THE GEOLOGICAL SURVEY OF WYOMING
HORACE D. THOMAS, State Geologist

REPORT OF INVESTIGATIONS NO. 7

RADIOACTIVE MINERAL DEPOSITS OF WYOMING

by
William H. Wilson

UNIVERSITY OF WYOMING
Laramie, Wyoming

APRIL, 1960

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CONTENTS

CONTENTS—Continued

ILLUSTRATIONS

RADIOACTIVE MINERAL DEPOSITS OF WYOMING

by

WILLIAM H. WILSON*

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ABSTRACT

Uranium deposits in Wyoming are known to occur in rocks of pre-Cambrian age and at least 33 different formations ranging in age from Cambrian to Pliocene. Most of the current production comes from the Eocene Wind River formation in the Gas Hills area of Fremont and Natrona counties. Additional production comes from the Madison formation (Mississippian) in Big Horn County, the Fall River and Lakota formations (Lower Cretaceous) in Crook County, the Wasatch formation (Eocene) in Campbell, Converse, and Johnson counties, and the Browns Park formation (Miocene?) in Carbon County.

Thorium and rare earth mineralization in Wyoming occurs in pegmatites and veins in rocks of pre-Cambrian age; in consolidated placer-type deposits of Middle Cambrian, late Cretaceous, and Tertiary ages; and in Quaternary alluvial deposits. Euxenite is mined from a pegmatite in Carbon County.

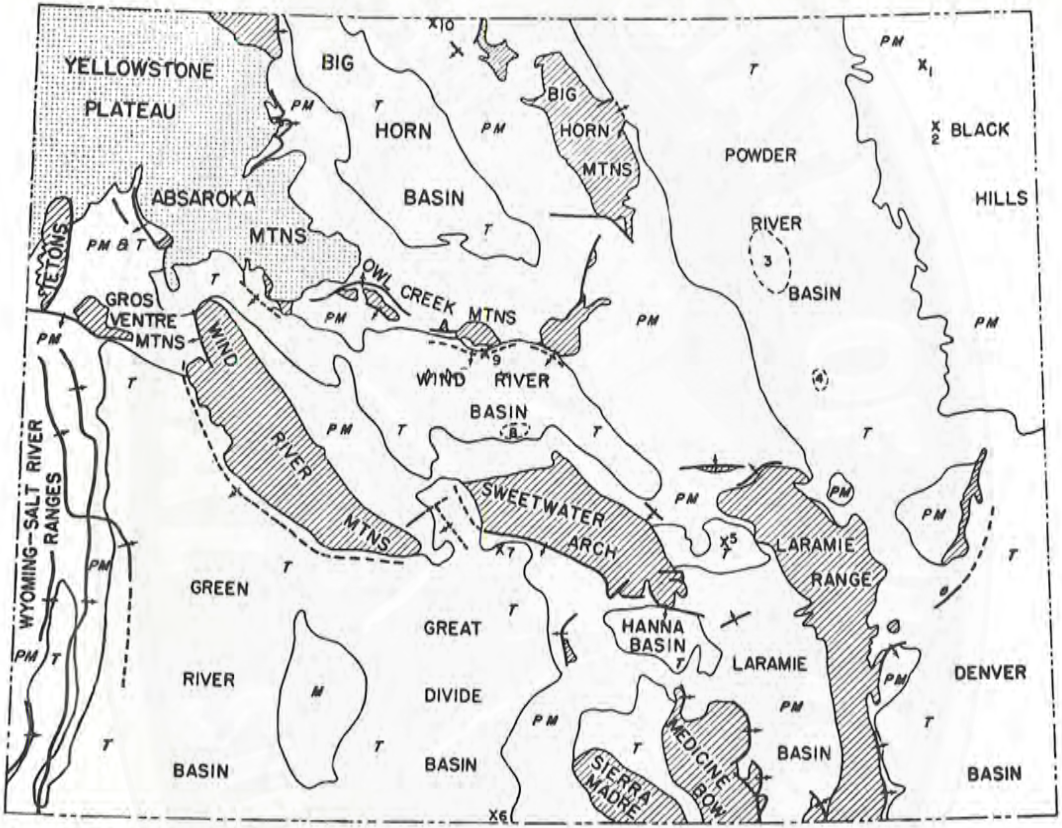

Figure 1. Generalized geological index map of Wyoming showing major structural features and producing uranium areas. Precambrian areas are cross hatched. Paleozoic and Mesozoic areas are indicated by the symbol PM. Tertiary areas are indicated by the symbol T. Tertiary volcanics are shown by coarse stipple. Faults are shown as heavy lines with arrows showing direction of movement of hanging wall of thrust faults. Uranium producing areas are: 1) New Haven, 2) Carlile, 3) Pumpkin Buttes, 4) So. Powder River Basin, 5) Shirley Basin, 6) Baggs-Poison Basin, 7) Crooks Gap, 8) Gas Hills, 9) Copper Mountain, and 10) Little Mountain.

URANIUM DEPOSITS

INTRODUCTION

Significant uranium deposits were first discovered in Wyoming at the Silver Cliff mine near Lusk in 1918. In 1936, schroeckingerite (formerly called dakeite) was discovered in the Lost Creek area of Sweetwater County. The first discovery of minable uranium ore deposits was made in the Pumpkin Buttes area in October, 1951. These were later followed by discoveries in the Aladdin, Carlile, and Hulett Creek areas, Crook County; Crooks Gap and Gas Hills areas, Fremont County; Baggs-Poison Basin area, Carbon County; southern Powder River Basin area, Converse County; and the Little Mountain area, Big Horn County; during the years 1952 through 1955.

During the earlier years of the uranium boom in Wyoming, the principal uranium production came from the deposits in the Lower Cretaceous Inyan Kara group in the Black Hills area; now, however, most of the current (1960) production comes from the Eocene Wind River formation in the Gas Hills area. It is anticipated, however, that important production will eventually come from the Wind River formation in the Shirley Basin as evidenced by recent exploration in that area.

At the present time (1960), there are four uranium mills operating in Fremont County and one in Natrona County. Western Nuclear Corporation operates an 845-ton mill at Jefffry City, near the Crooks Gap area, which utilizes acid leach and resin-in-pulp cirquits. The Lucky Mc Uranium Company's (division of Utah Construction and Mining Company) 980-ton mill in the Gas Hills area employes acid leach and moving bed column ion exchange cirquits. In the central Gas Hills area, Federal-Radorock-Gas Hills Partners operate a 522-ton mill which utilizes acid leach and resin-in-pulp cirquits. Susquehanna-Western, Inc., (formerly Fremont Minerals, Inc.) operates a 500-ton custom mill at Riverton, which incorporates both acid leach and carbonate leach processes and solvent extraction. Susquehanna-Western has also constructed a 250-ton sulfuric acid plant adjacent to the mill. The output from this plant will be sufficient to supply all the acid required by the uranium mills of the area. The sulfur used in the plant is obtained from the Big Horn Basin, where it is produced as a byproduct from "sour-gas" wells.

A fifth mill, operated by Globe Mining Company (subsidiary of Union Carbide Corporation), is located in the eastern Gas Hills area of Natrona County. This is a 492-ton mill which employes acid leach and a resin-in-pulp process.

At the present time (1960), the production of uranium is the largest mining industry in the State. Wyoming is considered to have the second largest reserves of uranium in the United States; New Mexico ranks first. Estimate of the State's reserves (measured, indicated, and inferred) by the U. S. Atomic Energy Commission (December 31, 1959) amounted to 15.8 million tons of 0.34 percent U_3O_8. In 1957, 122 mining operations produced 274,699 short tons of ore containing 1,189,947 pounds of U_3O_8, while in 1958, 145 operations produced 651,790 short tons containing 3,282,698 pounds of U_3O_8 (117). The estimated 1959 production was 668,734 tons with an average grade of 0.25 percent U_3O_8.

There are known occurrences of uranium (excluding uraniferous coal, phosphate, and carbonaceous shale) in 20 of the State's 23 counties. In addition to pre-Cambrian vein-type deposits, local concentrations of uranium occur in at least 33 different formations which range in age from Cambrian to Pliocene. Uranium has even been reported from Quaternary pediment gravels near Saratoga (94, 98) and in alluvial clays in the Lost Creek area. Most of the uranium ore production, however, has come from the Madison formation of Mississippian age, the Fall River and Lakota formations of Lower Cretaceous age, the Wasatch and Wind River formations of Eocene age, and the Browns Park formation of Miocene (?) age.

Most of the uranium deposits in Wyoming, irrespective of the type of deposit, are clustered: (a) where large northwestward-trending structures, such as major basins and mountain ranges, are intersected by later northeastward-trending structures; (b) the intersection of northwestward-trending structures by en-echelon faults and folds; or (c) near the axial parts of major basins (71, 72). Individual deposits are localized along structural terraces, monoclines, anticlinal crests, synclinal troughs, faults, joints, regional unconformities, regional and local lithologic changes and chemically and physically favorable host rocks.

The principal uranium-bearing minerals in Wyoming are autunite, metaautunite, carnotite, schroeckingerite, tyuyamunite, metatyuyamunite, uranophane, uraninite and coffinite. The deposits in the Powder River Basin and Black Hills areas are composed mainly of uranium-vanadium minerals with some vanadium minerals and uranium silicates, while those in other major producing areas contain uranium phosphates, arsenates, carbonates, and silicates with minor occurrences of vanadium minerals (12). Selenium is known to occur in all the producing areas with the possible exception of the Little Mountain area in Big Horn County.

The original source of uranium is still subject to controversy, and the problem will not be discussed further; suffice to say that the majority of the evidence supports the "volcanic ash leach" hypothesis. The interested reader is advised to consult publications 115 and 116 listed at the end of the bibliography for further information on this topic. There can be no doubt, however, of the influence of ground water movement and position of the ground water table with respect to local structural features in localizing the uranium deposits.

In addition to the deposits listed in the following pages of this bulletin, low-grade uranium deposits are known to occur in the Permian Phosphoria formation which crops out in various areas in the western half of the State. The maximum uranium content increases areally from east to west as the total phosphate of the phosphatic members increases. Analyses from the upper phosphate zone, Sublette Ridge. Lincoln County, are reported to contain a maxima of 0.010 to 0.018% uranium (53). Most of the uranium is in dispersed form in the phosphate beds and is mainly concentrated in the carbonate-fluorapatite grains (53). Because of the large tonnages of these low-grade deposits, it is possible that some uranium could be recovered in the future as a by-product of the manufacture of triple superphosphate.

Finally, uraniferous coals and carbonaceous shales have been reported from the Auburn area, Lincoln County; Evanston area, Uinta County; Burnt Fork area, Sweetwater County; Cambria coal mines, Weston County; Powder River Basin area, Campbell, Converse, and Johnson Counties (19, 42, 99); as well as the Red Desert area, Sweetwater County (which is described in the following pages).

Future exploration for uranium will undoubtedly be directed toward the deeper parts of the sedimentary basins in the State. Additional vein-type deposits may be found in the pre-Cambrian rocks, since many of these areas have been little prospected because of their remoteness. Finally, in view of the uranium occurrences on Little Mountain in Big Horn County, it would seem that some attention should be directed toward exploring the Madison-Tensleep sequence on the west flank of the Big Horn Mountains.

At the present time most of the uranium is being used for military requirements; however, some is being utilized in reactor programs. The future of nuclear fuel is very bright, particularly for those countries where shortages of water resources and fossil fuels exist. Civil applications of nuclear explosions may be useful in the following: construction of harbors, production of artificial aquifers for replenishing water tables, breaking up of low-grade ore deposits prior to leaching, increased recovery of oil fields, direct recovery of oil shales and tar sands by loosening and heating, and production of fill and riprap for road construction. Radioactive isotopes are being used in medicines and surgery and in determining rates of wear in machines and various mechanical devices.

Two items of significant interest to the uranium prospector in Wyoming should be recognized: (1) the Supreme Court of Wyoming has indicated that radiation counter readings are, in themselves, held to be insufficient proof of discovery to justify staking a lode mining claim; and (2) a discoverer of a mineral deposit may, in lieu of a discovery shaft, drill one hole, or holes, to aggregate at least 50 feet of which no hole shall be less than 10 feet, and at least one of which shall cut or explore deposits of valuable minerals.

The writer wishes to acknowledge the cooperation of various members of the U. S. Atomic Energy Commission and U. S. Geological Survey, who made available much unpublished data used in compiling this report on uranium deposits. The writer has endeavored to make it as complete and as representative as possible; however, it is also recognized that there are undoubtedly occurrences of uranium in the State for which no data are available.

PRODUCING AREAS

BIG HORN COUNTY

Little Mountain Area; T. 58 N., R. 94 W. The Little Mountain area is a long anticlinal ridge trending northwest-southeast between East Pryor Mountain, Montana, and the main mass of the Big Horn Mountains in Wyoming. Rocks cropping out on Little Mountain consist mainly of the upper part of the Madison limestone of Mississippian age, and are overlain by remnants of the Amsden and Tensleep formations of Pennsylvanian age.

Uranium mineralization occurs in the upper part of the Madison formation, which consists of gray dense crystalline brecciated limestone with abundant caverns and Amsden redbed fill. The ore deposits range up to 5,000 to 8,000 tons in size and occur as enrichments of silt-clay-rock fills of caverns and solution cavities. The deposits conform to the size and shape of the cave or cavity in which they are contained. Most deposits are less than 500 tons in size, and many contain only a few tons or pounds of ore. The tenor usually exceeds 0.50% U_3O_8.

The major ore deposits consist of tyuyamunite and metatyuyamunite associated with calcite interstratified with silts and clays within caverns and solution cavities. Uranium minerals associated with crystalline calcite also form encrustations on thin slabby limestone collapse blocks, debris on the floors, and through the solution breccias.

The east ore body of the Fusner mine (Lisbon Uranium Corporation) was one of the largest deposits mined in the area and produced about 5,000 tons of ore averaging about 0.80% U_3O_8. The ore occurred in an irregular cavern whose western side terminated against a north-south trending joint. The length of the cavern followed this joint for about 150 ft., and the width varied from 35 to 80 ft. The floor and back paralleled essentially flat-lying bedding with an average height of 20 to 25 feet. Tyuyamunite and metatyuyamunite occurred in a fanlike deposit, which was composed of reddish-brown 'Amsden derived' silts and angular limestone fragments, as well as in two separate interstratified beds in the intercavern sediments. The lower ore bed varied in thickness from 1 to 3 feet, and the upper ore bed varied from 2 to 8 feet (33).

Lisbon Uranium Corporation has been the major producer in the area; however, early in 1958, Modern Mines Development Company sank a 740-foot inclined shaft to open up a newly drilled ore body, 13 feet thick, 100 feet wide and 260 feet long.

CAMPBELL AND JOHNSON COUNTIES

Pumpkin Buttes Area. The Pumpkin Buttes uranium area consists of about 350 square miles near the center of the Powder River Basin. Uranium mineralization was discovered in the area in October, 1951 (43).

The Pumpkin Buttes area lies along the axis of a broad anticline that plunges gently northwest. The major part of the area is underlain by the Wasatch formation of Eocene age and this is unconformably overlain by thin remnants of the White River formation of Oligocene age. The Wasatch formation is about 1,200 feet thick and consists of lenses of sandstone that are dispersed throughout a sequence of drab siltstone, claystone, and carbonaceous shale beds.

The uranium deposits are associated with, and occur within, the boundary of the area of the red standstone lenses in the lower half of the exposed Wasatch (87). All known deposits occur within 150 feet of the surface and do not extend more than a few feet below the water table. Minable deposits may be classified into two general types, based on size, grade, and mineralogy:

(1) Small high-grade concretionary deposits usually containing less than 25 tons of uranium ore with an average grade of 1% and over. The concretions are composed of uraninite associated with manganese or iron oxides and surrounded by uranophane and/or secondary uranium vanadates. The majority of mines in the Pumpkin Buttes area were developed in this type of deposit (61).

(2) Deposits containing as much as 5,000 tons of ore averaging about 0.50% uranium. This type of deposit occurs in the buff-colored sandstone at the contact with the pink to red sandstone. Uranium minerals occur as a shell, varying from several inches to several feet thick, representing the furthermost penetration of red coloration and transecting all sedimentary features. The uranium vanadates, where the contact is irregular, are also disseminated throughout the area between the red-colored stringers and may attain a thickness of 8 to 12 feet. Small high-grade uraninite pods associated with pyrite and selenium (21) are found in the buff sandstones at or near the contact. To a lesser extent, the uraninite-manganese-iron oxide pods are found in the red sandstones at the contact (61).

At least 200 uranium occurrences are known within the Pumpkin Buttes area. The first ore was shipped by Jenkins and Hand in July, 1953. As of January, 1958, there have been 62 producers, of which 10 were still active. The total production from each deposit mined has varied from less than 100 to 1,000 tons. More than 5,000 tons of ore has been mined by one operator. The ore is shipped to the Mines Development mill at Edgemont, South Dakota.

CARBON COUNTY

Baggs-Poison Basin Area; secs. 2, 3, 4, 5, 8, 9, 10, 11, T. 12 N., R. 92 W., secs. 32, 33, 34, 35, T. 13 N., R. 92 W. Uranium mineralization occurs in the Browns Park formation of Miocene age. The Browns Park formation, which covers much of the topographic basin that coincides with the asymmetric westward plunging Poison Basin syncline, is an outlying remnant here and consists of 300 feet of conglomerate, highly cross-bedded sandstone, and tuffaceous sandstone and quartzite.

Uranophane, metaautunite, and schroeckingerite are erratically distributed through a strongly cross-bedded sandstone overlying the basal conglomerate of the Browns Park formation. The uranium, in many places, is usually so finely disseminated in the sandstone that little or no mineralization is visible even in strongly radioactive samples (74).

Uraninite and coffinite, associated with pyrite and ilsemannite (hydrous molybdenum oxide), occur in the unoxidized or "blue" zone at depths of 20 to 70 feet (75). These deposits, which occur in a pale to moderate blue argillaceous very fine to fine-grained sandstone, are up to several feet in thickness and are in the shape of gently dipping blankets following the bedding (23). Faults in the area have also been instrumental in determining the shape of some deposits.

The blue pyritic sandstone, which is usually found below the local water table, is believed present under many square miles of the Poison Basin area.

Selenium is associated with the uranium deposits as an unknown compound and appears in greater concentrations in the unoxidized rather than in the oxidized zone (75).

Intermittent production has occurred from Shawano Development Corporation's and Basins Engineering's operations since the discovery of mineralization in October, 1953. Current production is being shipped to the Trace Elements Mill at Maybell, Colorado.

Shirley Basin Area; approximate location, Ts. 27, 28 N., Rs. 77, 78 W.

The subsurface uranium mineralized zone, as reported in March, 1959, occupies an irregular area approximately 11 miles long (north to northwest direction) by 5 miles wide (east-west direction). Uraninite (?), which is reported to be the principal uranium mineral, coats, cements, and replaces detrital mineral grains in the lenticular arkosic sandstones of the lower part of the Wind River formation of Eocene age. In the southern part of the area (T. 27 N., R. 78 W.), the mineralized zone, or zones, varies from 80 to 270 feet in depth. These appear to have a general northwesterly trend which may be related to a pre-Tertiary erosional trough or valley. The mineralized zones in the northern part of the area (T. 28 N., R. 78 W.) are reported to vary from 370 to 450 feet in depth. Individual mineralized bodies are reported to vary in thickness from one-half to 25 feet; however, the average is between four and five feet. Reserves of several million tons averaging about 0.50 percent U_3O_8. have been reported from the Shirley Basin area (78, 89).

Utah Mining Company, which has an ore allocation of 150 tons per day, has sunk a 365-foot shaft to penetrate a reported 4,000-foot long ore body. Production will be initiated in 1960, and the ore will be shipped to the Lucky Mc mill in the Gas Hills. Tidewater Oil Company has developed an extensive subsurface ore body west of Utah Mining Company's property, and is reported to be currently negotiating a contract with the U. S. Atomic Energy Commission for the allocation of ore in the 1962-1966 period. Kerr McGee Industries has developed a large near-surface ore body which will permit strip mining if an allocation is received.

CONVERSE COUNTY

Southern Powder River Basin Area

The most prominent uranium deposits here occur in the Monument Hill area in the Dry Fork area of the Cheyenne River and in the Box Creek area to the south. A few scattered uranium prospects, such as the Turner Crest area, lie between the Monument Hill area and the Pumpkin Buttes area to the north.

In general, the geology of the area is similar to that previously described for the Pumpkin Buttes area, in that the area is predominantly underlain by the Wasatch formation of Eocene age. These rocks, which dip gently northwest, are underlain by the Fort Union formation of Paleocene age. The Wasatch formation varies from 500 to 1,000 feet thick and consists of claystone and siltstone beds interbedded with irregularly spaced sandstone lenses, and coal and carbonaceous shale beds. The uranium deposits occur in the central part of the area of Wasatch outcrop where the lenses of sandstone are reddish in color.

The yellow uranium minerals, tyuyamunite, carnotite, uranophane, and locally, liebigite, are disseminated in the sandstone. Small masses of uraninite and pyrite-cemented sandstone, commonly rimmed by thick halos of yellow oxidized uranium minerals, also occur in places (88).

Monument Hill Area. Uranium mineralization in the Monument Hill area was discovered by an AEC airborne radiometric survey in October, 1952. The uranium deposits occur in the bottom 100 to 120 feet of a Wasatch sandstone unit, of which the lower 65 feet is a red ferruginous stained sandstone. Here, the most productive deposits occur in a north-trending belt about ½ mile wide by 6 miles long. With the exception of two, all mines are in the buff to white sandstones as much as several hundreds of feet from the red-buff contact (59).

The ore bodies are generally irregularly tabular with the long axes parallel to the red-buff contact in a rude north-south direction. They are apparently confined to a relatively narrow zone and may occur at various elevations within the zone. These bodies pinch and swell and may be interconnected by areas of submarginal mineralization. The average size of an ore body is approximately 100 feet long, 70 feet wide and 9 feet thick; however, one body is 1,000 feet long, as much as 400 feet wide, and as much as 50 feet thick. The deposits range in size from a few hundreds of tons to as much as 50,000 tons of ore with grades averaging between 0.2 and 0.3% uranium (61).

Carnotite and tyuyamunite are the most common minerals and occur as dusty grain coatings or are disseminated interstitially in the sandstone. The uranium vanadates also occur as secondary haloes surrounding uraninite and as replacement of carbonaceous material and clay galls. Uraninite-pyrite-calcite concretions occur locally. In some cases uraninite is found as a cementing material forming small tabular masses that may weigh as much as several hundred pounds. Uranophane, gummite, liebigite, metaautunite, and, occasionally, native selenium have also been reported from this area (59, 61).

Sixteen producers have been active in this area with production varying from less than 100 to over 2,500 tons. As of January, 1958, Loma Uranium Corporation has produced 20,000 tons from the Hardy pit (NW ¼ sec. 27, T. 38 N., R. 73 W.), and 15,000 tons from the Zee pits (NW ¼ sec. 27, T. 38 N., R. 73 W.). Jenkins and Hand have produced 15,000 tons from the Pat mines (NW ¼ sec. 3, T. 37 N., R. 73 W.).

CROOK COUNTY

Aladdin Area; SE ¼ SE¼ sec. 7, NW¼ NW¼ sec. 17, NE¼ NE¼ sec. 18, T. 54 N., R. 60 W. Uranium mineralization is reported to occur in three stratigraphic units: the lower 30 to 50 feet of the Fall River sandstone, the upper one-third of the Fuson shale and the upper one-third of the Lakota sandstone; all of Lower Cretaceous age. Carnotite and autunite are the principal uranium minerals (20).

Several small mines are reported to be operating in the area.

Hauber Mine; sec. 3, T. 55 N., R. 67 W. Uranium mineralization occurs at or near the base of the Lakota sandstone of Lower Cretaceous age. The ore zone, which varies in depth from 290 to 360 feet below the surface, is a dark-gray to black medium-grained carbonaceous sandstone which in some places is conglomeratic. The uranium minerals are believed to be uraninite and coffinite (90).

The ore deposit is currently being mined underground by the Homestake Mining Company.

Hulett Creek Area; sec. 3, SE 1/4 sec. 4, sec. 10, T. 55 N., R. 67 W. (79). The uranium deposits mined in this area occur in the upper sandstone unit of the Fall River formation of Lower Cretaceous age. A gentle north-plunging anticline, about one mile and a half long and a mile wide, cut by a series of steeply dipping northeast-trending normal faults, crosses the area.

The ore deposits occur near the base or along the edges of a sandstone lens and are generally elongate parallel to the margins of this lens. The greatest known mineralization is localized in a synclinal trough that abuts against and dips towards a normal fault (80).

Mineralized areas are 200 to 1,200 feet long, 5 to 400 feet wide, and trend in a northwesterly direction. Individual ore bodies are 5 to 200 feet long, 5 to 80 feet wide, and a few inches to 10 or more feet thick. Minable deposits are made up of one or more ore bodies.

Depending upon the position of the water table, the deposits consist of the oxidized minerals, carnotite, metaautunite, and metatyuyamunite, or the unoxidized uraninite-coffinite association. These minerals fill the interstices between, and coat sand grains, or are disseminated in the carbonaceous material.

Most of the production has come from the six open pits of the Homestake Mining Company; however, Sodak Uranium and Mining Company has mined a nearby deposit.

FREMONT COUNTY

Copper Mountain Area

Uranium mineralization occurs in an area of about 14 square miles lying between Cedar Ridge and Copper Mountain. Most of the known deposits occur in Tertiary rocks (see additional descriptions under Prospects); however, local concentrations occur in pre-Cambrian granite, schist, gneiss, and dikes. These are irregular, scattered, and vary in depths up to 100 feet (41).

Little Mo Mine; NW 1/4 sec. 29, T. 40 N., R. 92 W. Uranium mineralization occurs in the Tepee Trail (?) formation of late Eocene age, and also in adjacent deeply weathered pre-Cambrian granitic rock. The Tepee Trail (?) formation here consists of a generally well decomposed arkosic eluvial and clayey material with abundant granitic boulders up to 4 to 5 feet in diameter. Uranophane and metaautunite occur throughout the clayey matrix and granitic boulders as streaks and intergranular and fracture fillings and coatings.

Much of the mining (1955) has been from the underlying zone of decomposed pre-Cambrian granitic rock which contains pods of clay, hornblende-biotite schist, and pegmatite. Uranophane, metaautunite, coffinite and uraninite occur disseminated in, and as streaks and specks in, the decomposed zone (108).

Limited but consistent production from the open-pit operations of the Little Missouri Mining Company has been going on here since early 1955.

Bonanza Mine; sec. 4, T. 39 N., R. 92 W. Uranium mineralization occurs in the Wind River formation about 30 to 70 feet below the bentonitic late Eocene Tepee Trail (?) formation. The ore deposits are associated with pyritic and carbonaceous siltstones which were deposited in a shallow trough eroded in pre-Cambrian rocks. Autunite and metaautunite occur in the oxidized zone which is in a buff to yellow medium-grained sandstone. The average grade is 1.3% U_3O_8. Uraninite and coffinite occur in the unoxidized zone about 30 to 45 feet below the oxidized zone (14).

Ore estimates from drilling total 30,000 tons. The deposit was formerly mined in 1958 by the Shoni Uranium Corporation (14).

NW 1/4 sec. 3, T. 39 N., R. 92 W. Several hundred tons of uranium ore were shipped from the Kermac mine in the summer of 1955 (41).

Crooks Gap Area; secs. 8, 9, 16, 17, 20, 21, 28, 29, T. 28 N., R. 92 W. The uranium mineralization, which was first discovered by a private airborne radioactive survey in February, 1954, occurs on the east side of Crooks Gap in a northerly trending belt about 4 miles long by 2 miles wide.

Rocks, ranging in age from pre-Cambrian to Miocene, crop out in the Crooks Gap area. Asymmetric anticlines and thrust faults characterize the pre-Tertiary rocks, while gentle folds and normal faults occur in the Tertiary rocks. The major structural feature of the area is a northward-dipping thrust fault zone which trends somewhat west-northwest at the northern edge of the area.

The most significant uranium deposits occur in the conglomeratic arkose of the Eocene Wasatch formation; however, uranium ore has been mined (sec. 9, T. 28 N., R. 92 W.) along the plane of a high angle reverse fault which places the Triassic Chugwater formation on the Cretaceous Cody shale (93). Additional uranium occurrences are reported from the overthrust Cambrian rocks in the northern part of the area. Uranophane, metaautunite, and autunite, which are the principal uranium minerals, occur in the latter deposits.

The uranium mineralization in the Wasatch formation occurs in six or sometimes more, zones in the lower part of the formation (58). Minerals identified are uranophane, uraninite, coffinite, becquerelite, phosphyranylite, and metatyuyamunite (58). The mineralized bodies appear to be localized along axes of shallow synclinal troughs (which may be sedimentary channels) that are superposed at right angles to, and situated on the flanks of, a northerly trending anticline. Other factors that appear to control the localization of deposits are: (1) presence of carbonaceous material, (2) changes in permeability of host or surrounding rocks, and (3) synclinal structures and faults.

The latter control the movement of uranium-bearing groundwater and hence influence the deposition of uranium in the area. Mineral deposits are known to ocurr at depths of up to approximately 470 feet in this area.

Open-pit mining operations have been intermittent. The Coke River Development Company, mining the Sno-Ball claims (now owned by Western Nuclear Corporation) in sec. 29, T. 28 N., R. 92 W., were the earliest uranium producers in the area. Trial shipments were also made by Wyoming Uranium, Gaddis Mining, San Juan and Split Rock Mining companies. Recent exploration by the Green Mountain Uranium Corporation (Phelps-Dodge Corporation) on Wyoming Uranium's property has indicated a reserve of over a million and one-half tons of potential uranium ore. Underground development work on this property was initiated in 1959, and the ore is being shipped (1960) to the Western Nuclear mill.

In 1957 and 1958, Continental Materials Corporation was the principal producer in the area, mining from a deep pit on the Gaddis claims. In 1958, Continental completed the shaft to its Seismic mine and developed the first large underground uranium mine in central Wyoming. In 1959, additional production came from Lucky Mc's operation on the Heald property.

FREMONT AND NATRONA COUNTIES

Gas Hills Area; NW 1/4 T. 32 N., R. 90 W.; NE 1/4 T. 32 N., R. 91 W.: T. 33 N., Rs. 89, 90 W.; SE 1/4 T. 33 N., R. 91 W. Uranium mineralization was first discovered in the area on September 9, 1953, by Neil McNeice, of Riverton, Wyoming. A month later, additional discoveries were reported as a result of reconnaissance studies of the U. S. Geological Survey (44).

The uranium deposits, with the exception of two minor occurrences in underlying Mesozoic rocks and in upper and middle Eocene rocks (44), occur in the upper part of the Wind River formation of Lower Eocene age. The Wind River formation dips gently south and rests unconformably on rocks ranging in age from Cambrian to Late Cretaceous. Overlying the Wind River formation are tuffaceous rocks of middle and late Eocene and Oligocene ages.

Both the upper and lower units of the Wind River formation vary considerably in thickness because of deep and irregular pre-Wind River erosion and post-Miocene normal faulting. The upper coarse-grained unit, in which the ore deposits are found, varies from 300 to 800 feet in thickness and consists dominantly of coarse-grained sandstones, commonly cross-bedded, and some mudstone, carbonaceous shale and siltstone beds. Conglomerate beds, 10 to 15 feet thick, are common in the western part of the area (114).

Two periods of normal faulting appear to have been important in affecting the uranium deposits of the Gas Hills area. Early Eocene age normal faults (which generally trend in a northeasterly direction) appear to be pre-ore in age and may have acted as barriers to the flow of uranium-bearing ground water solutions. Post-Miocene and later normal faults, which trend from east-west to northwesterly, have controlled the present position of the water table and caused secondary enrichment of some of the deposits by damming up ground waters with the precipitation of uranium near the top of small perched water tables (111). A small belt of horsts and grabens, the largest of which is a graben with over 300 feet of vertical displacement, occurs in secs. 16, 17, 20, 21, T. 31 N., R. 89 W. Several deposits, such as those at the P-C and Ran Rex mines, occur in the horst-like structures, and the tops of the deposits coincide with the tops of the perched water tables.

In addition to structure, the following controls appear important in localizing uranium deposits in the area: (1) changes in permeability at the contact of the upper coarse-grained part of the formation with that of the fine-grained lower part, and the interbedding of permeable and impermeable sediments in the upper part of the formation, (2) faults acting as solution dams, and (3) presence of carbonaceous material, iron oxide and calcium carbonate. The mineralized bodies vary in depth from surface exposures to more than 250 feet. Some of the deeper uranium mineralized zones vary from 4 to 20 feet thick.

Autunite, metaautunite, phosphuranylite, and metatyuyamunite are the most common ore minerals in the oxidized zone and generally occur as interstitial filling in irregular blankets in brownish-red to gray coarse-grained arkosic sandstone. Uraninite, coffinite and pyrite are predominant in the unoxidized black to gray ore zones. Some secondary enrichment of uranium mineralization occurs at the interface between oxidized and unoxidized zones. Among the other uranium minerals found in the area are: liebigite, rutherfordine, uranospinite, becquerelite, metatorbenite, metazeunerite, uranophane, sabugalite, tyuyamunite, and carnotite (113).

Native selenium occurs as interstitial material in lenses above, below, and adjacent to lenses of uranium ore in the oxidized zone of the Lucky Mc mine. Two channel samples from this zone are reported to contain 0.24 to 2.73% selenium. Selenium is also reported from the oxidized ore zone at the Upetco and Vitro mines (112). Ilsemannite (hydrous molybdenum oxide) is reported to occur in both the oxidized and unoxidized uranium ore at the Lucky Mc mine and in the unoxidized zone at the Vitro mine (112). Selenium, associated with arsenic and pyrite, has also been reported from the unoxidized ore of newly discovered deposits (111).

Major known uranium ore reserves in the Gas Hills area are controlled by five companies: Federal Uranium Corp., Lucky Mc Uranium Corp., Union Carbide Nuclear Corp., Vitro Minerals Corp., and Western Nuclear Corp. During 1958, the Lucky Mc Uranium

Corp. replaced Vitro Minerals Corp. as the largest uranium producer in Wyoming. In addition to the companies listed above, important production has also come from the operations of Bengal, Gas Hills, Globe, Dale B. Levi, P-C, Radorock, Ran Rex, Two States-Valley Dean, Joe Wentz, and Western Standard uranium mining companies. Almost all operations have been open cut; however, with the discovery of deeper ore bodies, Lisbon Uranium (Hidden Splendor Mining Company) continued to sink its 500-foot shaft in 1959 to develop the only underground uranium mine in the Gas Hills area.

PROSPECTS

ALBANY COUNTY

Metatyuyamunite has been found in the upper and lower sandstone of the Lower Cretaceous Cloverly formation in sec. 9, T. 13 N., R. 76 W. (50). Where exposed in an 8-foot pit, the mineralization occurs disseminated in, and localized along, fractures and bedding planes of a 6-foot thick highly carbonaceous ferruginous fine-grained thin-bedded sandstone. A selected sample from the lower sandstone contained as much as 0.8% U_3O_8; however, random samples from three nearby hand-picked stockpiles from the same sandstone contained 0.1 to 0.14% U_3O_8 (50).

Night Owl Claims; sec. 12, T. 28 N., R. 77 W. Uranium occurs along a narrow breccia zone 5 feet thick in the basal Pennsylvanian part of the Casper formation. The uranium mineral questionably identified as staffelite (uraniferous carbonate fluorapatite), is disseminated in a pale botryoidal apatite up to several mm. in size (85).

In the Marshall area, T. 26 N., R. 75 W. (?), uranium occurs in a cherty manganiferous limestone of the upper part of the Casper formation (Pennsylvanian age). A random sample yielded 0.14% U_3O_8 (46).

Albany County No. 1 Claim (?); sec. 19, T. 27 N., R. 73 W. Uranophane occurs as coatings along north-northeast trending, vertical joint surfaces which are adjacent to a N. 53° E. striking vertical fault vein in pre-Cambrian granite. Uranophane also occurs in small clay fillings localized along horizontal joint surfaces (28).

Diamond Bell Mine (?); sec. 27, T. 28 N., R. 71 W. Uranophane occurs sparsely disseminated in a sheared diabase dike that is about 50 feet long and 2 feet wide. The dike lies with irregular contact along several exposures of biotite and chlorite schists, phyllite, and tactite. Both occur along the contact of two large granitic bodies (28).

Coffinite occurs at the Maggie-Murphy mine 3 miles south of Esterbrook (28).

BIG HORN COUNTY

Reeves Ranch; SE 1/4 sec. 11, T. 52 N., R. 92 W., 10 miles east of Greybull and 3 miles southeast of Shell Creek. The Morrison formation strikes N. 45° W. and dips 8° SW. at the east wall of a gulch 40 feet deep. Radioactive material is found in dinosaur bones at the base of a 12-foot lens of gray medium-grained cross-bedded sandstone. The bones are composed of a black medium-grained crystalline material with very little internal structure left. Fossil logs in the same bed are not radioactive.

Assay reports in possession of the owners show 0.2% to 0.8% U_3O_8 in the bone material. A specimen analyzed by the Natural Resources Research Institute, University of Wyoming, for the Geological Survey of Wyoming yielded 0.14% U_3O_8 (70).

Radioactive concretions occur in the Lower Cretaceous Cloverly formation, and anomalous radioactivity occurs in the Jurassic Morrison formation cropping out east, northeast, and northwest of Greybull (12, 107).

CAMPBELL COUNTY

There are many prospects in the Wasatch formation in the Pumpkin Buttes area; see discussion under producing areas.

CARBON COUNTY

Sec. 11, T. 24 N., R. 82 W. Crystal aggregates of carnotite occur in both sandstone and claystone of an erosional remnant of the Tertiary North Park (?) formation. A 1-foot channel sample of the claystone contained 0.051% U_3O_8 (49).

Secs. 30, 31, T. 25 N., R. 81 W., and *sec. 36, T. 25 N., R. 82 W.* Metatyuyamunite associated with vertical calcite veins occurs in the gray fine-grained cross-bedded Tensleep formation of Pennsylvanian age. The calcite veins average 3 feet in thickness with some as wide as 24 feet. Some of the veins are more than 1,000 feet long, and some are exposed vertically for more than 500 feet. A 2-foot channel sample across the vein, exposed in a test pit, assayed 0.03% U_3O_8. Selected samples from other pits assayed 0.89% and 0.39% U_3O_8 (48).

Little Man Mine; NW 1/4 NE 1/4 SE 1/4 sec. 14, T. 27 N., R. 84 W. Exposures in a 30-foot adit driven in pre-Cambrian rocks show a 6-foot graphite bed underlain by a thin gray quartzite and intruded and surrounded by gray and brown granite. Yellow uranium minerals including kasolite (51), occur along fractures and disseminated through weathered granite within 4 to 6 feet of the graphite bed. The quartzite is less mineralized. Below the weathered zone, the bluish-gray unweathered granite contains disseminated uraninite, molybdenite and pyrite (48). Other minerals identified are uranophane, chalcopyrite, and galena (21). A small shipment of uranium ore was made from this mine in 1954.

Saratoga Area; secs. 7, 18, 19, T. 16 N., R. 83 W., and secs. 13, 14, 15, T. 16 N., R. 84 W. Uranium mineralization occurs in the Tertiary North Park formation (47).

North of Saratoga, approximately in secs. 15, 22, T. 18 N., R. 84 W., carnotite occurs in fractures in a thick cliff-forming sandstone in the Tertiary Browns Park formation (47).

Miller Hill Area; approximate location, SW 1/4 T. 17 N., R. 87 W., and SE 1/4 T. 17 N., R. 88 W. Erratic uranium mineralization occurs in the fresh water limestone beds in what Vine has called the North Park (?) formation of probable Miocene age (100). Uranophane occurs as vug fillings and is localized along fractures in the silicious, brecciated limestone and sandy limestone beds. Several hundred tons of rock averaging about 0.02 to 0.03% uranium are believed present in the area (100).

Ketchum Buttes; sec. 9, T. 15 N., R. 89 W. Uranophane occurs in the lower part of what Vine has called the North Park (?) formation of probable Miocene age (100). On the east side of the easternmost "Butte", the mineralization occurs sparsely disseminated in the sandstone. A grab sample assayed 0.031% U_3O_8. Near the top of the westernmost "Butte", a small prospect pit shows uranium mineralization in 3-foot thick limonite-stained claystone. A 3-foot channel sample in the claystone assayed 0.32% U_3O_8 (97).

Doane-Rambler Mine; NE 1/4 sec. 25, T. 14 N., R. 86 W. A sample of malachite-bearing quartzite from the dump assayed 0.04% U_3O_8 (51).

Carnotite has been reported from a White River (Oligocene) outcrop in NE1/4, NE1/4 sec 36, T. 28 N., R. 78 W. (85).

Metatyuyamunite occurs coating sand grains in the Wind River formation at the Arbob claims located in NE1/4 sec. 3, T. 28 N., R. 78 W. AEC assays of drill cuttings in a coaly shale indicate 0.27% U_3O_8. (85)

Uranium, believed to be a disseminated constituent of lignitic beds, has been reported on the Martha claims in NE 1/4 sec. 11, T. 27 N., R. 78 W. (85).

Autunite (?) occurs in a gray, carbonaceous, finely pyritic sandstone of the upper Wind River formation in the center of sec. 34, T. 28 N., R. 80 W. (85).

CONVERSE COUNTY

Trail Creek Mine; sec. 10, T. 29 N., R. 71 W. A small lens of uraninite mineralization in wall rock of fresh unaltered hornblende schist occurs 8 feet below the adit floor at the junction of two vertical-dipping shear zones that trend north and northeast. Both shear zones are radioactive where intersected by the adit. The uraninite, which is coated by erythrite (cobalt bloom), occurs as botryoidal and sooty coatings along shear zones and as disseminations in the hornblende schist (28).

Shawnee Area; N ½ secs. 33, 34, T. 32 N., R. 69 W. Uranium mineralization occurs in steeply dipping fault zones which displace gently dipping rocks of Oligocene-Miocene age. The fault zones average about 4,000 feet long and 8 feet wide, and the mineralized bodies are discontinuous lenses which vary from 1-6 inches wide, 2-20 feet long and of undetermined depth. The uranium minerals generally occur as coatings on chalcedony and calcite, and as cavity fillings in the middle of the brecciated fault zones (27). Uranium minerals in the Shawnee area are believed to be metatyuyamunite and some carnotite (27).

In SW ¼ sec. 32, T. 32 N., R. 69 W., uranium mineralization occurs in an Oligocene-Miocene sandstone channel (27). Several occurrences of uranium (in NE part T. 32 N., R. 69 W.) are disseminated interstitially in a 6-foot thick gray to buff sandstone in the Fort Union formation of Tertiary age (27).

Box Creek Area: see discussion of producing uranium deposits of Southern Powder River Basin area.

CROOK COUNTY

Busfield Mine; sec. 26, T. 56 N., R. 66 W. Coffinite-uraninite mineralization occurs in the basal part of the upper Fall River sandstone of Lower Cretaceous age. Carnotite and metatyuyamunite are confined to the oxidized zone; the upper 30 feet of the sandstone. Prior to mining, the size of the deposit was estimated at 17,000 tons of 0.23% U_3O_8. Mining operations conducted by the Sodak Uranium and Mining Company were both open cut and underground (52).

Carlile Mine; W ½ sec. 26, T. 52 N., R. 66 W. Prior to mining, four uranium ore bodies occurred in a sandstone lens in the upper unit of the Lakota-Fuson formations undivided, of Early Cretaceous age. Carnotite and tyuyamunite are the principal ore minerals, and samples high in uranium are also high in selenium and arsenic.

Mining operations, both open cut and underground, by Homestake Mining Company ceased in 1955. At that time samples from underground workings varied from a trace to 1.93% U_3O_8; those from surface workings 0.005-0.34% U_3O_8 (3).

Jubilee Mine; sec. 15, T. 54 N., R. 66 W. Carnotite and a fluorescent uranium mineral occur in the Fuson shale of Early Cretaceous age (13).

Poison Creek; sec. 12, T. 54 N., R. 67 W. Sabugalite and zeunerite reported; no geological formation listed (21). These minerals probably occur in the Inyan Kara group.

Thorn Divide; sec. 27, T. 52 N., R. 66 W. Concentrations of a sooty black uranium mineral occur in several drill holes at two intervals in the Lakota-Fuson formations undivided of Early Cretaceous age. The deposits lie at depths of 175-275 feet below the ground surface (3).

Vickers Mine; NW ¼ sec. 26 (?), T. 56 N., R. 66 W. Unidentified black uranium mineralization occurs in a zone, 3 to 4 feet thick, in the upper sandstone unit of the Fall River formation of Early Cretaceous age (9).

FREMONT COUNTY

Gas Hills Area; see discussion under producing areas.

Sheep Mountain Area; sec. 31, T. 31 N., R. 97 W. A yellow carnotite-type of mineral is disseminated in, and impregnated in, the more porous sections of a fine-grained sandstone in the Tensleep formation of Pennsylvanian age (69).

Secs. 7, 10, T. 30 N., R. 97 W. Yellow-green uranium minerals coat fractures and vugs in a cherty dolomite of the Phosphoria formation of Permian age (38, 68).

Sec. 24 (?), T. 41 N., R. 108 W. A radioactive dull-yellow and light-greenish mineral coats fracture planes in north-south trending quartz-feldspar veins in light colored pre-Cambrian granite gneiss (65). The minerals have been identified as uraninite, allanite and uranophane (22).

Sec. 22, T. 40 N., R. 92 W. Uranium mineralization occurs in an inlier of schist and gneiss in pre-Cambrian granite. Uranophane occurs as coatings on granite layers and autunite coats fractures in schist (40).

Sec. 20, T. 28 N., R. 90 W. Autunite (?) occurs in fault gouge in pre-Cambrian granite (35).

Sec. 7, T. 7 N., R. 5 W. A 5-foot thick zone of radioactivity occurs in a fine-grained sandstone bed of the Aycross formation of Eocene age (66).

Whiskey Mountain; sec. 13 (?), T. 40 N., R. 107 W. Carnotite occurs in cavernous silicified rocks of Cambrian age (95).

McComb Area; SE ¼ NE ¼ NW ¼ sec. 3, T. 39 N., R. 92 W. Metaautunite occurs abundantly (?) in green bentonitic plastic claystone and green bentonitic coarse-grained arkosic sandstone of the Tepee Trail (?) formation of Eocene age. A sample contained 0.80% U_3O_8 (47).

NW ¼ SE ¼ sec. 27, T. 40 N., R. 92 W. A yellow nonfluorescent uranium mineral appears sporadically along the walls of a 15-foot shaft. The mineralization occurs in a claystone and sandstone matrix between granitic, mafic, and quartzite boulders of the upper part of the Tepee Trail (?) formation of Eocene age (47).

NW ¼ NW ¼ SE ¼ sec. 2, T. 39 N., R. 92 W. Schroeckingerite (?) occurs in a coarse-grained arkosic gray sandstone in the Tepee Trail (?) formation of Eocene age (47).

DePass (Williams-Luman) Mine; sec. 14, T. 40 N., R. 92 W. Uraninite is reported from the dump (51).

Sec. 3, T. 32 N., R. 94 W. Uranium mineralization occurs in asphaltic sandstone and medium-gray arkosic conglomeratic sandstone of middle and upper Eocene rocks (109, 112). Limited ore shipments from open-cut operations were made in 1955 by the Cheyenne Mining and Uranium Company.

FREMONT AND NATRONA COUNTIES

Split Rock Area. A sample collected from a limestone deposit of Pliocene (?) age contains 0.023% uranium. One-half mile northeast of the limestone outcrop, a white tuffaceous shale, believed to be stratigraphically below the lenticular limestone, assayed 0.013% uranium (46).

GOSHEN COUNTY

South Copper Belt Mine, sec. 1, T. 30 N., R. 64 W. Radioactivity has been reported from the dump and is associated with fracture surfaces of pre-Cambrian rocks that contain secondary copper minerals (39).

Radioactivity, mainly confined to fault zones in pre-Cambrian rocks, is also reported from other old copper mines in T. 30 N., R. 65 W., and T. 31 N., R. 64 (?) W. (55).

JOHNSON COUNTY

See discussion of Pumpkin Buttes under Producing Areas.

Mayoworth Area; NE¼ NW¼ SW¼ sec. 3, T. 44 N., R. 83 W. Metatyuyamunite occurs along fracture planes and replaces oolites in the basal limestone of the Sundance formation of Late Jurassic age (45). Radioactivity also occurs in the limestone north and south of the above area. Samples from these deposits range from 0.017 to 0.32% U_3O_8 (29).

NE ¼ sec. 14, T. 44 N., R. 83 W. Radioactive dinosaur bones occur in a medium-grained gray and brown sandstone in the middle part of the Morrison formation of Late Jurassic age (45).

Sec. 4, T. 43 N., R. 83 W. Coffinite has been identified in the Tensleep formation of Pennsylvanian age (22).

LARAMIE COUNTY

Autunite and torbernite are reported from the Silver Crown mining district, in the Carbonate Belle, Thunder Cloud, Heromosetta, Grant, Pacific and other mines (1).

LINCOLN COUNTY

Two coal beds that crop out along U. S. Highway 40, 0.4 miles west of Sage, contain as much as 0.013% U_3O_8 in the ash (4).

NATRONA COUNTY

East Gas Hills Area; see discussion under Gas Hills producing areas.

Hiland-Clarkson Hill-Poison Spider Area. A zone of uranium mineralization occurs about 35 feet above the base of the Wind River formation of Eocene age in an area about 500 feet long and 300 feet wide near the base of Clarkson Hill (76). About 2.5 miles northwest of Hiland, uranium also occurs in an east-northeast trending channel in the "middle" unit of the Wind River formation (76). Additional occurrences of uranium are known in the White River formation of Oligocene age in T. 31 N., R. 83 W. (77). Metaautunite (21) is reported from the Wind River (?) formation in sec. 17, T. 31 N., R. 82 W.

Schroeckingerite (21) is reported 20 miles southwest of Casper in the Poison Spider area.

Sec. 33, T. 32 N., R. 83 W. A green fluorescent uranium mineral occurs in a buff medium-grained sandstone of the Wind River formation (26).

S ½ sec. 9, T. 32 N., R. 81 W. A zone of radioactivity, adjacent to a small fault, occurs in a shale bed at the top of the Jurassic Morrison formation (25).

Sec. 35, T. 33 N., R. 82 W. A radioactive zone of 0.5 to 5.0 milliroentgens per hour occurs in exposures and pits in a 0.5- to 2-foot thick black carbonaceous mudstone lying above the basal conglomerate of the Lower Cretaceous Cloverly formation (7).

Sec. 33, T. 35 N., R 79 W. Carnotite (21) occurs on partings and splits and as erratic disseminations with carbonaceous shard-like fragments in a carbonaceous shale which is up to 2 feet thick. Yellow uranium minerals also occur in a sandstone bed adjacent to the shale. The occurrences are in the Mesaverde formation of Late Cretaceous age (67).

Pine Ridge Area; secs. 5 and 8, T. 39 N., R. 77 W. Uranium mineralization occurs in the Lance (?) formation of Late Cretaceous age. Carnotite- or tyuyamunite-type minerals occur in a pink to red sandstone that strikes N. 12° E., and dips 10° E. Approximately 1,200 tons of uranium ore were mined from the deposit in 1957 by the Globe Mining Company (60).

NIOBRARA COUNTY

Silver Cliff Mine; sec. 7, T. 32 N., R. 63 W.; located near the top of a hill about 150 ft. high; is about ½ mile west of Lusk. Most of the hill is composed of pre-Cambrian metamorphic rocks, unconformably overlain by a southeast-dipping calcareous sandstone of Cambrian (?) age.

The uranium deposits lie in and adjacent to a high-angle reverse fault that strikes N. 15° E. Uranophane, secondary copper minerals, and native silver occur in the fault zone. Samples of the fault zone material vary from 0.001 to 0.12% U_3O_8. Uranium mineralization also occurs in two types of sandstone in the footwall of the fault. The most radioactive is a brown to black sandstone that contains pitchblende, gummite, uranophane, chalcocite, secondary copper minerals, and native silver. The uranium content varies from 0.61 to 1.48%. The more common type of uraniferous sandstone is light-buff to rust-brown and contains uranophane and minor quantities of metatorbernite, azurite, and malachite. The uranium content in this zone varies from 0.001 to 3.39% (104).

The mine was opened about 1880, and worked for silver and copper on a small scale (2). Between 1918 and 1922, six carloads containing about 3% U_3O_8 were shipped to the Radium Company of Denver, Colorado (104).

Rawhide Buttes Area; SW ¼ NW ¼ sec. 23, T. 31 N., R. 64 W. Uranium mineralization, believed to be pitchblende, occurs in a narrow fault zone in pre-Cambrian mica schists. Ten tons of 0.1% ore were reported shipped in June, 1955 (24).

Lance Creek Area

Sec. 25, T. 36 N., R. 65 W. Uranium minerals, tyuyamunite and metazippeite, are concentrated along the northern margin of a fault which strikes N. 80° W. and dips 70° N. The mineralized zone is confined to a 2-foot thick, poorly consolidated, conglomeratic hematite sandstone of the White River formation of Oligocene age (8).

Secs. 19, 20, T. 35 N., R. 65 W. Uranium minerals, carnotite and tyuyamunite occur in a 15-foot thick, fractured, well cemented conglomeratic sandstone in the White River formation (8).

Sec. 24, T. 34 N., R. 67 W. Radioactive mineralization occurs in a lignitic coal lens in the Fort Union formation of Paleocene age (8).

Sec. 24, T. 36 N., R. 65 W. Abnormal radioactivity occurs in the steeply dipping Fox Hills sandstone of Cretaceous age on the northern flank of the Lance Creek anticline. No uranium minerals were observed (8).

Central part *T. 37 N., R. 62 W.,* and *sec. 17 (?), T. 36 N., R. 62 W.* Uranophane (21) and carnotite are reported from the Dakota formation of Early Cretaceous age near Old Woman anticline.

PARK COUNTY

Secs. 18, 24, 30, T. 52 N., R. 101 W. Metaautunite is sparsely and erratically distributed through both the Lower Cretaceous Cloverly formation and underlying Jurassic Morrison formation (32).

Secs. 2 or 3, T. 50 N., R. 104 W. Autunite occurs in the base of the Cloverly formation and top of the Morrison formation. Samples varied from .0708 to .177% U_3O_8 (11).

Dead Indian Creek Area; SE ¼ NW ¼ sec. 8, T. 55 N., R. 104 W. Anomalous radioactivity occurs localized along a N. 34° W. striking joint set in a brown-weathering massive hard quartzite of the Flathead formation of Cambrian age. No uranium minerals were identified, but two grab samples assayed .059 and .378% U_3O_8 (105).

Russell Creek Area; NE ¼ sec. 31, T. 56 N., R. 104 W. Anomalous radioactivity of 0.24 milliroentgens per hour was recorded from a ferruginous-stained sandstone bed in the Flathead formation. No uranium minerals were identified (106).

PLATTE COUNTY

Big Mac Claim; sec. 19, T. 23 N., R. 69 W. Radioactivity of 1.0 milliroentgens per hour was recorded from the bottom of a small prospect pit excavated in pre-Cambrian graphite schist. No visible uranium minerals were observed; however, pyrite, chalcopyrite, malachite, and azurite are present in the deposit (91).

SUBLETTE COUNTY

Union Peak; sec. 2 (?), T. 40 N., R. 108 W. A uranophane-like (21) mineral occurs as coatings on fractures in, and a crystalline black mineral is impregnated in, a dark gray pre-Cambrian granite gneiss on the east side of the mountain (63).

Radioactive pre-Cambrian granite occurs in N ½ SE ¼ secs. 17, 21, T. 32 N., R. 107 W.; however, assays of these specimens are relatively low in uranium content (48).

SWEETWATER COUNTY

Lost Creek Area; secs. 30, 31, T. 26 N., R. 94 W. Schroeckingerite deposits occur within the Cyclone Rim fault zone, a structural feature that trends northwest for 12 to 15 miles. The deposits occur predominantly in green claystone and arkosic sandstone and grit of the Wasatch (?) formation; however, subordinate deposits occur in thin interbeds of Green River-type platy shale, and some is in alluvial deposits. The more continuous mineralized bodies occur in platy shale overlying sandstone or in gray-green massive silty claystone.

A typical shale-sandstone type of mineralized body varies from 6 to 15 inches thick, extending 5 feet or more in depth and of unknown length. A trench, along the strike of such a body, however, exposed mineralization for a length of 150 feet.

The schroeckingerite occurs as (1) platy crystals in round aggregates and pellets up to ¾ inch in diameter; (2) individual, small flaky crystals; and (3) very thin layers of numerous small crystals that coat grains of quartz, of efflorescent salts (110). Samples of schroeckingerite vary in grade from 0.013 to 0.28% U_3O_8.

Red Desert Area. Radioactive coal deposits are located near the central part of the Great Divide Basin, extending from a few miles south of Wamsutter north-northwest to a few miles south of the Lost Creek area. The outcrop pattern, as is presently known, trends northwest over an area 24 miles long and 12 miles wide.

The radioactive coal, which occurs in the Wasatch formation of early Eocene age, is subbituminous B to subbituminous C in rank. Estimates of measured and indicated reserves in the central part of the Great Divide Basin amount to 700,000,000 short tons of coal, of which 83,000,000 tons are inferred to contain 2,600 tons of uranium (73).

In the Eastern Red Desert area, estimates of inferred reserves amount to 544,000,000 tons of coal averaging 8 feet in thickness and overlain by 75 feet or less overburden. The coal contains about 14,000 tons of uranium (57).

Secs. 3, 6, 9, 10, T. 24 N., R. 93 W. Uranophane and becquerelite (21) have been identified in the Wasatch formation of Eocene age.

Sec. 2, T. 20 N., R. 102 W. Schroeckingerite and metaautunite (22) have been identified in the Ericson sandstone of Late Cretaceous age. Unidentified yellow uranium minerals have also been reported in the Ericson sandstone at the following localities: sec. 18, T. 15 N., R. 102 W.; sec. 28, T. 18 N., R. 101 W.; sec. 22, T. 18 N., R. 101 W.; sec. 34, T. 19 N., R. 101 W.; sec. 13, T. 20 N., R. 105 W.; sec. 35, T. 21 N., R. 102 W. (83).

Sec. 35, T. 25 N., R. 95 W. A carnotite-like mineral is reported in the Wasatch formation (83).

West Side of Rock Springs Uplift. Four low-grade uraniferous zones occur in the Laney shale tongue of the Green River formation (50).

TETON COUNTY

Sec. 5, T. 42 N., R. 113 W. An unidentified uranium mineral associated with carbon trash occurs in a 1½-foot by 75-foot lens in the Morrison formation of Jurassic age. The formation strikes east-west and dips 15° north (86).

Gros Ventre River. In the Morrison formation, near Kelly Slide, dinosaur bones have been found which contained 0.13% U_3O_8 (92).

UINTA COUNTY

Sec. 28, T. 14 N., R. 119 W. Tyuyamunite (?) occurs in calcareous sandstones and conglomerate beds of the Jurassic-Cretaceous Beckwith formation, or the Cretaceous Bear River formation, on the steeply dipping east limb of the Fossil syncline and on the Absaroka fault. The formation strikes about N. 60° E. and dips about 85° N. (62).

WASHAKIE COUNTY

Secs. 21, 22, T. 47 N., R. 89 W. Autunite occurs in the Morrison formation of Jurassic age. In March, 1955, 46,775 pounds of uranium averaging 0.02% were reported shipped from the property (34).

Sec. 26, T. 48 N., R. 86 W. Anomalous radioactivity occurs in the Flathead formation of Cambrian age (64).

WESTON COUNTY

Elk Mountain; NW ¼ sec. 16, T. 42 N., R. 60 W. Metatyuyamunite (21) associated with pyrite and pods of lignitic material occurs in the Fall River formation of Early Cretaceous age. The property has been explored by 340 feet of underground workings (5).

THORIUM AND RARE EARTH DEPOSITS

Introduction

Thorium and rare earth minerals usually occur as accessory minerals in granitic, pegmatitic, and alkalic igneous rocks; however, some deposits occur in hydrothermal veins and placers or placer-type deposits. Thorium is more plentiful than uranium with respect to distribution in the earth's crust and approximates lead, molybdenum, and some rare earths in abundance. More uranium than thorium deposits are known principally because of the more concentrated exploration expended on uranium during the past decade.

The rare earth elements, although little known metals, constitute about one-sixth of the known elements. Because they possess similar chemical and physical characteristics, the rare earths are always associated with thorium and varying amounts of yttrium.

Most of the thorium compounds are produced from monazite (rare earth-thorium phosphate) and thorite-type (thorium silicate) minerals, while the rare earth compounds are generally produced from monazite and bastnaesite (fluo-carbonate of the cerium rare earths group). Neither the thorite mineral group nor bastnaesite has been reported in Wyoming. Deposits containing monazite, allanite (calcium-iron-cerium-aluminum-yttrium silicate), euxenite (niobate and titanate of yttrium, cerium, erbium, uranium and iron), fergusonite (niobate and tantalate of yttrium, with erbium, cerium, uranium, etc.), and samarskite (similar to euxenite) have been reported from various areas in the State. All these minerals contain minor amounts of thorium and/or uranium and hence are radioactive.

There are three major uses of thorium: (1) manufacture of incandescent gas mantles, (2) the manufacture of magnesium-thorium alloys which have excellent mechanical strength at high temperatures and are used in jet engine castings and air frame structures, and (3) as a possible substitute for uranium in nuclear reactors. Thorium is also used in refractories, catalysts, optical glass, reagent chemicals, thoriated tungsten for electric tube and lamp use, and as cathode coatings in electronic tubes.

Rare earth mixtures are used as cores for high-luminosity carbon electrodes, dryer for paint and ink, textile waterproofing and dyeing, preparation of misch metal and ferrocerium, and as an additive to special high alloy steel. The individual rare earth elements have applications in the glass industry as colorizing and decolorizing agents, polishing agents, ultraviolet absorbency without affecting the color of the glass, ingredients in highly refractive optical glass, etc. Other uses include neutron absorbers in nuclear reactor construction, low temperature transistors, electrically conductive ceramics, as tracers in medical research, small portable X-ray units, etc.

Potential prospecting areas in Wyoming include the pegmatites in the many pre-Cambrian mountain areas; alkalic igneous rock areas such as the Leucite Hills, Bear Lodge and Rattlesnake Mountains; stream deposits, especially those draining areas of pre-Cambrian rocks; and conglomerates and coarse-grained sandstones ranging in age from Cambrian to Quaternary. In addition, some of the titanium-bearing black sandstone deposits of Wyoming carry significant amounts of uraniferous and rare earth bearing zircons and minor amounts of monazite. All are radioactive to some extent. These deposits are located in the Bighorn Basin; eastern part of the Wind River Basin; Sheep Mountain, in the Laramie Basin; Rock Springs uplift; Cumberland Gap, south of Kemmerer; and Gibbs Creek, 20 miles south of Jackson. With the exception of one, all the deposits occur in rocks of Upper Cretaceous age. Additional details on these deposits are listed in Geol. Survey Wyo. Bull. 49, titled "Titanium-Bearing Black Sandstone Deposits of Wyoming."

PRODUCING MINES

CARBON COUNTY

T. 13 N., R. 81 W. Rare earth bearing pegmatites in pre-Cambrian rocks were discovered in 1956 by the Ralph Platts, Jr. and Sr. The pegmatites occur in a hornblende gneiss unit that has interbedded felsic gneisses and local areas of metasomatic granite gneiss and gneissic granite (37).

SW ½ sec. 3, T. 13 N., R. 81 W. Niobium, yttrium, and uranium oxides occur in a pegmatite that has been mined intermittently since 1956. In addition to the ordinary pegmatite minerals, the following are known to occur: euxenite, monazite, columbite, and allanite. Euxenite is the most abundant rare earth mineral. The pegmatite, which is 160 feet long by 70 feet wide, has been mined to a depth of 75 feet (37). In 1957, 3,115 pounds of euxenite valued at $5,297 were produced from this deposit (117).

PROSPECTS

ALBANY COUNTY

Many Values Prospect; SE ¼ sec. 32, T. 13 N., R. 78 W. Minor quantities of fergusonite (?) occur in a pegmatite that cuts pre-Cambrian tourmalinized mica schist and gneiss. The pegmatite strikes N. 50° E. and dips 85° NW., with exposures for 140 feet. The pegmatite was mined for mica, beryl, and tantalite in 1942 and 1943 (30).

Allanite has been found in a pre-Cambrian pegmatite near Albany, near the line between secs. 3 and 10, T. 14 N., R. 79 W. (82).

Sec. 2, T. 18 N., R. 72 W. A 4-inch allanite crystal was found in a pre-Cambrian pegmatite in the Laramie Range and is associated with 4 inch labradorite crystals and graphic granite. The allanite is highly radioactive (17).

Sec. 2, T. 15 N., R. 71 W. Euxenite (?) associated with feldspar, biotite and beryl occurs in a 75 foot wide pegmatite that cuts pre-Cambrian granite (102). The deposit has been mined intermittently for feldspar and mica.

BIG HORN AND SHERIDAN COUNTIES

Bald Mountain Monazite Deposit; T. 56 N., R. 91 W. The deposit occurs in the basal conglomerate of the Deadwood formation of Middle Cambrian age. The conglomerate, which varies between 2.5 to 10 feet in thickness, rests unconformably on pre-Cambrian granitic rocks, and ranges from a well cemented pale-buff fine-grained sandstone to a deep-red soft conglomerate containing well-rounded quartz pebbles. The latter contains the greater concentrations of heavy minerals and monazite.

Microscopic analysis of heavy mineral concentrates from samples of better portions of the deposit contain the following: ilmenite, 38.3%; monazite 8.7%; magnetite, 4.0%; zircon, 0.2%; impurities, 48.8%.

In 1952, ninety-two holes, averaging 22 feet and totaling 2,020 feet were drilled and sampled by the U. S. Bureau of Mines. Four hundred twenty-seven samples were taken and reduced to 216 by compositing. This resulted in a weighted average of 2.162 pounds of monazite per ton by panning. Samples from individual holes ran as high as 19.484 pounds of monazite per ton. An average analysis of six samples of pure monazite from the deposit yielded 8.8% ThO_2.

The average ilmenite content is 4 to 5 times greater than the monazite as indicated by microscopic examination of concentrates from the samples. An average gold assay from 6 samples yielded 0.003 oz. per ton (54).

CARBON COUNTY

Sec. 9, T. 27 N., R. 80 W. A zone of radioactivity, about 100 feet in diameter, occurs in an arkosic sandstone in the upper part of the Wind River formation (47). No uranium minerals were observed, but monazite (51) has been tentatively identified in samples.

Sec. 29, T. 27 N., R. 80 W. A zone of radioactivity at least 180 feet long occurs in arkosic sandstone in the upper part of the Wind River formation (47). No uranium minerals were observed, but monazite (51) has been tentatively identified in samples.

King Claims; sec. 32, T. 13 N., R. 81 W. Samarskite (?) has been reported from pre-Cambrian granite (22).

CROOK COUNTY

Bear Lodge Mountains; Tps. 51, 52 N., Rs. 63, 64 W. Thorium, uranium, and rare earth oxides occur essentially in iron-manganese veins that fill fractures in monzonite and syenite porphyries and in zones of intensely altered igneous rocks. The iron-manganese veins occur in the area covered by the Inum and Climax group of claims, located somewhat north of Warren Peak. One set of veins trends predominantly northwest and dips 12° to 30° NE.; another set trends northeast and dips 60° to 85° NW. They range in width from 1 inch to 2 feet and are exposed for as much as 300 feet along the strike. No discrete uranium, thorium, or rare earth minerals have been observed, although monazite was detected by X-ray analysis. It is believed that these elements occur as absorbed salts on clays or the iron and manganese oxides (103).

Analytical results of six samples show that the U_3O_8 content varies from 0.005 to 0.018% and the rare earth oxide content from 0.20 to 12.99%. The ThO_2 content is approximately 10 times greater than the U_3O_8 content (103).

Beneficiation and utilization of the material may be difficult.

A diamond drilling program for rare earth oxides was completed by the U. S. Bureau of Mines in July, 1950. Ten holes, varying from 26 to 87 feet, were drilled with an aggregate footage of 844 feet.

The Climax No. 8 claim has about 4,000 indicated tons of 3.9% rare earth oxides. The Climax No. 10 claim has about 40,000 tons of 1.5% rare earth oxides indicated (96).

FREMONT COUNTY

S ½ secs. 28, 29, and *N ¼ sec. 33, T. 42 N., R. 108 W.* Monazite bearing alluvial deposits occur along Warm Spring Creek above the Union Pass road and along South Fork at least as far upstream as its junction with Cow Creek. The monazite-bearing sands are reported in terrace deposits along Warm Spring Creek as well as in the alluvial material in and adjacent to the creek. The alluvial deposits on Warm Spring Creek vary from ¼ to ⅝ of a mile in width and are about 1 2/3 miles long. The highest terraces are more than 100 feet above the creek bottom (10).

The alluvial material on South Fork is several hundred feet in width and extends for more than 3 miles. Thickness of both deposits is unknown (10).

A portable sluice box was operated as a test operation in 1957 by the Little Jim Mining Company. Radiometric assays of six samples reported by the above company varied from 1.3 to 2.33% ThO_2 (18).

JOHNSON COUNTY

North line sec. 6, T. 46 N., R. 83 W. Allanite occurs in a vein-type of structure in pre-Cambrian granitic rocks. The vein, which is concordent with the foliation in the granite, strikes N. 70° W., and dips about 65° NE. Radiometric studies indicate that the vein is at least 100 feet long with a maximum width of 7 feet as exposed in a prospect pit. The mineral assemblage is complex and includes the following: calcite, diopside, garnet, soda amphibole, epidote, oligoclase, and magnetite. Epidote is banded parallel to the foliation in the country rock, and the allanite occurs as irregular masses feathering into the epidote and country rock (36).

Assays report 10% to 11% CeO_2, and 1.5% combined oxides of La, Di, Yt, etc. One sample yielded 0.7% ThO_2 (15).

NATRONA COUNTY

Allie Claims; secs. 12, 13, T. 39 N., R. 88 W., and secs. 7, 18, T. 39 N., R. 87 W.; 37.6 miles north of Waltman. Allanite crystals, varying in size from ¼ inch to 3 inches, are found in a pegmatite in pre-Cambrian gneiss. The allanite usually occurs in the crests of folds. Indicated reserves of all grades, 0.1% to 0.5% allanite-bearing rock, total 4,700,000 tons (81).

PLATTE COUNTY

Allanite occurs in a pre-Cambrian pegmatite 14 miles northwest of Wheatland. The analysis is as follows: ThO_2, 1.28%; CeO_2, 14.63%; $(La, Di)_2O_3$, 7.34%; U_3O_8, 0.02% (101).

REPORTED OCCURRENCES

CARBON COUNTY

Monazite is reported in the black sands of the Bald Mountain district (84).

LARAMIE COUNTY

Allanite associated with a feldspar deposit in pre-Cambrian rocks is reported from the east flank of the Laramie Range (16).

PARK COUNTY

Sec. 25, T. 56 N., R. 104 W. Allanite and radioactive rare earth bearing pegmatite has been reported in pre-Cambrian rocks (31).

UNKNOWN LOCALITY

Eight hundred pounds of samarskite an Fe, Ca, U, Ce, Y niobate were reported shipped to California in 1931. No location or other information is available (56).

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