RADIOACTIVE MINERAL OCCURRENCES IN LARAMIE COUNTY, WYOMING

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ABSTRACT

Uranium is the primary radioactive mineral of economic value with reported occurrences in Laramie County, although small amounts of thorium are present in pegmatite occurrences. There has been no reported production of uranium from Laramie County. However, one occurrence, a roll front encountered at depth in the Fox Hills Sandstone in a recently-drilled oil well (occurrence #6) may have the potential for in-situ production. A few types of occurrences (having over 50 parts per million uranium) have been reported.

Several uranium occurrences in the county are in Oligocene age rocks. One occurrence, noted above, is in the Cretaceous Fox Hills Sandstone, which hosts many occurrences in the Pawnee Buttes area of northeastern Colorado. Although uranium minerals were reported by early investigators in vein-type deposits in the Silver Crown district, later geologists have been unable to verify these reports. It may be that these mineral identifications were misidentified copper minerals. Additional uranium and thorium mineral occurrences are reported in Precambrian pegmatites.

INTRODUCTION

Uranium, thorium and potassium-40, and their daughter products are the commonly-occurring radioactive elements and isotopes. The element radium and its isotopes are rare in nature. Isotopes are atoms of an element that have different numbers of neutrons in their nucleus, and therefore have a different atomic mass.

The importance of uranium is based on the ability of uranium to undergo fission, a process in which uranium atoms release energy and particles, and form other atoms. The energy released is used to produce steam for electricity generation.

Thorium, another radioactive element, though never produced in Wyoming or in large amounts anywhere, is used in refractory materials and aerospace alloys.

Radium, which is only found in nature in any abundance in uranium ores, was produced from the Silver Cliff Mine near Lusk, in Niobrara County, in the years just after World War I. Present radium demands, mostly for medicinal purposes, are met by recycling and as a by-product of reactions in nuclear reactors.

Information for this report was gathered and compiled over a period of 12 years through library research, permit examinations and reconnaissance field examinations. In addition to the author, Jon K. King and W. Dan Hausel have compiled information for the report. William L. Chenoweth and J. D. Love have been valuable sources of information throughout this process.

Because uranium has been reported in nearly every time-rock unit in the State, Wyoming is often considered to be an uranium metallogenic province (Stuckless and Nkomo, 1978; Houston, 1979). In the United States, Wyoming ranks second to New Mexico in cumulative uranium production and estimated resources, though ranking first in economic (mineable) reserves Wyoming currently (1997) produces more uranium than any other state, and all of its current production is by in-situ mining methods (Energy Information Administration, 1997). Many uranium minerals have been identified in Wyoming. These are listed in Table 1. The classification of uranium occurrences in this report is modified after a classification developed by Mickle and Mathews (1978)

The largest and most important uranium deposits discovered to date in Wyoming occur in Paleocene and Eocene sedimentary rocks in

Tertiary basins. Large amounts of uranium have been mined from and are still present in what are called roll-front deposits in the Gas Hills, Shirley Basin, Crooks Gap, Southern Powder River Basin, and Pumpkin Buttes uranium districts

Other types of uranium deposits in Wyoming have been mined to various extents. Large amounts of ore have been mined from tabular uranium and vanadium deposits in Lower Cretaceous rocks in the Black Hills of northeastern Wyoming (Hulett Creek and Carlile uranium districts). Ore has also been mined from Tertiary unconformity related deposits in the Copper Mountain uranium district, and from paleokarst deposits in Mississippian limestones in the Little Mountain uranium district and in the Shirley Mountains.

Thorium is abundant at several locations in Wyoming. These locations include large potential thorium resources in Tertiary peralkaline igneous rocks in the southern Bear Lodge Mountains of northeastern Wyoming and in fluvial Cambrian paleoplacers at Bald Mountain in north-central Wyoming. Thorium is also abundant in other Cambrian paleoplacers and in Cretaceous, marine, beach paleoplacer deposits (black sandstones) scattered about central and western Wyoming.

Potassium-40 occurs in all rocks in the State. It has no commercial use. Because potassium is so abundant in granitic and arkosic rocks that are common in the state, a large portion of the natural gamma radiation in Wyoming is from the decay of potassium-40.

Uranium deposits and occurrences are of many different types, based upon their method of formation. The classification scheme used in this report is modified by the author from Mickle and Mathews (1979), and is presented in Table 2. This classification is based on type of host rock (sedimentary, igneous, metamorphic) and suspected origin. Unconformity-related occurrences are separated because they are found in Wyoming in all types of host rocks. Other occurrences are unclassified, because the characteristics of classes often overlap and the differences between classes are gradational. Other occurrences are classified as unknown due to insufficient data. Because radioactive sedimentary occurrences have been intensively studied in Wyoming, the classification system reflects this with more and better defined classes of occurrences in sedimentary rocks. Redox occurrences comprise by far the most common class in Wyoming, and all of the large mines in the state produced uranium from deposits of this type. Because most uranium production outside of the United States is from other classes of deposits, particularly unconformity-related and the Precambrian quartz-pebble conglomerate deposits, information on these classes are also presented.

USES OF URANIUM AND THORIUM

Uranium is used as a fuel in nuclear power plants for the production of electricity. Minor uses include the manufacture of detonators for nuclear weapons, armor-piercing projectiles, reactor shielding, chemical catalysts, and some counterweights (Kirk, 1980).

Yellowcake (U_3O_8) from Wyoming's mills is purchased by electric utilities. The utilities stockpile yellowcake, and ship it to enrichment plants when fuel is needed for their power plants. Enrichment plants concentrate the fissionable uranium isotope ^{235}U from the less than 0.7 percent that is present in natural uranium to 3 percent for use in nuclear power plants. Nuclear weapons require more than 90 percent ^{235}U (Beckmann, 1976). The uranium remaining after the fissionable isotope has been removed is called depleted uranium metal and is used in armor-piercing projectiles, counterweights, chemical catalysts, reactor shielding (Kirk, 1980) and, recently, in armor plating itself (Bob Peck, personal communication, 1988).

Thorium is used in refractory materials (57 percent), the light-producing material in gas lantern mantles (17 percent), aerospace alloys (10 percent), electronic components, and in chemical catalysts. Refractory materials containing thorium oxide (thoria) are used in molds and crucibles that are used for casting and making high temperature alloys. As an alloying material, thorium is primarily added to magnesium. This gives the magnesium higher strength and deformation resistance at high temperatures. Thorium as thorium nitrate is used to improve tungsten welding rods, and to facilitate welding of stainless steel and nickel alloys. The development of breeder reactors which use thorium for fuel, and experimental applications using thorium in fuel rods and core retention beds in conventional reactors in order to prevent core meltdown would require increased production (Hedrick 1985, 1994).

RADIOACTIVE MINERAL OCCURRENCES IN LARAMIE COUNTY

Laramie county is located in the southeastern corner of Wyoming. The eastern 3/4 of the county is part of the Denver-Julesburg Basin, while the western 1/4, the Laramie Mountains, is part of the Southern Rocky Mountains Province. This report is the seventh in a series of county-by county reports on radioactive mineral occurrences in Wyoming. Figure 1 shows the locations and Open File numbers of the previous six reports, and the location of Laramie County.

There are few radioactive mineral occurrences in Laramie County (Figure 2). These are mostly found along the east flank of the Laramie Mountains. Four samples (1-4) taken near Curt Gowdy State Park on the east flank of the Laramie Mountains had elevated levels of uranium (greater than 50 ppm) and are probably related to leaching of uranium from tuffs in the White River Formation (Oligocene). These occurrences are geologically similar to the producing (1997) uranium deposit at Crow Butte, near Crawford, Nebraska. Just west of these locations, uranium minerals were reported with copper-silver mineralization in the Silver Crown mining district. However, since the first reports in 1886 and 1905, prior to the discovery of gamma radiation from these minerals, no uranium mineral has been verified. It is probable that uranium minerals were mistakenly identified visually, and the identification should have been a copper or other metallic mineral. Allanite is reported in pegmatites on the eastern flank of the Laramie Mountains. Most importantly, a roll front is present at depth in the upper Cretaceous Fox Hills Sandstone northwest of Cheyenne. With the present in-situ mining technology, this occurrence should be tested for possible development.

Numbers of the following listed occurrences refer to the numbered localities on the map, Figure 2.

1 U(RX?, UC?, Kp) **unnamed** (sample 153); SE1/4NW1/4SW1/4 sec. 31, T.15N., R.69W.; chemical analysis. This sample contained 66 ppm cU3O8 and was taken from the Pierre Shale (Upper Cretaceous), which unconformably underlies the Oligocene White River Formation (Griffin and Warner, 1982).

2 U(RX?,Twr) **unnamed** (sample 106); SE1/4SE1/4SW1/4 sec. 10, T.14N., R.69W.; chemical analysis. A sample of a pebble conglomerate from the Oligocene White River Formation contained 90 ppm cU3O8 (Griffin and Warner, 1982).

3 U(RX?,Twr) **unnamed** (sample 107); NW1/4SW1/4NE1/4 sec. 16, T.14N., R.69W.; chemical analysis. A sample of a silica-cemented, lithic sandstone from the Oligocene White River Formation contained 79 ppm cU3O8 (Griffin and Warner, 1982).

4 U(RX? UC? Twr, Kp) **unnamed** (samples 114-115); NE1/4NE1/4 NW1/4 sec. 30, T.14N., R.69W.; chemical analysis. Two samples were taken from an intensely limonite-stained

gravel that is present along a drainage. The limonite-stained area was 17 times more radioactive than background. The gravel is apparently a mixture of Oligocene Chadron Formation [White River Formation] and decomposed Pierre Shale (Upper Cretaceous). The samples contained 51 and 179 ppm cU3O8 (Griffin and Warner, 1982).

5 U?(MR?,PC) **Silver Crown mining district**; roughly SE1/4 T.14N., R.70W, unverified occurrences. Uraninite, autunite, and torbernite were reported from the Carbonate Belle, Thunder Cloud, Hermosetta, Grant, Pacific, and other claims in Precambrian rocks in the Silver Crown district (Aughey, 1886). The presence of these minerals in the Silver Crown district has never been verified. Uranium was also reported in a very fine-grained, black powder or wax on a property of John Morse. The material was not pitchblende and the uranium was reportedly in paying quantities (Mining Reporter, 1905). These reports were not confirmed by later work (Smith, 1954; McGraw, 1954; Smith, 1953a; Smith, 1953b; Moore and Butler, 1950). The exact locations of these properties within the Silver Crown district are not known.

6 U(RX,Kfh) **Barrett Energy Corporation, John Morris #1-13 oil well**; NW1/4 SW1/4 sec. 1, T.14N., R.68W. down hole gamma ray log. Roll-front mineralization is present in the uppermost sandstone of the Fox Hills Sandstone (Upper Cretaceous) at a depth of 2,825 to 2,840 feet below the

surface. The gamma log from this oil well, which was drilled in 1983, exhibits characteristics that are indicative of intersection with a roll front immediately behind the C shape on the concave side. The anomaly is 100 times the background gamma for the Fox Hills, with a maximum of over 400 American Petroleum Institute (API) gamma units.

7 - 9 Th?(PG,PCpg) **unnamed feldspar deposit**; uncertain T.15 & 16N., R.70 &71W. (JKK); unverified occurrence. Allanite is reportedly associated with a feldspar deposit in Precambrian rocks on the east flank of the Laramie Range (Osterwald reference #16 in Wilson, 1960). Feldspar deposits with this general location are present in the Sherman Granite about 25 miles northwest of Cheyenne, and the source of the allanite could be any of them. These deposits include the: Bear pegmatite which contains fluorite (SW1/4NW1/4 sec. 5, T.15N., R.70W.; Cox, 1944) (#7); state lease pegmatite (Albany County; sec. 36, T.16N., R.71W.; Hagner, 1943b); Beaver pegmatite (sec. 26, T.16N., R.70W. (Hagner, 1943a, USGS, 1946) (#8); unnamed allanite-bearing pegmatite (in Albany County; sec. 2, T.18N., R.72W. (Osterwald reference #17 in Wilson, 1960); and the Weddle claims pegmatite that might contain euxenite (sec. 2, T.15N., R.71W. (Whalen and Shepard, 1954) (#9). In addition to these specific sites, many pegmatites are located within a few miles of the Bear deposits (Cox, 1944). The setting is similar to the Tie Siding pegmatites in the Sherman Granite

in Albany County, therefore many more pegmatites in this area might contain radioactive mineralization.

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Table 1. Uranium- and thorium-bearing minerals identified in Wyoming.

URANIUM MINERALS

Reduced forms (U^{4+})

brannerite $(U,Ca,Ce)(Ti,Fe)_2O_6$ placers, pegmatites
coffinite $U(SiO_4)(OH)_4$ widespread
uraninite-thorian uraninite $(U,Th)O_2$ widespread

Oxidized forms (U^{6+})

abernathyite $K_2(UO_2)_2(AsO_4)_2 \bullet 8H_2O$ sedimentary redox
autunite $Ca(UO_2)_2(PO_4)_2 \bullet 8\text{-}12H_2O$ igneous and metamorphic
bayleyite $Mg_2(UO_2)(CO_3)_3 \bullet 18H_2O$ sedimentary redox
becquerelite $CaU_6O_{19} \bullet 10H_2O$ sedimentary redox
carnotite $K_2(UO_2)_2V_2O_8 \bullet 3H_2O$ sedimentary redox
liebigite $Ca_2(UO_2)(CO_3)_3 \bullet 11H_2O$ widespread
meta-autunite $Ca(UO_2)_2(PO_4)_2 \bullet 4\text{-}6H_2O$ igneous and metamorphic
meta-torbernite $Cu(UO_2)_2(PO_4)_2 \bullet 8H_2O$ widespread
meta-tyuyamunite $Ca(UO_2)_2V_2O_8 \bullet 3\text{-}5H_2O$ sedimentary redox
phosphuranylite $(H_3O)_2Ca(UO_2)_3(PO_4)_2(OH)_4 \bullet 4H_2O$ widespread
rutherfordine $(UO_2)(CO_3)$ various
sabugalite $HAl(UO_2)_4(PO_4)_4 \bullet 16H_2O$ widespread
schoepite $UO_3 \bullet 2H_2O$ sedimentary redox
schroeckingerite $NaCa_3(UO_2)_2(CO_3)_3SO_4F \bullet 10H_2O$ evaporites, widespread
sklodowskite $(H_3O)_2 Mg(UO_2)_2(SiO_4)_2 \bullet 4H_2O$ widespread
torbernite $Cu(UO_2)_2(PO_4)_2 \bullet 8\text{-}12H_2O$ widespread
tyuyamunite $Ca(UO_2)_2V_2O_8 \bullet 8H_2O$ sedimentary redox
umohoite $(UO_2)(MoO_2)(OH)_4 \bullet 2H_2O$ sedimentary redox
uranocircite $Ba(UO_2)_2(PO_4)_2 \bullet 12H_2O$ various
uranophane $(H_3O)_2Ca(UO_2)_2(SiO_4)_2 \bullet 3H_2O$ widespread
uranopilite $(UO_2)_6(SO_4)(OH)_{10} \bullet 12H_2O$ widespread
weeksite $K_2(UO_2)_2Si_6O_{15} \bullet 4H_2O$ various
zellerite $Ca(UO_2)(CO_3)_2 \bullet 5H_2O$ sedimentary redox
zeuherite $Cu(UO_2)_2(PO_4)_2 \bullet 40H_2O$ various
zippeite $K_4(UO_2)_2(SO_4)_3(OH)_{10} \bullet 16H_2O$ various

THORIUM MINERALS

thorianite-uranoan thorianite $(Th,U)O_2$ pegmatites, placers
thorite-uranothorite $(Th,U)SiO_4$ igneous rocks
thorutite $(Th,U,Ca)Ti_2O_6$ igneous rocks

MINERALS THAT OFTEN CONTAIN ACCESSORY URANIUM AND(OR) THORIUM[1]

allanite $(Ce,Ca,Y,U)_2(Al,Fe_2)_3(SiO_4)_3OH$ carbonatites, pegmatites
apatite $Ca_5(PO4)_3(F,OH,Cl)_3$ carbonatites, phosphorites
brockite $(Ca,Th,Ce)PO_4 \bullet H_2O$ carbonatites
euxenite $(Y,Ce,U,Th,Ca)(Nb,Ta,Ti)_2(O,OH)_6$ pegmatites, placers
fergusonite $(Y,Er,Ce,Fe)(Nb,Ta,Ti)O_4$ pegmatites, placers

fluorite CaF_2 carbonatites, veins
monazite $(Ce,La,Th,U)PO_4$ placers, carbonatites, and veins
mckelveyite $Na_2Ba_4(Y,Ca,Sr,U)_3(CO_3)_9 \bullet 5H_2O$ trona, phosphorite
rhabdophane $(Ce,Y,La,Di)PO_4 \bullet H_2O$ sedimentary, siliceous
samarskite $(Y,Fe,Ca,U,Ce,Th)(Nb,Ta,Ti)_2(O,OH)_6$ pegmatites, placers
xenotime YPO_4 placers, veins(?)
zircon $ZrSiO_4$ placers

GENERAL OR NONSPECIFIC TERMS

pitchblende: amorphous of cryptocrystalline variety of uraninite that can contain thorium.
gummite: fine-grained, secondary, hydrous uranium minerals associated with uraninite that can be amorphous.
thucolite: uranium and thorium-bearing carbonaceous material.

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[1] Apatite, fergusonite, fluorite, rhabdophane, xenotime, and zircon may sometimes contain either uranium or thorium in the interstitial spaces, but not always. Because the uranium and thorium **are not** part of the crystal structure of these six minerals, the accessory uranium and thorium are not shown in the chemical formulas. For the other minerals listed, the accessory uranium and thorium **are** part of the crystal structure and the radioactive elements are shown in the chemical formulas.

Table 2. Classification of uranium and thorium mineralization, with Wyoming examples (modified from Mickle and Mathews, 1978).

Symbol	Classification	Wyoming examples
	OCCURRENCES IN SEDIMENTARY ROCKS	
RX	Redox[1]	Roll front Wasatch and Fort Union Formations (and equivalents); Statewide
RT	Tabular	Inyan Kara Group, northeastern Wyoming
Mechanical accumulations		
BP	Beach placer	Mesaverde Formation, Statewide
FP	Fluvial placer	Flathead Formation, northwestern Wyoming
QC	Quartz-pebble conglomerate	Magnolia Formation, Medicine Bow Mountains (Albany and Carbon Counties)
Chemical codeposition		
BS	Marine black shale	Minnelusa Formation, eastern Wyoming
MP	Marine phosphorite	Phosphoria Formation, western Wyoming
LP	Lacustrine phosphorite	Wilkins Peak Member, Green River Formation (Sweetwater County)
Carbonate		
CP	Paleokarst	Madison Limestone, Little Mountain district (Bighorn County)
CS	Surficial coating	Browns Park Formation, Carbon County
CR	Reduction related	Sundance Formation, Mayoworth area (western Johnson County)
DE	Desert evaporite	surface deposits, Lost Creek area (northeastern Sweetwater County)
CL	Coal	Wasatch Formation, Great Divide Basin (eastern Sweetwater County)
	OCCURRENCES IN IGNEOUS ROCKS	
IM	Initial magmatic	Precambrian granites; Statewide
PG	Pegmatitic	Sherman Granite, Tie Siding area (southeastern Albany County)
MH	Magmatic hydrothermal	Eocene intrusives, Bear Lodge Mountains (Crook County)
AT	Autometasomatic	Eocene intrusives, Bear Lodge Mountains (Crook County)
PN	Pneumatolytic	Yellowstone National Park
SP	Postmagmatic silica-poor	uncertain
SR	Postmagmatic silica-rich	Moonstone Formation, central Wyoming
	OCCURRENCES IN METAMORPHIC ROCKS	

CM	Contact metamorphic	uncertain
AN	Anatectic	Platt pegmatites, Saratoga Valley (southern Carbon County)
MR	Redox[1]	Little Man mine, Pedro Mountains (northern Carbon County)
MV	Vein	Esterbrook area (southern Converse County)
UNCONFORMITY RELATED		
UC	Unconformity Related	Arrowhead prospect (Fremont County)
UNKNOWN		
UN	Unknown	numerous
OTHER OCCURRENCES		
SZ	Shear-zone-hosted	Sierra Madre (southern Carbon County)
VN	Vein-hosted	Esterbrook area (southern Converse County)
FR	Fracture-filling	Michigan mine (Goshen County)
RP	Replacement	Bear Lodge Mountains (Crook County)

[1]Formed at a geochemical interface between oxidizing and reducing environments where oxidation-reduction chemical reactions occur.

Table 3. Chemical symbols for radioactive elements and radioactive anomalies.

Symbol	Element or anomaly
Ra	Radium
Th	Thorium
U	Uranium
rad	radioactive material
ra	anomalous radioactivity

Table 4. Key to formation names or rock types used in the descriptions of the occurrences of radioactive elements in Laramie County, Wyoming.

Formation name	Symbol
CENOZOIC	
TERTIARY	
Oligocene White River Formation	Twr
MESOZOIC	
Cretaceous Fox Hills Sandstone	Kfh
Cretaceous Pierre Shale	Kp
PRECAMBRIAN	
Precambrian undivided	pC
Precambrian pegmatites	pCpg

Table 5. Status and/or type of occurrences of radioactive elements.

Symbol	Status and/or occurrence	Symbol	Status and/or occurrence
ALL RADIOACTIVE ELEMENTS		URANIUM OCURRENCES ONLY	
mn	minerals noted or observed	p	prospect
mi	minerals identified	pr	prospect--reserve delimited
ca	chemical analysis	ma[1]	mine (active)
ra	radiometric analysis	ms[1]	mine-surface (inactive)
		mu[1]	mine-underground-(inactive)
rs	radiometric survey		
rl	radiometric down-hole log		
uo	unverified occurrence		
		ia	in-situ operation (active)
		ir	in-situ operation-research

[1] An occurrence is considered a mine (instead of a prospect) when the reported cumulative uranium ore production exceeds 500 short tons.

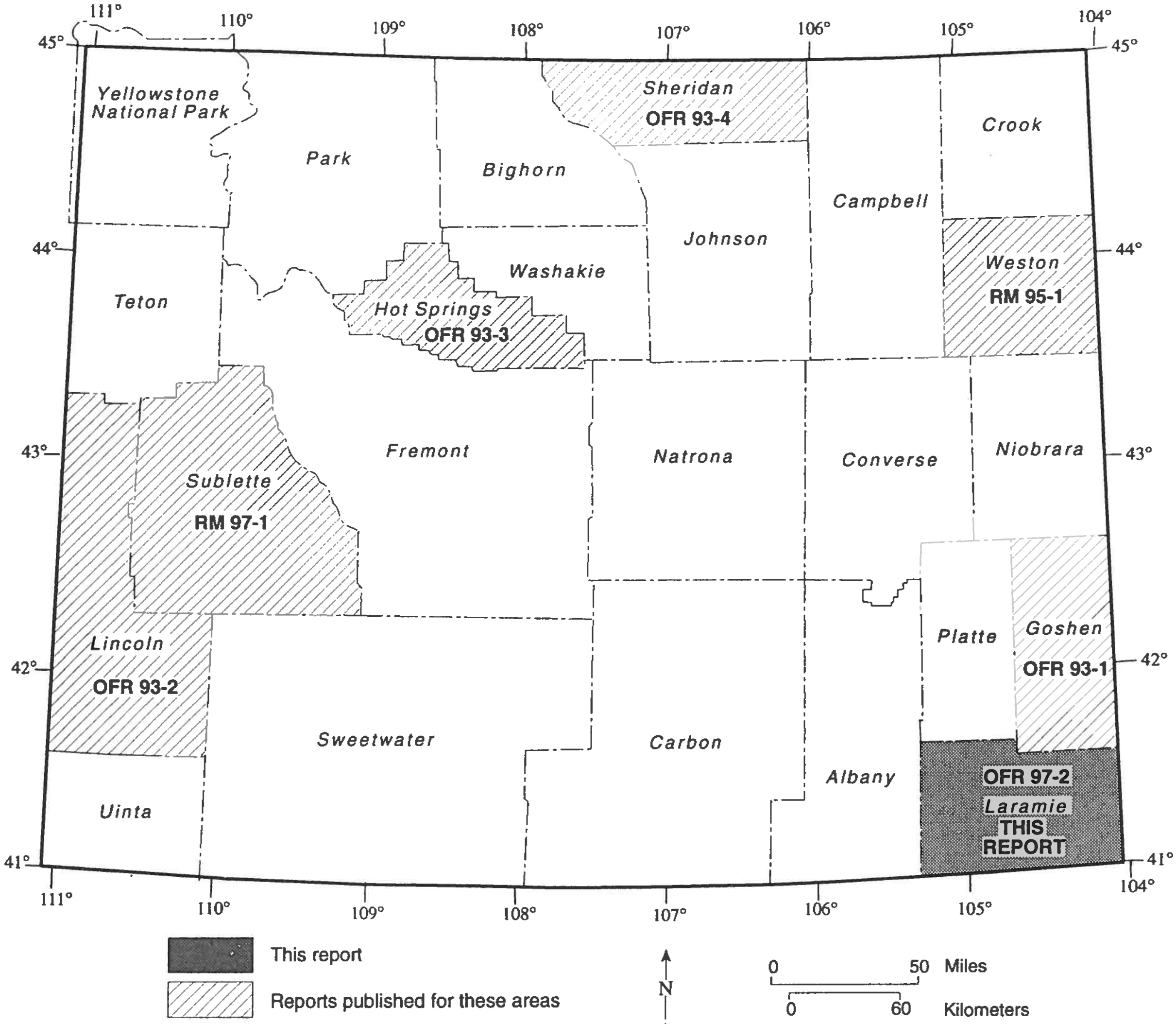

Figure 1. Index map of Wyoming showing the location of Laramie County and the counties for which radioactive mineral and uranium mine information have been released by the Wyoming State Geological Survey.

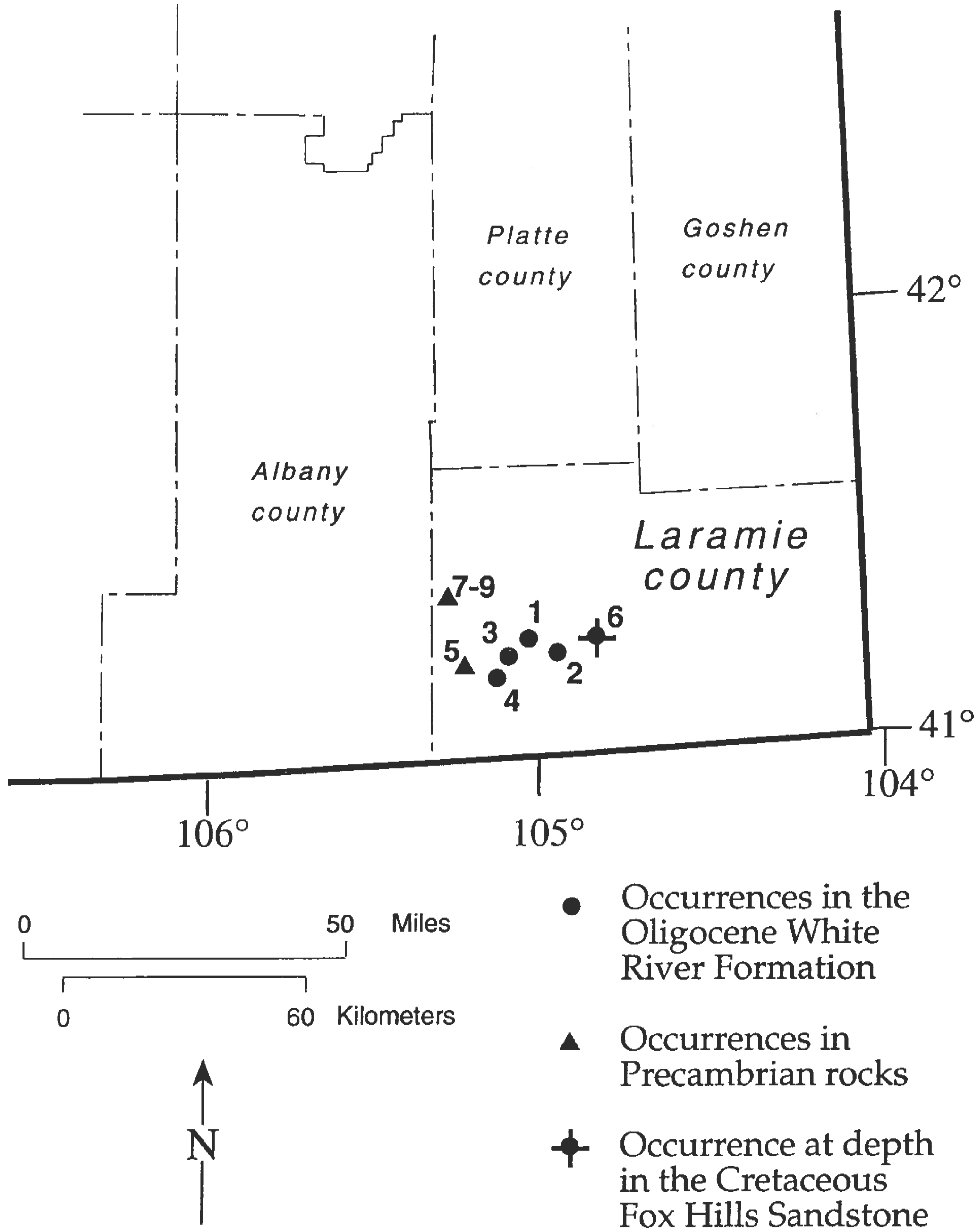

Figure 2. Index map of Laramie County showing the location of radioactive mineral occurence discussed in this report.