MPERG Report 2009-1

Uranium: Facts, Myths and Phobia

By

Y.T.J. Kwong

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CANMET Mining and Mineral Sciences Laboratories

Uranium: Facts, Myths and Phobia

by Y.T.J. Kwong

Work performed for:

The Mining and Petroleum Environment Research Group
Yukon Department of Energy, Mines and Resources

Project: 603504
Report CANMET-MMSL 09-016(CR)

Version: April 2009

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INTRODUCTION

In the search for an alternative source of energy that would produce less green-house gas, exploration for uranium has drastically increased throughout the country. However, in the Yukon Territory, concerns about exploring for this commodity have often been voiced through the environmental assessment processes and other vehicles. It appears that the relatively low risk associated with uranium in its natural mineral forms is poorly understood. To assist with educating community members and other stakeholders about uranium, the Yukon Mining and Petroleum Environment Group has engaged the CANMET Mining and Mineral Sciences Laboratories (CANMET-MMSL) to prepare fact sheets explaining the properties of uranium and providing information on modern uranium mining, processing and end product storage. It is hoped that such fact sheets will help Yukoners better understand the geochemistry of uranium and the uranium mining cycle, dissipating the apprehension over uranium exploration and facilitating a more detailed assessment of the uranium potential in the Yukon Territory.

To facilitate preparing the fact sheets, CANMET-MMSL has conducted research on the basic facts of uranium geochemistry, current exploration practices, the uranium mining cycle, and the risks and benefits of uranium exploitation. Information has been compiled from published literature and government databases as well as from consultation with uranium experts in both the public and private sectors. The gathered information is then synthesized into a technical paper, from which the relevant data is simplified in laymen’s terms to form the bases of three fact sheets with additional information specific to the Yukon.

The technical report, an earlier version of which was presented at the 2008 Yukon Geoscience Forum, forms Part I of this report. Part II consists of the reduced data for three fact sheets entitled Uranium 101, Uranium Exploration and Uranium Mining, respectively. The purpose of Part II is to provide the basic information that the Yukon Department of Energy, Mines and Resources may directly use or modify to produce brochures for public consumption.

Part I

Uranium: Facts, Myths and Phobias

A technical paper presented at the 2008 Yukon Geoscience Forum

November 23-26, Whitehorse, Yukon

Uranium – Facts, Myths, Phobias*

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Introduction

Uranium is a naturally radioactive heavy metal that has often been perceived as potentially dangerous. However, we cannot maintain our standard of living without it. This paper highlights some facts and myths about uranium, its mining cycle, and examines several possible causes of radiation phobias.

Uranium Basics

In its pure form, uranium (U) is a silvery metal almost twice as dense as lead. It originated in exploding stars billions of years ago and heat from its radioactive decay is believed to have kept the Earth's core in molten state. Uranium occurs most commonly in nature in oxide form as pitchblende (Fig. 1). Natural uranium consists of three isotopes, U-238 (~99.3%), U-235 (0.7%) and U-234 (~0.01%), all of which are radioactive but only U-235 is capable of sustaining a spontaneous fission reaction when the critical mass (~15 kg) is reached. Uranium exhibits two common oxidation states, U^{IV} and U^{VI}, with U^{IV} being relatively immobile and U^{VI} highly mobile under ambient environmental conditions. During groundwater transport, uranium preferentially adheres to soil particles, giving a concentration typically about 35 times higher than that in pore water. Although uranium can bioconcentrate in some biota, it is not known to biomagnify in terrestrial or aquatic food chains.

Fig. 1. Pitchblende from Cluff Lake.

***MMSL 08-145-2(OP), presented at the 36th Yukon Geoscience Forum, Whitehorse, November 23-26, 2008.**

Uranium is more abundant and widespread than often perceived

In the Earth's crust, uranium is only slightly less abundant than base metals such as Cu, Pb and Zn and is as common as Mo and W (Fig. 2). Uranium occurs in trace amounts in everything we encounter in our daily life, including our own body. The top 1 m of soil in a typical suburban garden in the UK has been reported to contain 2 kg U[1]. Table 1 compares the estimated content of several naturally occurring radionuclides in the body of a 70-kg human adult[1].

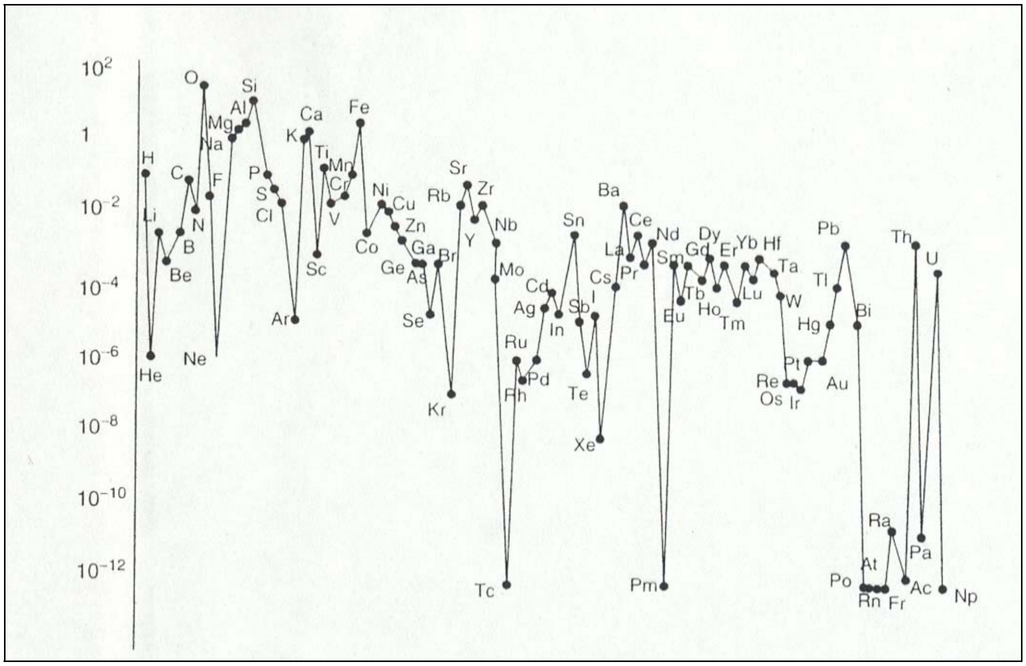


Fig. 2. Average concentration (in wt.%) of elements in the Earth's crust[1].

Table 1. Estimated content of several naturally occurring radionuclides in a 70-kg human adult[1]

Nuclide	Activity	Mass	Daily Intake
U-238	1.1 Bq	90 µg	1.9 µg
K-40	4.4 kBq	17 mg	390 µg
Ra-226	1.1 Bq	31 pg	2.3 pg
C-14	3.7 kBq	22 ng	1.8 ng

Uranium is less dangerous and more useful than often believed

The hazard of uranium is twofold: 1) the metal itself is toxic, and 2) its natural decay gives rise to ionization radiation, mainly in the form of alpha particles, and unstable intermediate daughter products such as radium and radon. On the issue of toxicity, the quote of Paracelsus (1493-1541) is worth reflecting: "*Everything is a poison, nothing is a poison, the dose alone makes the poison".* The current maximum contaminant level for uranium in drinking water established by the US Environmental Protection Agency is 0.03 mg/L. On the danger of radioactive decay of uranium, the radionuclide's half life is an important consideration. The long half-lives of U-238 (4.5 billion yr), U-235 (700 million yr) and U-234 (240,000 yr) render the radiation hazard of natural uranium insignificant compared to many of its shorter-lived daughter products. Uranium is a health hazard only if it is taken into the body by ingestion or inhalation. Once ingested most uranium is excreted within a few days while a small fraction (0.2-5%) absorbed into the bloodstream is deposited preferentially in the bone (~22%, where it can remain for years) and the kidney (~12%, where it is discharged in days)[2]. Similarly, only a small portion of inhaled uranium usually penetrates to the lung's alveolar region, where it may be retained for many years[2].

For many years, uranium was used to color ceramic glazes and for tinting in early photography. Today its primary use is as fuel in nuclear power reactors to generate electricity. 20 kg of uranium can produce as much energy as 400,000 kg of coal without generating greenhouse gas. Currently, nuclear power accounts for ~15% Canada's electricity supply. Besides electricity generation, uranium is also used as fuel for smaller reactors to power submarines, ice-breakers, aircraft carriers and different types of space craft. Another important use of uranium is in the creation of radioisotopes which have the following applications:

- Medicine: Radioisotopes are useful to both detect and treat illness like cancer. Canada leads the world in medical radioisotope production, accounting for ~60% current world's supply.

- Food and Safety: Radioisotopes can be used to preserve perishable food items, extending their shelf-life, and to control parasites and pests that infest some commodities. It should be noted that irradiated food does not become radioactive.

- Safety and Research: Radioisotopes are utilized in smoke detectors and also by the police to investigate crimes. Researchers often use radioisotopes to analyze pollutants in the environment and trace their movement in surface and ground waters.

Uranium Mining in Canada

Canada leads the world in uranium production, accounting for approximately one-quarter of the total global output. Uranium mining and milling directly employ over 1,000 Canadians and contribute over $500 million annually to the country's economy. In 2007, overall uranium exploration expenditures amounted to $350 million across Canada.

Worldwide, 14 major types of uranium deposits have been identified by the International Atomic Energy Agency. Deposit types known to occur in northern Canada include unconformity-associated deposits (Athabasca Basin, SK; Kiggavik, NU), paleoplacer (Elliot Lake, ON), volcanic U (Makkovik district, Labrador), sandstone (Mountain Lake, NWT; Amer Lake, NU) and the Iron Oxide-Copper-Gold (IOCG) associated U (Eldorado, NWT; Wernecke Breccia, YT) (Fig. 3). In 2007, Canada accounted for approximately 15% of the world's uranium resources, most of which are located in northern Saskatchewan.

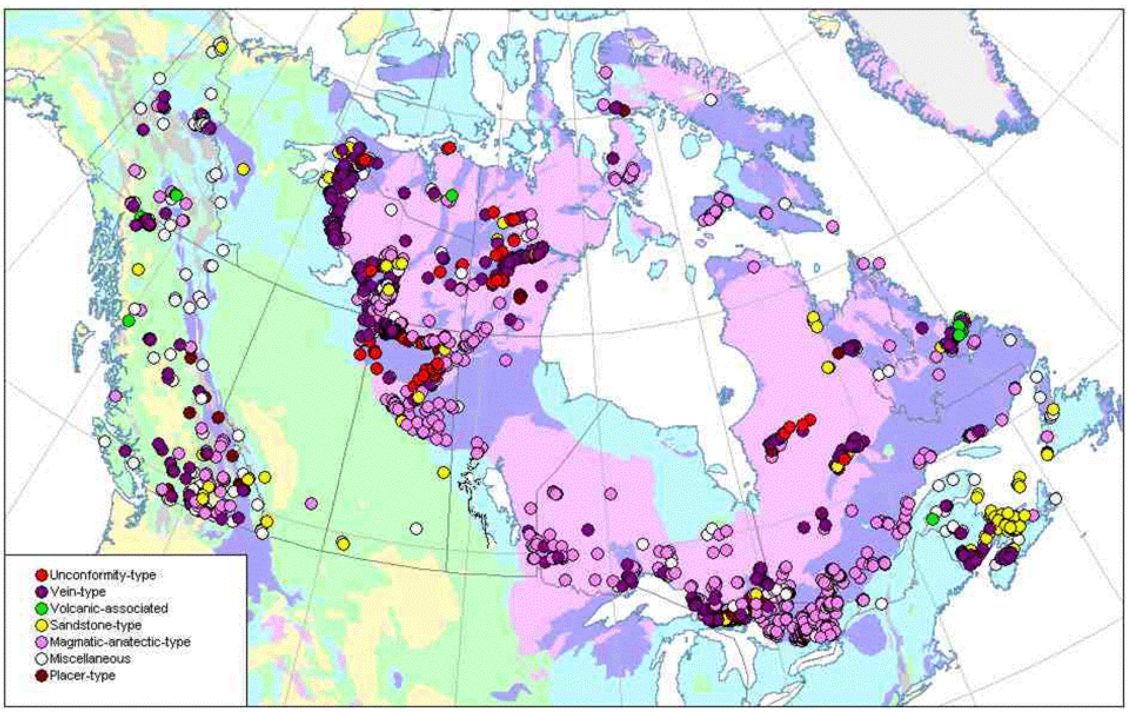


Fig. 3. Existing uranium deposit types in Canada (courtesy of Chorlton et al., GSC)

The mining cycle

Depending on the characteristics of a deposit, uranium is mined by open-pit or underground mining methods or a combination of both in sequence. Although not currently practised in Canada, in some circumstances low-grade uranium ore can be exploited by *in situ* leaching. Recently, to reduce the miners' exposure to radiation, the extraction of high-grade ores in the underground has become more mechanized such that people may not come into direct contact with the ores (Fig. 4). Ores extracted from underground workings or open pits are stockpiled for a short time on the surface and then ground to appropriate grain size before being subjected to a chemical leaching process to recover the uranium. Fig. 5 shows the mill schematic currently used at the McClean Lake Operation in northern Saskatchewan. The process residues remaining after the chemical extraction of uranium often contain elevated concentrations of intermediate radioactive decay products of uranium and other undesirable metals and/or metalloids. These must be impounded in properly designed tailings management facilities.

Fig. 4. Mechanized drilling at the Rabbit Lake underground mine. (Photograph by A. Liu, DFO)

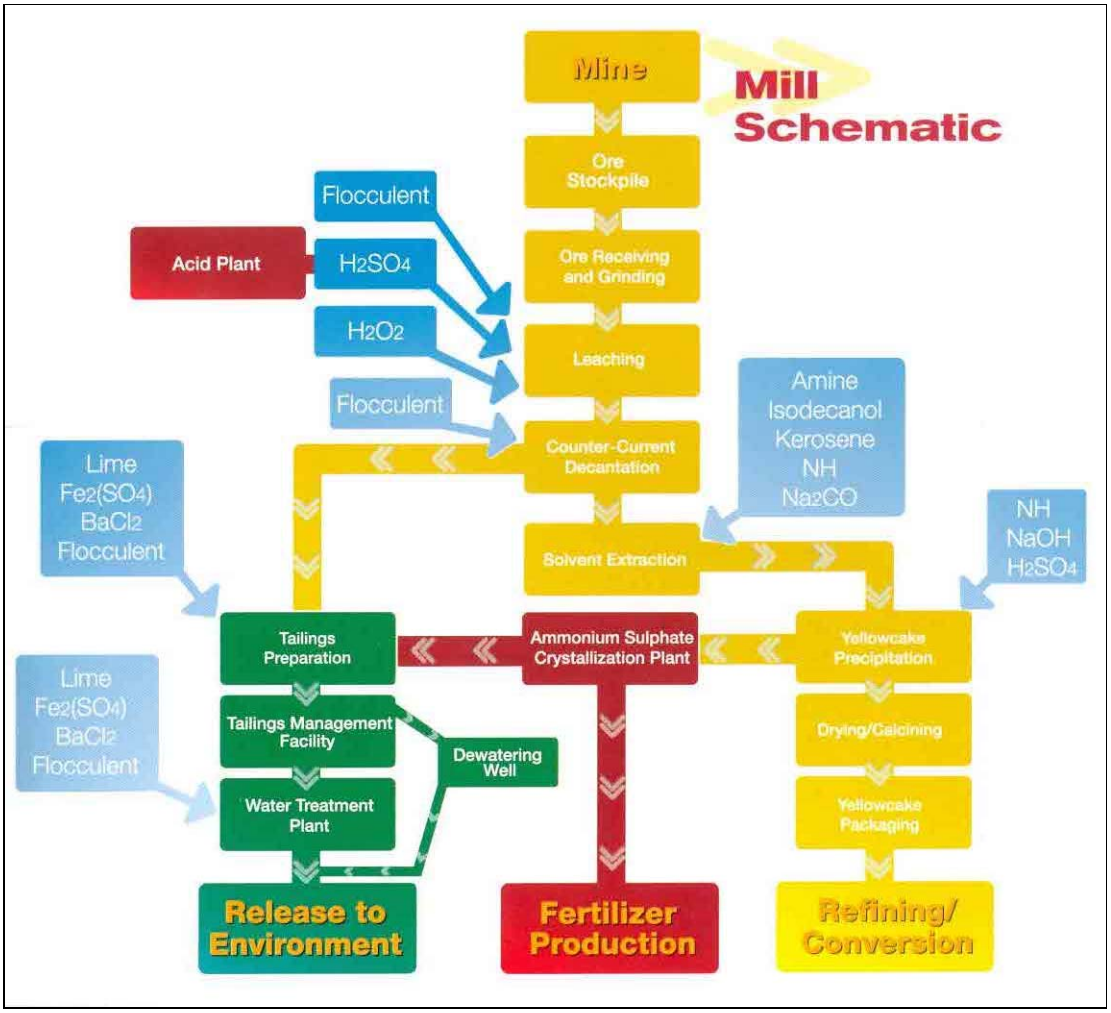


Fig. 5. Mill Schematic at McClean Lake, Saskatchewan. (Source: AREVA Resources Canada Inc.)

Compared to base-metal mining, the strip ratio in uranium mining is often high, resulting in the production of large amounts of waste rock. These are characterized and classified for disposal in appropriate facilities, either on-land or under-water with or without additional cover. Increasingly mined-out open pits are used for mine waste disposal (Figs. 6 and 7) and progressive reclamation is usually practised when mining is still on-going. Effluents from all mine components are collected and treated as required to meet discharge water quality criteria before being released to the receiving environment (Fig. 8).

Fig. 6. Waste rock disposal at mined-out open pit at McClean Lake. Potentially acid-generating rocks are disposed of under water while non-acid-generating materials with low radioactivity are placed dry under a till cover.

Fig. 7. In-pit tailings management facility (TMF) at McClean Lake. Water is pumped and circulated to ensure tailings consolidation at the pit bottom and designed water level is maintained in the pit lake.

Fig. 8. Collection and polishing ponds at the Rabbit Lake Operation, Saskatchewan. Only water meeting applicable regulatory guidelines is discharged to the receiving environment.

Possible Causes of Uranium Phobias

Insufficient knowledge or misconception about uranium: In addition to a poor understanding of how uranium actually behaves in the natural environment, fear of uranium is often accentuated by several factors including the following:

- Infamous nuclear accidents such as Chernobyl and Three Mile Island the consequences of which have often been exaggerated. For example, predicted genetic disorders in the Chernobyl survivors following the incident have not been proved[3].

- Horror resulted from the misuse of uranium in creating powerful, highly destructive weapons such as the atomic bombs dropped on Hiroshima and Nagasaki towards the end of World War II.

- Radiation safety guidelines set by the International Commission on Radiological Protection in 1991 (which are still in use today) are based on a conservative but incorrect assumption that there is no threshold dose below which detrimental biological effects do not occur. This gives an impression that radiation is never safe. Not only has recent research shown the existence of low dose thresholds of approximately 0.2 Sv, there is also increasing evidence that a low sub-threshold dose of radiation may have the reverse effect to high doses[3] (Fig. 9). For example, in the USA the cancer incidence is lower in regions with high rather than low background radiation[3].

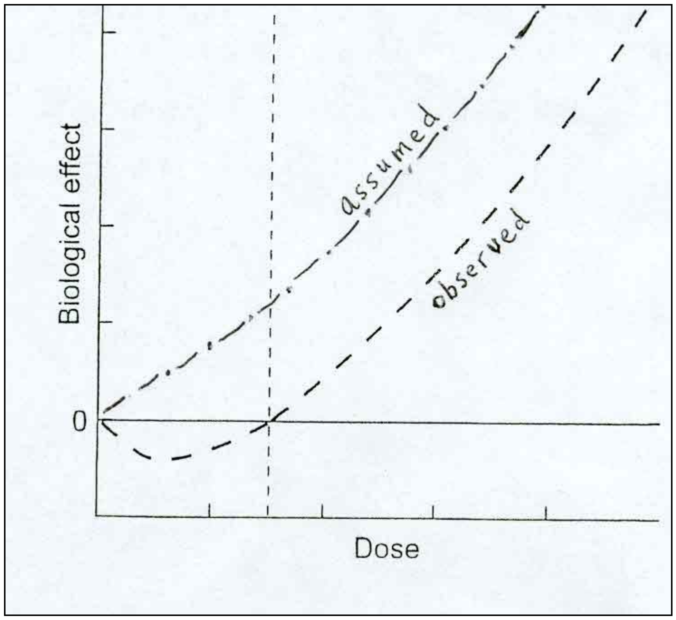


Fig.9. Dose and effect relationship with regard to radiation hazard. Very conservative assumptions have been made in setting guidelines.

Environmental legacies left behind from historic mining activities

Haphazard mine waste disposal and mine abandonment prior to the introduction of environmental regulations governing uranium mining in the 1970s has led to negative environmental impacts at many historic mining sites. This also contributes to fuel uranium phobia among the general populace. Since then, the Federal Government, especially through the Canadian Nuclear Safety Commission (CNSC), has been working with industry and provincial and territorial government officials to ensure that uranium mining and milling in Canada is conducted in a sustainable fashion. Licensing for new uranium mines is initiated immediately upon identification of a potential ore body in the exploration stage before specific physical activities to evaluate the best approaches for mining, ore processing, and milling for the ore body are carried out. Strategies for mine decommissioning are also thoroughly scrutinized. Nowadays, uranium mining bears little difference to other metal mining with respect to environmental impacts. Indeed, at many uranium operations, other metals/metalloids associated with the uranium mineralization often pose a greater environmental challenge than radioactivity. Figure 10 shows the relative toxicity of various metal/metalloids ores with spent nuclear fuels as function of time[1]. Honouring the Treaty on the Non-Proliferation of Nuclear Weapons, the CNSC also ensures that uranium produced in Canada will not be used in making weapons.

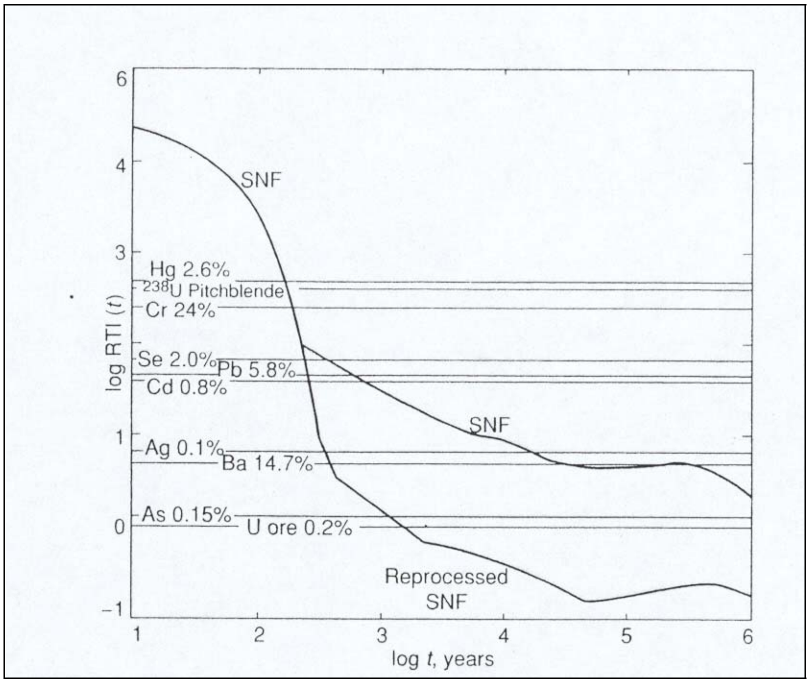


Fig.10. Relative toxicity of selected materials as a function of time[1] (SNF=spent nuclear fuel).

Concluding Remarks

Uranium mining in Canada is as safe as other metal mining nowadays. To ease the concerns of the general public, sound environmental practices should strictly be followed even during uranium exploration when there may not be a legal requirement to do so.

References Cited

[1]Ojovan, M.I. and Lee, W.E. (2005): An Introduction to Nuclear Waste Immobilisation. Elsevier, Amsterdam.

[2]Uranium. (2005): Human Health Fact Sheet, August 2005, Argonne National Laboratory, EVS.

[3]Wigg, D.R. (2007): Radiation: Facts, fallacies and phobias. *Australasian Radiology* **51**:21-25.

Part II

Basic Information Suitable for Preparing Fact Sheets on:

Uranium 101

Uranium Exploration

Uranium Mining

Uranium 101

What is uranium?

Uranium (chemical symbol U) is the heaviest known, naturally-occurring element. In its pure form, uranium is a silvery metal almost twice as dense as lead. Natural uranium is made up of three isotopes (i.e. various forms of the same element distinguished by the number of particles in the nucleus), all of which are radioactive, meaning that they will change to stable forms of lead through a process called radioactive decay. Uranium is believed to have originated in exploding stars when the universe was first formed. It is the heat from radioactive decay of uranium that keeps the Earth's core in a molten state.

Where does uranium occur?

Uranium occurs in trace amounts in everything we encounter in our daily life: food, rocks, soils, rivers, oceans and even our own body. In fact, there is 500 times more uranium than gold in the Earth's crust.

What is uranium used for?

For many years after its discovery in 1789, uranium was used to color ceramic glazes and for tinting in early photography. Today it is primarily used as fuel in nuclear power reactors to generate electricity. 20 kg of uranium can produce as much energy as 400,000 kg of coal without generating any greenhouse gas. Besides electricity generation, uranium is also used as fuel for smaller reactors to power submarines, ice-breakers, aircraft carriers and different types of space craft. Another important use of uranium is in the creation of radioisotopes (i.e. unstable atoms of various chemical elements that emit radiation) which are applied in the medical field to detect and treat illness such as cancer, in agriculture to preserve perishable food items and to control parasites and pests, and in environmental research to analyze pollutants and trace their movement in surface and ground waters.

Is uranium safe?

Uranium is potentially dangerous because it is toxic to animals and humans at high concentrations and its natural decay gives rise to harmful radiation and unstable intermediate by-products such as radium and radon. However, human must ingest or inhale significant amounts of uranium before any health effects will materialize. The current maximum contaminant level for uranium in drinking water established by the US Environmental Protection Agency is 0.03 mg/L, comparable to that for arsenic (0.025 mg/L).

The isotope U-238 makes up 99% of natural uranium found on earth. It degrades very slowly (over billions of years) and emits alpha particles so weak that they cannot penetrate a sheet of paper. Thus, natural uranium by itself does not pose a high risk to humans or animals. It is the accumulation of shorter-lived decay products in older rocks containing uranium that may pose a radiation hazard. These rocks should be handled with care both before and after uranium is extracted.

Illustration 1: Drill core from the Kiggavik deposit, Nunavut, illustrating the gradation from hematite alteration (red) through bleach clay alteration (biege) to deposition of uraninite (a uranium mineral, black).

Illustration 2: Calcite (white)-fluorite (purple)-apatite (yellowish)-uraninite (black) ore from the Cardiff Uranium Mine at Wilberforce, Ontario. (NRCan Photo Library, Ottawa, Photo Number KGS-1060).

Uranium Exploration

The Canadian scene

The phenomenal growth in world demand for energy in recent years has spurred new uranium exploration activities across the globe. Canada is no exception. The overall annual uranium exploration expenditures across Canada jumped from below $50 million before 2004 to about $350 million in 2007. To date, 14 major types of uranium deposits have been identified worldwide, of which eight are found in Canada. In fact, approximately 14% of the world's known uranium reserves are located in northern Saskatchewan. Smaller deposits can be found in every province and territory across Canada.

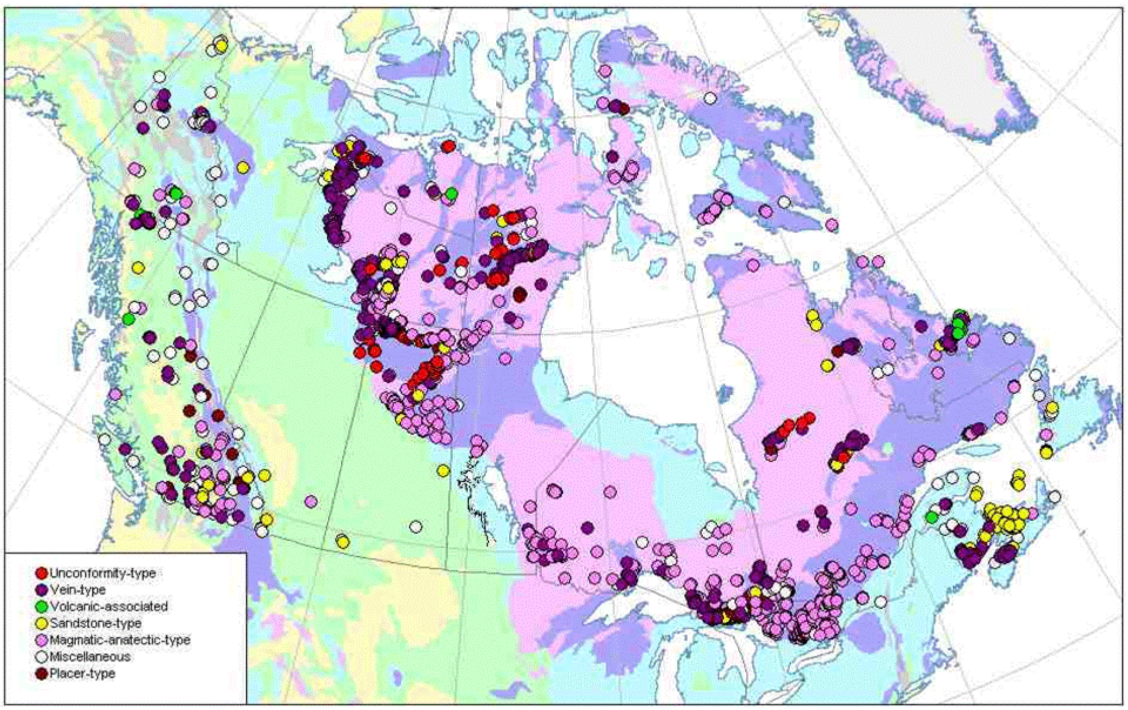


Illustration 3: Types of uranium deposits occurring in Canada.

Uranium exploration techniques

Because of the special properties of uranium, geologists have some unique tools making use of the radioactive decay products for its exploration. However, these tools are effective only if used in areas favourable for the occurrence of economic concentrations of uranium. As with any mineral exploration, understanding the geology of the area and shape and position of the ore deposit is key. Thus, like searching for other metals, a typical uranium exploration project will start with large scale reconnaissance surveys and prospecting to locate areas of interest. This is followed by targeted exploration and mapping, grid mapping and drilling with increasing density. It often takes years, if not decades, before the extent of mineralization can be established.

Does uranium exploration necessarily result in a uranium mine?

Although uranium is found almost everywhere on the earth's surface, it rarely occurs in sufficiently high concentration to make an ore body. Similar to exploration for other metals, the odds of a uranium exploration target eventually becoming a mine is about one in ten thousand.

Is Uranium exploration dangerous?

The ore grade of uranium deposits ever mined in Canada ranges from 0.03% to 12% as uranium oxide (U_3O_8). Because high-grade deposits are rare, uranium exploration is generally not dangerous. However, upon discovery of unusually high-grade material, special precautions must be taken to handle the disturbed geologic materials and to proceed with further development activities to ensure protection of human health and the environment. Many jurisdictions across Canada have specific directives for this purpose.

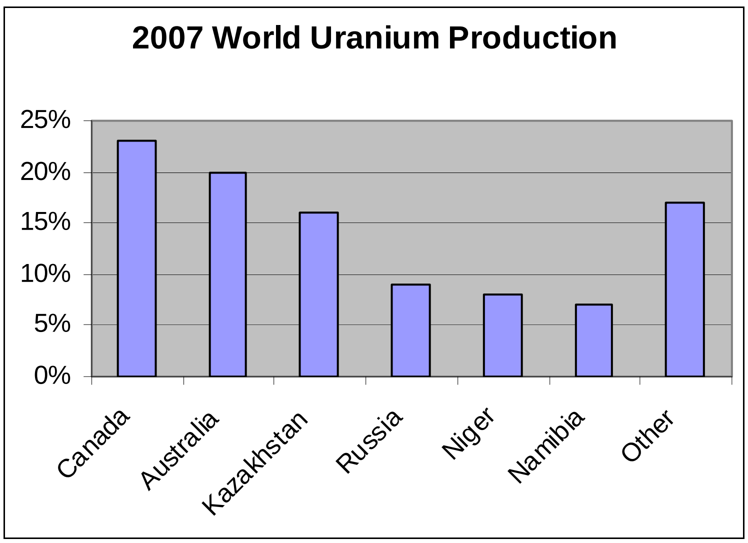
Operating conditions for a land use permit for uranium exploration in the Yukon

Uranium exploration projects are regulated in the same manner as any other mineral exploration projects. In the Yukon, there are a number of specific operating conditions attached to mining land use permits for uranium exploration to ensure that it is conducted in a safe and environmentally responsible way. These have been based on the Saskatchewan "Mineral Exploration Guidelines" and have provisions dealing with the precautions that must be taken when drilling or trenching encounters uranium mineralization. For more information on the specific conditions of mining land use permits, please contact any of the Mining Lands offices.

Uranium Mining

The Canadian picture

Canada leads the world in uranium production, currently accounting for approximately one quarter of the total global output. Uranium mining and milling directly employ over 1,000 Canadians and contribute over $500-million annually to the country's economy. Northern Saskatchewan hosts the richest concentration of uranium in the world. Two mines are operating and a few are under development. Uranium was previously mined at Port Radium in the Northwest Territories, near Uranium City in Saskatchewan, and in the Bancroft and Elliot Lake districts of Ontario. A prospective mine at a deposit west of Baker Lake, Nunavut, will soon enter the permitting stage.



The uranium mining cycle

Uranium is mined by both open-pit and underground methods, depending on the location and nature of an ore body. Low-grade uranium ores can be mined using a leaching in-place process though this is not currently practised in Canada. High-grade ores are often extracted mechanically and stockpiled for a short time on the surface before being ground to appropriate grain size and processed. Uranium is extracted from the ore by chemical leaching (i.e. a process whereby a liquid is passed through the raw materials to carry off the soluble components). The waste material left over after the uranium has been extracted often contains elevated concentrations of radioactive decay products of uranium and other undesirable metals and non-metals. These are impounded in properly designed tailings management facilities.

Compared to base-metal mining, uranium mining commonly produces larger amounts of waste rock because more materials have to be removed to access the ore. Excavated waste rock is classified according to their reactivity and disposed of accordingly. Once the ore is extracted from an open pit, the pit is often used for mine waste disposal.

Progressive reclamation is practised when mining is still on-going. Effluents from all mine components are collected and treated as required by the water and land use permits. Years of post-mine monitoring is necessary to ensure there are no residual environmental impacts and risk assessments are often conducted before the mine operator can walk away from the site.

Illustration 4: Mechanized drilling at the Rabbit Lake underground mine.

Role of the Canadian Nuclear Safety Commission in uranium mining

The Federal Government, through the Canadian Nuclear Safety Commission (CNSC), is working with industry and provincial and territorial government officials to ensure that uranium mining and milling are conducted in a sustainable fashion. In the Yukon, the licensing process can be triggered by such activities as developing shafts and declines, surface excavations for bulk sampling, test mining and drilling or development of site infrastructure. These processes would also trigger an environmental assessment under Yukon's YESAA legislation. The two regulatory processes, YESAA and CNSC licensing, would be conducted jointly since a uranium mine would have impacts in areas where both federal and territorial governments have jurisdiction. Also, under YESAA, a project proposal is submitted when the project goes for environmental review. An actual mine plan is not submitted until the project is approved by YESAB and the company applies for a Quartz Mine License. Until the Quartz Mine License is approved, no work can be done on the site.

Strategies for mine decommissioning are also thoroughly scrutinized. Modern uranium mining has environmental impacts similar to other metal mining. In fact, at many uranium operations in Saskatchewan, other metals and non-metals associated with the mineralization often pose a greater environmental challenge than the radioactive elements themselves. For example, more money is generally spent on dealing with elements such as arsenic and nickel leaching from tailings and waste rock than with radiation at these operations.

Some useful web links:

Canadian Nuclear Safety Commission (CNSC):
http://www.cnsc.gc.ca

Institute for Energy and Environmental Research, Maryland, USA:
http://www.ieer.org

Natural Resources Canada – Energy Sector:
http://www.nrcan.gc.ca/eneene/sources/uranuc/uranium/

World Nuclear Association:
http://world-nuclear.org/education/uran.htm

Acknowledgements

The author would like to thank Dr. Charlie Jefferson of the Geological Survey of Canada for providing relevant information and reviewing Part I of this report. Kellie Emon of the Yukon Department of Energy, Mines and Resources has kindly provided information specific to the Yukon Territory and coordinated the preparation and reviewing of Part II. This report has also benefited from the internal review by Bryan Tisch of CANMET-MMSL.