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OCCURRENCES OF RADIOACTIVE ELEMENTS IN SHERIDAN COUNTY, WYOMING

by

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Abstract

Although uranium has not been produced from Sheridan County, there is a paleoplacer deposit at Bald Mountain with uranium, thorium, and rare earth elements. The Bald Mountain paleoplacer was drilled by the U.S. Bureau of Mines in the early 1950's and a number of feasibility tests were performed on this material. Unfortunately, there has been little economic interest in this deposit, and no minerals have been produced commercially. There is also a Precambrian uraniferous quartz monsonite occurrence in the Bighorn Mountains. The eastern two-thirds of the county is underlain by the Paleocene Fort Union and Eocene Wasatch Formations, the units which contain the largest produced uranium deposits elsewhere in Wyoming. There are, however, few reported occurrences in these rocks in Sheridan County.

Uranium could be produced as a by-product if the rare earth elements or the thorium at the Bald Mountain paleoplacer were put into production. Given the present low demand for either of these commodities, this is not likely to happen in the near future.

Introduction

This open file report is the fourth in a county-by-county series of reports on uranium and other radioactive elements in Wyoming. The first three reports in this series covered Goshen, Lincoln, and Hot Springs Counties (Harris and King, 1993a, 1993b, 1993c). 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. William L. Chenoweth, Warren I. Finch, and J. David Love have been valuable sources of information throughout this project.

Uranium, thorium, potassium-40 (^{40}K), and their daughter products, such as radium, are the naturally-occurring radioactive elements. The first three elements and their isotopes commonly occur in nature. The element radium and its isotopes, however, 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. 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. Potassium-40 on the other hand occurs in nearly every rock type but has no commercial use.

Background

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 a uranium metallogenic province (Stuckless, 1979; Houston, 1979). In the United States, Wyoming ranks first in economic (minable) reserves of uranium (Energy Information Administration, 1990) and ranks second to New Mexico in cumulative uranium production and estimated resources. Twenty-eight uranium minerals and 12 other minerals known to contain accessory uranium have been identified in Wyoming (**Table 1**).

In Wyoming, the largest and most important discovered uranium deposits occur as roll fronts 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. One of the largest identified thorium resources in the United States occurs in Tertiary peralkaline igneous rocks in the southern Bear Lodge Mountains of northeastern Wyoming (Staatz, 1983). A smaller resource occurs in Cambrian fluvial paleoplacers at Bald Mountain in north-central Wyoming (Borrowman and

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

Mineral	Chemical formula	Common occurrence
	URANIUM MINERALS	
Reduced forms (U^{4+})		
brannerite	$(U,Ca,Ce)(Ti,Fe)_2O_6$	placers, pegmatites
coffinite	$U(SiO4)(OH)_4$	widespread
uraninite-thorian uraninite	$(U,Th)O_2$	widespread
Oxidized forms (U^{6+})		
abernathyite	$K_2(UO_2)_2(AsO_4)_2 \cdot 8H_2O$	sedimentary redox
autunite	$Ca(UO_2)_2(PO_4)_2 \cdot 8\text{-}12H_2O$	igneous and metamorphic
bayleyite	$Mg_2(UO_2)(CO_3)_3 \cdot 18H_2O$	sedimentary redox
becquerelite	$CaU_6O_{19} \cdot 10H_2O$	sedimentary redox
carnotite	$K_2(UO_2)_2V_2O_8 \cdot 3H_2O$	sedimentary redox
liebigite	$Ca_2(UO_2)(CO_3)_3 \cdot 11H_2O$	widespread
meta-autunite	$Ca(UO_2)_2(PO_4)_2 \cdot 4\text{-}6H_2O$	igneous and metamorphic
meta-torbernite	$Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$	widespread
meta-tyuyamunite	$Ca(UO_2)_2V_2O_8 \cdot 3\text{-}5H_2O$	sedimentary redox
phosphuranylite	$(H_3O)_2Ca(UO_2)_3(PO_4)_2(OH)_4 \cdot 4H_2O$	widespread
rutherfordine	$(UO_2)(CO_3)$	various
sabugalite	$HAl(UO_2)_4(PO_4)_4 \cdot 16H_2O$	widespread
schoepite	$UO_3 \cdot 2H_2O$	sedimentary redox
schroeckingerite	$NaCa_3(UO_2)_2(CO_3)_3SO_4F \cdot 10H_2O$	widespread
sklodowskite	$(H_3O)_2Mg(UO_2)_2(SiO_4)_2 \cdot 4H_2O$	widespread
torbernite	$Cu(UO_2)_2(PO_4)_2 \cdot 8\text{-}12H_2O$	widespread
tyuyamunite	$Ca(UO_2)_2V_2O_8 \cdot 8H_2O$	sedimentary redox
umohoite	$(UO_2)(MoO_2)(OH)_4 \cdot 2H_2O$	sedimentary redox
uranocircite	$Ba(UO_2)_2(PO_4)_2 \cdot 12H_2O$	various
uranophane	$(H_3O)_2Ca(UO_2)_2(SiO_4)_2 \cdot 3H_2O$	widespread
uranopilite	$(UO_2)_6(SO_4)(OH)_{10} \cdot 12H_2O$	widespread
weeksite	$K_2(UO_2)_2Si_6O_{15} \cdot 4H_2O$	various
zellerite	$Ca(UO_2)(CO_3)_2 \cdot 5H_2O$	sedimentary redox
zeuherite	$Cu(UO_2)_2(PO_4)_2 \cdot 40H_2O$	various
zippeite	$K_4(UO_2)_2(SO_4)_3(OH)_{10} \cdot 16H_2O$	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	$Ca_5(PO_4)_3(F,OH,Cl)_3$	carbonatites, phosphorites
brockite	$(Ca,Th,Ce)PO_4 \cdot H_2O$	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	$Na_2Ba_4(Y,Ca,Sr,U)_3(CO_3)_9 \cdot 5H_2O$	trona, phosphorite

Table 1. *(continued)*

Mineral	Chemical formula	Common occurrence
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 or cryptocrystalline variety of uraninite that can contain thorium.
gummite: fine-grained, secondary, hydrous, sometimes amorphous, uranium minerals associated with uraninite.
thucolite: uranium and thorium-bearing carbonaceous material.

[1]Apatite, fergusonite, fluorite, rhabdophane, xenotime, and zircon may sometimes contain either uranium or thorium in the interstitial spaces. 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.

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 1**).

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).

Although ^{40}K occurs in all rocks in the State, it has no commercial use. Because it 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.

Classification of deposits and occurrences

Deposits and occurrences of uranium and thorium are of many different types, based upon their method of formation. The classification scheme used in this report (**Table 2**) 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

Figure 1. Index map of Wyoming, showing major uranium districts and occurrences of radioactive elements (both areas and localities); the location of other county reports on radioactive elements (light stipple); and the location of Sheridan County, Wyoming (dark stipple). (OFR refers to a Geological Survey of Wyoming Open File Report number.)

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.

For the purposes of these county reports, an occurrence of a radioactive element is defined as a concentration in which the amount of the element, as determined by either radiometric or

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	
	Redox[1]	
RX	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	possibly Moonstone Formation, central Wyoming
	OCCURRENCES IN METAMORPHIC ROCKS	
CM	Contact metamorphic	uncertain
AN	Anatectic	Ralph 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)
UC	UNCONFORMITY-RELATED	Silver Cliff mine (southern Niobrara County)
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.

chemical analysis, is greater than 50 parts per million (0.005 percent). Equivalent uranium (eU), thorium (eTh), or other radioactive element concentration is determined by measuring the radioactivity of a sample. Chemical uranium (cU), thorium (cTh), or other radioactive element concentration is determined by quantitative chemical analysis. A concentration of radioactive elements greater than 50 parts per million (ppm), determined by **either** method, is sufficient to define an occurrence. Alternatively, an occurrence (or anomaly) is also defined as a locality with ten times or more radioactivity than the normal background radiation.

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 or have produced 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 resistance to deformation 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).

Occurrences of radioactive elements in Sheridan County, Wyoming

Summary

No uranium production has been reported from Sheridan County. Uranium and other radioactive elements occur in the Bighorn Mountains of western Sheridan County in rocks of Precambrian age and in rocks at the base of the Cambrian Flathead Sandstone; and in Tertiary age rocks in the eastern part of the county. The Flathead also contains paleoplacer concentrations of heavy minerals. Only three radioactive occurrences are reported from Tertiary sedimentary rocks, which cover the eastern three-fourths of the county (**Figure 2**). Terry and others (1974) reported that this northern part of the Powder River Basin in Wyoming and extending into Montana was not as favorable for uranium as the southern part of the basin.

The most important prospects for radioactive minerals in Sheridan County are in the Bighorn Mountains at the base of the Cambrian Flathead Formation. Although this area was prospected and drilled in the early 1950s, and prospected again in the 1970s, there has been no production.

Description of occurrences

The alphanumeric notation that precedes each of the following descriptions is keyed to **Figure 2** and **Tables 2** through **5**: the number refers to the map location (**Figure 2**), the letter(s) before

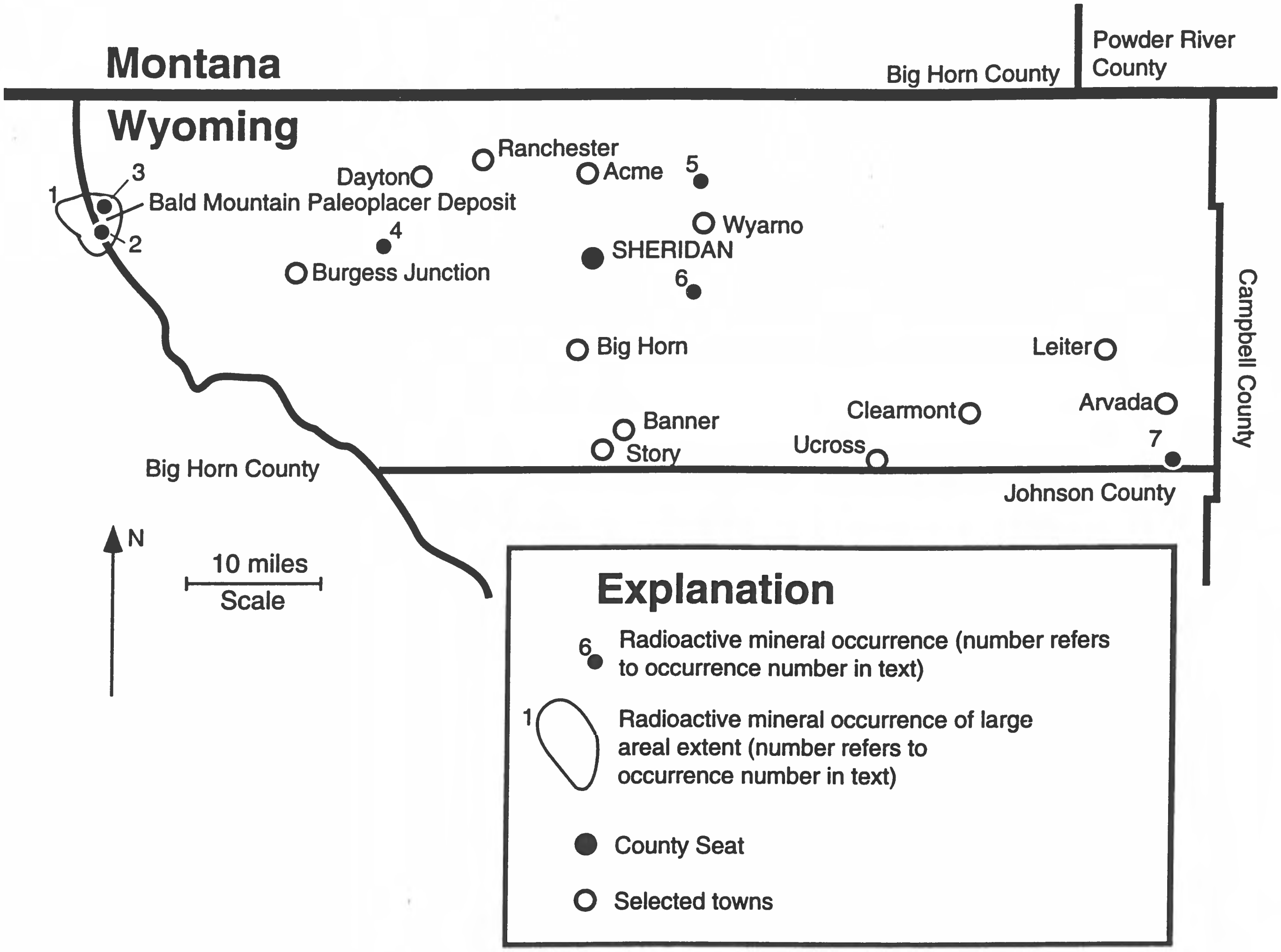

Figure 2. Index map showing the occurrences of radioactive elements and associated anomalies in Sheridan County, Wyoming.

the parentheses refers to the elements/anomaly present at the site (**Table 3**). In the parentheses, the group(s) of two letters refers to the deposit type(s) (**Table 2**); 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. Th,REE,U,Ti (FP) [Ꞓf] mn, rs. **Bald Mountain thorium (monazite) deposit;** located in parts of sections 19 through 23, and sections 27 through 33, T56N, R91W, and section 6, T55N, R91W. This area is divided by the Big Horn - Sheridan County line. Finnell and Parrish (1958) also plot a uranium occurrence in "terrestrial clastic sedimentary rocks" in section 21, T56N, R91W. The author examined this area in 1983 and located very high (0.5 milliroentgen per hour) radioactivity in several exploration trenches over 100 feet in length in sections 20 and 21. The radioactivity was from a poorly exposed paleoplacer deposit in the Flathead Formation in these trenches.

Table 3. Chemical symbols for elements and radioactive anomalies.

Symbols	Element or anomaly
Ag	silver
Cu	copper
Fe	iron
Mn	manganese
Ra	radium
Th	thorium
U	uranium
V	vanadium
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 Sheridan County, Wyoming.

Formation name	Symbol
CENOZOIC	
TERTIARY	
Eocene Wasatch Formation	Tw
Paleocene Fort Union Formation	Tfu
PALEOZOIC	
Cambrian Flathead Sandstone	Ꞓf
PRECAMBRIAN	
Granitoid rocks	pꞒgr

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—reserves delimited
ca	chemical analysis	ma[1]	mine (active)
ra	radiometric analysis	ms[1]	surface mine (inactive)
		mu[1]	underground mine (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 production of uranium ore exceeds 500 short tons.

McKinney and Horst (1953b) described the paleoplacers in the basal Flathead Formation at Bald Mountain as a potential thorium resource, with only minor uranium present. Recent work has indicated that these placers are fluvial, but their extent and geometry have not been determined (King and Harris, 1987).

2. Th, REE, U, Ti (FP)-[Cf] mn, pr. **Bald Mountain thorium (monazite) prospect**: located in S2 section 21, section 22, W2 section 23, N2 section 27, N2 section 28, S2 section 30, and section 31, T56N, R91W (McKinney and Horst, 1953b). Heavy minerals including monazite are found in the basal Flathead Sandstone (Middle Cambrian) on both sides of the Big Horn - Sheridan County line. The complete extent of the heavy mineral concentrations in this paleostream placer has not been determined, however, this location has proven, high concentrations of heavy minerals (King and Harris, 1987).

   The basal Flathead varies from a well-cemented, pale buff, fine-grained, arkosic sandstone to a deep-red, soft conglomerate, containing abundant subrounded quartz pebbles in an arkosic matrix. The heavy mineral zones vary from 2.5 feet to 15 feet in thickness and unconformably overlie Precambrian crystalline rocks.

   In 1952, the U.S. Bureau of Mines drilled holes, totaling 2,020 feet, in the Bald Mountain deposit. Their analyses of drill cuttings from the mineralized zones indicate that about 4,500 tons of monazite (in rock averaging 13.2 pounds of monazite per ton) is present in the deposit. An average of several samples of pure monazite yielded 8.8 percent ThO_2. Ilmenite is from 4.5 to 5 times more abundant than monazite in the samples. Six samples averaged 0.003 ounce per ton gold (McKinney and Horst, 1953b; Adams and Pritts, 1951a and b; McKinney and Horst, 1953a). Earlier sampling indicated gold concentrations of 0.1 ounce per ton (Darton, 1906; Darton and Salisbury, 1906).

3. Th, REE, u, Ti (FP) [Ꞓf] mn. **Bald Mountain recent thorium (monazite) placers**; located in sections 20 and 23, T56N, R91W, and section 6, T55N, R91W. Monazite-bearing Quaternary stream placers in the area were first noted by Wilson (1951). W. Dan Hausel (Geological Survey of Wyoming, written communication, 1989) also reported this occurrence from a reconnaissance examination of stream sediments for gold.

4. Th (IM?) [pꞒgr] ra. **unnamed (samples 18-20)**; located in section 36, T56N, R88W (Damp and Jennings, 1982). Three samples of Precambrian quartz monzonite contained from 53 to 133 ppm eTh, minor uranium (less than 10 ppm eU and cU_3O_8), yttrium (less than 100 ppm), and lanthanum (less than 100 ppm)(Damp and Jennings, 1982). Elevatorski (1976) also reports uranium in a quartz monzonite in this section.

5. U (CL) [Tw] ca, ra. **Enochs Draw (sample 2)**; located in NW SE section 25, T57N, R83W. Despite the lack of visible mineralization and low radioactivity (one to five times background), a sample of carbonaceous, brown silt near the Burgess coal bed in the Eocene Wasatch Formation contained 93 ppm cU_3O_8 (23 ppm eU and 12 ppm eTh) (Damp and Jennings, 1982).

6. U,V (CL) [Tw] ca, ra. **Hines (sample 209);** located in center SW section 14, T55N, R83W. A sample of baked rock (clinker) from a borrow pit in the Wasatch Formation contained 77

ppm cU_3O_8 (61 ppm eU and 26 ppm eTh). The radioactivity of the clinker bed was about three times background and the clinker did not contain visible uranium minerals (Damp and Jennings, 1982). Davidson (1953) previously reported that the clinker contained only 0.002 percent (20 ppm) uranium (0.005 percent or 50 ppm eU) and 0.14 percent V_2O_5.

7. rad (RX) [Tfu] rs. **Cottonwood Creek**; located in SE section 15, T53N, R77W. In 1969, the author measured radioactivity up to twenty times background in cuttings from an exploration drill hole. The anomalous material was from a sandstone containing carbonized plant debris in the Paleocene Fort Union Formation approximately 200 feet below the surface.

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