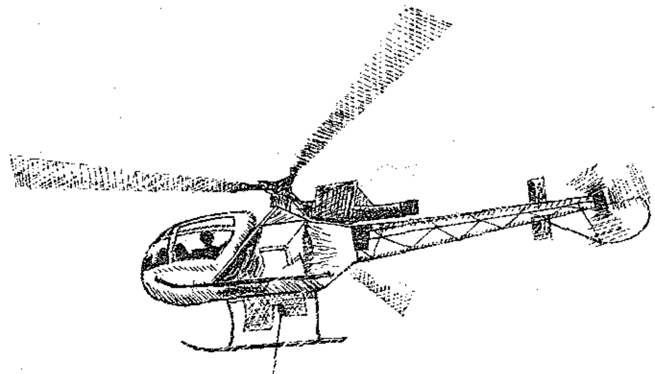
University of Wisconsin-Extension
GEOLOGICAL AND NATURAL HISTORY SURVEY



URANIUM

the Resource and Wisconsin

by
J.K. Greenberg
M.G. Mudrey, Jr.
T.J. Evans

1980

This booklet is intended to provide information regarding the environmental, economic, and energy-related concerns of uranium in Wisconsin.

What is uranium?

Uranium is a heavy, silver-colored metal that is naturally *radioactive*. Uranium does not occur as a pure metal, but if minerals containing uranium are found in large enough concentrations they can be processed to produce uranium compounds for various uses. One of the most important uses is in nuclear fuel materials. Uranium occurs most commonly as the black oxide, uraninite (pitchblende), and the yellow mineral, carnotite. Processed uranium produces a concentrate of *uranium oxide* known as *yellowcake*. The use of this concentrate for energy-generation processes and the relative scarcity of uranium in nature account for its high value today.

Thorium is another radioactive metal used in some experimental nuclear generators and, more commonly, in magnesium-based alloys. Thorium minerals are found near Wausau in Marathon County, Wisconsin in association with an *alkaline igneous* rock called syenite. Zircon, a thorium-bearing mineral, is concentrated in this syenite deposit, but tests conducted during World War II found this occurrence to be uneconomic.

What is uranium used for?

In addition to federal nuclear programs, including defense, uranium is used as a nuclear fuel for civilian electrical power reactors. Recently, about 88% of American uranium consumption has been for nuclear reactors. The uranium *isotope*, U-235, is critical for nuclear energy generation. Spent uranium, or processed uranium that has been depleted in U-235, is presently not suitable for nuclear use; however, it is used in small quantities in specialized non-energy applications. Only a little over 12% of annual industrial demand for uranium involves non-energy applications. For example, because of its high density, depleted uranium is a better shield against

radioactivity: The spontaneous decay of certain unstable elements (see: isotope) such as uranium, to form new isotopes, which may be stable or undergo further decay until a stable isotope is formed. Decay is accompanied by the release of atomic particles and energy.

uranium oxide: A compound of uranium and oxygen with a chemical composition of U_3O_8, as used in this booklet.

yellowcake: Yellow uranium concentrates produced as a final precipitate in the milling process. The word is commonly applied to U_3O_8—a powder formed from evaporation of an ammonia solution of uranium oxide.

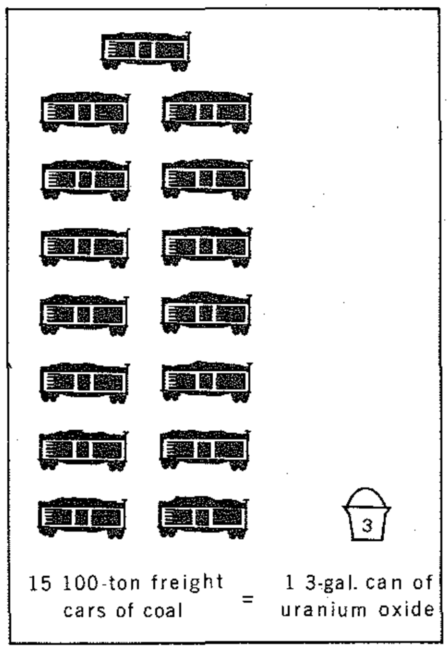
alkaline: A rock containing abundant alkali elements (sodium and potassium). Syenite is a coarse-grained alkaline igneous rock that contains very small amounts of quartz.

igneous: A rock or mineral that formed by the cooling and solidification of molten or partially molten material (magma).

isotope: An atom having the same atomic number (that is, the same chemical element) but having a different atomic weight. Uranium consists of two major isotopes, U-238, which has an atomic weight of 238 and the lighter, less common U-235.

gamma-rays and X-rays than commonly used lead shielding.

An average 1000 megawatt nuclear electric power plant (about the size of the Point Beach nuclear facility near Two Rivers) will use 4,000 - 6,000 tons of uranium oxide in a 30-year design life, or about 200 tons of uranium oxide yearly. For comparison, the same size coal-fired electric power plant will use over 3 million tons of coal per year, or 90 million tons in a 30-year design life.



Comparison of amounts of fuel used by 1000 megawatt power plant in a little over four hours.

Where is uranium found?

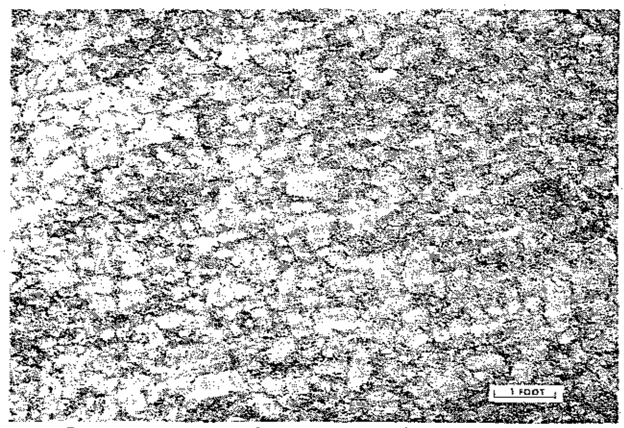
Economic uranium deposits occur in a large variety of geological environments. The igneous occurrences include disseminated uranium minerals in granite as well as concentrations in *pegmatite dikes* and vein and fracture fillings, often along with other rare minerals. Some well known igneous sources of uranium are: the pegmatites of Bancroft, Ontario; the granitic rocks of Rossing, Namibia and Kaffo Valley, Nigeria; and the alkaline syenite at Ilimaussaq, Greenland. Although uncommon, uranium deposits of volcanic origin do exist in alkaline volcanic rocks from Italy and Mexico. Uranium deposits are also

gamma ray: Electromagnetic radiation of very short wavelength and high energy, produced during atomic radioactive decay.

pegmatite dike: An exceptionally coarse-grained igneous rock body of vein-like or tabular form, which intrudes or cuts across other rocks.

relatively uncommon in *metamorphic* rocks, but they do occur in metamorphosed *sedimentary* rocks in Australia and India.

Weathering and erosion cause chemical and physical removal of uranium from minerals in their original sites in various rock types. The uranium is then deposited through the action of water in sedimentary environments. Among the many types of sedimentary uranium deposits, three are the most important economically: 1) sandstone or *roll-front* types, which characterize the large-scale mining operations in Wyoming, Utah, and Colorado; 2) deposits in *Precambrian* quartz-pebble *conglomerate* (or *Huronian* type), represented by the Elliot Lake occurrences in Ontario; and 3) deposits associated with erosional *unconformities* (the *Proterozoic* unconformity type), such as the Rabbit Lake deposit in Saskatchewan and the Ranger deposit in Australia. (See illustration in center of booklet.)



Exposure of Precambrian granite, Shawano County.

metamorphic: A rock which has been changed physically, chemically, or both by the influence of temperature, pressure, or both.

sedimentary: A rock that results either from the consolidation of loose material (such as mud or sand) that has accumulated (often in layers) usually underwater or from chemical precipitation in or evaporation from solutions in water.

roll-front: A major type of uranium deposit in sandstones that takes its name from the curved (roll) shape of the ore zone.

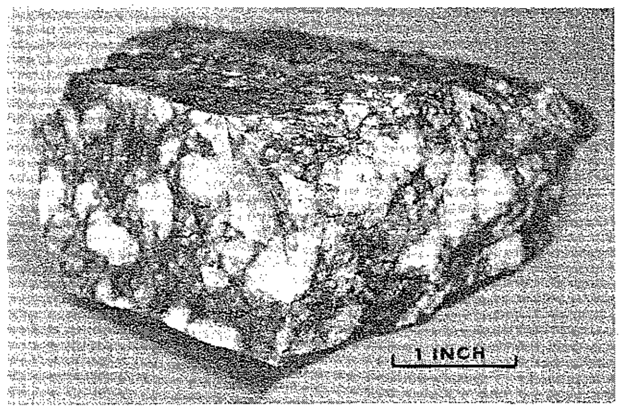
Precambrian: A major division of geologic time, comprising all time prior to about 600 million years ago.

conglomerate: A sedimentary rock with rounded fragments as large or larger than gravel or pebbles.

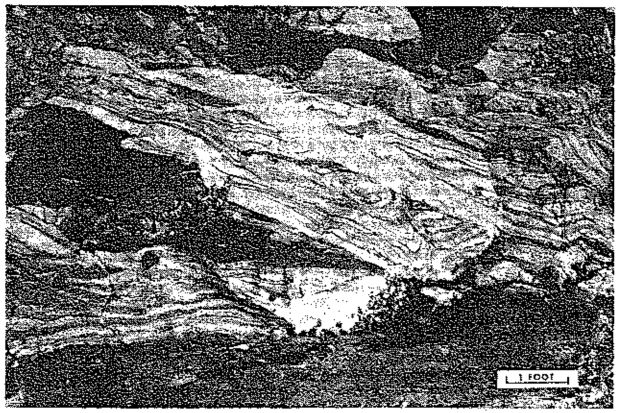
Huronian: A division of the Precambrian time between 2,500 and about 1,600 million years ago. The term is used to describe the quartz-pebble conglomerate type of uranium deposit which is well developed in rocks north of Lake Huron.

unconformity: A surface between two rock units of widely different age that shows evidence of a period of erosion or nondeposition upon the lower (older) rock unit.

Proterozoic: The most recent major division of the Precambrian, from about 2,500 million years ago to about 600 million years ago.



Hand specimen of quartz-pebble conglomerate, McCaslin Mountain.



Exposure of Precambrian banded metamorphic rocks in northeastern Wisconsin.

Is there uranium in Wisconsin?

Geological environments in parts of Wisconsin are similar to those in other areas where uranium deposits have been identified. These environments exist in igneous and metamorphic ("crystalline") rock terranes, as well as in some with sedimentary bedrock. The crystalline rocks, all of Precambrian age, are the oldest in the state and form the bedrock surface for a large portion of northern Wisconsin. Younger sedimentary rocks, up to 2,500 feet thick and typically with low uranium potential, overlie Precambrian rocks in the southern three-fifths of the state.

For many reasons, including the scarcity of bedrock exposures in northern Wisconsin, economic uranium deposits have not been found in the state. Uranium exploration has focused on the northeastern counties. This interest results from the occurrence of uranium concentrations in granitic rocks in Waupaca and Shawano Counties and from the reported, but unconfirmed, find of uranium-bearing quartz-pebble conglomerate near McCaslin Mountain, between Forest and Marinette Counties. Recently, mining companies have explored for uranium in the McCaslin Mountain area, in some metamorphic rocks near the Florence-Marinette county boundary, and in *graphite-bearing slates* in Florence County. (See map in center of booklet.)

No unconformity-type uranium deposits have been discovered in the United States. However, there are geological environments in Minnesota, Michigan and Wisconsin which are similar to those in Canada and Australia where unconformity deposits are major uranium producers. This geological similarity accounts for some of the exploration interest in Wisconsin and the upper Midwest. In addition to some company interest in Wisconsin, the U.S. Department of Energy has been engaged in the National Uranium Resource Evaluation (NURE) program. This program is designed to estimate the country's uranium reserves through the analysis of four basic types of information: 1) geochemical data from stream sediment and natural waters; 2) *aeroradioactivity* data; 3) geological evaluation; and 4) special studies. All the NURE results become public information upon publication and are or will be available for inspection at the Wisconsin Geological and Natural History Survey (see also below under further information).

Is there reason to believe that uranium occurs on my land?

The chance of finding uranium in mineable quantities in any particular area is remote. The chances naturally increase in favorable geologic regions, particularly near previously discovered uranium deposits. Mining companies may want to investigate the possibility of uranium occurrences in an area, but company interest alone does not mean that ore will be found. Actual deposits are confirmed only through intensive exploration programs.

Presently, considerable uranium exploration activity is occurring in many parts of the United States. However, few new sources of uranium in economic quantities have been discovered and all of these are in the western United States.

How is uranium found?

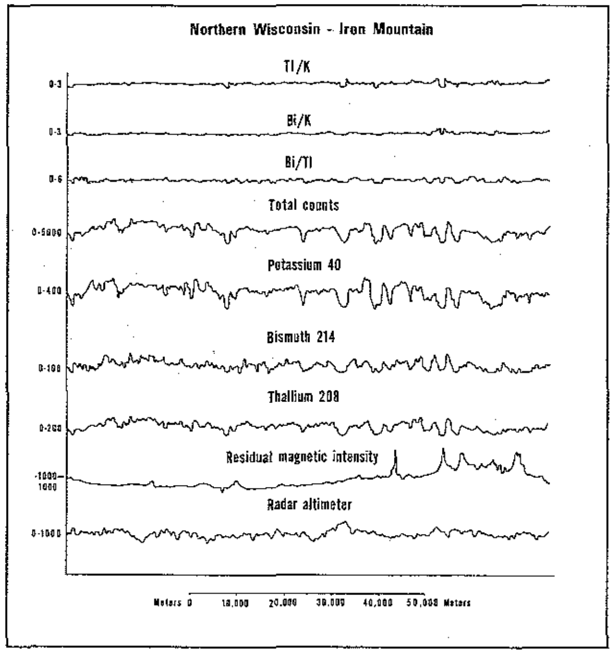
Uranium is found through exploration programs that examine geological, geophysical, and geochemical characteristics of rocks. Exploration programs are designed to identify areas where geologic conditions are known to be favorable for uranium mineralization. This procedure depends on good geologic maps showing

graphite-bearing slate: A metamorphic rock originally composed of clay and organic material, where the organic carbon had subsequently been converted to the mineral, graphite. The presence of graphite might indicate chemical conditions favorable for the accumulation of uranium minerals.

aeroradioactivity: A uranium survey that estimates the relative amounts of radioactive rocks on the ground by analyzing the airborne radioactivity with counting instruments aboard airplanes or helicopters.

bedrock and supplementary information from geophysical surveys of gravity, magnetic field, and *radiometric* information.

Principal geophysical and geochemical techniques which are now used in uranium exploration can be placed in two categories. The first includes those that detect and count the amount of radioactive emissions from the decay of uranium atoms of material in place (in the search area). In the second category are those techniques that directly analyze the amount of uranium, uranium decay products (such as radon or radium) or *pathfinder* elements in a sample of rock, soil, air, or water. In this category are techniques including ground and airborne *spectrometer* counting instruments and radiation sensitive ®*Track-etch* cups shallowly buried throughout exploration areas. The same counting instruments are also used in laboratory sample analysis in addition to geochemical methods not practical for use on material in place.



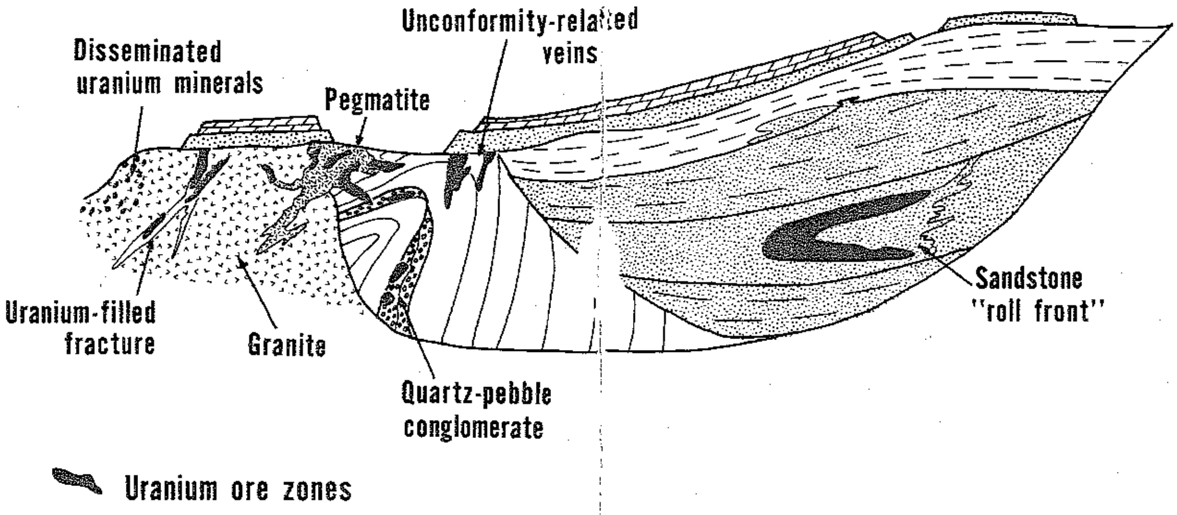
Example of output from aeroradioactivity survey.

radiometric: Said of a scientific instrument or survey that is designed to measure the amount of radioactivity in rocks or water samples.

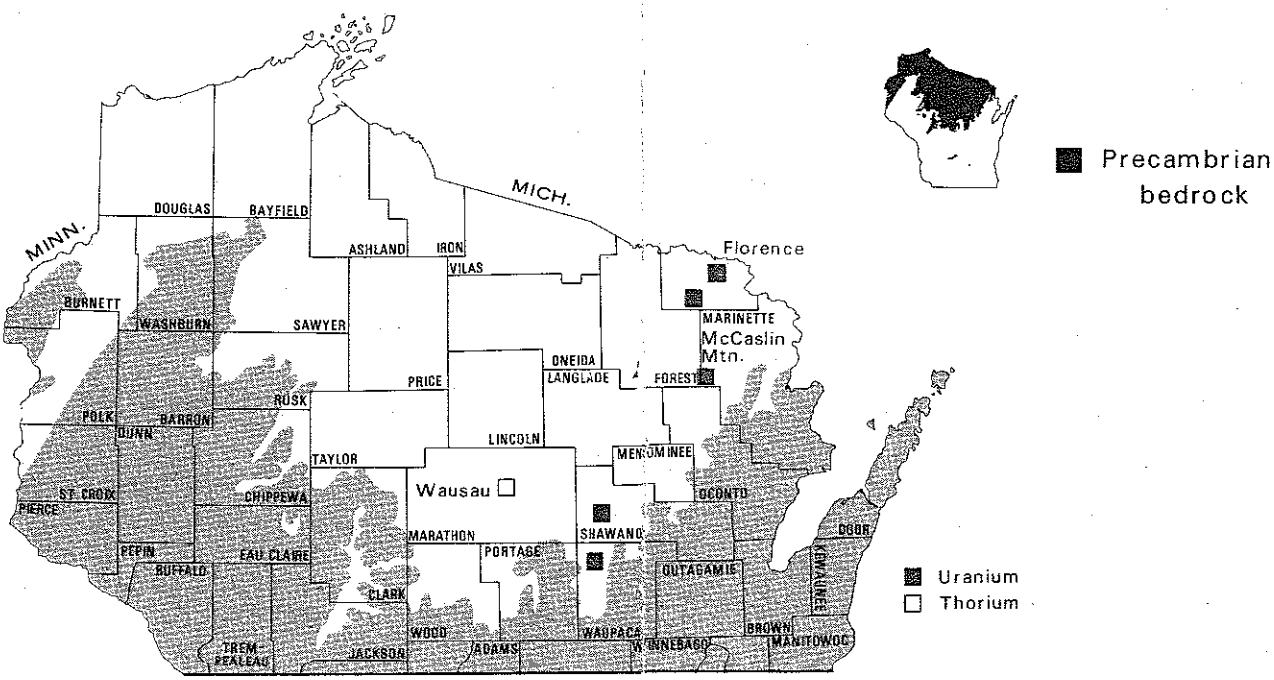
pathfinder: An element that is often found in association with economically important elements (including uranium) or minerals. The discovery of certain pathfinder elements is a helpful clue to the possible presence of concentrations of uranium.

spectrometer: A scientific instrument used to separate and measure various forms of energy, such as the gamma-rays from uranium decay.

®*Track-etch:* A container with film that is exposed by radioactive particles. As an element decays it emits particles that make "tracks" on the film. The number of tracks is proportional to the amount of radioactive material in the sampling area.



Idealized cross section showing important geological settings for uranium mineral occurrences



Referenced mineral occurrences and exploration areas

All of the above techniques may be utilized in both *reconnaissance* and detailed searches for uranium ore; however, many factors (including cost, climate, bedrock geology, and size of the area) usually determine which technique or combination is most appropriate. *Anomalies* discovered from early investigations are used to outline areas for further, more detailed exploration. Ultimately, rock-drilling must be done to determine if an ore body is present and, if so, to define its size and the abundance of uranium.

How large and rich are some uranium deposits?

The variable nature and scale of uranium ore deposits in comparison to many other metal deposits, such as zinc and copper, are shown in the table below. In the United States, most of the individual uranium deposits each contain less than one million tons of ore and less than 1,500 tons of uranium oxide. Where there are several mines in a district, the total tonnage of uranium oxide may be larger, but rarely exceeds 50,000 tons.

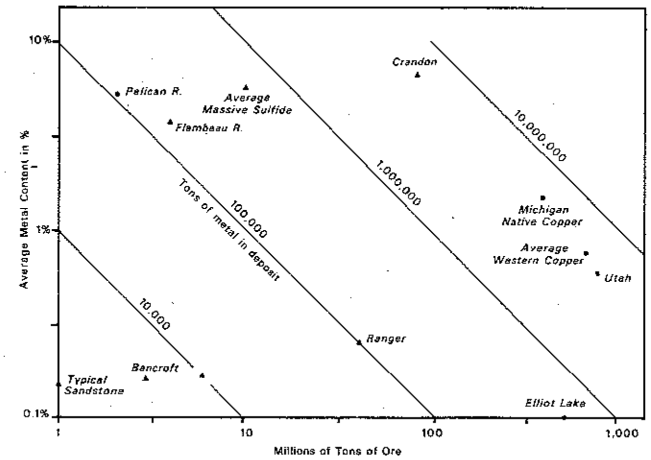
Type, Location, and Approximate Yield of Metal Deposits

Deposit	*Metal Content in Tons*	*Tons of Ore*
Uranium Deposits		
Precambrian Pebble-Conglomerate (Elliot Lake, Ontario)	500,000	500,000,000
Unconformity Related (Ranger, Australia)	100,000	40,000,000
Igneous Pegmatite (Bancroft, Ontario)	5,900	5,400,000
Typical Sandstone (Wyoming)	1,500	1,000,000
Wisconsin Zinc and Copper Deposits		
Pelican Deposit (Oneida County)	110,000	2,100,000
Flambeau Deposit (Rusk County)	160,000	4,000,000
Crandon Deposit (Forest County)	5,400,000	82,500,000
Average Massive Sulfide (World-wide)	596,000	10,000,000
Copper Deposits		
Average Western U.S. Copper	3,500,000	550,000,000
Michigan Native Copper	5,500,000	378,000,000

reconnaissance: A level of investigation designed to gain a broad, general knowledge of features in a region.

anomaly: Unusual characteristics, for example, of an area with radioactivity greater than the surrounding region.

GRADES AND TONNAGES FOR SELECTED METAL DEPOSITS



Although the amount of metal in a uranium deposit is small compared to metal in base-metal deposits, the value of the metal in these two kinds of deposits can be similar. Uranium sells for about 50 times the price of copper, and 100 times the price of zinc. Thus, for equivalent mining costs, a uranium deposit with a metal content of 0.1% will have the same monetary value as a base-metal deposit with 5.0% copper content or a 10.0% zinc content.

What is the value of uranium?

In 1979, the *spot market* price of uranium oxide was about $43 per pound. However, *long-term contracts*, negotiated several years previously, have prices set at $8 per pound and up, with the industry average around $18. An average uranium ore with about one pound of uranium per ton contains about $50 worth of uranium metal. For comparison, an average base-metal massive sulfide deposit, similar to the zinc-copper discoveries in northern Wisconsin, contains about $84 worth of these metals per ton of ore. These are the raw metal or gross values and do not include the costs of exploration, mining, milling, refining, and marketing. These costs must be subtracted from the dollar values to determine the feasibility of developing a mine operation. For uranium, these average production costs range from around $36 per ton of ore by open-pit methods, to over $54 per ton of ore by underground methods. To be as profitable, underground uranium mines must produce a higher grade of uranium ore than that produced by open-pit mines.

spot market: Refers to recent uranium sales calling for delivery in the near future (for example, one year). Spot market prices typically are higher than older contract-established prices.

long-term contract: Agreements to sell uranium at an established price over a period of time (for example, 10 years). Long-term contract prices tend to be lower than spot market prices.

How are these deposits mined?

Three mining methods are used to extract uranium: underground mining, open-pit mining, and solution mining. Underground and open-pit mining each extract over 9,000 tons of uranium oxide yearly in the United States. Underground mining involves tunneling into an ore body, blasting the rock loose, and bringing the ore to the surface for processing. In open-pit mining, the rock is blasted and taken from a pit on the land surface for processing. In both methods, large tonnages of waste rock are deposited at the surface in a mine waste pile. After processing, or milling, *mine tailings* are disposed of in a tailings pond. One of the largest sandstone mines in the world (in Wyoming) produces 1,660 tons of uranium oxide yearly from 1,148,000 tons of ore (3,230 tons daily); this operation moves 17,000,000 tons of waste yearly to recover the ore (about 10,300 tons of waste per ton of uranium oxide). Underground mines generally involve less waste per ton of recovered uranium than open-pit sandstone mines.

Solution mining involves the leaching or dissolving of uranium from ore. This leaching can be done in situ (in place), or in *heap-leaching* from ore piled at the surface. In the United States, about 1,400 tons of uranium oxide are obtained yearly by leaching methods.

Uranium waste contains a small percentage o uranium that cannot be economically recovered. Thi material may leach out of the waste material, and if no adequately contained, could move out of the waste are and into ground water.

What are the environmental concerns of mining uranium?

A recent two-volume report published by the U.S Nuclear Regulatory Commission presents a comprehen sive summary of the environmental impacts associate with uranium mining and milling. This "Draft Generi Environmental Impact Statement on Uranium Milling" (NUREG-0511) cannot be adequately summarized in thi pamphlet, but selected impacts can be identified. Th radioactive elements released in the milling process an their primary sources most critical to health are, i decreasing order of importance: 1) *radon* from tailing piles, 2) *radium* and lead from tailings piles, and 3

mine tailings: Waste material left after removal of the desirable metal content from the ore during the milling process. This material typically is disposed of at on-site locations near the mill.

heap-leaching: The removal by leaching or dissolving of metal from low-grade ore waste rock that is placed in piles and through which solutions are passed to extract the metal. The solutions, now containing metal, are then processed to extract the metal and recycle the original solutions.

radon: A heavy, naturally occurring radioactive gas. Radon is produced by the radioactive decay of radium.

radium: A naturally occurring, radioactive element, produced through the radioactive decay of uranium and commonly associated with uranium minerals.

uranium from the yellowcake operations. Health effects from short *half-lived* radon result from inhalation of longer-lived daughter elements and ingestion of the ground-deposited long-lived radioactive lead. Because radon is released as a gas, it can travel long distances at extremely small levels above normal atmospheric concentrations. However, radon quickly decays to non-gaseous elements and therefore does not remain long in the atmosphere.

Waters associated with mine tailings may contain a wide range of *trace metal*, radioactive, and chemical constituents in concentrations significantly above existing state and federal water quality limits. Seepage of such solutions could conceivably affect ground-water aquifers and drinking water supplies. Generally, the complex interaction of soils, bedrock, ground water, and climatic factors will immobilize many heavy metals and radioactive elements, such as radium and thorium, so that they cannot be leached out. Other heavy trace metals, such as selenium, arsenic, and molybdenum, may form mobile ions which could be leached.

Core drilling operations involve only minimal radioactive hazards. Usually, any radioactive rock obtained from the small hole (2″-3″ diameter) is removed from the site for laboratory testing and thus would not pose a local health threat. The amount of rock involved in such a core is small, and most of the radon is trapped within individual minerals; radon then decays to other elements. The drill holes present no lingering threat because the Wisconsin Department of Natural Resources requires that they be filled with concrete or cement.

Drinking water standards include an evaluation of radioactivity. Most Wisconsin water samples are well below any public health hazard level for radioactivity. Locally higher levels of radioactivity can be expected near known uranium occurrences, and this characteristic has been used as a mineral exploration tool. Such higher than average background values for radioactivity are due to naturally occurring radioactive minerals, and have been present since the rock was formed.

How is uranium exploration and development regulated in Wisconsin?

Numerous federal and state laws and regulations now control all phases of the search for and development of uranium. State legislation and rules currently address

half-life: The time necessary for one-half of the atoms in a radioactive element to decay. Half-lives range from billions of years to millionths of a second.

trace metal: A metallic element found in small, but measureable quantities in a substance. Trace metals are found in association with economically important minerals (including uranium-bearing minerals).

the environmental impacts and operational aspects of *exploration* (drilling), *prospecting (bulk sampling)*, and mining activities, as well as the disposal of mining wastes, worker safety and health, and mineral leasing practices. Federal laws and rules also deal with the environmental impacts of uranium mining, milling, and waste disposal. The National Environmental Policy Act (NEPA) and the Wisconsin Environmental Policy Act (WEPA) require a careful evaluation of the environmental issues surrounding any potential uranium development.

More detailed information on specific laws and rules controlling mineral development in Wisconsin can be obtained from the Mine Reclamation Section of the Wisconsin Department of Natural Resources and the Minerals Information Office of the Wisconsin Geological and Natural History Survey.

What laws protect the rights of landowners when a uranium lease is offered by an exploration company?

Companies looking for uranium (or other minerals) must have a lease from the person(s) owning the mineral rights before they can legally enter the property. Chapter 253, Laws of 1977 was passed in April, 1978 to protect the rights of persons signing leases for metallic mineral exploration. Under this law, the land owner has 10 days after signing the lease in which to change his mind. Prior to this 10-day period, the lease must have been publicly recorded and the financial terms of all such leases made available for public review. Leases signed after April, 1978 are limited to 10 years for exploration, with another 10 years possible for prospecting. Mining under a particular lease is limited to 50 years from the initial date of signing. This statute has become informally known as the "truth in leasing" law. Uranium is included in this and other state laws regulating metallic minerals.

Where can I go for more information?

The Wisconsin Geological and Natural History Survey distributes publications concerning mineral and mining issues at nominal cost.

- Directory of Wisconsin Mineral Producers - 1968, Information Circular No. 12, $2.00
- Mineral Prospecting and Mining Transactions, Information Circular No. 23, $2.00
- Model Mineral Reservation and Mine Zoning Ordinance, Information Circular No. 24, $2.50

exploration: Wisconsin law defines exploration as drilling to obtain rock cuttings or core. Surface activities, such as outcrop sampling, soil sampling, ground geophysical measurements, and so forth are not legally defined as exploration.

prospecting (bulk sampling): Wisconsin law defines prospecting as collecting a bulk sample for further testing by a mining company using such means as digging a shaft, pit, or trench. Typical amounts of material extracted range from hundreds of tons up to 10,000 tons.

Mineral Resources, Mining, and Land-Use Planning in Wisconsin, Information Circular No. 26, $3.00

Mining on your Land? Special Report No. 3, $.50

Zoning and Financial Incentives for Reservation of Mineral Lands in Wisconsin, Special Report No. 6, $2.00

Copper and Zinc Discoveries in Northern Wisconsin, Pamphlet (free)

The Mineral Industry of Wisconsin, U.S. Bureau of Mines Reprint (free)

Publications Available from the Geological and Natural History Survey (free)

Mines and Minerals in Wisconsin—An Update. Pamphlet (free)

The U.S. Department of Energy (DOE) has developed many technical reports on uranium deposits and the uranium industry as part of the National Uranium Resources Evaluation (NURE) program. Many of these reports can be examined at the Wisconsin Geological and Natural History Survey offices. Copies of the reports can be purchased from the Technical Library, Bendix Field Engineering Corporation, Grand Junction Office, P.O. Box 1569, Grand Junction, Colorado, 81501. Please do not write the Wisconsin Geological and Natural History Survey for copies of NURE reports.

Copies of open-file reports on Wisconsin completed in the NURE program are:

Uranium and thorium occurrences in Precambrian rocks, Upper Peninsula of Michigan and northern Wisconsin, with thoughts on other settings: Open-file Report GJBX-48 (76).

Uranium potential in Precambrian rocks in Minnesota and parts of Wisconsin: Open-file Report GJBX-62 (76).

Uranium, thorium, and potassium content of Precambrian rocks, Upper Peninsula of Michigan and northern Wisconsin [supplement to GJBX-48 (76): Open-file Report GJBX-43 (77)].

Criteria for uranium occurrences in Saskatchewan and Australia as guides to favorability for similar deposits in the United States: Open-file Report GJBX-114 (78).

Hydrogeochemical and stream-sediment reconnaissance surveys:

Map Areas

Ashland	Green Bay
Rice Lake	Iron Mountain
Eau Claire	

Aerial radioactivity surveys:

Map Areas

Ashland	Iron Mountain
Rice Lake	Iron River
Eau Claire	Green Bay

University of Wisconsin—Extension
GEOLOGICAL AND NATURAL HISTORY SURVEY
1815 University Avenue, Madison, WI 53706
Telephone: (608) 262-1705