Miles Goldstick, September 1980

Progression of Uranium Exploration Activities

Contents

Introduction

Modern uranium exploration is a complex, capital intensive business that has made the individual prospector, equipped with a pack-sack and Geiger counter, a thing of the past. Today's "explorer" must have the resources to make a large capital investment, and possess a high level of technical expertise.

Uranium exploration is distinguished from exploration of other scarce metals by the natural radioactivity of uranium. This characteristic is exploited to find ore deposits by measuring the emitted radiation and/or the decay products. Each of the decay products can be identified by its unique chemistry and half-life. Sensitive instruments used in air or ground surveys can detect extremely small quantities at a distance, making it possible to delineate areas of higher than normal radioactivity.

The process of exploring for uranium follows a sequence of activities. The area of search is progressively narrowed down by using methods which either respond directly to the presence of mineralization, or to features which may be associated with mineralization. Before any equipment goes into the field, research and preparation of field studies must take place. The next step is usually large scale gamma-ray surveys, followed by field geochemical sampling and drilling. The minimum time between preparation of field studies and mine production is about two years. Following is a detailed discussion of the progression of uranium exploration activities.

1. Research and Preparation of Field Surveys

The exploration process begins long before planes begin to fly overhead. Preparation of a field survey requires much advance research and planning. A basic prerequisite needed before systematic exploration can begin, are accurate typographic maps at a scale of 1:100,000 or better, together with up-to-date air photographs. The developer will also want to examine all available geological information on the area in question, and gain a basic understanding of vegetation, climate, surface hydrology, surface and air communications, general accessibility, availability of labour, and the extent and result of previous exploration work.

Particular importance is attached to the work of geologists, who apply theories of uranium mobilization and deposition to identify areas in which concentrations are likely to be found. Since ore bodies tend to occur in clusters, the most likely place to find uranium is close by and in similar geologic formations to already proven deposits. For example, the Central Okanagan area in B.C., Canada was known to be a favourable area for uranium long before deposits were discovered. This is because the same geological formations are present in the Central Okanagan as those in neighbouring Washington state, where uranium has been mined since the 1950s. (1)

2. Gamma-Ray Surveys

Gamma-ray surveys are usually the first field operation in a uranium exploration program. They are based on the concept that most uranium deposits occur within or near regions of the Earth's crust that contain higher than average amounts of uranium. Small abnormalities, or "anomalies", often provide the first clue to the location of a deposit. The major reasons for extensive use of gamma-ray surveys are:

- Each of the three naturally occurring elements - uranium, thorium, and potassium - can be distinguished by the characteristics of their gamma radiation.
- Detection is possible at distances of a few hundred metres in air, or a few tens of centimeters in water; while the instrument is in motion on a vehicle, ship or aircraft.
- Instrument response is almost instantaneous.
- The equipment is lightweight, compact, reliable, and relatively cheap and easy to use.
- Grade of ore can be estimated without removing samples.
- Airborne, and sea or lake bottom gamma-ray measurements can be made simultaneously with other types of geophysical surveys.

Airborne gamma-ray surveys are the most widely used regional reconnaissance tool. Their primary advantage is that a large amount of data can be gathered in a short period of time. They can be carried out from fixed wing aircraft or helicopters. Instruments used may be either scintillometers or spectrometers. The latter are more useful because of their uranium discerning ability. Flight height is usually about 120 meters, flown in parallel lines spaced at 200 to 400 meters (2), and normally covers hundreds of square kilometers a survey.

Though gamma-ray surveys have their advantages, they also have limitations. A major problem is that to be recordable, radioactive material must be within a few tens of centimeters of the surface. Gamma-rays cannot penetrate more than about 50 centimeters of loosely consolidated overburden (3). Another factor that causes difficulties is the need for appropriate support facilities. A minimum requirement is the ability to test, calibrate, and repair instrumentation, as well as the skill to recognize when the instrument is not working properly.

A further limitation of gamma-ray surveys is that when used to estimate uranium and thorium concentrations, it must be assumed that the respective decay series are in equilibrium, which is rarely the case close to the surface. When a decay system has reached equilibrium, the measurement of the amount of a daughter product provides a reliable measurement of the quantity of the parent element, allowing the calculation of uranium content. The problem with estimating the quantity of U238 is that the principal gamma emission is not directly associated with U238 itself, but with Pb 214 and Bi 214 - the 8th and 9th in the decay series. Under normal weathering conditions, some chemical and physical dispersal of parent and daughter products will take place, particularly of the daughter products that are more soluble than others. As the most soluble decay products are radium and radon, both of which occur in the decay series before Pb 214 and Bi 214, accurate calculations of U238 is highly unlikely.

In summary, since real world survey conditions are most often not the same as what equipment is calibrated for, gamma-ray surveys by themselves can only give rough quality estimates of uranium. Chemical analysis of core samples and cuttings will establish if equilibrium exists, or if it varies, and to what degree it varies. If out of equilibrium, a factor can be established to allow quantitatively accurate measurements.

3. Gamma-Ray Recording Methods

On the ground or in the air, there are two most commonly used methods of recording gamma-ray signals; either by gross gamma-ray counting, or by gamma-ray spectrometry. Gross gamma-ray counting devices register the total spectrum of gamma-rays, but cannot directly distinguish between uranium, thorium, and potassium. "Geiger-Muller counters" and "scintillometers" are both gross gamma-ray counters, and "spectrometers" are based on gamma-ray spectrometry.

Geiger counters are the cheapest gamma-ray sensors, as well as being easy to use, though they are relatively insensitive. Scintillometers are more sensitive and compact. They make use of sodium-iodide crystals which produce flashes of light, or scintillations, when gamma-ray energy strikes them.

Gamma-ray spectrometry is able to determine individual concentrations of uranium, thorium, and potassium. Spectrometers (also referred to as differential spectrometers) are more sensitive to uranium than gross counting devices. Under equilibrium conditions, spectrometers can give a direct quantitative figure for uranium content. Otherwise, chemical analysis is necessary for accurate measurements.

4. Geochemical Surveys

Areas that show a positive result from airborne gamma-ray surveys are selected for geochemical surveys. They are used to identify irregularities in the natural surficial distribution of uranium and its decay products - particularly radon, and other metals. It is at this stage of exploration that human contact with the ground is first required. A trained person must travel to the site to take samples, which are normally tested in laboratories far away. Samples may be taken from bedrock, soil, soil gas, lake and stream water and sediment, and water wells.

The objective is to locate "geochemical anomalies", or abnormally high concentrations, that are measured in the small quantities of parts per million (ppm) and parts per billion (ppb). Uranium, radium and radon, are each characterized by a different geochemical behaviour that can be identified through sample analysis. The existence of any of these in slightly higher than normal concentrations may indicate the presence of uranium minerals in underlying rocks.

Radon can be measured in soil, snow, or water. Radon diffuses upward from buried mineralization producing surface anomalies, particularly in soil gas, though it can diffuse only about seven meters through dry sandy soil before diminishing 100 fold in concentration. (4)

Radon content in soil can be measured on film sensitive to alpha particles, or by extraction of soil gas. In the "track-etch" system, an alpha-sensitive film is placed underground, a few tens of centimeters, in an inverted cup in such a way that only alpha-emitting gasses will effect the film. Radon is extracted from soil by making a one-foot hole with a two-inch auger, then inserting a probe when the auger is extracted. The soil gas is transferred to the instrument by means of a few squeezes on a rubber bulb pump.

Radon in soil air is influenced by ambient temperature and pressure, as well as soil moisture content. The radon content of water versus air increases as temperature decreases; about half the radon stays in water at 0 C. Radon's solubility coefficient in water (the ratio of its concentration in water to its concentration in a gas phase at equilibrium) increases from 0.17 at 37 C to 0.25 at 20 C, and 0.51 at 0 C. (5)

Portable battery operated alpha-scintillometers allow very sensitive radon determinations to be made rapidly in the field. Analytical techniques can distinguish between the radon and radium isotopes found in both the thorium and uranium decay series.

Mineral deposits can sometimes be roughly located by mapping the uranium content in stream sediments. The solubility, and hence mobility of uranium often results in high concentrations in close proximity to the are body. The richest deposit in B.C. (the Blizzard Property) was located in this manner. However, geochemical samples only provide indirect evidence of what is under the surface. If the evidence is good enough, the next and more expensive step is to drill and take out deep rock samples.

5. Drilling

Regardless of the results of geochemical samples, and the theories of geologists, the only way to find out what is under the ground, is to look there. Most often this is done by drilling, though drilling may be preceded by digging of pits by hand or with a backhoe, through bulldozing, or blasting. Hole diameters can vary between six to eight inches and in depths from less than 100 feet to over a 1,000 feet. Due to its expense, drilling is only used in the advanced stage of exploration, after all other techniques have been used to narrow down a target area. Drilling must take place to establish grades and tonnages, and thus the viability of a deposit.

Drill rigs can be moved by air or land. In remote areas, use of helicopters is usual. Moving a rig in by land may require construction of a road. Though, however the rig arrives, about 100 to 300 square foot area needs to be cleared.

There are three basic types of drill samples - cores, cuttings and down-hole logs. Except for in Alberta, all samples are considered private property. Alberta is the only province that requires half of all samples, and copies of down-hole logs, to be deposited with the government. However, a five to eight year period of confidentiality keeps the information out of the public domain.

Drill cores are extracted by using a hollow drill bit with a diamond studded edge that cuts in a ring, leaving a cylindrical core of rock inside. The core is removed in log sections, laid in sequence in cases, then sent to assay laboratories to discover the rock's composition. As uranium is not identifiable by sight, cores are scanned with scintillometers or spectrometers to determine which section of rock to sample separately. Common practice is to split cores along their length before analysis.

When a hollow drill bit is not used, samples are extracted in the form of "cuttings", or small dime sized chunks of material. Small bags of cuttings are taken at regular intervals, marked, and as with cores, sent to a laboratory for analysis. An advantage of down-hole logs is that results can be viewed immediately, without the lag time involved in laboratory analysis. Drill holes can be scanned down their entire length. A scintillometer or spectrometer sensor is lowered down the hole on a cable that carries electrical signals to the surface where they are recorded. Counts per second can then be converted to estimated percent U308 by use of a simple graph (see attached figure). (6)

Assay information is fed into computers, with the result being an evaluation in terms of tons, grade, and pounds of uranium ore segregated into grade categories (e.g. approximately 0.10% U308 spread). The same initial information can be used to calculate ore reserves and waste tonnage.

6. Intensive Drilling and Mine Evaluation

If the results of a particular drill sample look promising, intensive drilling will begin. At this point it is acknowledged that an ore body has been found and further drilling serves to define the size and shape of the deposit. In order to outline the deposit, the mineralized area itself will be drilled in an X shape, or a grid pattern which may gradually narrow to less than 100 meters between holes. In B.C. four deposits had been drilled in a narrow grid pattern before the exploration and mining moratorium was called. (7)

Intensive drilling shifts to the mine evaluation phase when developers begin to gather the detailed information necessary to design a mine. Enough information can be gathered from several dozen drill holes to begin mine design, and with a hundred or so, nearly all the basic information needed for mine feasibility studies can be obtained. (8) Planning the development of a mine may require narrowing the space between drill holes to less than 50 meters, as well as the sinking of a few shafts in order to extract bulk samples for mill process studies. On the Blizzard Property, in B.C., the grid pattern was narrowed to only 30 meters between holes.

Footnotes

(RCUM = B.C. Royal Commission on Uranium Mining)

1. Milne, P. C. April, 1979 "Uranium in Washington State: Proven Deposits and Exploration Targets". Washington State - Department of Natural Resources, Division of Geology and Earth Resources, Olympia, WA., U.S.A. 7 pp. Published in The Canadian Mining and Metallurgical Bulletin, April, 1979. RCUM #232A.

2. British Columbia and Yukon Chamber of Mines. September 1979. "Phase II - Exploration Submission to RCUM" 40 pp. See Page 19.

3. International Atomic Energy Agency. 1979 "Gamma-Ray Surveys in Uranium Exploration". Technical Reports Series No. 186. 90 pp. See Page 13.

4. Doyle, P. J., December 1978. "Exploration Geochemistry of Uranium and Selected Radiogenic Daughter Elements: a Review". Chemex Labs. Ltd., 43 pp. RCUM #571A. See Page 5.

5. Morse, R. H., 1976. "Radon Counters in Uranium Exploration". Originally presented to the IAEA-NEA International Symposium on the Exploration of Uranium Ore Deposits, Vienna, 1976. 11 pp. RCUM #484A. See Page 4.

6. PNC Exploration (Canada) Ltd., September 21st, 1979. "Geology of PNC Uranium Properties, Kelowna-Beaverdell Region, B.C." Phase I - Overview Submission to RCUM. see Page 4.

7. The four deposits are: Blizzard, Cup Lake, Fuki, and Hydralic Lake, all in the Central Okanagan.

8. Lovins, A. B. L., 1973 "Openpit Mining". Earth Island Ltd., 56 Doughty Street, London, WClN 2 Ls. 119 pp. See Page 35.

Fig 1

PNC PI Brief p.4

FIGURE 4 : CALIBRATION OF TOTAL CPM WITH RESPECT TO ASSAY GRADE IN BORE HOLES