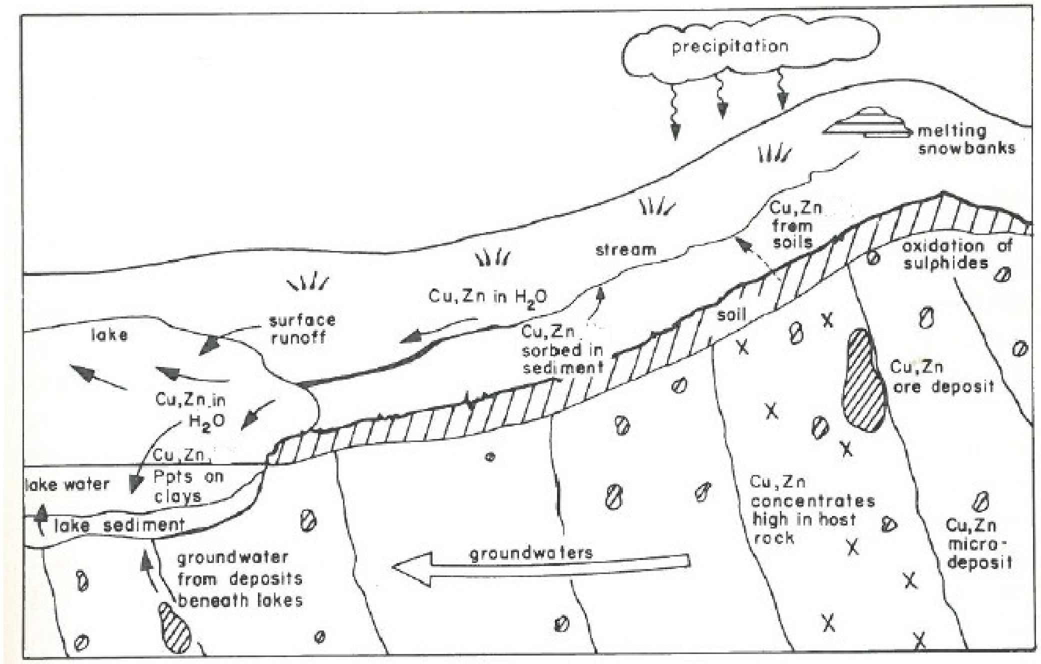


Figure 2: Dispersion of metals from sulphide deposits by groundwater and streams into lakes and lake sediments. From Allan *et al*. (1973), reproduced in Levinson (1980).

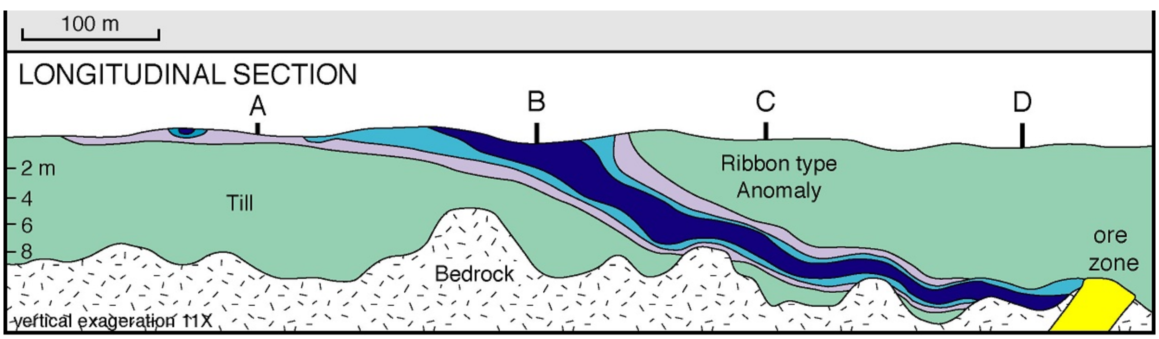


Figure 3: Glacial dispersion from metals from sulphide deposit into till; from Miller (1984).

LAKE SAMPLING

The method of sampling lake sediments and waters is ideally suited to large-scale regional projects that only a government or large company could undertake, although some prospectors carry out lake surveys of more limited scope, particularly in winter when access is easier.

There are also large online databases of lake data collected by both the provincial and Federal governments (Figures 4 & 5).

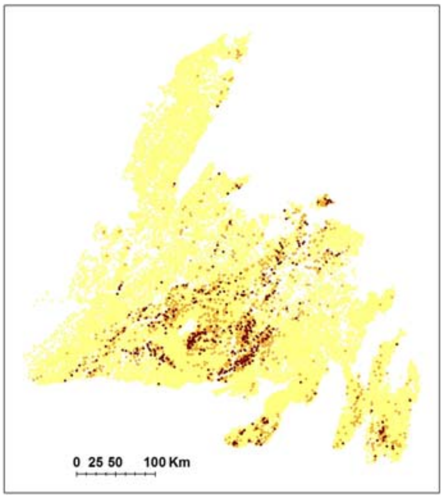


Figure 4: Anomalous arsenic (As1) in lake sediments, Newfoundland. Samples collected by Geological Survey of Newfoundland and Labrador (GSNL)

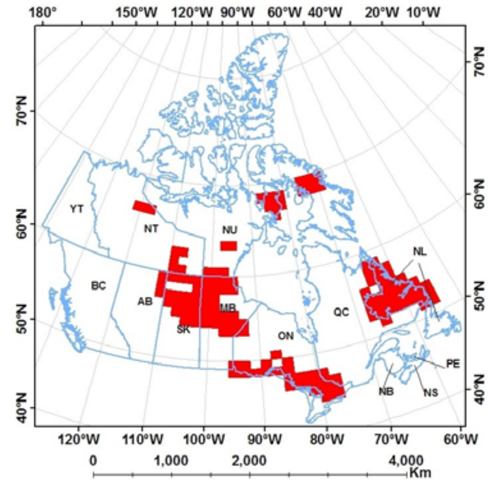


Figure 5: Coverage of lake-sediment and water sample collection by Geological Survey of Canada (GSC). Data can be downloaded from http://gdr.agg.nrcan.gc.ca/gdrdap/dap/search-eng.php

These data are available for free download and the prospecting opportunities they contain have not been fully tested.

The provincial government has also carried out a number of more detailed lake-sediment and water surveys in Labrador, and continues to do so.

Lake water samples are collected in Nalgene bottles (Figure 6); normally this should be done before collecting sediment samples, so that disturbed sediment does not get into the sampled water.

Figure 7 shows one design for a lake-sediment sampling device, informally referred to as a "Hornbrook Bomb".

Other designs of lake-sediment sampling device exist, and in shallow lakes sediment can be collected in a simple rigid plastic pipe, as long as the sediment is not too sandy.

Figure 6: Collecting a lake-water sample

Figure 7: Retrieving a lake-sediment sample from a “Hornbrook bomb”

STREAM SAMPLING

This method is more suitable for areas of high relief. There is no government stream-sediment or water coverage of Newfoundland, although the Torngat Mountains and certain other parts of Labrador were sampled by the GSC and the results can be downloaded from http://gdr.agg.nrcan.gc.ca/gdrdap/dap/search-eng.php.

Stream sampling has, however, been used effectively on a smaller scale by prospectors in hilly parts of Newfoundland.

Like lake sampling, stream sampling is a first-pass method that can be used to identify targets for more detailed geochemical work (soil or till sampling) or prospecting.

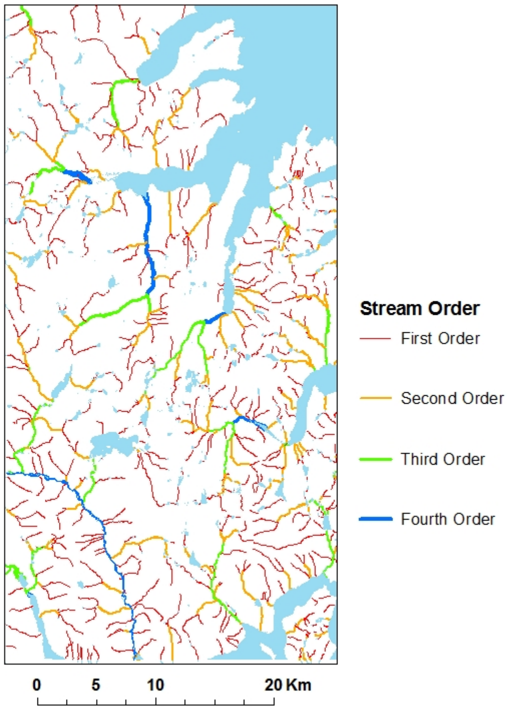


Figure 8: Stream orders in an area of the Torngat Mountains, northern Labrador

The planning of an effective stream-sampling program requires knowledge of the concept of stream order.

First-order streams form the headwaters of every river system and are open at their upstream end. A second-order stream is created when two first-order streams meet; a third-order stream results from the confluence of two second-order streams; and in general, the order of a stream increases by one, every time two streams of the same order come together. If a first-order stream flows into a second-order stream, the order of the confluence remains at 2.

The order of a stream is an indication of its level of maturity, and the higher the stream order, the less abundant the stream.

As much as possible, a stream-sampling plan should aim at sampling sites in streams of the same order over the entire sampled area, in order to avoid the "apples and oranges" problem. If mixed-order streams are sampled (which is sometimes unavoidable) it should be borne in mind that the dilution effect of many barren feeder streams in a higher-order stream will result in a more subdued response to the mineralization in a single feeder stream that drains a mineralized catchment, than if that single feeder stream were sampled.

In any case, streams of order higher than 3 should be avoided.

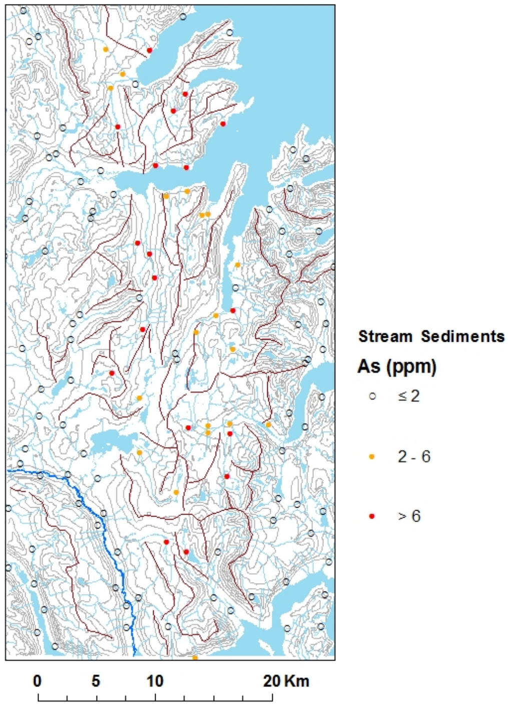


Figure 9: Delineating the catchments of sampled streams. Boundaries between the catchments are marked in red.

Interpreting the results of a stream-sampling survey involves the delineation of the catchment basins of streams whose samples returned geochemical values deemed to be anomalous. The boundaries of the catchment basins (or "watersheds") consist of ridges, and can be identified from topographic contours.

The areas of the anomalous catchments determine the scope of the follow-up work, whether it consists of detailed stream sampling of lower-order streams, soil sampling, till sampling or prospecting.

Samples should be collected at a point in the stream where the water flow slows down, allowing some of the fine suspended material to settle out. The inside of a bend in the stream is usually a suitable site.

Avoid collapsed bank material as this is locally derived and not representative of the stream's catchment basin as a whole.

Samples should be collected in wet-strength "Kraft" paper bags (Figure 10), which can be obtained from the Matty Mitchell Prospectors' Resource Room, or ordered in bulk from Deakin Equipment in Vancouver. Poly bags should be avoided, although they can be used to protect the wet paper bags until the return to base camp, where the samples should be allowed to dry as soon as possible.

It is a good idea to number sample packets in advance.

Collect the sample with a plastic scoop (which can be fashioned from a detergent bottle, Figure 11).

The design of the Kraft bags allows the bag to be hung on a line (or better, on a wire S-hook) that is threaded through a single hole that is created by closing it correctly (and not overfilling it).

Do not allow the drying temperature to exceed 40º C.

Figure 10: "Kraft" sample bag

Figure 11: Plastic sample scoop. The cap can also be removed to enable pouring off excess water.

PAN CONCENTRATES

Pan concentrates have the advantage that all or most of the heavy minerals in a very large volume of sediment can be concentrated into a small sample (Figure 12). The minerals in the pan will probably be dominated by magnetite and certain dense rock-forming minerals like garnet, but they may also include gold, sulphides or other indicator minerals. A skilled panner can continue to pan until only a "tail" of gold is left, but a reduced sample can also be submitted to the lab in its entirety, or subjected to a heavy-liquid separation (Figure 13).

Panning is generally more suited to higher-order streams as their beds tend to contain more gravel, which is the preferred material for panning. It is also possible to pan tills (see below) but this is much harder work as they contain a good deal more unsuitable material than stream gravels, which must all be washed away.

Figure 12: Panning stream gravels. In the larger photograph, a conical "Batea" pan is being used. The inset shows a typical panned concentrate in a flat-bottomed pan. This can be anayzed in its entirety, panned further, or subjected to heavy-liquid separation.

Figure 13: Heavy-liquid separation of a panned concentrate. The lighter minerals can be seen floating in the tetrabromoethane separating medium is which has a specific gravity of 2.97. The heavy minerals are drawn off at the bottom, filtered and washed.

SOIL SAMPLING

Soil sampling may be a second-stage prospecting procedure used to follow up a drainage anomaly. It may also constitute the first geochemical work to be carried out, if mineralization is already known to occur nearby.

The soils of Newfoundland are mainly humoferric (Figure 14) and ferrohumic (Figure 15) podzol. Both consist of an organic-rich Ah horizon and ash-grey, leached Ae horizon, neither of which should be sampled, underlain by a rusty brown B horizon, which is the preferred sample medium for many prospectors as it is enriched in metals leached from the A horizons. The base of the soil profile is the C horizon, consisting of the relatively unweathered source material of the soil, which in Newfoundland mainly consists of till (see below).

In unglaciated regions, the C horizon consists of partly weathered bedrock.

Figure 14: Humoferric podzol profile

Figure 15: Ferrohumic podzol profile

Both profiles show (from the top) the organic-rich Ah horizon, the leached Ae horizon, the rusty brown metal-enriched B horizon and the relatively unweathered C horizon.

It is important to be consistent in sampling the same soil horizon (not necessarily the same depth) at all sites wherever possible, and to take notes of which horizon is being sampled. If the sampled horizons are known, the analytical results can be evaluated separately and the risk of creating false anomalies reduced.

Figure 16, created from data recovered from a 1981 assessment report, shows what happens if there is insufficient horizon control in a soil-sampling program.

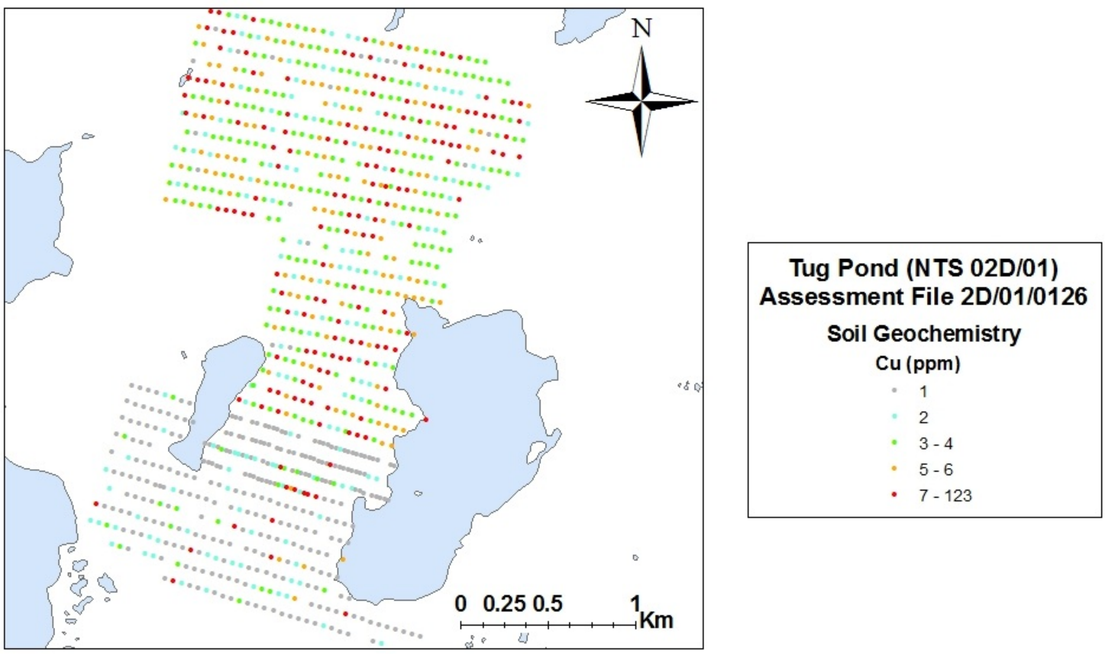


Figure 16: Copper (Cu) in soils, Tug Pond area. The crew responsible for sampling in the south of the grid appears to have sampled the C horizon, while the B horizon was sampled in the north. However, no notes were taken.

Samples can be collected with an auger, which can be borrowed from the Matty Mitchell Prospectors' Resource Room, or ordered from Deakin Equipment (Figure 17). If the soil and underlying till are particularly rocky, it may be easier to get a sample using a shovel, aided by a crowbar and a small garden saw (for roots). This is more time-consuming. Remember to back-fill the soil pit when the sample has been collected, before moving on.

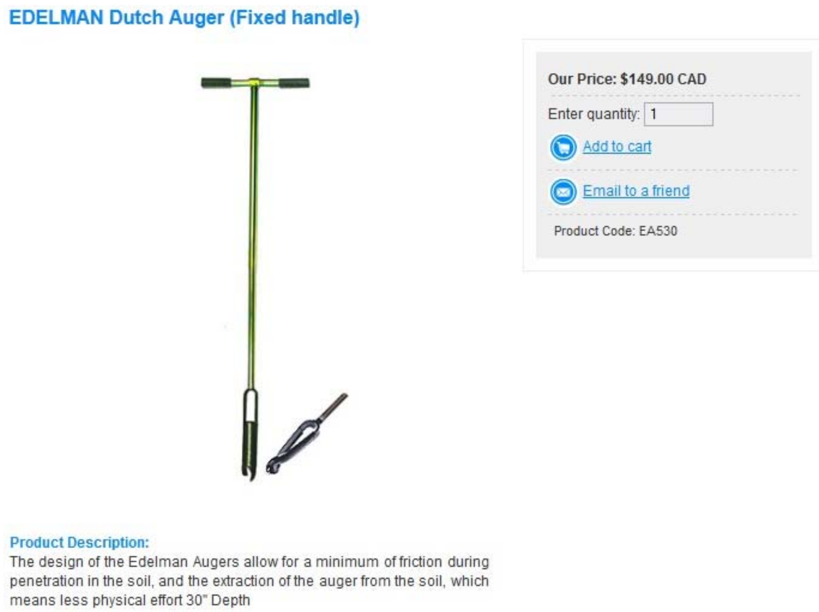


Figure 17: Example of a soil auger

The Kraft paper bag (see above) is also suitable for soil samples. Prenumbering, using a separate numbering system, is important. It is <u>not</u> recommended that samples be numbered by their position on the grid (or other coordinates). These should be recorded, against the sample number, in a notebook and not disclosed to the lab.

The position of the sample can be marked with an aluminum tag (see Figure 18), for permanence, with flagging tape to assist finding the site again. If the sample number is written on flagging tape it will fade quickly.

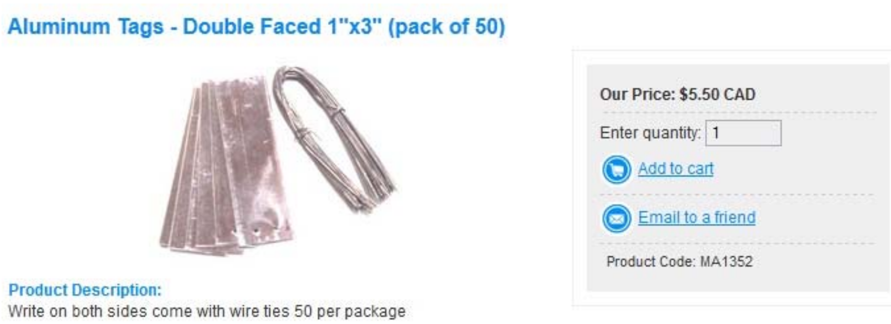


Figure 18: Aluminum sample tags. The sample number can be written on the tag with a ballpoint pen.

Soil samples are laid out on a grid, normally in the form of regularly spaced cut lines.

The sampling lines should be spaced so that any important feature should be cut by at least two of them; and samples should be spaced in such a way that the feature should be manifested in at least two adjacent samples (Figure 19). Normally this means that the spacing between the samples is much less than the spacing between the lines; typically, samples are spaced at intervals of 10 to 25 metres, on lines 100 to 200 metres apart. Therefore, the sample density varies from 200 to 1,000 per square kilometre, or 50 to 250 per 250-hectare claim.

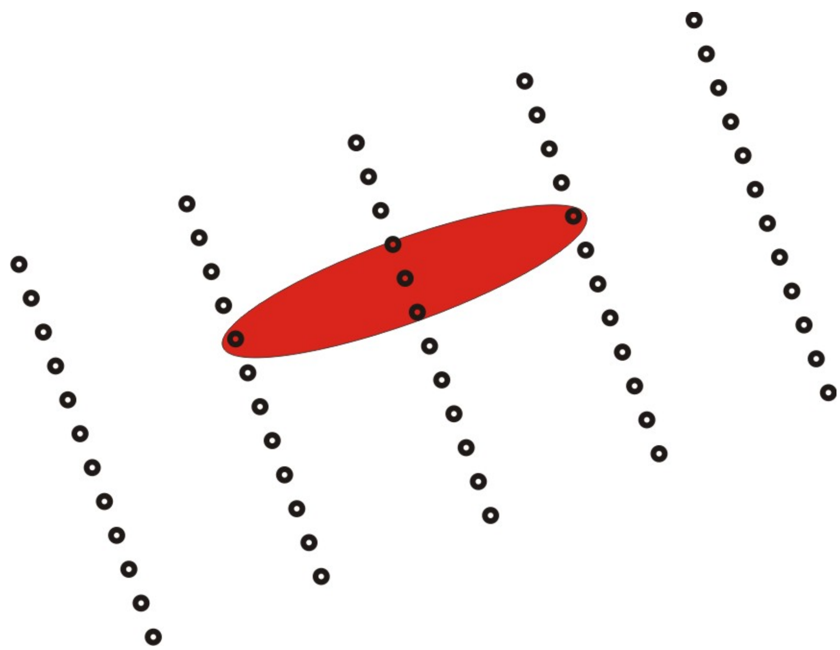


Figure 19: Selection of line and sample spacing should reflect the size of the expected target.

TILL SAMPLING

Till (sometimes called drift) is the sediment that results from the movement of glacier ice over the land surface and the plucking and grinding of bedrock. It is typically unsorted, meaning that fragments of all sizes are intimately mixed together (Figure 20).

The interpretation of till geochemistry requires knowledge of the glacial history of the area; in particular, the direction(s) of ice movement. However, because glaciation in Newfoundland is so widespread, this is also true of soil and stream geochemistry.

Figure 21 shows in schematic form how metals are dispersed in till from their bedrock source, and how the resulting geochemical response would appear at various depths, and at surface.

Figure 20: Typical rocky till, exposed in a roadcut.

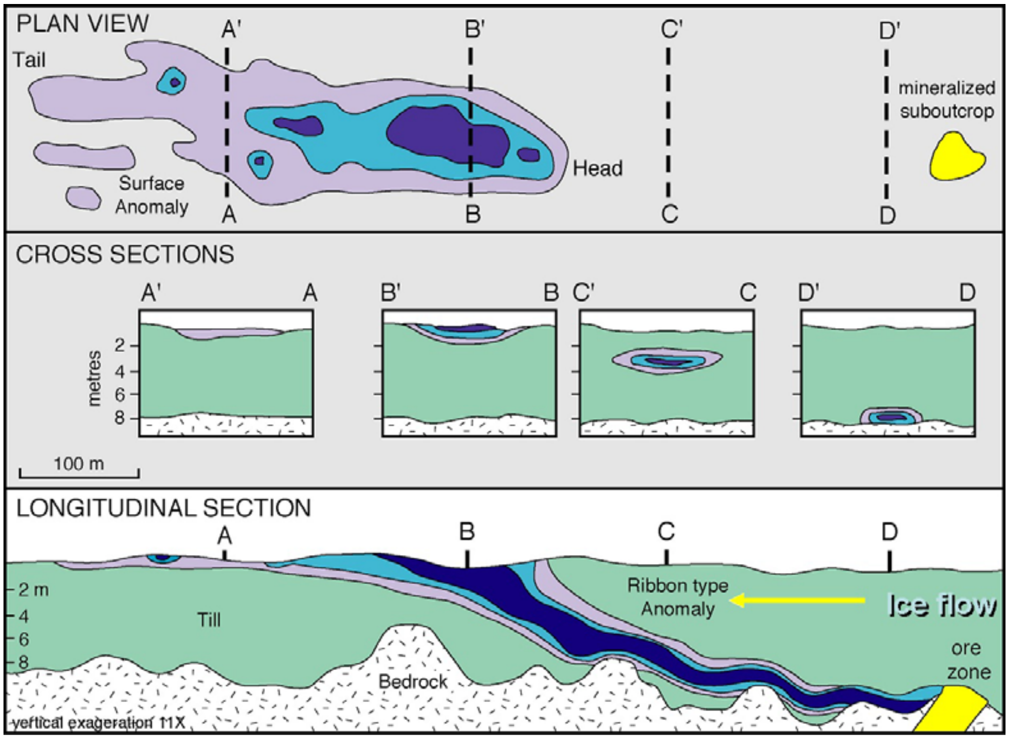


Figure 21: Schematic sections and plan of glacial dispersion from an ore zone. (from Miller, 1984). Assuming a single till-depositing event, the distance "up-ice" to the bedrock source of a geochemical anomaly, or mineralized boulder, detected at surface is dependent on the till thickness.

As a first approximation, the ice-movement direction is generally towards the coast, but large- and small-scale deviations from this rule are not uncommon.

There are a number of field methods for determining the direction of ice movement. One of the most common is to measure the direction of striations on glaciated rock surfaces. There is a large downloadable database of striation measurements in the GSNL's Geoscience Atlas (Figure 22).

In its purest form, the dispersion pattern from a geochemically-distinct feature looks like Figure 23. When there has been more than one glacial episode, with different ice-movement directions, more complicated patterns can result; Figure 24 is an example.

Till samples are normally recovered from hand-dug pits, although specialized drills, like the Atlas-Copco Pionjar, can be used to recover till from greater depths.

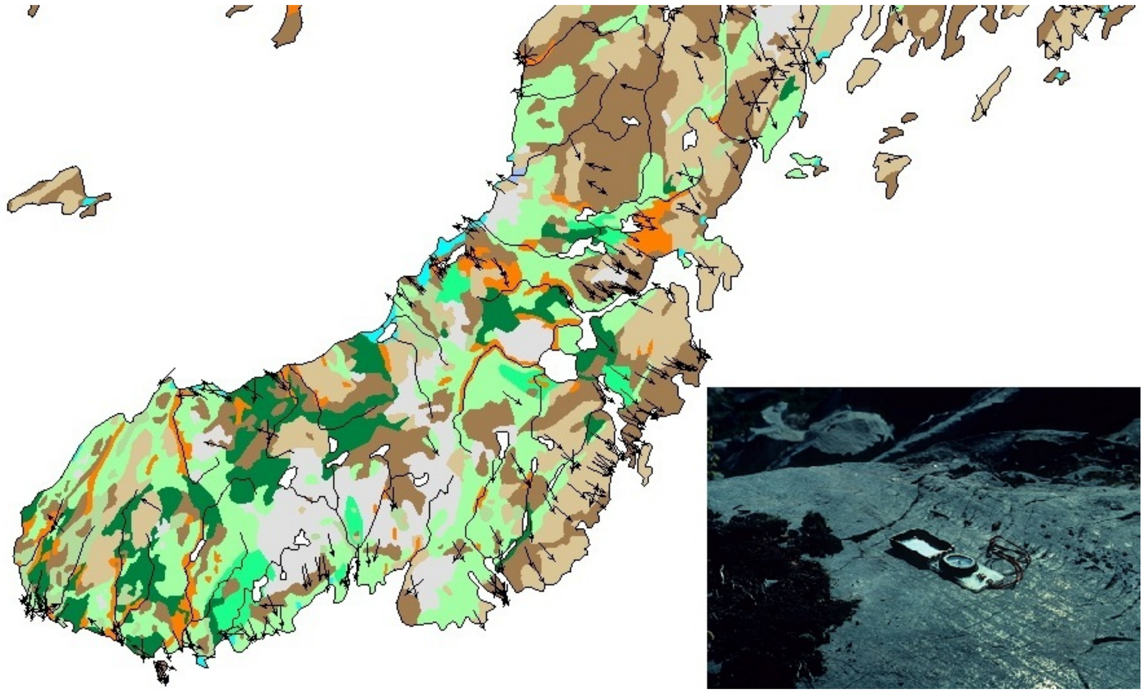


Figure 22: Striation directions in the Burin Peninsula, from the Geoscience Atlas. Inset: striations on a flat rock surface

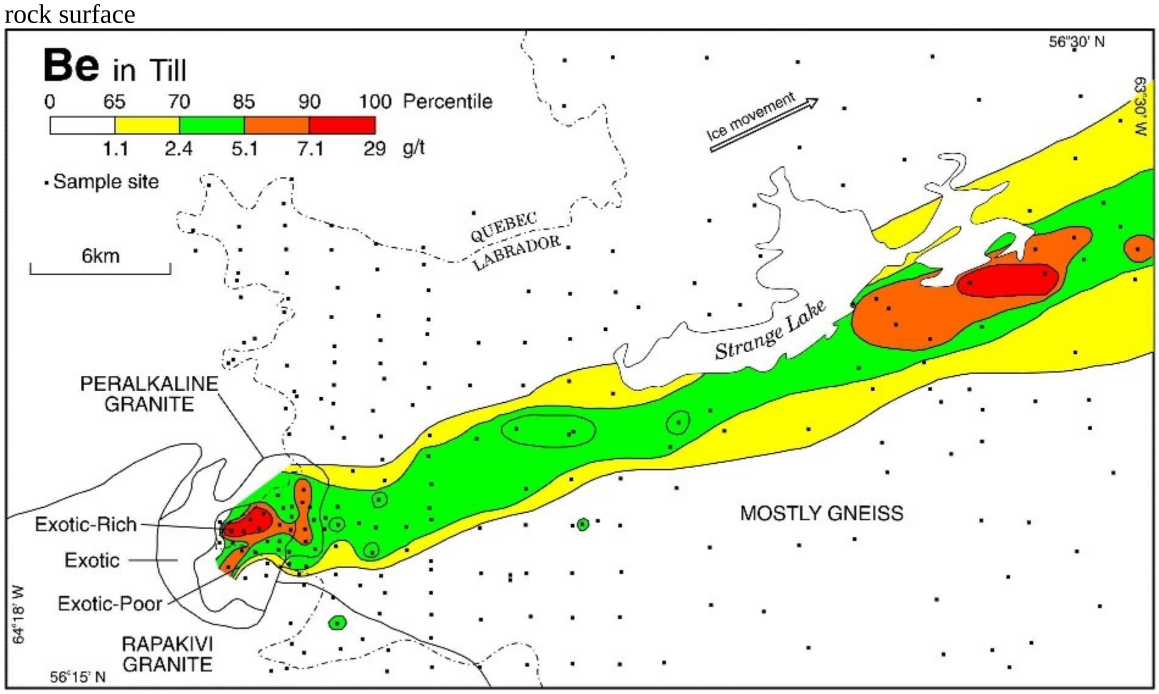


Figure 23: Glacial dispersion of beryllium (Be) from the Strange Lake rare earth-rare metal deposit, Labrador (from Batterson 1989).

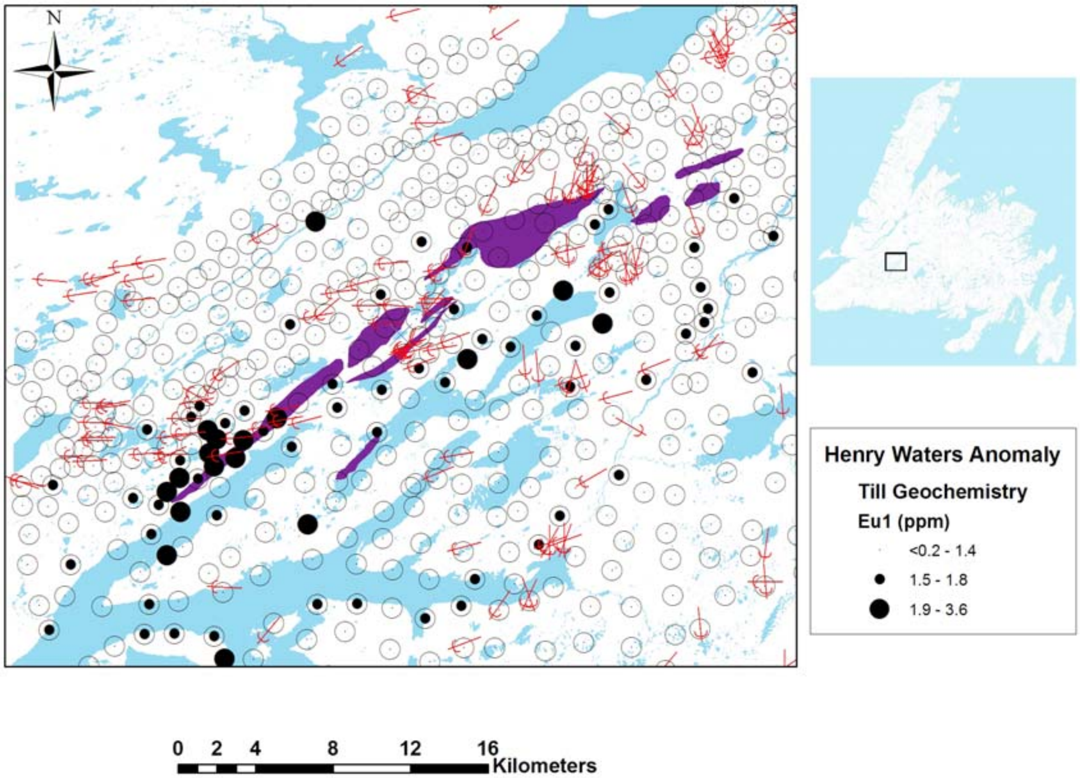


Figure 24: Till dispersion of europium (Eu) from the Roebucks Intrusive Suite (marked in purple), central Newfoundland. There have been at least two glacial episodes in the area: an earlier, southward moving episode and a later, westward-moving episode which has modified the southerly dispersion in the centre of the map.

DATAMINING

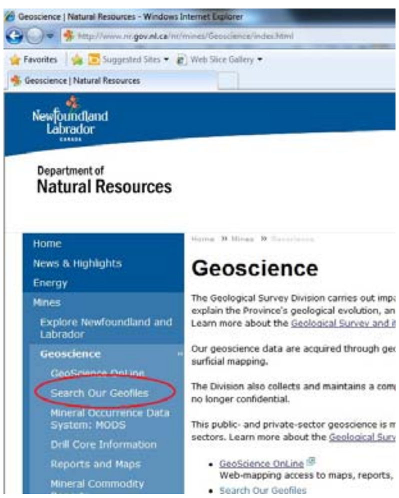
The mineral-assessment files of the provincial government contain reports of all kinds of prospecting and exploration work, including stream, till and especially soil geochemistry.

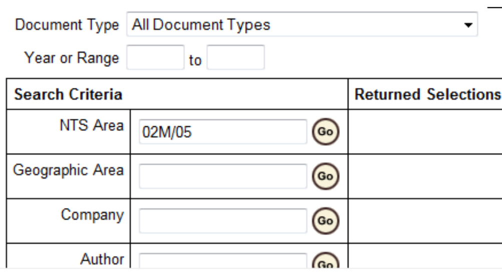
In some cases, encouraging results were not fully investigated; this may have been because the company was focused on only one metal and ignored evidence of enrichment in any other. The company's ability to do the follow-up work as it wished may have been prevented by its inability to raise the necessary funds; it may have realigned its goals and priorities; or there may not have been anyone competent to evaluate the results fully.

Figures 25-28 show the process of researching the assessment database for reports of geochemical work for a particular map sheet.

Searching for underutilized geochemical data in the assessment files involves no additional dollar cost to anyone with a computer and Internet access. It does involve a lot of work, however, and the results will often be disappointing. One of the most common issues is the difficulty of establishing the locations of the old samples.

Persistence will, however, usually be rewarded.





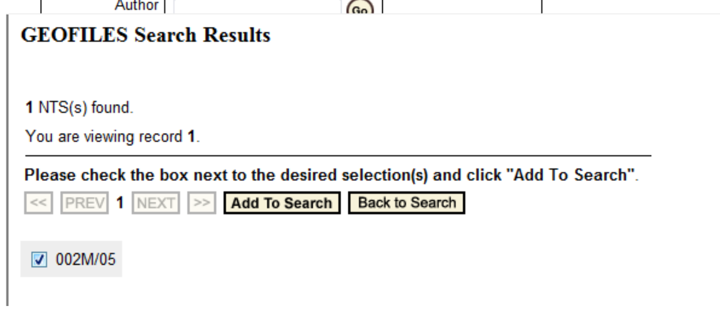


Figure 25: Datamining for assessment files (1)
First screenshot: The link to the Geofiles pages on www.nr.gov.nl.ca/nr/mines/Geoscience
Second screenshot: Specifying an NTS map area of interest
Third screenshot: Confirming an area of interest found by the system

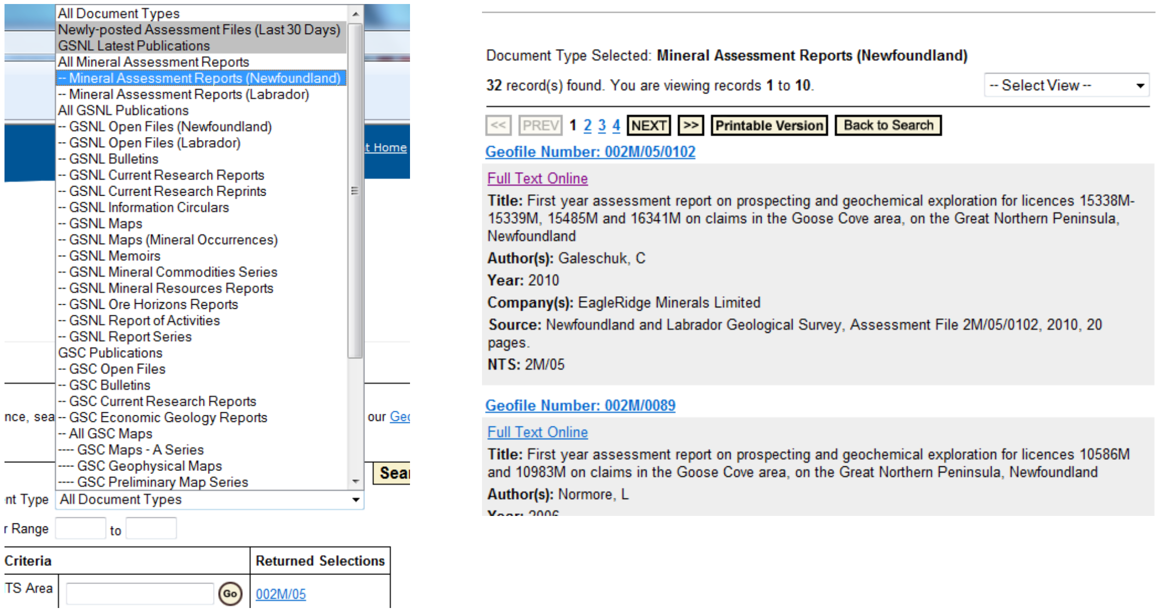


Figure 26: Datamining for assessment files (2)
First screenshot: Selecting "Mineral Assessment Files" from the pop-up menu
Second screenshot: There are 32 assessment files for NTS map area 2M/05.

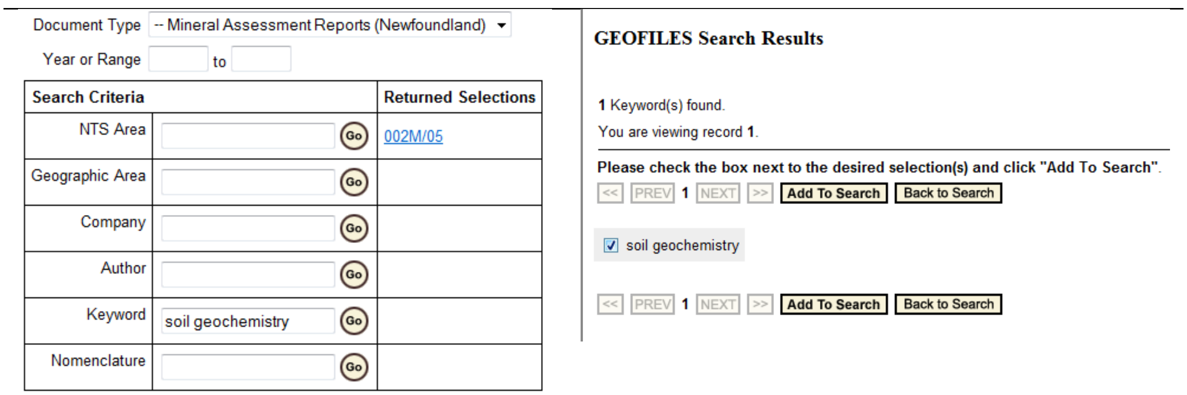


Figure 27: Datamining for assessment files (3)
First screenshot: refining the search criteria by searching for "soil geochemistry"
Second screenshot: The system recognizes the phrase (not always the case) and asks the user to confirm

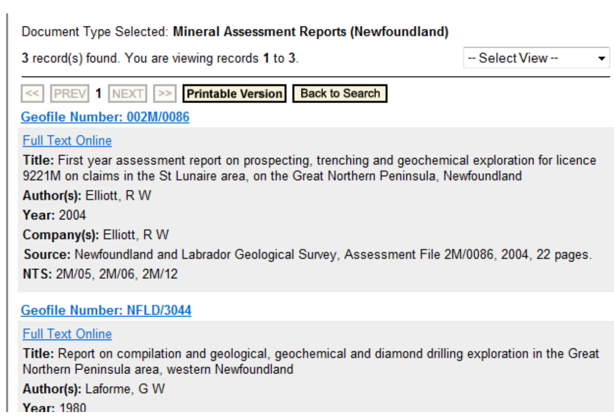


Figure 28: Datamining for assessment files (4)
The refinement of the search criteria reduces the number of "hits" from 32 to 3

INTERPRETING GEOCHEMICAL DATA

This is a complex subject!

Table 1 was extracted from the Guide to Prospectors produced by the Matty Mitchell Prospectors' Resource Room and shows a table of general threshold values for a number of important elements in rocks, soils and stream sediments. "Threshold" is defined as "the upper limit of background variation"; values exceeding it are considered anomalous.

These values are very general and exploration geochemists do not interpret their data through the blanket application of a series of thresholds.

Table 1: Threshold values for various important elements in rocks, soils and "silts" (stream sediments). To be used as a general guide only.

Range of Threshold - For Anomalous Values

Elements	Crustal Abundance	Rocks (ppm)	Soils (ppm)	Silts (ppm)
Au	4 ppb	50 - 100 ppb	40 - 100 ppb	20 - 50 ppb
Ag	70 ppb	0.5 - 1	0.2 - 0.5	0.2 - 2.5
Cu	55 ppm	100 - 200	50 - 200	100 - 200
Pb	13 ppm	40 - 100	40 - 100	40 - 100
Zn	70 ppm	100 - 500	200 - 300	200 - 300
Mo	1.5 ppm	5 - 20	2 - 5	2 - 5
W	1.5 ppm	10 - 50	2 - 10	2 - 10
Ni	75 ppm	100 - 200	100 - 200	100 - 200
As	1.8 ppm	5 - 10	5 - 20	2 - 5
Sb	0.2 ppm	5 - 10	5 - 20	2 - 5
Co	25 ppm	10 - 40	5 - 20	-
Hg	80 ppb	100 - 500 ppb	-	50 - 200 ppb
Te	10 ppb	2 - 5 ppm	-	-
Pt	10 ppb	50 - 100 ppb	-	-
Ba	425 ppm	500 - 10,000	500 - 10,000	500 - 10,000

Figure 29 shows the results of applying a threshold of 20 ppm arsenic (As), from Table 1, to real assessment soil data from central Newfoundland. It is clear that the threshold has been set much too low. This is because regional background levels of As in the rocks, and the tills, stream sediments and soils derived from them, are unusually high in the region.

The moral of the story is (to quote the Guide to Prospecting) "To get some idea of background for an area of interest, prospectors should examine **all** open file, regional and local survey data with respect to that area"

The map of the same data in Figure 30 was compiled without previous knowledge of a threshold value. Instead, the arsenic values were sorted and the points coloured in descending order; the highest value first, followed by the second highest, and so on. It soon becomes obvious where the spatial concentrations of high values are situated. Some of these concentrations (which coincide with high values of molybdenum and other pathfinder elements) were trenched, while others were not tested before the claims were dropped.

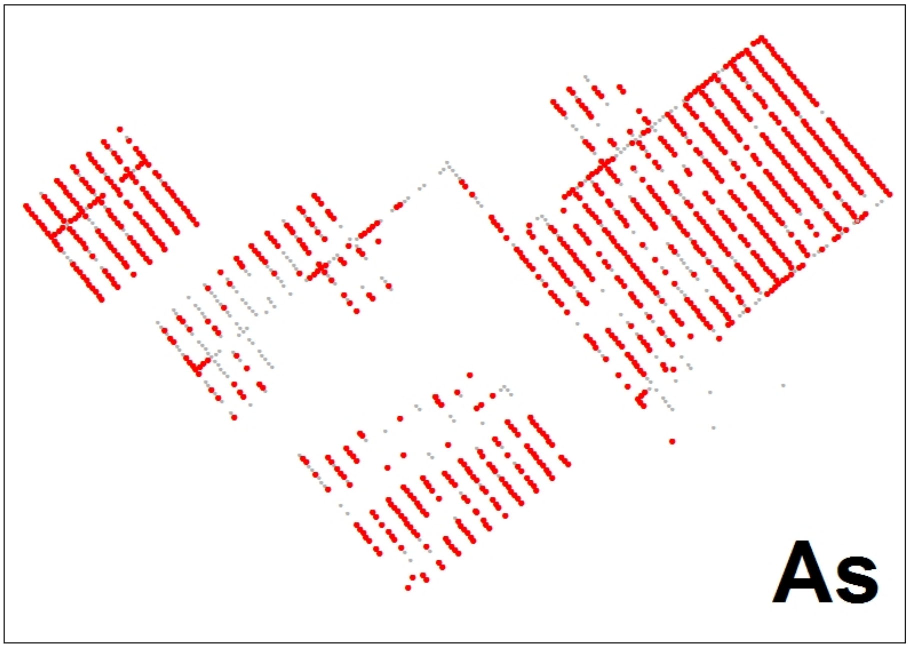


Figure 29: Results of applying a general threshold of 20 ppm to arsenic soil analyses from central Newfoundland. “Anomalous” values are indicated by red dots; “background” by grey dots.

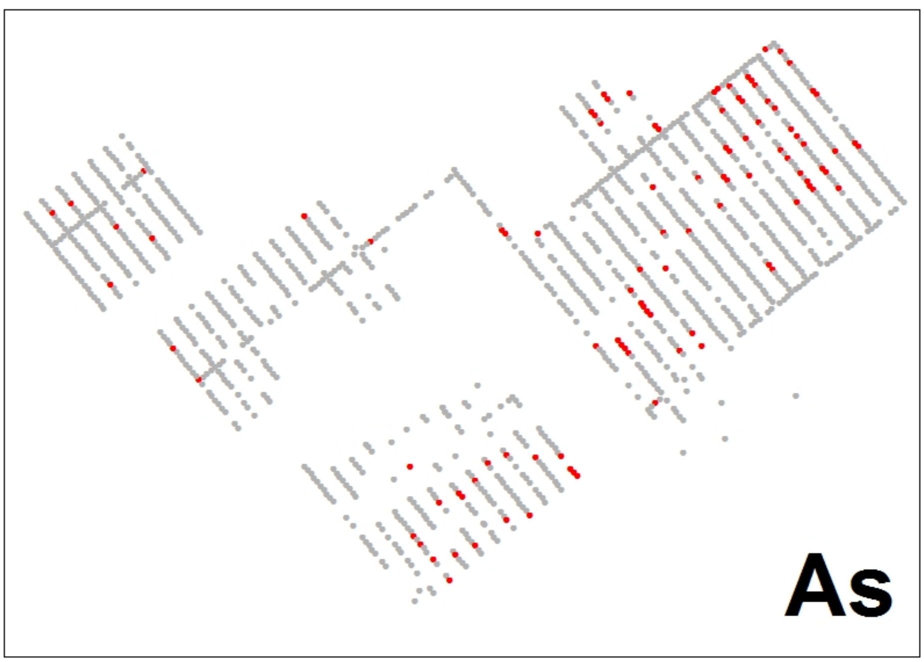


Figure 30: The same data as displayed in Figure 30, with spatial concentrations of high As values identified by highlighting the highest values, in descending order. Red symbols have been assigned (coincidentally) to As values exceeding 100 parts per million (ppm).

THE ELEMENTS (SOME OF THEM)

Table 2 lists some of the elements with their chemical symbols. They are subdivided into "Primary Targets", which are the elements (all metals) that are most commonly sought by prospectors; "Secondary Targets" (all metals except fluorine) which may be sought under special geological and economic circumstances; and "Pathfinders" which are elements, normally uneconomic, that are useful in leading to a deposit of an element other than themselves. Usually, the target element presents some sampling or analytical difficulties that the pathfinders do not.

Some of the primary and secondary target elements may also serve as pathfinders; for example, Ag, Cu, Mo, Pb and W are often used as pathfinders for Au.

Table 2: Primary elements, secondary elements and pathfinders

Primary Targets		**Secondary Targets**		**Pathfinders**	
Ag	Silver	Ba	Barium	As	Arsenic
Au	Gold	Be	Beryllium	B	Boron
Cr	Chromium	Cs	Cesium	Bi	Bismuth
Cu	Copper	F	Fluorine	Cd	Cadmium
Mo	Molybdenum	Hg	Mercury	Te	Tellurium
Ni	Nickel	In	Indium	Tl	Thallium
Pb	Lead	Ir	Iridium		
Pt	Platinum	La	Lanthanum		
Sn	Tin	+Ce,Pr,Nd,Sm,Eu,Gd,Tb,Dy,Ho,Er,Tm,Yb,Lu (Rare Earth Elements)			
U	Uranium	Li	Lithium		
W	Tungsten	Nb	Niobium		
Zn	Zinc	Pd	Palladium		
		Rh	Rhodium		
		Sb	Antimony		
		Ta	Tantalum		
		Ti	Titanium		
		V	Vanadium		
		Y	Yttrium		
		Zr	Zirconium		

Iron (Fe) and manganese (Mn) are known as “scavenger” metals. They can influence the content of many other metals and give rise to false anomalies in stream and lake sediments, and soils. Therefore, it is advisable to analyze for these elements so that potential false anomalies can be screened out.

Opinions vary on which elements are most susceptible to Fe and Mn scavenging; the consensus seems to be that (in descending order of strength) Pb, Cu, Zn, Ni, Cd and Co are most strongly scavenged by Fe, while Co, Zn, Ni and Ba are most strongly scavenged by Mn (Levinson, 1980).

In Newfoundland and Labrador lake sediments, for which the most local data are available locally, the phenomenon seems to be most pronounced for Co and Zn.

PREPARATION AND ANALYSIS

When budgeting a geochemical sampling program it is important to remember that the quoted cost of an analysis does not include tax; nor does it include preparation, which normally consists of drying and sieving a sample, with the fine material submitted for analysis and the coarse fraction either stored, returned to the client, or discarded. The latter cost is not trivial (neither, of course, is the former!); Eastern Analytical charges $2.75 to dry and sieve a soil sample and $3.80 for a stream-sediment or till sample.

Eastern Analytical in Springdale (www.easternanalytical.ca) offers three multi-element ICP (inductively-coupled plasma) analytical packages:

ICP-9: (Ag, Co, Cu, Fe, Mn, Mo, Ni, Pb and Zn) for $8.35 per sample

ICP-11: (all of the ICP-9 elements, plus Sb and As)

ICL-30: (all of the ICP-11 elements, plus Al, Ba, Be, Bi, Ca, Cd, Ce, Cr, Hg, K, La, Mg, Na, P, Sn , Sr, Ti, V and W)

ICP-30 offers the most elements for the money and most of Eastern's clients seem to opt for this package. However, the additional elements offer little added value to the prospector, for various reasons, and the apparently slight difference in price per sample can make a substantial difference to the number of samples that can be treated for a given sum. For example, with a typical $3,000 prospecting grant, and taking into account preparation costs and tax, an additional 23 ICP-11 analyses (total 222), or 40 ICP-9 analyses (total 239), could be performed compared to the 199 ICP-30 analyses.

Accurassay Laboratories (www.accurassay.com/analysis) has a preparation facility in Gambo, from where the samples are shipped to Thunder Bay for analysis. Their prices and turnaround times are similar to Eastern's.

ACME Labs in Vancouver and Activation Labs in Ancaster also offer ICP packages; ACME's per-sample preparation and analytical costs are the cheapest of all these labs but there are shipping costs, and the longer turnaround time, to consider.

Most labs, including Eastern (Figure 31), will also do gold determinations by fire assay; either as a stand-alone analysis or as a package with one of the ICP packages. Each analysis will cost at least $13.

Gold analyses in geochemical samples are subject to the “nugget effect” which can cause an anomaly to be missed, or alternately for an unrealistically high value to be returned; the outcome depends very much on chance (Figure 32). Although ultimately a gold property can only be evaluated on the strength of the gold assays that have been performed, gold analyses are not necessarily the most prudent use of the funds allotted to a preliminary geochemical program; pathfinder elements like arsenic will do a better job of identifying areas for follow-up.

Figure 31: Page from Eastern Analytical’s website describing Fire Assay

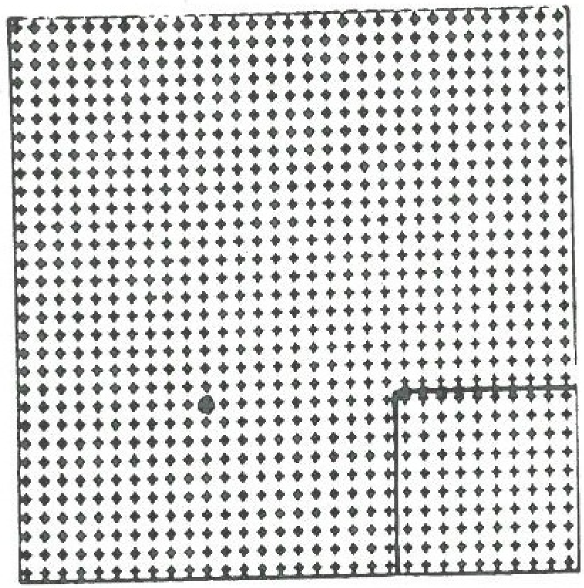


Figure 32: Graphical illustration of the "nugget" or "particle sparsity" effect. Because of gold's typically particulate dispersion, a scoop of sample material represented by the smaller square will return a very low assay; if the scoop picks up the single gold particle (represented by the larger dot), the assay will be very high. As indicators of the bulk gold composition of the sample, neither will be correct (from Harris, 1981). A pathfinder element like arsenic is more evenly distributed and not subject to this problem.

Panning a sample of stream gravel or till,or subjecting it to one of various other methods of separating and identifying the heavy minerals it contains, is one way of overcoming the nugget effect.

Depending on the skill of the panner, or the amount that is spent on commercial processing of the sample, a great deal of additional information can be extracted. For example, Overburden Drilling Management in Ottawa will identify various suites of indicator minerals (including KIMs, or kimberlite indicator minerals). They also examine individually each gold grain that is extracted from the sample, with the aid of a Wilfley shaker table (Figure 33) and based on its degree of angularity or roundness, estimate how far it has travelled from its bedrock source.

Figure 33: Extracting and examining the heavy minerals from a till sample with the aid of a Wilfley table.

DETECTION LIMITS

Figure 34, which consists of an analytical certificate from ACME Analytical, shows a number of analyses preceded by the “less than” (<) sign. This means that there is so little of the element in question in the sample that the analytical method is not sensitive enough to measure it. The < sign is sometimes replaced by a minus sign (-) or, rarely (though it may turn up in old assessment documents) the words “ND” meaning “Not detected”.

Eastern Analytical reports analyses that fall below the detection limit as being <u>at</u> the detection limit. In Figure 35, all of the tungsten (W) analyses are reported as being 10 ppm, as that is the detection limit; the actual values are in most cases, probably much, much less. They do, however, use the “greater than” sign (>) to indicate an analysis that exceeds the method’s upper range; for example, one iron (Fe) analysis is reported at “>10.00” while one aluminum (Al) analysis is “>5.50”.

ACME ANALYTICAL LABORATORIES LTD. **Final Report**

Client:	Exploratus Ltd.
File Created:	28-Jan-2009
Job Number:	VAN08009350
Number of Samples:	206
Project:	Nunavut 2008
Shipment ID:	
P.O. Number:	
Received:	16-Sep-2008

	Method	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX
	Analyte	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au
	Unit	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	%	PPM	PPM	PPB
	MDL	0.1	0.1	0.1	1	0.1	0.1	0.1	1	0.01	0.5	0.1	0.5
Sample	**Type**												
S0001	Till	0.2	8.0	4.3	11	<0.1	13.3	4.0	130	1.15	1.6	0.9	<0.5
S0002	Till	0.5	79.7	6.5	37	<0.1	41.0	9.2	243	2.14	3.3	2.1	0.5
S0003	Till	0.1	8.7	18.3	12	<0.1	9.1	3.0	88	0.88	1.4	0.9	<0.5
S0004	Till	0.1	6.9	8.7	11	<0.1	9.9	3.3	93	0.94	1.7	0.8	24.5
S0005	Till	0.1	7.9	3.5	10	<0.1	10.4	3.7	113	0.90	1.5	0.9	1.9
S0006	Till	0.1	4.2	3.8	7	<0.1	6.2	2.7	63	0.87	1.1	0.7	0.6
S0007	Till	0.1	5.7	3.6	9	<0.1	9.5	3.6	104	1.00	1.4	0.8	8.5
S0008	Till	<0.1	7.3	3.5	13	<0.1	13.1	4.2	126	1.10	1.3	0.8	3.0
S0009	Till	<0.1	3.5	3.5	7	<0.1	5.3	1.5	40	0.41	<0.5	0.9	<0.5
S0010	Till	<0.1	6.9	3.9	11	<0.1	11.0	3.5	117	1.10	1.5	0.9	1.6
S0011	Till	0.1	9.7	3.0	12	<0.1	10.8	3.5	98	0.97	1.0	0.9	<0.5
S0012	Till	0.1	8.2	3.4	9	<0.1	6.9	2.2	74	0.92	1.1	0.9	<0.5
S0013	Till	0.1	11.7	3.4	11	<0.1	11.3	3.5	96	0.97	1.9	1.2	<0.5

Figure 34: ICP Analytical certificate from ACME, that includes many "undetectables"

SCANNED IMAGE

[redacted]

(403)
(909)

ICP Geochemistry Certificate

Client: Celtic Minerals Limited
Geologist: Barry Greene
Project: #3 HarPoon Brook
Sample: Soils

DskFile: 251-1450

DateIn: June 10, 1996
DateOut: June 17, 1996

Eastern Analytical Limited
P.O. Box 187,
Little Bay Road,
Springdale,
Newfoundland.

Phone: 709-673-3909
Fax: 709-673-3408

Signed by: G. Smith
(Concentrations in assay range may cause interferences in associated elements.)

SAMPLE #	Ce ppm	Sr ppm	Ba ppm	Fe %	P %	Hg ppm	Mg %	As ppm	V ppm	Na %	Mo ppm	Al %	Be ppm	Ca %	Zn ppm	Cu ppm	Sb ppm	Ag ppm	Pb ppm	Bi ppm	Ti %	Cd ppm	Co ppm	Ni ppm	W ppm	La ppm	K %	Mn ppm	Rb ppm	Cr ppm
L0+00 0+00BL	17	4	41	4.21	0.20	1	0.29	37	35	0.01	7	1.64	0.5	0.04	59	28	5	0.5	21	2	0.01	1.6	34	9	10	10	0.05	5742	[illegible]	20
L0+00 0+25S	19	2	25	2.29	0.07	1	0.18	15	29	0.01	4	1.86	0.5	0.01	27	18	5	0.2	11	2	0.01	0.6	3	4	10	12	0.03	377	20	12
L0+00 0+50S	10	2	42	6.55	0.48	1	0.18	32	46	0.01	4	5.08	0.9	0.02	83	23	5	0.7	15	3	0.01	2.7	19	5	10	10	0.03	1955	20	45
L0+00 0+75S	12	2	49	5.52	0.31	1	0.28	39	49	0.01	4	4.05	0.8	0.02	91	31	5	0.6	18	2	0.01	2.0	11	11	10	10	0.03	1020	20	52
L0+00 1+00S	12	1	49	5.22	0.26	1	0.34	33	48	0.01	4	3.81	0.8	0.01	79	33	5	0.3	19	2	0.01	2.0	7	13	10	10	0.03	436	20	34
L0+00 1+50S	10	2	48	8.13	0.45	1	0.22	40	75	0.01	1	>5.50	1.2	0.02	62	18	5	0.5	26	3	0.01	3.0	12	5	10	10	0.04	1303	20	51
L0+00 1+75S	63	45	77	1.23	0.53	1	0.17	25	30	0.02	29	1.68	0.9	0.57	108	97	5	1.8	38	2	0.01	2.5	27	15	10	13	0.08	1177	20	46
L0+00 2+00S	26	10	51	2.58	0.06	1	0.40	11	25	0.01	2	1.48	0.5	0.11	37	8	5	0.2	12	2	0.01	0.9	6	9	10	15	0.06	796	20	15
L0+00 2+25S	21	4	30	3.07	0.07	1	0.45	23	27	0.01	5	1.67	0.5	0.04	34	59	5	0.2	15	2	0.01	1.2	18	11	10	12	0.03	608	20	16
L0+00 2+50S	12	2	42	4.35	0.21	1	0.18	25	44	0.01	3	2.84	0.6	0.02	50	19	5	0.2	12	3	0.01	1.6	4	6	10	10	0.02	295	20	23
L0+00 2+75S	25	3	47	3.50	0.20	1	0.49	26	42	0.01	2	1.74	0.5	0.03	57	45	5	0.2	19	2	0.03	1.4	14	17	10	12	0.05	857	20	19
L0+00 3+00S	15	2	42	4.50	0.25	1	0.40	36	39	0.01	5	3.14	0.6	0.02	53	55	5	0.2	18	2	0.02	1.7	7	11	10	10	0.03	530	20	26
L0+00 3+25S	19	3	33	1.52	0.05	1	0.27	6	20	0.01	1	1.08	0.5	0.03	26	6	5	0.2	10	2	0.01	0.6	7	5	10	11	0.03	543	20	10
L0+00 3+50S	25	4	36	3.03	0.10	1	0.36	17	31	0.01	4	1.84	0.5	0.03	41	18	5	0.2	15	2	0.01	1.1	6	6	10	15	0.04	406	20	14
L0+00 4+25S	21	5	64	2.98	0.15	1	0.38	25	31	0.01	6	1.69	0.5	0.05	41	15	5	0.5	15	2	0.01	1.2	8	6	10	14	0.06	1393	20	14
L0+00 4+50S	25	8	73	2.76	0.18	1	0.24	20	31	0.01	6	1.67	0.5	0.10	37	21	5	0.4	11	2	0.01	1.0	6	6	10	14	0.05	462	20	12
L0+00 5+00S	14	4	41	2.18	0.05	1	0.56	5	20	0.01	1	1.77	0.5	0.02	35	1	5	0.2	10	2	0.01	0.8	3	10	10	10	0.05	285	20	19
L0+00 5+25S	25	9	113	>10.00	0.23	1	0.06	113	55	0.01	24	1.98	0.7	0.08	97	33	5	0.3	29	5	0.01	5.7	81	44	10	14	0.02	6895	20	23
L0+00 5+50S	15	5	23	2.19	0.04	1	0.50	6	21	0.01	2	1.49	0.5	0.04	30	1	5	0.2	7	2	0.01	0.9	3	8	10	11	0.04	277	20	19
L0+00 5+75S	26	3	34	2.99	0.08	1	0.48	5	20	0.01	3	2.17	0.5	0.02	39	9	5	2.3	9	2	0.01	1.0	5	11	10	15	0.05	408	20	19
L0+00 6+00S	24	19	167	4.32	0.38	1	0.19	37	42	0.01	19	2.10	0.9	0.18	133	62	5	1.9	55	2	0.01	4.4	34	39	10	13	0.08	18844	20	29
L0+00 6+50S	18	2	23	2.31	0.07	1	0.35	7	25	0.01	2	1.66	0.5	0.01	35	4	5	0.2	14	2	0.01	0.6	4	10	10	11	0.05	169	20	15
L0+00 6+75S	15	5	204	6.15	0.45	1	0.14	32	48	0.01	9	3.42	0.9	0.02	66	70	5	1.6	17	2	0.01	3.9	38	10	10	10	0.04	19666	20	49
L0+00 7+00S	10	2	25	3.85	0.11	1	0.20	10	34	0.01	4	1.60	0.5	0.01	51	10	5	0.2	9	2	0.01	1.5	5	8	10	10	0.05	555	20	17
L0+00 7+25S	19	10	47	0.52	0.12	1	0.10	5	8	0.01	3	0.91	0.5	0.10	14	10	5	0.3	10	2	0.01	0.5	1	4	10	13	0.06	136	20	8
L0+00 7+50S	33	11	82	1.22	0.12	1	0.23	5	10	0.01	1	1.59	0.7	0.09	28	57	5	0.2	30	2	0.01	0.6	5	12	10	18	0.06	340	20	15
L0+00 7+75S	38	9	66	3.90	0.11	1	0.55	36	26	0.01	11	1.71	0.5	0.10	62	35	5	0.2	16	2	0.01	1.7	20	26	10	20	0.07	523	20	23
L0+00 8+00S	17	4	58	6.07	0.35	1	0.34	39	51	0.01	7	3.29	0.7	0.05	77	48	5	1.8	17	2	0.01	2.4	18	10	10	11	0.04	2461	20	28
L1+25E 10+00TL	38	2	22	5.18	0.18	1	0.55	56	24	0.01	6	1.54	0.5	0.01	35	5	5	0.2	11	2	0.01	2.2	4	7	10	21	0.10	406	20	17
L1+50E 10+00TL	27	3	30	2.29	0.08	1	0.52	7	25	0.01	4	1.39	0.5	0.01	39	13	5	0.2	18	2	0.01	0.6	4	10	10	15	0.07	418	20	15
L1+75E 10+00TL	10	17	31	7.25	0.18	1	2.20	18	77	0.01	5	4.08	0.7	0.17	421	96	5	0.2	13	2	0.01	3.4	59	150	10	10	0.14	953	20	155
L2+00E 0+00BL	23	4	62	1.93	0.11	1	0.18	9	25	0.01	3	1.77	0.5	0.06	31	10	5	0.2	9	2	0.01	0.8	4	4	10	13	0.03	251	20	10
L2+00E 0+25S	18	3	38	2.86	0.13	1	0.29	20	35	0.01	4	1.38	0.5	0.04	33	14	5	0.3	13	2	0.01	1.1	3	5	10	12	0.04	333	20	11
L2+00E 0+50S	18	5	48	1.93	0.09	1	0.21	11	23	0.01	3	1.41	0.5	0.05	24	8	5	0.3	10	2	0.01	0.9	5	3	10	11	0.03	430	20	10
L2+00E 0+75S	12	3	52	6.75	0.32	1	0.29	48	47	0.01	6	2.94	0.7	0.03	67	39	5	0.3	26	2	0.01	2.0	13	8	10	10	0.03	888	20	25

Figure 35: Analytical certificate from Eastern Analytical

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GLOSSARY

Anomaly
Departure from what is considered normal. In the context of prospecting, a geochemical or geophysical feature that may be related to mineralization.

Assessment file
A report submitted to the government by a prospector or mining company describing the work carried out, and funds expended, on a mineral licence, in order to keep it in good standing. The file becomes public after the property lapses, or is dropped.

Catchment basin
The geographic area providing sediment to a stream. Bounded by *watersheds*.

Colours
In the context of prospecting, grains of gold left in the pan when panning of a sample is complete.

Datamining
Researching publicly available data for underutilized information and previously unrecognized opportunities.

Detection limit
The concentration level below or above which a particular analytical method is unable to provide reliable analyses for a particular element.

Digestion
The process of extracting the metals from a geochemical sample using a reagent, usually (but not always) a strong acid or combination of acids.

Drainage geochemistry
Study of the composition of the sediments and waters in streams and lakes.

Drift
Essentially, an old word for *till*. Still much used in the term “drift prospecting”.

Erosion
The physical removal of the earth’s surface by wind, water, heat, cold and ice.

Fire Assay
A special, quite sensitive method of analysis for gold. Involves fusion of the sample in a furnace.

Geofiles
A comprehensive online database of the Government of Newfoundland and Labrador. Includes assessment reports and geological reports and maps of all kinds. Most are available for download.

Graphite
Soft, black, crystalline form of carbon, common in metamorphic rocks. May be an economic resource in itself, but more commonly a nuisance in geophysical prospecting because it conducts electricity like a sulphide mineral.

Grassroots
The first phase of prospecting and exploration in a virgin territory. Usually consists of drainage sampling, often complemented by airborne geophysics.

Heavy-liquid separation
Extraction of dense minerals from a *panned* concentrate (usually) by immersing it in a heavy liquid like bromoform (specific gravity 2.89), tetrabromoethane (2.97) or

methylene iodide (3.33) in which most common rock-forming minerals will float, while potentially economic suphides, oxides and *native metals* will sink.

Heavy-mineral concentrate
Concentrate of minerals from a *panned* concentrate that sink in a dense liquid (see *heavy-liquid separation*). Consists mainly of suphides, oxides and *native metals*.

Hornbrook bomb
A torpedo-like device dropped to the bottom of a lake to retrieve a core of sediment.

ICP
Sometimes referred to as ICP-ES (Inductive Coupled Plasma – Emission Spectrometry). A popular method of analysis in exploration geochemistry. Enables the simultaneous determination of multiple elements from a solution.

Kimberlite
An unusual magnesium-rich rock, occurring in vertical pipe-shaped bodies. Originates from the earth's mantle; a primary source of diamonds. Kimberlite indicator minerals are known as *KIMs*.

Kraft bag
A wet-strength paper bag, highly suitable for the collection of soil and stream-sediment samples. Design allows for easy hanging and drying.

Magnetite
Magnetic iron oxide. One of the most common components of *panned* concentrate, from which it can be removed with a magnet. An important ore of iron when present in sufficient quantities (which is rare).

Mass-wasting
The process by which rock from the earth's surface is transported into streams after being loosened by *weathering* and *erosion*.

Micron
Unit of measurement; one thousandth of a millimetre. Stream sediments and soils are usually sieved to less than 180 microns (0.018 millimetres; 80 mesh).

Mineralization
Strictly speaking, the process by which any potentially economic minerals are emplaced in a rock. Has come to mean the presence of any potentially economic minerals, or even uneconomic minerals like *pyrite*.

Native metal
A metal occurring in its uncombined state, rather than as a sulphide or oxide. Precious metals are most commonly found in their native state, along with certain others like copper and bismuth.

Nugget effect
The tendency of certain rare metals, notably gold, to occur as separate particles rather than being evenly distributed through the sample material. May give rise to extremely imprecise, "noisy" analytical results.

Panning
A process of concentrating the heavy (dense) minerals in a sample of stream gravel or (more rarely) till. In the former case it is usually carried out on site. A skilled panner can reduce his sample to a "tail" of dense minerals, including gold; alternately, a panned concentrate can be finished by *heavy-liquid separation*.

Pathfinder
An element, normally uneconomic, that is useful in leading to a deposit of an element other than itself. Arsenic is used as a pathfinder for many types of gold deposit.

Podzol
A type of soil that is very common in Newfoundland and over much of Canada. Characterized by rusty brown B *horizon*, which is a good medium for soil sampling, under an ash-grey leached A *horizon*, which is not.

Pyrite
The commonest form of iron sulphide, sometimes called "fool's gold". Though rarely of economic value, it often accompanies sulphides of more valuable metals, as well as gold, and its presence in the rock is generally considered encouraging.

Rare earth
One of the following elements: lanthanum (La), cerium (Ce), praesodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), lutetium (Lu). Yttrium (Y) is usually included with the rare earth elements (REE) as its properties are similar. Many rare earths have unusual chemical and physical properties that make them technologically useful; for example, neodymium is used to make powerful magnets used in wind generators.

Scavenger
An element (iron or manganese) that can control the content of certain other elements in soil and drainage sediment and give rise to false anomalies.

Soil grid
A series of lines cut in the bush at regular intervals, along which soil samples are collected, also at regular intervals. The grid may do double duty as a geophysical grid and may also be used for geological mapping. Marking stations on the lines at regular intervals enables sample points to be re-located if encouraging results are received.

Soil horizon
One of the distinct layers in the soil, that characterizes it. *Podzols* common in Canada are characterized by an organic Ah horizon (topmost), passing downwards into a leached Ae horizon, a metal-enriched B horizon and a relatively unweathered C horizon.

Stream order
The degree of maturity and magnitude of a stream. First order streams have no tributaries; second-order streams have at least two first-order tributaries; third order streams have at least two second-order tributaries; and so on. The higher the order of a stream, the larger (and less commonly encountered) it becomes.

Striation
A scratch or groove on a rock surface caused by the movement of glacier ice. The orientation of striations can be used to work out the direction of ice movement.

Threshold
The upper limit of background variation of an element, in a given geological and physical environment. Analytical values that exceed the threshold are considered "anomalous", or deserving of follow-up, although this is something of an oversimplification.

Till
A typically chaotic, unsorted sediment created by the movement of glacier ice over the land surface and the plucking and grinding of bedrock. An old term for it is *drift*.

Watershed
The boundary between two *catchment basins*.

Weathering
The chemical process by which rocks at the earth's surface are broken down, by air and water, into a form that can be removed by *erosion*.

Wilfley table
A shaker table used to sort the mineral grains in a bulk sample of till or stream sediment, according to their specific gravity.