WYOMING STATE GEOLOGICAL SURVEY

RADIOACTIVE MINERAL OCCURRENCES AND URANIUM MINES IN WESTON COUNTY, WYOMING

by

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RADIOACTIVE MINERAL REPORT RMR 95-1

This report has not been reviewed for conformity with the editorial standards of the Wyoming State Geological Survey.

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Abstract

Uranium occurrences in Weston county are redox occurrences found exclusively in rocks of the Lower Cretaceous Inyan Kara Group in the Black Hills in the northeastern and eastern areas of the county. The single uranium mine in Weston County produced small amounts of uranium ore in the early 1950's

It is unlikely that larger occurrences of uranium are present near the surface in the sandstone units in the Inyan Kara Group in Weston County. Subsurface exploration may locate ore bodies of a size similar to larger past producing

deposits in Crook County, Wyoming and other areas in the Black Hills Uranium District in South Dakota. The remainder of Weston County is relatively unexplored. Uranium occurrences are found in other Cretaceous units elsewhere (for example the Fox Hills Sandstone in the Denver Basin in northeastern Colorado), but the Cretaceous and Paleocene and Eocene units (Fort Union and Wasatch Formations) exposed in Weston County have not been thoroughly explored.

Introduction

This open file report is the fifth in a county-by-county series of reports on uranium and other radioactive elements in Wyoming. The other reports in this series are shown in **Table 1**. Information for these reports (which are part of a regional study of all Wyoming uranium mines, radioactive elements, and radioactive mineral occurrences) was gathered and compiled over a period of 11 years from publications, mine permits, company data, and field investigations. In addition to the author, Jonathan K. King and W. Dan Hausel have compiled information for the report. William L. Chenoweth, Warren I. Finch, and J. David Love have been valuable sources of information throughout this process.

Uranium, thorium, potassium-40 (^{40}K), and radium, and their daughter products, are the naturally-occurring radioactive elements. The first three elements and their isotopes commonly occur in nature. The element radium and its isotopes are rare in nature. Isotopes are different species of the same chemical element that have different numbers of neutrons in the nucleus of their atoms, and therefore have different atomic masses.

Uranium is the most important radioactive element because of its ability to undergo fission, a spontaneous or induced process in which uranium atoms release large amounts of energy and subatomic particles, and form other atoms. The energy released can be used to produce steam for the generation of electricity.

Thorium is used in refractory materials and aerospace alloys. It also has limited use as a nuclear fuel. Potassium-40 occurs in nearly every rock type and has no commercial use. Radium, which is only found naturally in any abundance in uranium ores, is used mostly for medicinal purposes. Current demands for radium are met both by recycling and through production as a by-product of reactions in nuclear reactors.

Table 1 Previously released county radioactive mineral reports (See **Figure 1** for locations)

County	OFR Number	Reference
GOSHEN	93-1	Harris 1993a
HOT SPRINGS	93-3	Harris 1993c
LINCOLN	93-2	Harris 1993b
SHERIDAN	93-4	Harris 1993d

Radioactive elements in Wyoming

The radioactive element uranium is one of the best known mineral products of Wyoming. Uranium exploration and production has had a colorful history in Wyoming that dates back to about 1918.

Because uranium has been reported in nearly every time-rock unit in the State, Wyoming is often considered to be a uranium metallogenic province (Stuckless, 1979; Houston, 1979). In the United States, Wyoming ranks first in economic (mineable) reserves of uranium (Energy Information Administration, 1990) and ranks second to New Mexico in cumulative uranium production and estimated resources. In 1994, Wyoming produced more uranium than any other state. Twenty-eight uranium minerals and 12 other minerals known to contain accessory uranium have been identified in Wyoming (**Table 2**).

In Wyoming, the largest and most important discovered uranium deposits occur in Paleocene and Eocene sedimentary rocks in Tertiary basins. Over 187 million pounds of uranium oxide concentrate have been produced from roll-front deposits (Chenoweth, 1991) in the Gas Hills, Shirley Basin, Crooks Gap, Southern Powder River Basin, Pumpkin Buttes, and other uranium districts (**Figure 1**).

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 of the Black Hills. 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 (**Figure 1**).

Although thorium has never been produced in Wyoming or anywhere else in large amounts, the element is abundant at several locations in Wyoming. These locations include one of the largest identified thorium resources in the United States, which occurs in Tertiary peralkaline igneous rocks in the southern Bear Lodge Mountains of northeastern Wyoming (Staatz, 1983), and smaller resources in Cambrian fluvial paleoplacers at Bald Mountain in north-central Wyoming (Borrowman and Rosenbaum, 1962) (**Figure 1**). Thorium is also abundant in other Cambrian paleoplacers and in Cretaceous beach paleoplacer deposits (black sandstones) scattered about central and western Wyoming (Houston and Murphy, 1970). Three thorium minerals and 12 other minerals known to contain accessory thorium have been identified in Wyoming (**Table 2**).

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 ^{40}K.

Radium was produced from the Silver Cliff mine near Lusk, in Niobrara County, Wyoming, in the years just after World War I. Radium is a daughter product in the four decay series ^{238}U, ^{235}U, ^{234}U, and ^{232}Th. It is found in small amounts in all uranium and thorium deposits and occurrences. The only recorded radium production from Wyoming was from the Silver Cliff mine. Some of this radium production reportedly was shipped to the Curies in France for their experiments with radiation (Peck, 1969).

Classification of deposits and occurrences

Uranium and thorium deposits and occurrences are of many different types, based upon their method of formation. The classification scheme used in this report (**Table 3**) is modified from Mickle and Mathews (1978). In part, this classification is based on the type of host rock (sedimentary, igneous, or metamorphic) and the suspected origin. Because the characteristics of classes often overlap and the differences between classes are gradational, some occurrences are unclassified (and are placed in the unknown category). Unconformity-related occurrences are separated because they are found in Wyoming in all types of host rocks. Shear-zone-hosted, vein-hosted, fracture-filling, and replacement occurrences are not dependent on the type of host rock and are also classified separately. Still other occurrences are classified as unknown due to insufficient data.

Because occurrences of radioactivity in sedimentary rocks have been intensively studied in Wyoming, the classification system for this category has more and better defined subdivisions. Redox occurrences are by far the most common class in Wyoming, and all of the large mines in the State produce(d) uranium from deposits of this type.

By way of explanation, uranium is soluble in water as various complex ions under oxidizing conditions. Under reducing conditions uranium is not soluble. Redox occurrences are formed by precipitation at geochemical boundaries where the Eh (oxidation-reduction potential) changes from oxidizing to reducing. Most uranium production outside of the United States is from classes of deposits other than redox, particularly from unconformity-related deposits and deposits of Precambrian quartz-pebble conglomerates.

Uses of uranium and thorium

Uranium is primarily used as a fuel in nuclear-powered electrical generating plants. Yellowcake produced from Wyoming's uranium mills is purchased by electric utility companies. Yellowcake (uranium oxide concentrate) contains uranium oxide as ammonium diuranate, sodium diuranate, or uranium peroxide (List and Coleman, 1979). 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 and yellowcake to the 3 percent needed for nuclear power plants.

Minor amounts of uranium are also used in the manufacture of detonators for nuclear weapons. In the United States, uranium was used as the explosive in the first fission weapons. Nuclear weapons and detonators require concentrations of more than 90 percent ^{235}U (Beckmann, 1976).

The uranium remaining after the fissionable isotope has been removed is called depleted uranium metal. This uranium is used in armor-piercing projectiles, in counterweights (especially for elevators), in chemical catalysts, in reactor shielding (Kirk, 1980), and recently, in armor plating itself (Bob Peck, personal communication, 1988).

Most thorium is used in aerospace alloys. Other uses include refractory materials, the light-producing material in gas lantern mantles, electronic components, and in chemical catalysts. A few nuclear reactors in foreign countries use ^{232}Th as fuel. The last nuclear reactor in the United States to use thorium as a fuel was the Fort St. Vrain power plant in Colorado. The plant closed over a decade ago. 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 to give 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. New uses of thorium under development include breeder reactors which use thorium for fuel, and in fuel rods and core retention beds in conventional reactors in order to prevent core meltdown. If these new uses are developed, increased production of thorium would be necessary (Hedrick, 1985; 1992a; 1992b).

Uranium occurrences in Weston County

The six uranium occurrences in Weston County are all found within rocks of the Lower Cretaceous Inyan Kara Group (Lakota and Fall River Sandstones) in the Black Hills in the northeastern and eastern parts of the County. Only one property has produced uranium in Weston County. The Wicker-Baldwin mine produced 219 tons of uranium ore during the early and mid-1950s. More information about the origins of uranium mineralization in the Inyan Kara Group in Weston County is present in Laughery (1956), and in Gott and others (1974).

The majority of Weston County is underlain by Cretaceous and lower Tertiary (Paleocene and Eocene) rocks. Uranium occurrences are found in some Cretaceous units elsewhere (for example the Fox Hills Sandstone in the Denver Basin). The Paleocene and Eocene units (Fort Union and Wasatch Formations) are the most important uranium producing rocks in Wyoming in terms of total production. However, these rocks have not been thoroughly explored in Weston County. A surficial radiometric survey (Harris, 1989) presents the surficial gamma radiation background for most of Weston County.

Definitions

In this report, an occurrence of uranium is defined as a concentration in which the amount of uranium (as determined from either radiometric or chemical analysis) is greater than 50 ppm (0.005 percent). A mine is a property whose production exceeded 100 tons.

Description of occurrences

The alphanumeric notation that precedes each of the following descriptions is keyed to **Tables 3** through **5**: the first number refers to the map location (**Figure 2**). In the parentheses, the group(s) of two letters refers to the deposit type(s) (**Table 3**); in the brackets, the group(s) of letters refers to the formation name(s) or rock type(s) of the host rock(s) (**Table 4**). The lower case letters after the parentheses indicate the status of development and the type of data available for the occurrence (**Table 5**).

1 U(RT),[Klk] ca,ra **unnamed**; SW1/4 sec. 31, T.48N., R.62W
A channel sample of black shale from the Lakota Formation at this site contained 0.005 percent uranium (0.005 % eU)(Duncan, 1953;).

2 U(RT),[Kfr] ra **Farley**; secs. 3, 4, and 10, T.47N., R.63W.
Samples of a one-foot-thick, fine-grained, white, quartz sandstone with some carbonaceous seams contained 0.002 and 0.008 percent eU3O8. The sandstone is underlain and overlain by shaley sandstone and all these sandstones are in the lower Fall River Formation (Laughery, 1955a).

3 U(RT),[Klk], ra Farella;
SE1/4 sec. 7, T.46N., R.61W. High radioactivity (up to 30 times background) was found in a dark gray, fine grained, carbonaceous sandstone in the upper Lakota Formation. Samples submitted by the operators (Aimonetto [?]; illegible), contained 0.04 and 0.07 percent eU3O8. Eight or more shallow drill holes have explored the property (Laughery, 1955b).

4 U(RT,CL),[Klk], ca, ra **Cambria area**; secs. 19, 20, 29, and 30, T.46N., R.61W.
Samples were taken from a gray, fine to medium grained sandstone that contains abundant (about 30 percent) carbonaceous trash as well as seams and partings of carbonaceous material. Carbonaceous material contained 0.23 percent eU3O8, while the sandstone contained 0.07 percent eU3O8. This sandstone is directly above the coal beds that were mined at Cambria (Efthinion and Laughery, 1955).

Mapel and Pillmore (1963) report that coal from the Cambria coal mines in the Lakota Formation contain from 0.002 to 0.010 percent uranium (0.002 to 0.016 % eU).

5 U(RT),[Kfr] mn,ra,ca **Allray (Alray) prospect (Foster lease)**; NW1/4NE1/4 sec. 8, T.42N., R.60W.

The Allray property was first examined by drilling(Laughery, 1955c). Soon afterwards, an adit was driven to explore the surficial high radioactivity in the middle sandstone unit of the Fall River Formation, near a yellow-gray color boundary. Secondary yellow uranium minerals (probably phosphates and vanadates) are associated with a pyritiferous, carbonaceous siltstone and are peripheral to siliceous nodules in the yellow channel sandstone in the adit. Black uraniferous material is associated with the siltstone and might be primary. Analyses of five sandstone and siltstone grab samples varied from 10 ppm to 1,200 ppm uranium (Cuppels, 1963, Laughery, 1956). There is no report of any production from this property.

A composite sample was taken from this area (as plotted on the sample location map by Santos [1982]). However, due to the large scale of the map, it cannot be determined whether the "mineralized" composite sample in the report came from the Allray adit, or from an outcrop nearby. No numerical data is available for this sample from this report.

6 U,V(RT),[Kfr] mu,mn,mi,ca **Wicker-Baldwin mine**; NE1/4NE1/4 sec. 16, T.42N., R.60W.

The Wicker-Baldwin, also known as the School Section 16, property was operated by Wicker in 1953, 1955, and 1956, and produced about 219 tons of uranium ore containing 859 pounds of by-product vanadium oxide according to Atomic Energy Commission data (AEC). These production figures may not be accurate because another Wicker-Baldwin mine is located in South Dakota in sec. 26, T.6S., R.1E. Potter and Smith (1957) report production of 300 tons of ore from the Wyoming mine. These two mines with the same name probably both shipped ore to the Edgemont mill; and the production figures from the Atomic Energy Commission could therefore include production from both mines.

The workings were underground in the middle sandstone unit of the Fall River Formation in the lower Cretaceous Inyan Kara Group, just above an impermeable claystone. The length of the workings was about 340 feet. Yellow, carnotite-like, uranium minerals were associated with irregular pods of carbonaceous and lignitic material on the margin of a ferruginous, but light brown, fluvial, channel sandstone near a red to tan color boundary (Laughery, 1956; Brobst, 1961). In contrast, Laughery (1955d) states that the uranium mineralization was along bedding planes and fractures in the limonite-stained sandstone. Gruner and others (1956) identified meta-tyuyamunite, opal, pyrite, and kaolinite in samples from the mine. Laughery (1956) determined that chemical vanadium/uranium ratios in samples from the workings were 3:1 , and gangue minerals were opal, pyrite, kaolinite and limonite.

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TABLE 2. Uranium and thorium minerals reported in Wyoming

URANIUM MINERALS

Reduced(U4+)

Mineral	Chemical formula	Common occurrence
brannerite	(U,Ca,Ce)(Ti,Fe)2O6	placers, pegmatites
coffinite	U(SiO4)(OH)4	widespread
uraninite- thorian uraninite	(U,Th)O2	widespread

Oxidized(U6+)

Mineral	Chemical formula	Common occurrence
abernathyite	K2(UO2)2(AsO4)2+8H2O	sedimentary redox
autunite	Ca(UO2)2(PO4)2+8-12 H2O	igneous and metamorphic
bayleyite	Mg2(UO2)(CO3)3+18H2O	sedimentary redox
becquerelite	CaU6O19+10H2O	sedimentary redox
carnotite	K2(UO2)2V2O8+3H2O	sedimentary redox
liebigite	Ca2(UO2)(CO3)3+11 H2O	widespread
meta-autunite	Ca(UO2)2(PO4)2+4-6H2O	igneous and metamorphic
meta-torbernite	Cu(UO2)2(PO4)2+8H2O	widespread
meta-tyuyamunite	Ca(UO2)2V2O8+3-5H2O	sedimentary redox
phosphuranylite	(H3O)2Ca(UO2)3(PO4)2(OH)4+4H2O	widespread
rutherfordine	(UO2)(CO3)	various
sabugalite	HAl(UO2)4(PO4)4+16H2O	widespread
schoepite	UO3+2H2O	sedimentary redox
schroeckingerite	NaCa3(UO2)2(CO3)3SO4F+10H2O	widespread
sklodowskite	(H3O)2 Mg(UO2)2(SiO4)2+4H2O	widespread
torbernite	Cu(UO2)2V2O8+8-12H2O	widespread
tyuyamunite	Ca(UO2)2V2O8+8H2O	sedimentary redox
umohoite	(UO2)(MoO2)(OH)4+2H2O	sedimentary redox
uranocircite	Ba(UO2)2(PO4)2+12H2O	various
uranophane	(H3O)2Ca(UO2)2(SiO4)2+3H2O	widespread
uranopilite	(UO2)6(SO4)(OH)10+12H2O	widespread
weeksite	K2(UO2)2Si6O15+4H2O	various
zellerite	Ca(UO2)(CO3)2+5H2O	sedimentary redox
zeuherite	Cu(UO2)2(PO4)2+40H2O	various
zippeite	K4(UO2)2(SO4)3(OH)10+16H2O	various

THORIUM MINERALS

Mineral	Chemical formula	Common occurrence
thorianite-uranoan thorianite	$(Th,U)O_2$	pegmatites, placers
thorite-uranothorite	(Th,U,)SiO4	igneous rocks
thorutite	$(Th,U,Ca)Ti_2O_6$	igneous rocks

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

Mineral	Chemical formula	Common occurrence
allanite	(Ce,Ca,Y,U)2(Al,Fe2)3(SiO4)3OH	carbonatites, pegmatites
apatite	Ca455(PO4)3(F,OH,Cl)3	carbonatites, phosphorites
brockite	(Ca,Th,Ce)PO4+H2O	carbonatites
euxenite	(Y,Ce,U,Th,Ca)(Nb,Ta,Ti)2(O OH)6	pegmatites, placers
fergusonite	(Y,Er,Ce,Fe)(Nb,Ta,Ti)O4	pegmatites, placers
fluorite	CaF2	carbonatites, veins
monazite	(Ce,La,Th,U)PO4	placers, carbonatites, veins
mckelveyite	Na2Ba4(Y,Ca,Sr,U)3(CO3)9+5H2O	trona, phosphorite
rhabdophane	(Ce,Y,La,Di)PO4+H2O	sedimentary, siliceous
samarskite	(Y,Fe,Ca,U,Ce,Th)(Nb,Ta,Ti)2(O,OH)6	pegmatites, placers
xenotime	YPO4	placers, veins(?)
zircon	ZrSiO4	placers

1 uranium and(or) thorium are present in some of these minerals as individual ions held in interstitial spaces. The radioactive elements are not part of the crystal structure of these minerals and are listed in the chemical formulas. U or Th is only shown in those minerals in which U or Th have always been reported.

General terms

pitchblende: variety of uraninite that can contain thorium and be amorphous.

gummite: fine-grained, secondary, hydrous uranium minerals associated with uraninite that can be amorphous.

Table 3

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

OCCURRENCES IN SEDIMENTARY ROCKS		
	Redox	
RX	roll front	Tertiary basins; widespread
RT	tabular	Inyan Kara Group
	Mechanical accumulations	
BP	beach placer	Mesaverde Formation
FP	fluvial placer	Flathead Formation
QC	quartz-pebble conglomerate	Magnolia Formation
	Chemical codeposition	
BS	marine black shale	Minnelusa Formation
MP	marine phosphorite	Phosphoria Formation
LP	lacustrine phosphorite	Wilkins Peak Mbr., Green River Fm.
	Carbonate	
CP	paleokarst	Madison Limestone, Little Mountain
CS	surficial coating	Browns Park Formation, Carbon County
CR	reduction related	Sundance Fm., Mayoworth area
DE	Desert evaporite	surface deposits, Lost Creek area
CL	Coal and lignite	Wasatch Fm., Great Divide Basin
OCCURRENCES IN IGNEOUS ROCKS		
IM	Initial magmatic	Precambrian granites
PG	Pegmatitic	Sherman Granite, Tie Siding area
MH	Magmatic hydrothermal	Eocene intrusives, Bear Lodge Mtns.
AT	Autometasomatic	Eocene intrusives, Bear Lodge Mtns.
PN	Pneumatolytic	possibly Yellowstone area
SP	Postmagmatic silica poor	uncertain
SR	Postmagmatic silica rich	possibly Moonstone Formation
OCCURRENCES IN METAMORPHIC ROCKS		
CM	Contact metamorphic	uncertain
AN	Anatectic	R. Platt pegmatites
MR	Redox	Little Man mine
MV	Vein	Esterbrook area
OTHER OCCURRENCES		
UC	Unconformity related	Silver Cliff mine
UN	Unknown	numerous
DESCRIPTIVE TERMS		
sz	shear zone hosted	
vn	vein hosted	
fr	fracture filling	
rp	replacement	

Table 4 Formation names used in this report

CENOZOIC	
Wasatch Formation	Tw
Fort Union Formation	Tfu
MESOZOIC	
Fox Hills Sandstone	Kfh
Inyan Kara Group	Kik
Fall River Sandstone	Kfr
Lakota Sandstone	Klk

Table 5 Status of information regarding the occurrences

unverified occurrence	uv
minerals noted	mn
minerals identified	mi
chemical analysis	ca
radiometric analysis	ra
radiometric survey	rs
prospect	pt
prospect--reserve delimited	pr
mine (active)	ma
mine (inactive)	mi
mine-surface	ms
mine-underground	mu
in-situ operation (active)	iso(a)
in-situ operation-research	iso(i)

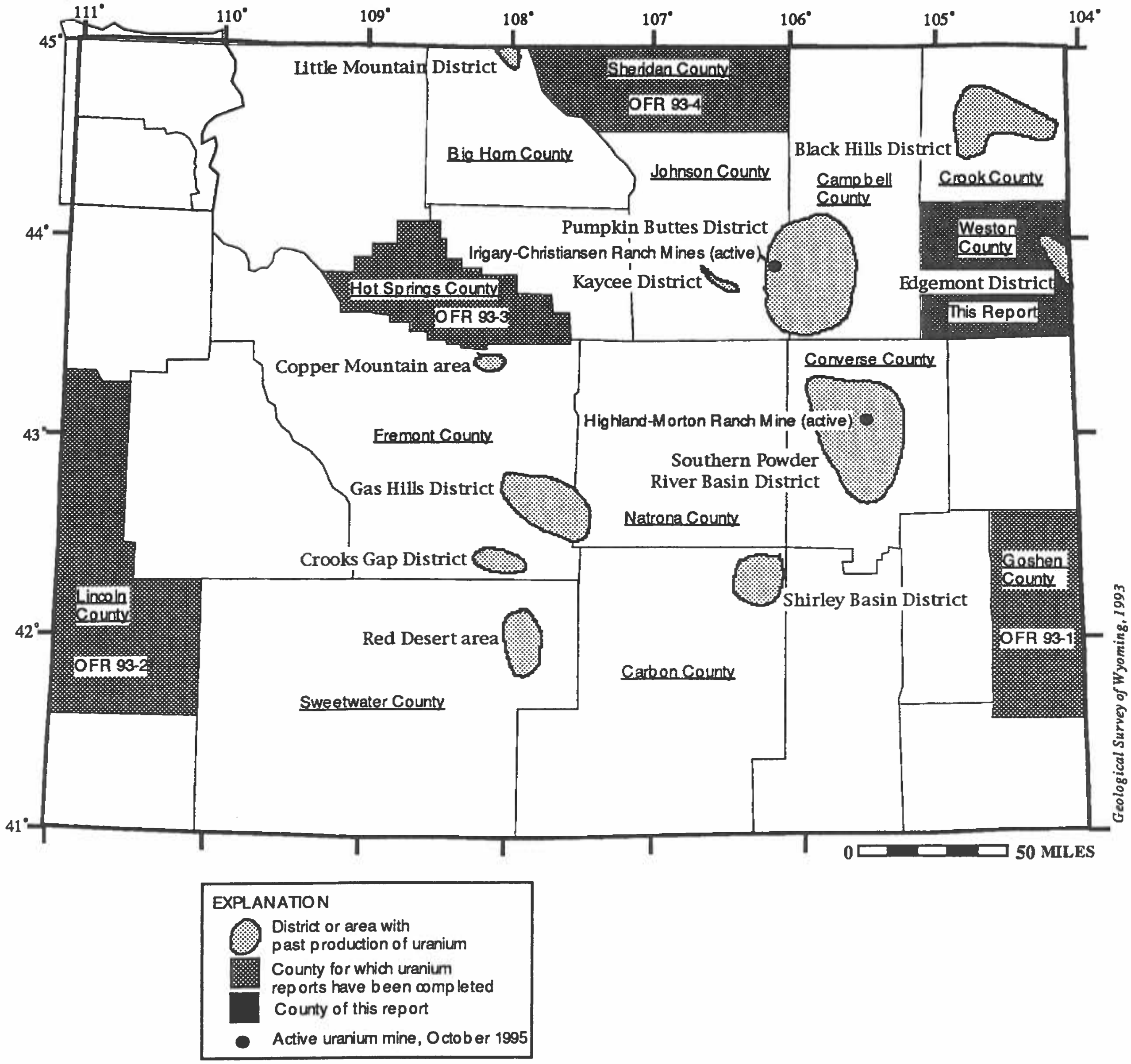

Figure 1 Index map of Wyoming showing the location of Weston County, counties for which uranium reports have been prepared, past producing uranium areas and districts, and mines active in October 1995.

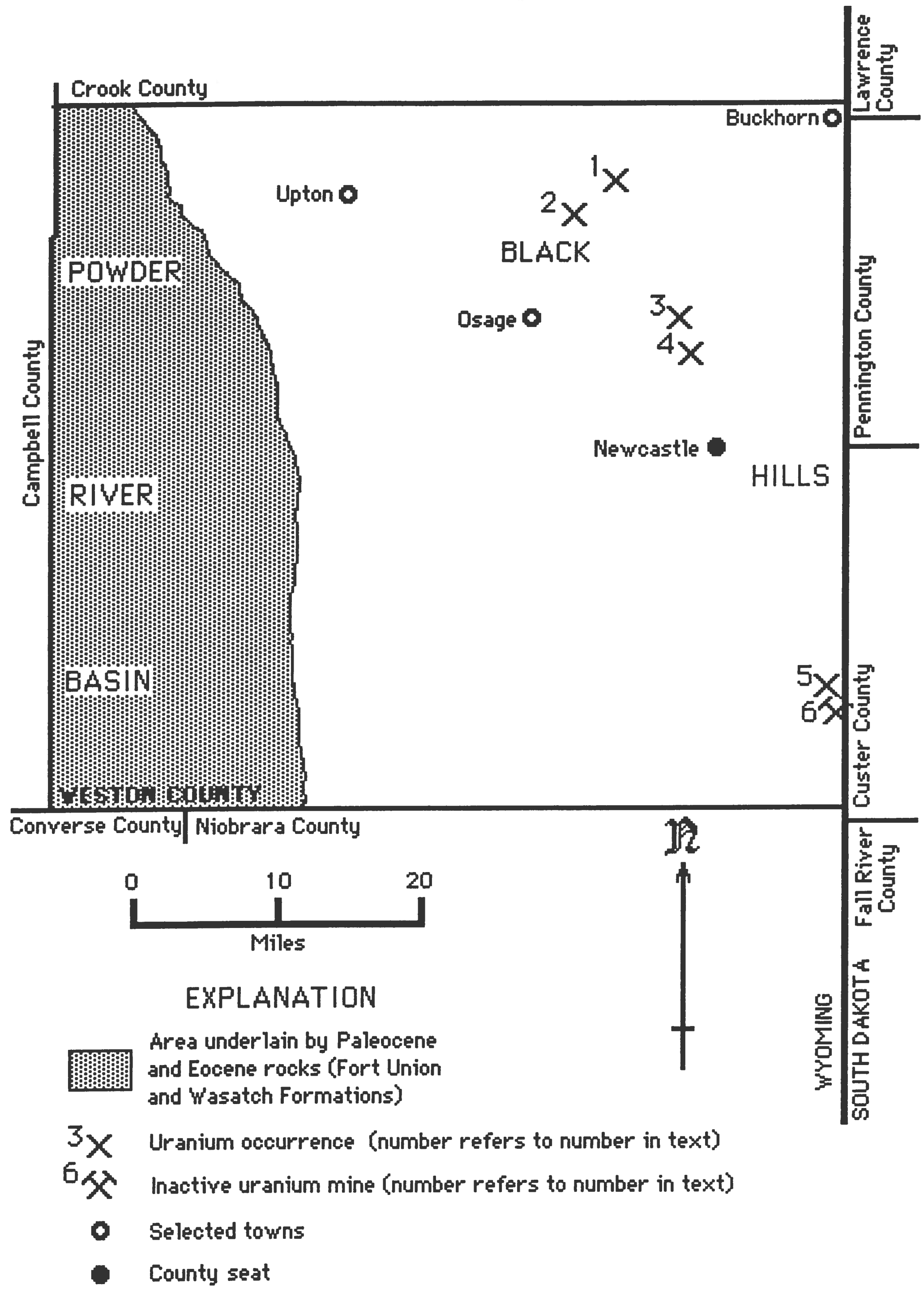

Figure 2 Map of Weston County, Wyoming, showing the location of uranium anomalies (number refers to the number in the text)