Cost -Effective Helium Surveys in Uranium Exploration

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Introduction

The Petro-Find Geochem soil gas method, which is well proven for the exploration of oil and gas reservoirs using light hydrocarbons as pathfinders, has been adapted for uranium exploration. Helium concentrations in soil gas can be related to underlying uranium deposits, which generates alpha particles during the radioactive decay process. Alpha particles pick up two electrons to form helium. Hydrogen, produced by the radiolysis of water by uranium, is also a useful pathfinder. It is becoming clearer that neon, an indirect product of uranium decay, can be used as a pathfinder for uranium mineralization. Helium, hydrogen and neon migrate by diffusion and mass flow vertically to the surface unless short-circuited by fractures/faults.

Industry attempts to develop an alternative geochemical exploration system using helium as a pathfinder to reduce costs and accelerate exploration of uranium in the Athabasca Basin and elsewhere have been unsuccessful. The lack of success is attributed to: poor sampling equipment and methods; inability to sample wet sediments and muskeg; leakage problems with long-distance transport in containers or vials from field to laboratory; and inappropriate analyzers for helium. The measurement of helium and hydrogen in soils requires special care because of their volatility. Previous researchers have used hydrogen in soils for earthquake prediction along major faulting as well as groundwater tracing, but have never employed this gas as a pathfinder for uranium exploration. Neon has been used mainly by other researchers to monitor the accuracy of helium surveys, but the premise of this approach is considered to be inaccurate.

A new cost-effective geochemical exploration system for uranium is considered highly desirable by industry to reduce: the heavy costs of exploration and the unusually large lag time between discovery and production. While geochemical exploration can be used at any time during the exploration process, it is usually employed after aerial/ground geophysics to increase the success ratio of drilling, the most costly step in the exploration process. Any technological breakthroughs with new survey methods will make structural improvements to ways uranium exploration is conducted in Canada. Petro-Find has experience in the Athabasca basin at depths from 15 to 400 meters, in Nunavut on the tundra and in Nebraska (roll front).

Passive Sampling **Direct Sampling**

Figure 2. Sampling Techniques

Sampling

In general, the basic approach to any exploration program is to use methods that provide the maximum information at the lowest cost possible. For large areas, reconnaissance surveys can be conducted first to establish anomalous trends. In follow-up, higher-density surveys are conducted to further define the aerial extent and configuration of the anomalies. However, because the targets are relatively small, helium surveys over radiometric or gravity anomalies are usually conducted on 20- to 50-meter spacing with parallel lines 20 to 200 meters apart.

For the dry areas, a cordless rotary drill is used to drive a proprietary soil gas probe to an average depth of 2.5 feet, or well into the C-zone of the soil profile to avoid the effects of barometric pressure (See accompanying picture). Most soils in the Athabasca region consist of a thin layer of forest litter, humus and lichen overlying a zone of porous sandy clay and bouldery till. The thin but durable drill stem can easily penetrate the omnipresent bouldery till except in rare cases where bedrock is too close to the surface.

Once at the required depth, some 30cc of soil gas is extracted by a syringe through a septum at the head of the probe and discarded to purge the inner volume of the probe. A sample of 24 cc is then extracted and injected through the septum of a 12cc EXETAINER vial that had been previously evacuated to 1/5 Torr or 0.0003 bar. The vials are inserted into holes cut into Styrofoam and placed in firm boxes for transport to a field lab or Petro-Find's fixed lab in Saskatoon (See accompanying picture).

A passive probe was developed to sample the low concentrations of helium, neon and hydrogen in water-saturated sediments and muskeg in the Athabasca region (See accompanying picture). This sampler is a modification of the soil gas probe used for sampling soil gas in dry soils. A cordless rotary drill is used to drive the passive sampler to an average depth of 2.5 feet below the surface to avoid the possible effects of barometric pumping. The sampler is left for 24 hours in the ground to allow the helium and hydrogen in water to equilibrate with the ambient air in the stem of the probe. Diffusion of helium and hydrogen into and out of the passive sampler moves in the direction of lower concentration. Unlike sampling in dry soils, purging is not required.

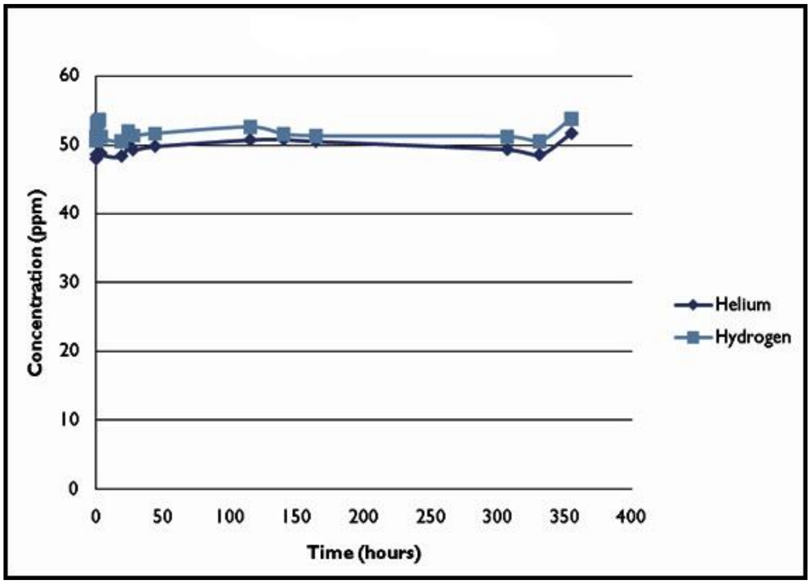
Figure 4D. Hummocks and Frost Boil

A survey on the tundra tested for the first time the suitability of Petro-Find's soil gas surveys to locate a drill-indicated uranium deposit in thick permafrost. It was found that ice (permafrost) is permeable to highly volatile helium and hydrogen. Although surveys for hydrocarbons have been tested in Alaska and Russia, the methods that were used are dependent on analysis of permafrost cores rather than soil gas. This survey also tested the suitability of conducting soil gas surveys by sampling hummocks, which widely exist in Arctic tundra. The paucity of soil gas in the hummocks required a modification of the probe so that less volume is required to be purged.

For the tundra operation, a cordless rotary drill was used to drive a proprietary soil gas probe about 1-2 feet into the hummocks, the only place on the tundra suitable for soil gas sampling (See accompanying picture). Hummocks suitable for sampling were higher than one foot, but some were too wet to sample (passive sampling will be used in future projects). The probes were modified with lower internal volume to take into account limited soil gas availability in the wet hummocks. Only 10cc were required to purge the inner volume of the probe. This amount gas was extracted by a syringe through a septum at the head of the probe and discarded. A sample of 24 cc was then extracted and injected through the septum of a 12cc EXETAINER vial that had been previously evacuated to a high vacuum. The vials were inserted into holes cut into Styrofoam and placed in firm boxes for transport to the portable lab installed at the project site.

Petro-Find developed and tested an appropriate system for transport of samples from the project site to a lab. This system replaced the traditional geochemical sampling equipment, such as leak-proof large-volume stainless steel canisters and ***Tedlar*** bags, which are highly permeable to helium and hydrogen. As only about 50cc of soil gas are normally available around the head of the probe in dry ground, the soil gas is quickly exhausted with suction pumps causing dilution of the sample with ambient air drawn in from around the annulus of the probe. These obstacles were resolved by the use of a syringe for extraction of soil gas through a septum port at the head of the probe and the injection of this gas into a leak-proof 12cc vial for transport to the lab (See accompanying picture). A Micro-GC is used for analysis. Unlike helium leak detectors, it requires only a small sample, 3cc, because it is equipped with a septum and sample port for direct injection.

A Petro-Find geochemical survey program begins with the preparation of sample vials and checking of the probes. Shown is the apparatus for the evacuation of vials down to 1/5 Torr so that a sample extracted by a syringe is not contaminated with residual ambient air. Also shown is a picture of three types of vials used for sampling. To avoid breakage in transit to the laboratory, the glass vials are inserted into holes cut into Styrofoam and placed in firm boxes. The evacuation system is of Petro-Find's own design.



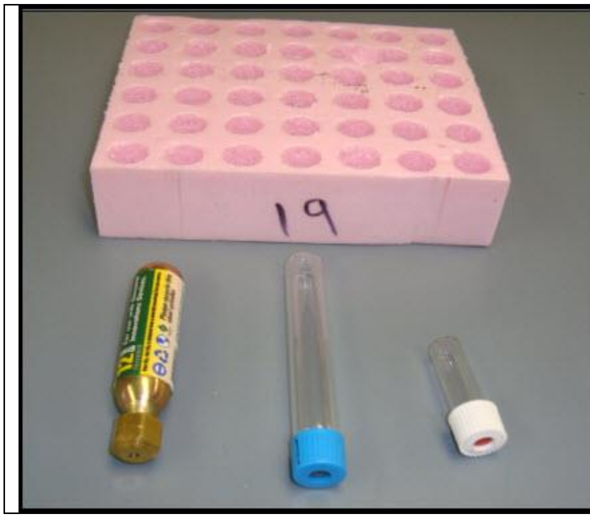
Containment of Helium and Hydrogen in Vials

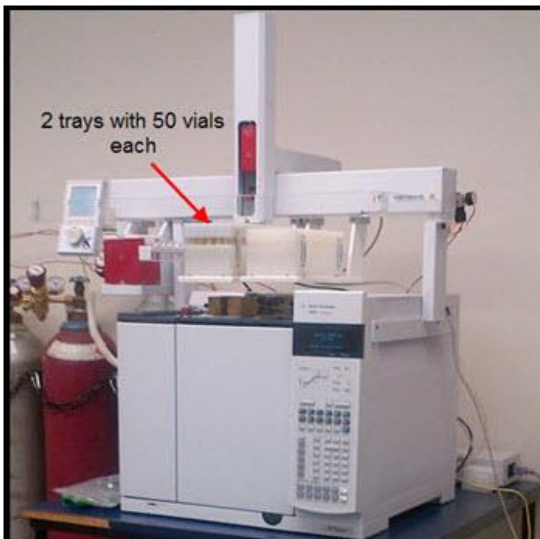
The accompanying graph depicts the results of a containment study using helium and hydrogen to ascertain if the vials are subject to leakage. Leak-proof sample vials are particularly important for international projects because of the time lag between sampling and analysis. No leakage was detected in a 3.5 week testing period. Further testing showed no leakage over a period of five weeks. A testing of the syringes showed no leakage up to 45 minutes, which is well beyond the 30 seconds needed for a sample to be taken.

Analysis

The technology to analyze helium and hydrogen was developed by Petro-Find to meet specific requirements: analysis of helium, neon and hydrogen in a single unit, fast turnaround on analysis, high resolution, lightness and portability, and a port/septum for direct sample injection. After considerable research and close coordination with the premier supplier of analytical equipment, ***AGILENT***, a Micro-gas chromatograph was designed and tested to meet all requirements. It is the first time that the AGILENT Micro-GC had been used for this purpose.

Shown in the accompanying picture is the highly sensitive Micro Gas Chromatograph installed in a field shack. It was transported from Petro-Find's lab in Saskatoon and set up in a core shack prior to field operations. Other equipment brought in included 3 tanks containing calibration gases, one large tank with argon carrier gas and one laptop to run the GC. In the field office lab the septum of the vials is pierced with syringe and 3cc is withdrawn for injection into the GC.





Gas Chromatograph with Autosampler

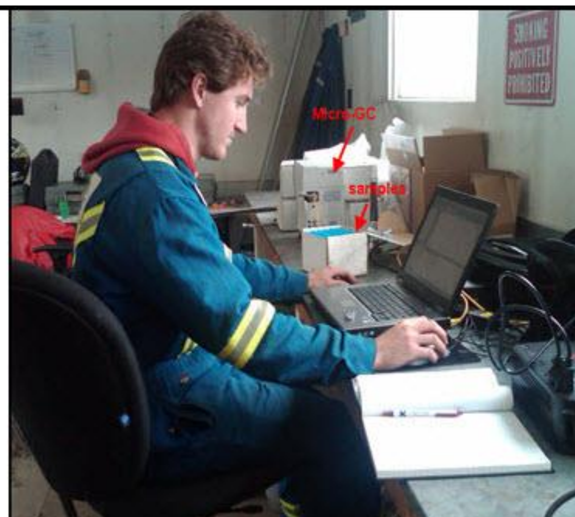
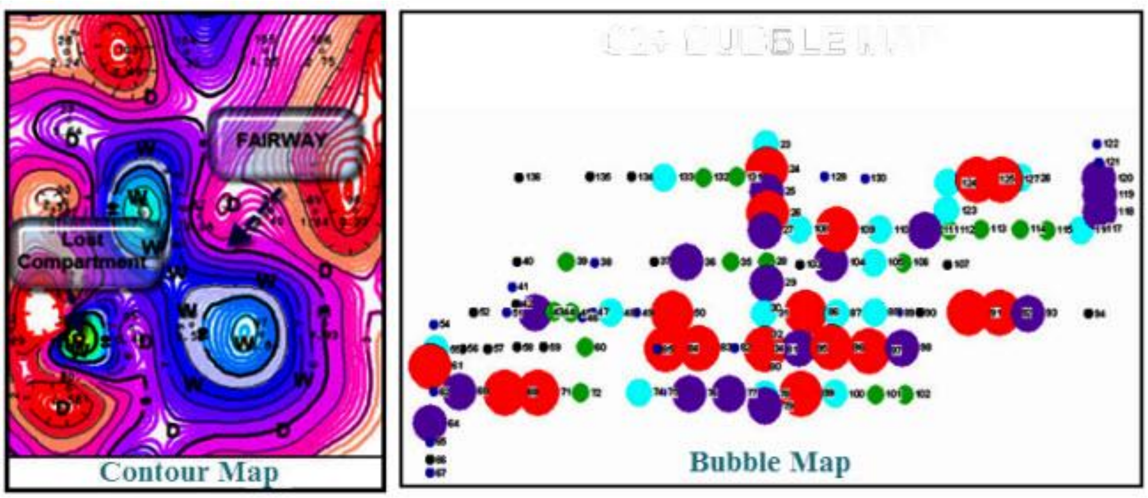


Figure 6. Micro-GC Installed in Field Office for Analysis of Helium/Hydrogen

Figure 3. Analysis of Hydrocarbons and CO2 by Gas Chromatograph and Helium/Hydrogen by Micro-GC in Field Hut

A Micro-GC at or near a project site with fast turnaround time has the following major advantages:

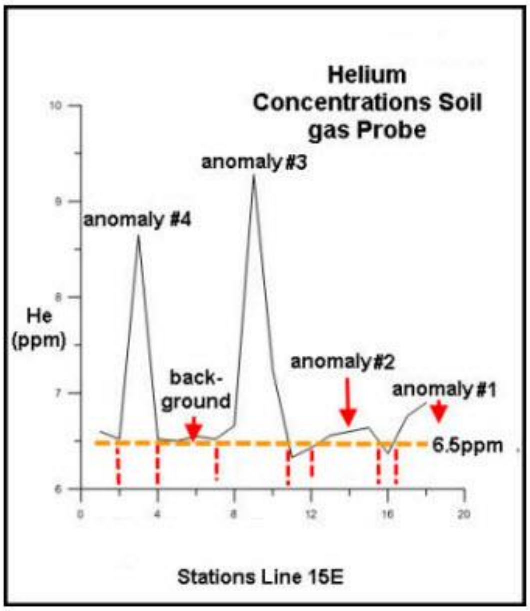
- A quick turnaround on sampling and analysis allows the follow-up of interesting trends before demobilization. Real-time decision-making thereby minimizes the number of trips necessary to adequately explore an area.
- Field efforts are optimized by providing intelligent location of infilling data points during a single survey day while minimizing the uncertainty from almost daily transient changes in soil gas concentration.
- It allows for the immediate checking of data that appears to be in error (i.e. false positives and negatives).

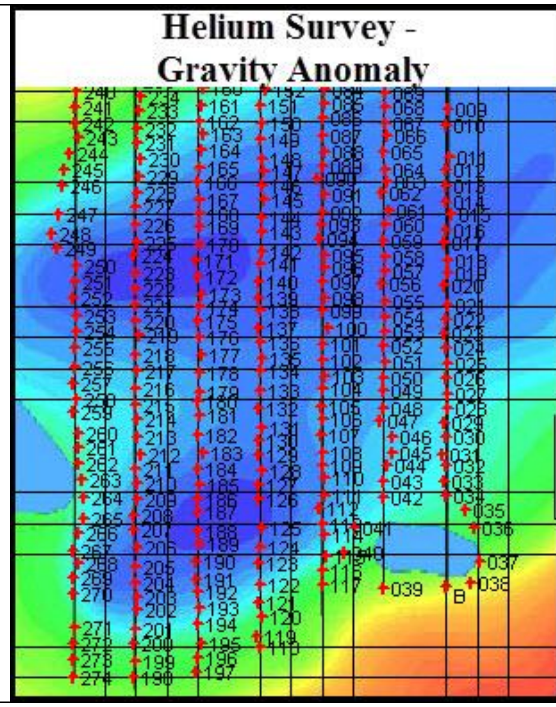


Contour and Bubble Maps – Hydrocarbon Examples

Interpretation

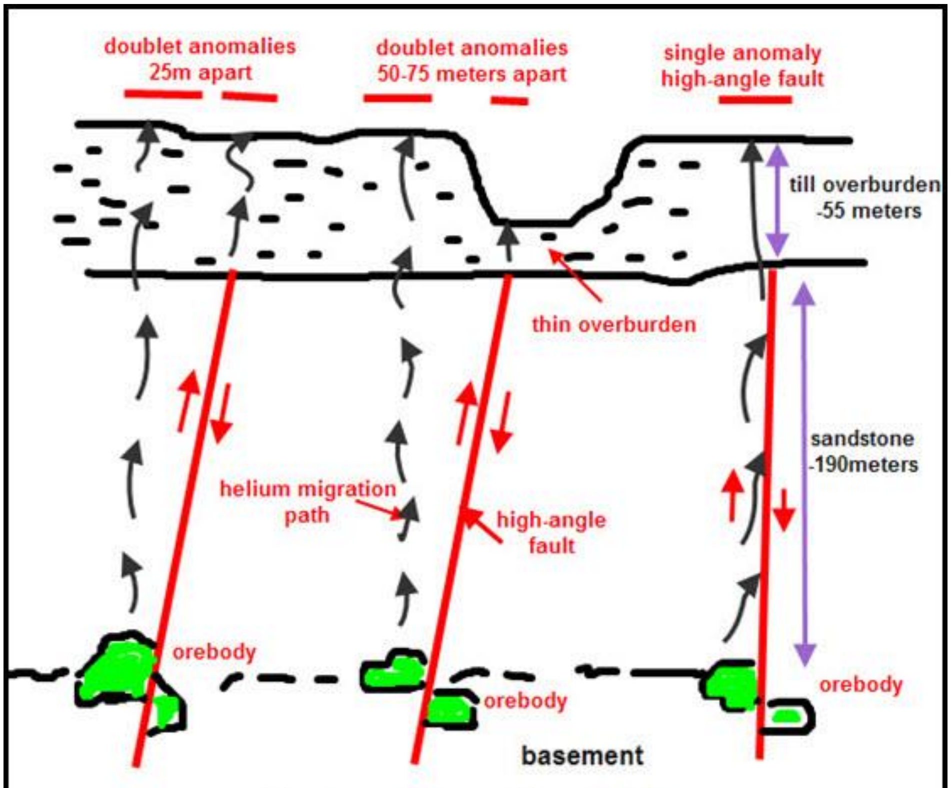
Of major importance to the explorationist is the surface location and pattern of the anomalous areas. For this purpose, two types of maps are produced – contour and bubble maps (see examples of hydrocarbon surveys; contour maps of helium surveys are proprietary). In the mapping process, the coordinates and analytical data are downloaded to a computer and saved as an EXCEL file. Petro-Find's state-of-the-art software program is used to produce contour maps of helium, neon and hydrogen concentrations. From experience, scattered data points are best contoured with a triangular, non-gridded computer program such as provided by Scientific Computer Applications, Inc, Tulsa, Oklahoma. All printing is done in-house to maintain confidentiality. Contours are printed permanently on clear film for overlay on previously prepared georeferenced base maps. However, for some reconnaissance surveys where sampling points are very wide apart, contour maps can be very misleading. The anomalous areas and trends of widely spaced data are best depicted by bubble maps, an example of which is shown in the accompanying right hand picture.





The purpose of surface geochemistry in uranium exploration is to discover abnormal geochemical patterns or anomalies that relate to helium, neon and hydrogen seepage from underlying deposits. A geochemical anomaly is defined as a departure from values that are considered normal background variations. Typically, computer contouring identifies “islands” of high values in a “sea” of low values. The choice of interval is important in identifying the true anomalies. If the contour interval for each set of values is too low cluttering will result; if too high, the high-grade anomalies will stand out but their connectivity and patterns will be lost. The helium profile in the accompanying graph shows a background of 6.5 ppm and a maximum value of about 9.4 ppm (the concentration of helium in ambient air is 5.5 ppm). Concentrations of helium as high as 12 ppm over uranium deposits at 350- meter depth have been recorded in the Athabaska Basin. The high background depicted in the accompanying figure of 6.5 ppm indicates a disseminated uranium aureole around the mineral deposit.

Normally, uranium at shallow depths will exhibit well defined anomalies directly above. However, for deeper uranium deposits, interpretation must take into account whether the helium has migrated along an assemblage of fractures/faults that have intersected a uranium deposit or vertically upwards along micro-fractures (See accompanying schematic). The distance between traces of doublet anomalies can vary depending on the depth of till and dip of the faults. It is obvious that only one of the anomalies of a doublet should be drilled vertically (except where they both coincide as in the example on the right of the schematic). Knowing the type and dip of faulting would be helpful in the interpretation.



Helium Migration Paths

Helium will correlate with radon where the uranium mineralization is close to the surface, but at deeper depths only helium can be relied upon as a pathfinder because of the short half-life of radon. Both radon, a product of uranium decay, and helium are direct indicators of uranium. Both helium and radon surveys have been proven to be successful in the identification of shallow uranium deposits, uraniferous boulder trains as well as leakage anomalies from deeper mineralization along structures. If the uranium is close to the surface, just beneath the over burden, the helium anomalies will be well defined showing little lateral diffusion. With deeper deposits, plumes of helium, hydrogen and neon can be expected upon reaching the surface.

The correlation of radiometric counts per second (cps) of boreholes with helium concentrations have shown that helium surveys are highly accurate in locating uranium in both bedrock and till. This correlation is important is assessing whether a high-grade helium anomaly is derived from a shallow or deeper uranium deposit and whether a dispersion train exists. The strength of a helium anomaly as expressed by concentration is a function of the amount of uranium directly below. For example, a thick low-grade anomaly has the same signal as a thin high-grade anomaly if the amount of uranium is the same.

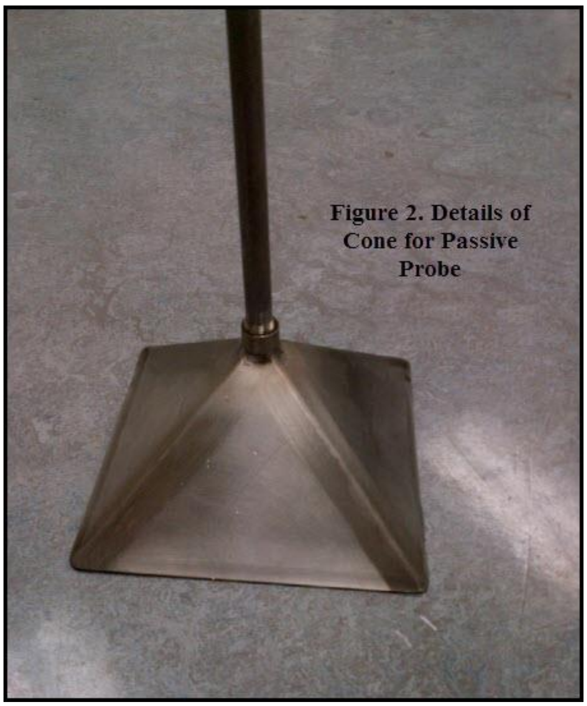
Helium prospecting is an ideal method for uranium exploration in the Athabasca Basin because it can find shallow/deep deposits as well as locate and define the shape of dispersion trains that could lead to the discovery of uranium deposits up-ice. The location of dispersion trains by helium surveys is especially important in areas where uraniferous boulders can be hidden by muskeg and wet sediments. Boulder fields in till areas should be assessed with geochemical soil gas surveys to locate underlying and hidden uraniferous material that can better point to uranium deposits up-ice. It should be noted that boulder trains have led to the discovery of uranium deposits in the Athabasca Basin. Helium surveys are also ideal for eliminating areas and even properties for further exploration.

The axes of the elliptical patterns of helium anomalies as well as any monadnocks all point in an up-ice direction towards the source of uranium in bedrock. An elliptical helium anomaly is typical of dispersal trains, but not uranium deposits which are usually linear and thin.

Only the high-grade helium anomalies, especially those with at least two contingent high values, should be drilled initially. Once drilled, the average counts per second (cps) for the total length of the borehole in both bedrock and till should be determined to ascertain the contribution of uranium from both the bedrock and till. If the cps is high over a considerable width in a borehole further drilling would be employed to block off the deposit. This approach would eliminate chasing deposits that are too small for economic development.

Further Developments

A passive system for sampling of lake beds for helium, neon and hydrogen in both summer and winter months has been developed. It has yet to be tested for commercial use. This unit will complement our current technology for sampling of dry (direct) and wet (passive) sediments. It is well known that major deposits of uranium exist under lakes, but are difficult to explore with traditional methods. The sampling system consists of a short probe attached to a conical shape that will be lowered by a string to the lake bottom where it will be retrieved and sampled after 24 hours. The conical shape will capture helium, neon and hydrogen that have migrated vertically from uranium deposits. Moreover, the conical shape and short attached probe will prevent tipping of the probe even in strong currents.



Prototype of Lake Sampler

It has been long assumed by researchers that the sole contributor of neon in soil gas has been the neon in ambient air, which is at a concentration of 18.2 ppm on average. This lead geologists to "normalize" the helium concentrations (high values were reduced and low values were increased) resulting in the disappearance of the helium anomalies because of the relatively close helium/neon correlation. The contribution of nucleogenic neon produced from the decay of uranium has been completely ignored. Literature is replete with references to the fact that nucleogenic neon is produced indirectly by the decay of uranium in complex reactions involving alpha particles.

The interpretation and significance of hydrogen as a pathfinder for uranium deposits is well advanced. It is well known that hydrogen is produced in large amounts from radiolysis of water by alpha, beta and gamma rays from the decay of uranium. Hydrogen is only produced if the uranium is in contact with water. Hydrogen migrates in high concentrations to the surface where it can be sampled successfully. Hydrogen is also produced from redox reactions in the till and soil, but the amount is minimal in comparison to that emanating from radiolysis. (Excess hydrogen has been reported to mark the boundary between the reduced and oxidized parts of roll-front uranium deposits.). New data suggests that hydrogen is particularly useful in locating uranium deposits that are close to the surface and underlying highly porous and permeable sandy tills.

Future R&D efforts include isotope studies of helium, neon and hydrogen to trace their provenance.

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