Wyoming's Uranium Resources

Summary Report

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Introduction

Due to its radioactive decay, uranium provides a natural source of heat inside the Earth's crust. This concentrated energy source, found in numerous minerals, is highly valued for its use in nuclear powered electrical generation.

Wyoming is home to the largest known economic uranium ore reserves in the United States. In the 1980s, Wyoming's uranium mining industry was hit hard due to a drop in price, but if prices increase the state is poised to make a comeback with 24 mining operations in the planning or permitting phase.

Wyoming ranks No. 1 among uranium producing states, accounting for approximately 65 percent of the more than 5 million pounds of yellowcake (U_3O_8) produced nationwide in 2014 (estimated from preliminary data from company websites and the U.S. Energy Information Administration). Last year in the United States uranium was also produced in Nebraska and Texas. There is also a mill in Utah, which processes stockpiles and a small amount of ore from Arizona.

Wyoming Mines and Production

Currently, there are five active uranium mining operations in Wyoming. Four are located in the Powder River Basin of northeast Wyoming and one in the Great Divide Basin, which is in the northeastern region of the Greater Green River Basin in southwestern Wyoming. All five employ the *in-situ rec*overy (ISR) mining method (page 2). Smith Ranch-Highland, operated by Cameco-owned Power Resources, has been in continuous ISR operation since the early 1990s. In late 2012, Uranium One, Inc. resumed uranium mining at what was previously known as the Irigary and Christensen Ranch operations; these two areas comprise one operation named Willow Creek and is situated near the Johnson-Campbell county line west of Pumpkin Buttes. In May 2013, mining commenced at Cameco's North Butte operation, also near Pumpkin Buttes. Three months later mining began at Ur-Energy's Lost Creek mine in northeastern Sweetwater County. In April of 2014, ISR operations commenced at Nichols Ranch, a few miles south of the Willow Creek well fields (see map on back cover).

All totaled, 2014 yellowcake production in Wyoming was approximately 3.3 million pounds, a figure that will likely be surpassed this year, with several more mining operations at various stages of regulatory review and approval. Since uranium mining began in 1951, Wyoming's mines have produced more than 230 million pounds of yellowcake.

Wyoming ranks **No. 1** in **U.S.** uranium production and has the **LARGEST** economic uranium **RESERVES** in the country

In-Situ Recovery in Wyoming

In-situ recovery (ISR) is a sophisticated underground mining technique and most uranium deposits in Wyoming are easily "mineable" by this method. The process involves circulating aquifer water fortified with oxidizing agents through the ore zone to mobilize uranium. The next process in production is pumping the water back to the surface to extract the uranium, which is ultimately used to produce yellowcake (see below for more on the chemistry of ISR).

The ISR method has a huge advantage over underground or surface/open pit mining (both conventional mining techniques). ISR mining does not require removing millions of tons of rock and soil in order to extract the uranium resource. Uranium is removed from the rock while still in the subsurface, essentially reversing the processes by which the uranium ore deposit originally formed millions of years ago.

Chemistry of In-situ Recovery

Injection water with oxidizing agents added is known as *lixiviant*. Since no two uranium ore deposits are exactly alike, lixiviant chemistry may vary somewhat from one mine to the next but most in-situ recover (ISR) operations in Wyoming will likely inject such ingredients as oxygen, carbon dioxide, and/or sodium bicarbonate. In contrast, many mines in Kazakhstan – the global leader in uranium production – use agents such as sulfuric acid. The geochemistry (mineralogy, or types of rocks) of the deposits will impact which agents can or cannot be used. Most uranium ore deposits in Wyoming contain minerals such as gypsum or calcite, which would neutralize acids before they could mobilize the uranium.

When the lixiviant is injected, the oxygen added to water will react with uranium minerals such as uraninite (UO_2), followed by a reaction with bicarbonate ($NaHCO_3$) form a soluble and mobile compound such as uranyl dicarbonate:

$$O_2 + 2\underline{\mathbf{U}}O_2 \rightarrow 2\underline{\mathbf{U}}O_3$$
$$UO_3 + 2NaHCO_3 \rightarrow Na_2\underline{\mathbf{U}}O_2(CO_3)_2 + H_2O$$

The compound on the right side of the second equation is suspended in the water and pumped to the surface where extraction process continues in controlled, closed system.

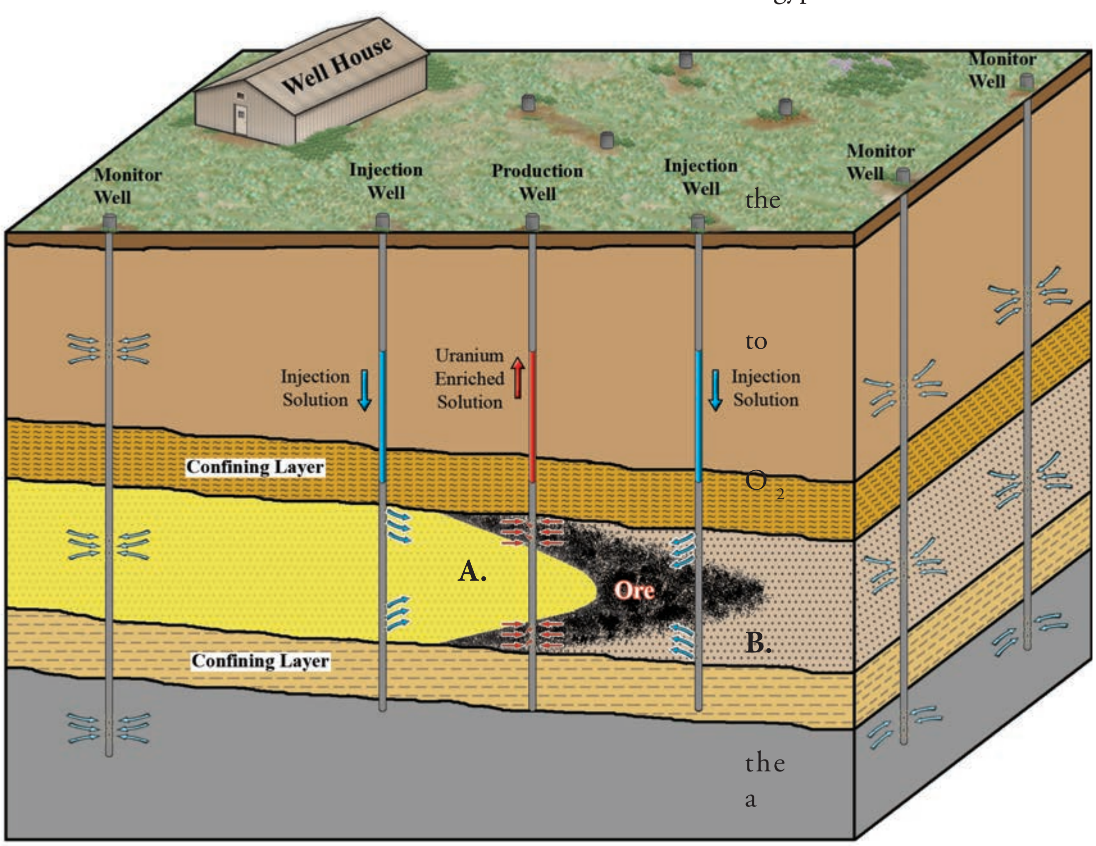

Figure 1. In-situ recovery mining of uranium. The majority of mines in Wyoming use this method. This process does not require moving rock and soil to access the resource as mining occurs in the subsurface. **A.** Altered/oxidized sanstone. **B.** Unaltered and mineralized sandstone. *Graphic by James R. Rodgers, 2015.*

Figure 2. To process uranium into yellowcate, large ion exchange columns are used to concentrate uranium-bearing compounds onto resin beads.

Figure 3. Various tanks are used in the yellowcake production process, including for water storage and the elution and precipitation processes.

Ion Exchange

The water containing the uranium-bearing compounds is then run through large ion exchange columns (see fig. 2). This is where tiny resin beads charged with chlorine anions allow separation of sodium from uranyl carbonate:

$$Na_2\underline{U}O_2(CO_3)_2 + 2Cl \rightarrow \underline{U}O_2(CO_3)_2 + 2NaCl$$

The resin beads contain countless sites at which negative charges are created by the chlorine (Cl) anions, and which attract $\underline{U}O_2(CO_3)_2$ to the site on the bead as the sodium cations are attracted to the chlorine anions, forming NaCl, or salt. The uranium-rich water is pumped through a series of ion exchange columns until the uranium compounds are removed from the water; the water is re-oxidized and re-injected to continue the removal of uranium from the ore zone.

Uranium is stripped from the resin beads by a process call *elution*. The specific steps in the elution process may vary depending on the chemistry of the ore deposit as well as the uranium concentration levels of the fluid pumped from the ground. The process essentially involves the removal of uranium compounds from the resin and into solution, followed by further cycles of chemical treatment to further oxidize uranium and initiate the precipitation of yellowcake (U_3O_8 uranium oxide) crystals out of the solution (see fig. 3, elution tanks).

The resin beads are recharged after ion exchange so that they can be reused again for ion exchange. The final stages of yellowcake production involves collecting wet yellowcake in a *settling tank*, followed by *filtration* to remove the last of the liquids, and finally drying and packaging in preparation for shipment.

A Commodity Resource

U.S. uranium reserves are strongly dependent on price. Uranium supply shortages, or even the perception of such shortages is expected to drive prices higher which in turn will lead to more exploration and ultimately increased production. When uranium prices drop, the U.S. lower grade uranium deposits tend to be less profitable. In 2014, the average uranium spot price ranged from $28 to $44, averaging $33.41. Although uranium spot prices have been in an overall decline since reaching record highs in 2007, many experts agree that a gap between worldwide demand and supply of yellowcake may apply upward pressure to prices in the future.

Sources:
Wyoming Mining Association
U.S. Energy Information Administration
USEC, Inc.
Nuclear Energy Institute
World Nuclear Association

Check out NEW website on Wyoming's URANIUM resource, www.wsgs.wyo.gov/research/energy/uranium

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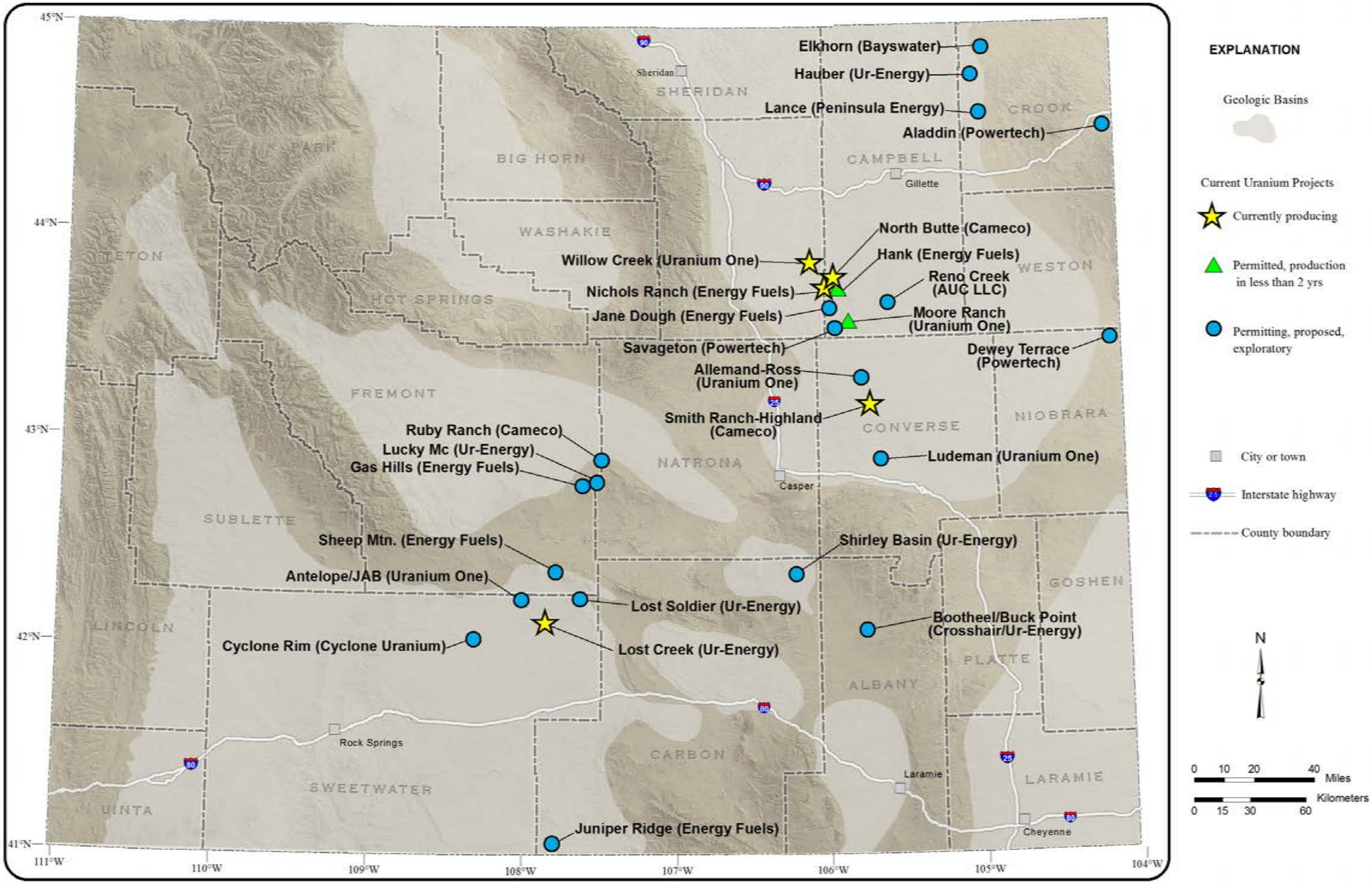
Geology - Interpreting the past - Providing for the future



Wyoming Uranium Projects

Map design by Phyllis Ranz 1/2015