

URANIUM DEPOSITS IN TERTIARY SEDIMENTARY ROCKS IN WYOMING AND NORTHERN COLORADO

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ABSTRACT

The discovery of carnotite ores in sandstone strata of the Wasatch formation (Eocene) in the Powder River Basin of Wyoming in 1951 was the forerunner of other uranium discoveries in widely separated parts of Wyoming and in adjacent Moffat County, Colo.

The deposits all have similar geologic environments in sedimentary host rocks of Eocene, Oligocene, or Miocene age. Most deposits occur in medium- to coarse-grained or conglomeratic sandstones of fluvial origin. Torrential crossbedding is a common feature of these sandstones, and they characteristically contain carbonaceous material and calcareous, ferruginous, or phosphatic cement.

The character of ore mineralogy in different areas suggests the probability of mineral provinces. Uranium vanadates are abundant in the Powder River Basin; phosphates and arsenates are the common minerals in the Wind River Basin; and silicates and sulfates are plentiful in the Green Mountains, Great Divide Basin and Washakie basin. The presence of uraninite has been established in the Wind River Basin, Powder River Basin, Green Mountains, and the Washakie basin.

Stratigraphic and lithologic ore controls are important in all districts, and evidence indicates that structural features play an important though often obscure role. Fractures have been mapped as an ore control at several deposits. The size and shape of individual deposits differs greatly within the same area. The deposits containing uranium minerals disseminated in sandstone strata as grain coatings and interstitial fillings seem to be the best.

INTRODUCTION

Discoveries of uranium in clastic sediments of Tertiary age in Wyoming were made in the Red Desert of the Great Divide Basin in 1936 by the recognition of schroekingerite in shales of the Wasatch formation (Eocene) and in 1951 by identification of carnotite in sandstone beds of the Wasatch formation in the Pumpkin Buttes area, Powder River Basin (fig. 118). Ores containing carnotite were discovered in clastic sediments of the Inyan Kara group (Cretaceous) in the Black Hills of South Dakota and Wyoming in 1951.

These deposits occur in outwardly dipping strata that flank the southern and western parts of the Black Hills uplift. In September 1953, uranium phosphates were discovered in the Wind River formation (Eocene), in south-central Wind River Basin. Subsequent prospecting uncovered deposits in widely separated parts of Wyoming, northern Colorado, and southeastern Montana.

ACKNOWLEDGMENTS

The author is indebted to his colleagues for much of the field data presented herein, and to the many friendly mine owners. Dr. John Gruner supplied much of the mineralogical data.

GEOLOGIC SETTING

The area is characterized by rugged mountains with Precambrian granite cores, flanked by strata of Paleozoic and Mesozoic age, which dip beneath Tertiary formations in intermontane basins. Much of the present relief is due to Tertiary faulting, commonly localized near the margins of basins.

Sedimentary rocks in the uranium-bearing areas range in age from Cambrian to Pliocene, with only the Silurian period not represented (fig. 118). Thickness and character of individual formations differs laterally, and in general the sedimentary units are thickest in the western part of Wyoming. All rocks of the Paleozoic and Mesozoic eras, through the Sundance formation of Late Jurassic age, were deposited in epicontinental seas. The Morrison formation of Late Jurassic age is of fluvial origin, and in general the Cretaceous strata are of brackish-water or marine origin. Sedimentary rocks of Tertiary age are fluvial, derived from erosion of local highlands and deposited as valley fill. Formations of Eocene, Oligocene, and Miocene age, the most frequent hosts for uranium, are composed of shales, siltstones and fine- to very coarse-grained arkosic sandstones and conglomerates. The widespread occurrence of permeable arkosic sandstones in these formations contributed to deposition of uranium. Widespread lignite beds are present in sedimentary rocks of Paleocene and Eocene age. Rocks of Oligocene, Miocene, and Pliocene age, in addition, commonly contain large quantities of tuffaceous material and other volcanic debris.

Stratigraphic correlation is difficult within Tertiary formations, as few strata are continuous over large areas. As a rule, strata are nearly horizontal or gently dipping, except in areas of faulting or folding, where steep dips have been measured.

OCCURRENCE OF URANIUM

Uranium occurs in clastic sedimentary rocks of Tertiary age in widely scattered localities in eastern and

middle Wyoming, in southeastern Montana, and in a small part of northern Colorado. Ore in more than 5-ton test lots has been produced from over 50 individual properties, and a number have produced more than 1,000 tons.

Most of the uranium produced has been from deposits detected by abnormally high surface radioactivity in sandstones of the Wind River, Wasatch, and Browns Park formations. Although sandstone is the usual host rock, uranium has been found in granite, schist, shale, mudstone, lignite, and limestone. Stratigraphic and lithologic features have been major controls of mineralization, but both regional and local structural features are also important.

Definable mineral provinces in Wyoming are shown on figure 119 where mineral types are arranged in approximate order of importance under each listed area. Recent discoveries of uraninite in the Wind River Basin, Powder River Basin, Washakie basin, and the Green Mountains indicate that much of the near-surface secondary ore came from oxidation of uraninite or coffinite.

SELECTED URANIUM DEPOSITS

LUCKY MC MINE

The Lucky Mc mine is near the southwest limb of the dissected Gas Hills anticline, Fremont County, Wyo., 50 miles east of Riverton, Wyo. (fig. 120). In this area the Wind River formation was deposited unconformably on an irregular surface eroded on sedimentary rocks of Mesozoic age. Formations exposed on the flanks of the Gas Hills anticline range from the Chugwater formation (Triassic) to the Frontier formation (Cretaceous age). Sedimentary rocks ranging from Eocene to Miocene in age are exposed on the Beaver Rim escarpment several miles to the south. This southward receding escarpment, the southern margin of the Wind River Basin, has a relief of 500-1,000 feet.

The Lucky Mc mine is in the upper part of the Wind River formation, host for most deposits in the area. This formation, which dips gently to the south in this area, ranges from a knife edge to slightly more than 500 feet. Claystones, siltstones, and thin redbeds predominate in the lower part of the Wind River formation, but crossbedded very coarse-grained arkosic sandstones, conglomerates, and thin mudstones make up the thicker upper part.

The host rocks are friable coarse-grained gray and brown arkosic sandstones and conglomerates interbedded with thin gray and brown lenses of carbonaceous shale and mudstone. The lenticular nature of beds and torrential crossbedding are consistent features, indicating deposition in turbulent streams. Some car-

URANIUM DEPOSITS IN TERTIARY SEDIMENTARY ROCKS IN WYOMING AND NORTHERN COLORADO

	SYSTEM	FORMATION	CHARACTER
Tertiary	Pliocene(?)	North Park formation	Tuff, sandstone, and bentonitic claystone
	Miocene(?)	Browns Park formation	Sandstone, tuffaceous, conglomerate, and marl
	Oligocene	White River formation	Claystone, tuffaceous, and arkosic conglomerate
	Eocene	Green River formation	Shale, marlstone, and sandstone
		Wasatch and Wind River formations	Sandstone, shale, claystone, and conglomerate
Paleocene	Fort Union formation	Sandstone, shale, and coals	
Cretaceous	Upper	Lance formation	Sandstone, shale, and coals
		Lewis shale	Shale, gray, and lenticular sandstone
		Mesaverde formation	Sandstone, shale, and coals
		Cody shale	Shale, gray, and lenticular sandstone
		Frontier formation	Shale and sandstone
	Lower	Mowry shale	Shale and some bentonite beds
		Thermopolis shale	Shale, black, and some sandstone
		Cloverly formation	Sandstone, conglomerate, and bentonitic claystone
Jurassic	Upper	Morrison formation	Claystone, siliceous, and silty sandstone
		Sundance formation	Sandstone, glauconitic, and shale
	Middle	Gypsum Springs formation	Siltstone, gypsum, and anhydrite
	Lower	Nugget sandstone	Sandstone, massive, bedded
Triassic	Chugwater formation	Shale, red, siltstone, and gypsum beds	
	Dinwoody formation	Siltstone, dolomitic, shale, and sandstone	
Permian	Phosphoria formation	Dolomite, phosphatic, and mudstones	
Carboniferous	Pennsylvanian	Tensleep sandstone	Sandstone, limestone, and chert
	Pennsylvanian, Mississippian	Amsden formation	Shale, limestone, and some sandstone
	Mississippian	Madison limestone	Limestone, massive, bedded
Devonian	Darby formation	Dolomite and shales	
Silurian	(Missing)		
Ordovician	Bighorn dolomite	Dolomite, massive	
Cambrian	Gallatin limestone	Limestone, shaly, and limestone	
	Gros Ventre formation	Shale, fissile, and some limestone	
	Flathead quartzite	Sandstone, conglomeratic	
Precambrian	Unnamed	Granite and schist	

FIGURE 118.—A generalized stratigraphic chart of Wyoming.

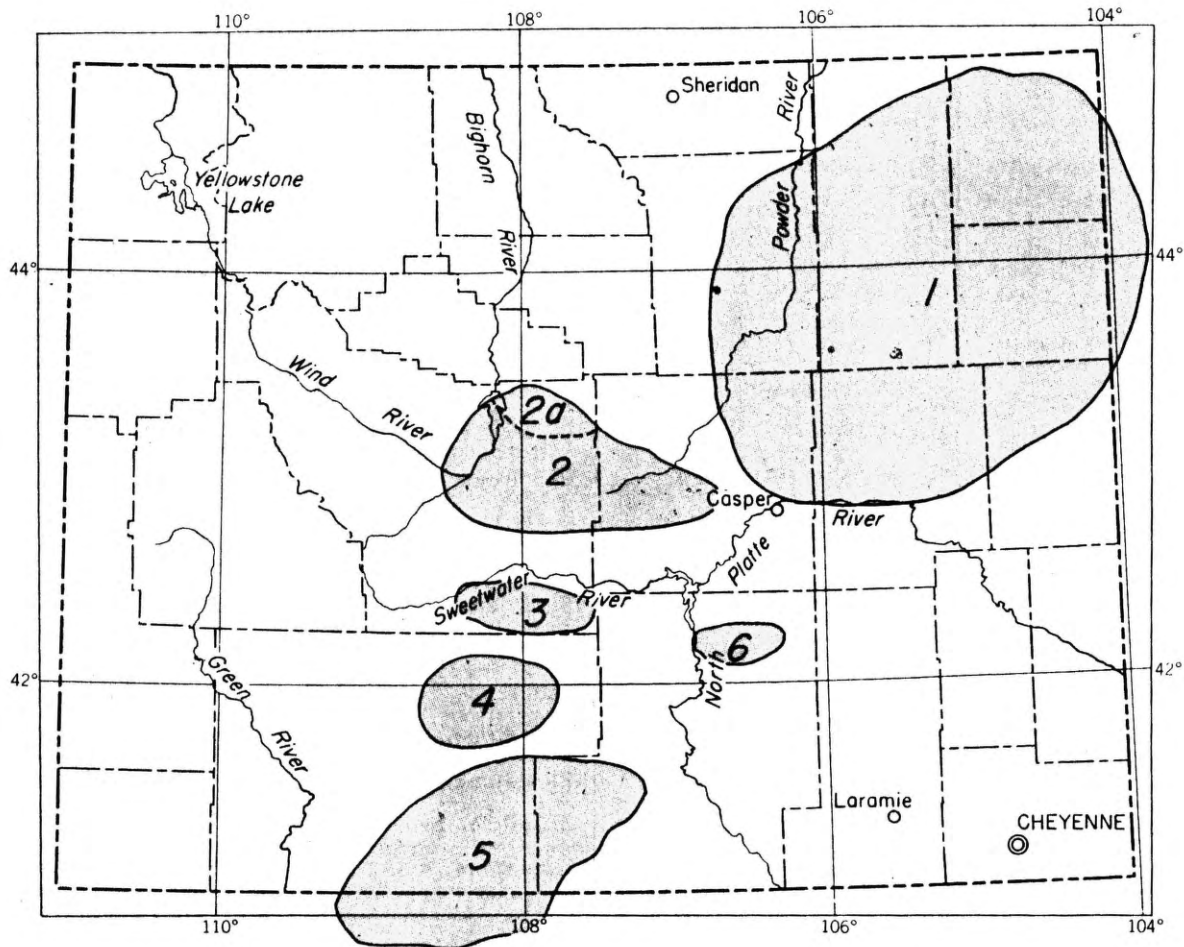


FIGURE 119.—Map showing ore-bearing areas of Wyoming. Mineral groups characteristic of each are listed in order of decreasing abundance in the ore.

1. Powder River Basin and Black Hills: vanadates, silicates, oxides.
2. Wind River Basin: phosphate, oxide, arsenate, fluor-phosphate, carbonate. 2a. Owl Creek Mountains: silicate, phosphate, sulfate.
3. Green Mountains: silicate, phosphate, oxide.
4. Great Divide Basin: sulfate.
5. Washakie basin and surrounding area: silicate, phosphate, sulfate, oxide.
6. Shirley Mountains: vanadates.

bonaceus fossil plant remains are disseminated in the sandstone, which is cemented with ferruginous, argillaceous, calcareous, or phosphatic materials.

Open pit mining has exposed shallow irregular southward-dipping ore bodies which differ greatly in size and shape. The closely spaced bodies, which together form the deposit, typically follow bedding and sedimentary structural features but locally transect such features in later fractures or faults.

The dark primary ores usually occur as ellipsoidal deposits within the main body of mineral concentration. These ore lenses, which are up to several feet thick and as much as 15 feet wide, characteristically pinch and swell. Uranium seems to be most concentrated in places of greatest fracture density and in the lenses of coarse-grained sandstone that were the most permeable. A set of vertical fractures which

strike N. 70° W. to N. 35° E. are prominent and appear to have been important in localizing ore (J. P. Hadfield, Jr., 1955, oral communication).

The primary ore minerals uraninite and coffinite are disseminated in microscopic particles in dark very coarse-grained angular arkosic sandstone cemented by gypsum and calcium carbonate. Waxy gray-green uraniferous carbonate-fluorapatite, found as cement and in fracture fillings, may also be primary. The ore contains large amounts of finely divided pyrite which imparts the dark coloration. Liebigite, a light-green secondary uranium carbonate, commonly occurs on fracture faces and fills seams in the richest primary ore.

Many secondary minerals found in this deposit, in addition to liebigite, are meta-autunite, yellow uranium phosphate (unidentified), phosphuranylite, sabugalite, rutherfordene, metazeunerite, metatorbernite, and uran-

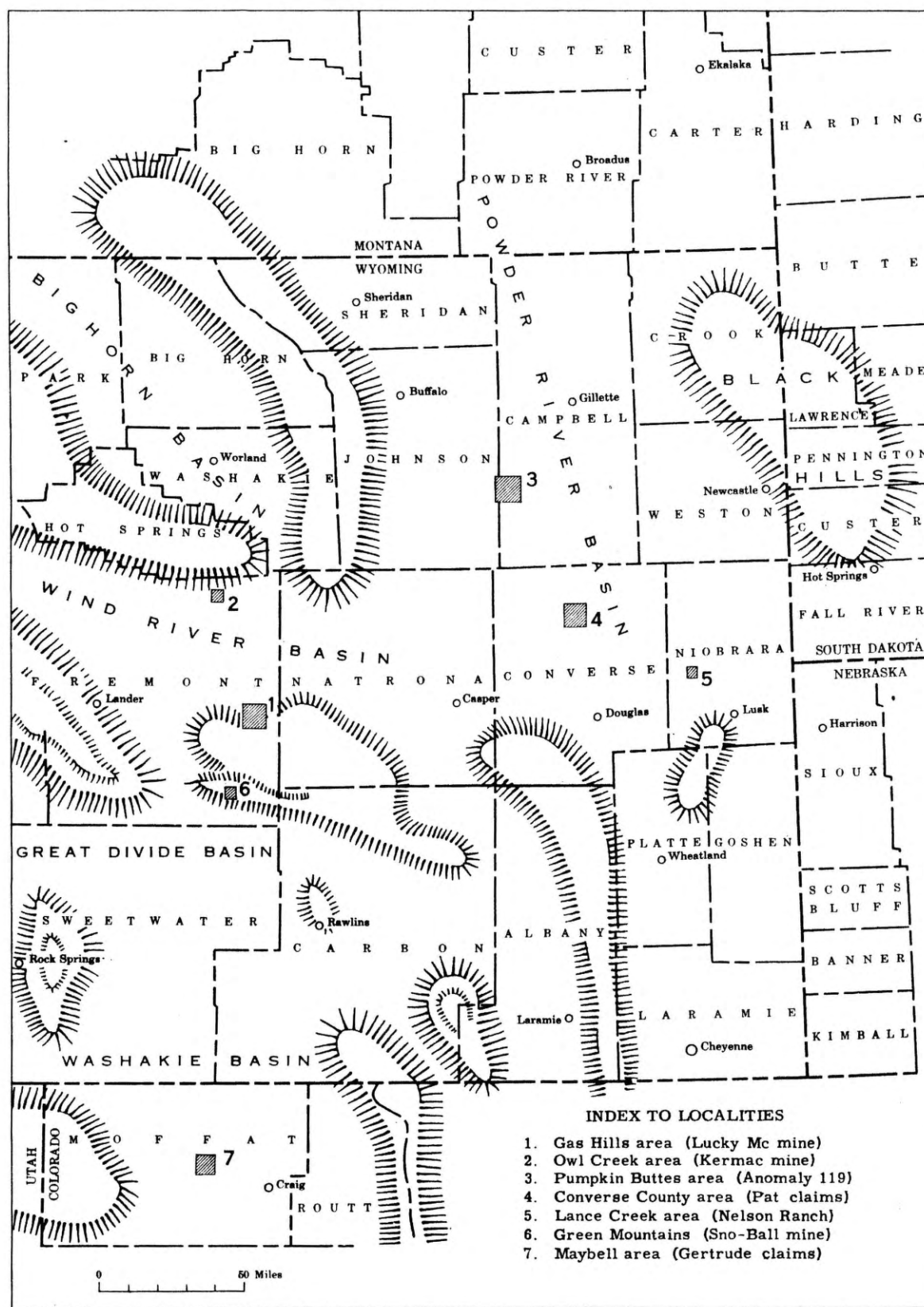


FIGURE 120.—Index map to localities.

ophane (John Gruner, 1954, written communication; Coleman, 1954).

Secondary uranium minerals surround the primary ores as halos or are irregularly disseminated throughout the oxidized sandstone strata in pockets, bands, or "rolls." The deposit as exposed is a partially oxidized ore body containing unoxidized remnants of original ore (fig. 121).

Limonite, jarosite, pyrite, and gypsum are common associated minerals. Native selenium has been identified in minute particles, and an unknown selenite or selenate mineral occurs in reddish streaks (John Gruner and Robert Coleman, 1954, written communication). The presence of molybdenum is revealed by conspicuous bluish coatings of illsemanite on mine walls as a result of oxidation. A large halo of bleached and ferruginous yellow- to orange-stained sandstone laterally surrounds the entire deposit. This alteration is probably a secondary effect of oxidation of pyrite. Oxidized ores commonly show equivalent uranium to be higher than uranium determined chemically, whereas primary or partly unoxidized ores tend to have higher chemical assays than radiometric assays (Grutt and others, 1954).

The small amount of carbonaceous material present is not enough to constitute a control on uranium deposition. Many recognizable fragments of carbonaceous

material contain no uranium. Higher than normal content of calcium carbonate in the sandstone cement may be an important factor in the precipitation of uranium, and proximity to an underlying unconformity and impervious shales capable of regulating solution flow may also have been important.

BULLRUSH CLAIMS

The Bullrush claims, situated in the Gas Hills area in sec. 29, T. 33 N., R. 90 W., contain uranium in a geologic environment similar to that of the Lucky Mc mine (fig. 120). Uranium occurs in several gently dipping blanketlike zones, conformable with bedding, in coarse-grained arkosic sandstones of the upper Wind River formation. The near-surface mineral concentration, as shown by preliminary exploitation, consists of autunite, meta-autunite, and uranophane. The lowest ore deposit (fig. 122) is unoxidized, as determined by drilling. This dark-gray ore contains pyrite but the primary uranium minerals have not been determined.

ANOMALY NO. 119

Anomaly no. 119 mine is northeast of the Pumpkia Buttes in sec. 11, T. 45 N., R. 75 W., Campbell County, Wyo. (fig. 120). The immediate region, near the synclinal axis of the Powder River Basin, is rolling,

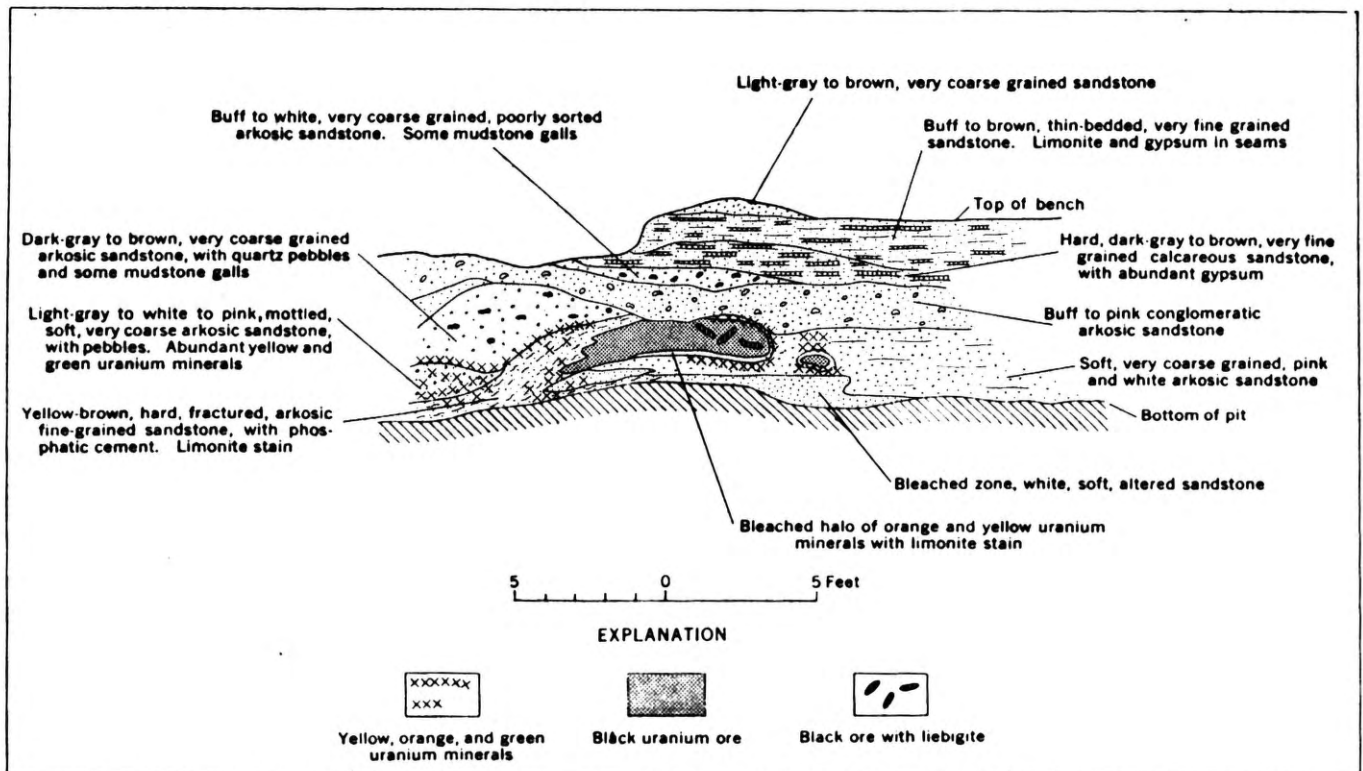


FIGURE 121.—Vertical section through an ore bench, Lucky Mc mine, sec. 23, T. 33 N., R. 90 W., Fremont County, Wyo., showing distribution of uraninite and liebigite.

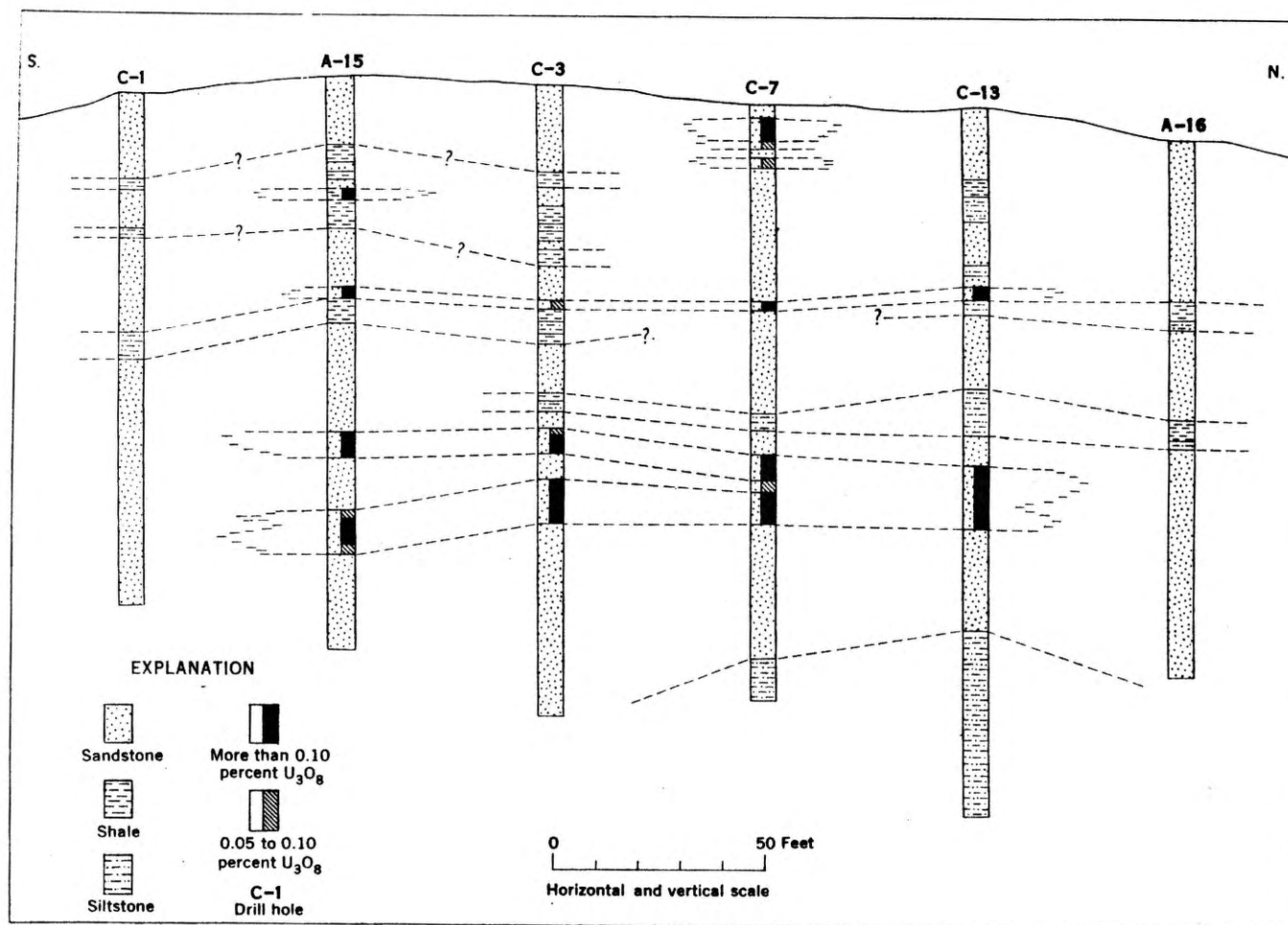


FIGURE 122.—Cross section through Bullrush prospect, sec. 29, T. 33 N., R. 90 W., Fremont County, Wyo.

well-dissected terrain. Pumpkin Buttes rise almost 1,000 feet above the surrounding area.

All rocks of the area are assigned to either the Wasatch formation of Eocene age or to the White River formation of Oligocene age. The Wasatch formation is up to 1,500 feet thick and is composed of shales, mudstones, interbedded lenticular beds of fine- to coarse-grained crossbedded sandstones, and several persistent coal beds. The White River formation capping the buttes is a coarse-grained to conglomeratic sandstone with siliceous cement.

The Wasatch formation is host for all large occurrences of uranium in the area, and most of the 121 uranium deposits, of which Anomaly 119 is one, are found in a red sandstone which is up to 500 feet thick and stratigraphically near the middle of the formation (Troyer and others, 1954). The sandstone of this zone is arkosic and contains much calcareous and ferruginous cement and, in places, considerable fossil carbonaceous material.

Uranium concentrations have been disclosed by two elongate open pits. The host is thin- to massive-bedded

coarse-grained arkosic sandstone with abundant cross-bedding. Uranium occurs in extremely irregular zones and impregnations following bedding in a few places but elsewhere transecting all sedimentary structural features. No obvious feature seems to control emplacement of the ore deposit. Hard layers and calcareous sandstone concretions occur sporadically throughout areas where uranium ore is commonly mined; most of the friable mineral-bearing sandstone contains uranium as grain coatings or interstitial matter between sand grains. Carbonaceous plant material is disseminated in the sandstone and in places is associated with high-grade pockets of ore.

The uranium mineralogy here in the Powder River Basin is simple as compared with that of the Wind River Basin. Although the primary mineral uraninite has been discovered intimately associated with disseminated pyrite in an unoxidized part of the deposit (Sharp, 1955), the dominant uranium minerals are carnotite and tyuyamunite. Minor uranophane has also been identified. The secondary minerals are in tortuous bands ranging from bodies a fraction of an inch

to several feet in thickness. The most striking single feature of the entire deposit is the concentration of carnotite-bearing ores along the zones of contact between pink sandstone and gray or buff sandstone that appears bleached. Ore is more plentiful on the gray and brown side of the contact zone (fig. 123). In all probability the mineralizing solutions were responsible for the alteration of the pink sandstone to brown and gray. This color change is the best single guide to ore.

Coarse-grained sandstone of high permeability and lenticular mudstone lenses may have exercised control over deposition by influencing flow of mineralizing solutions. Some ore is concentrated in areas of higher than average fracture density, with abnormal amounts of calcareous cement, and a persistent underlying shale bed determines the lower limit of mineral concentration in several parts of the pit. Much of the mined ore assayed about 0.4 percent U_3O_8 .

JEANETTE MINE

The Jeanette mine in sec. 22, T. 45 N., R. 75 W., in the Pumpkin Buttes area (fig. 120), is similar in many respects to Anomaly 119. Pink sandstones of the Wasatch formation are altered to gray in carnotite-bearing zones, and uranium shows marked tendency to concentrate in and around fossil carbonaceous material. Uraninite in intimate association with pyrite also has been reported from this mine (Sharp, 1955).

BROWN'S RANCH DEPOSIT

The Brown's Ranch deposit in sec. 22, T. 43 N., R. 76 W., in the Pumpkin Buttes area (fig. 120), lies within coarse-grained sandstone lenses of the Wasatch forma-

tion but shows marked differences to those described above.

A cluster of uranium-bearing concretions, which range individually from a fraction of a cubic foot to several cubic feet, has yielded over 200 cubic feet of ore assaying about 5 percent U_3O_8 . Uranophane and small amounts of carnotite occur in these concretions, intergrown with manganese and iron oxides and calcium carbonate. Color changes and carbonaceous materials do not appear to be ore guides.

PAT CLAIMS

On the Pat claims in sec. 3, T. 37 N., R. 73 W., Converse County, Wyo. (fig. 120), carnotite and uraninite occur disseminated in bedded deposits in gray and brown sandstone strata of the Wasatch formation. This deposit has been investigated only by drilling, and many details of its character are not known. Deposition has favored coarse-grained arkosic sandstones containing carbonaceous materials and some calcareous cement. A distinct change in lithology, which seems to influence the local ground-water level, occurs at the discomformable contact with the underlying Fort Union formation and may have been a factor in localization of ore (fig. 124). Native selenium has been identified in the primary ore as tiny particles in association with pyrite, uraninite, and carbonaceous material (J. Gruner, 1954, written communication).

SNO-BALL MINE

The Sno-Ball mine, on an anomaly discovered by airborne radiometric surveying, is in the Crooks Gap section of the Green Mountains in sec. 28, T. 28 N.,

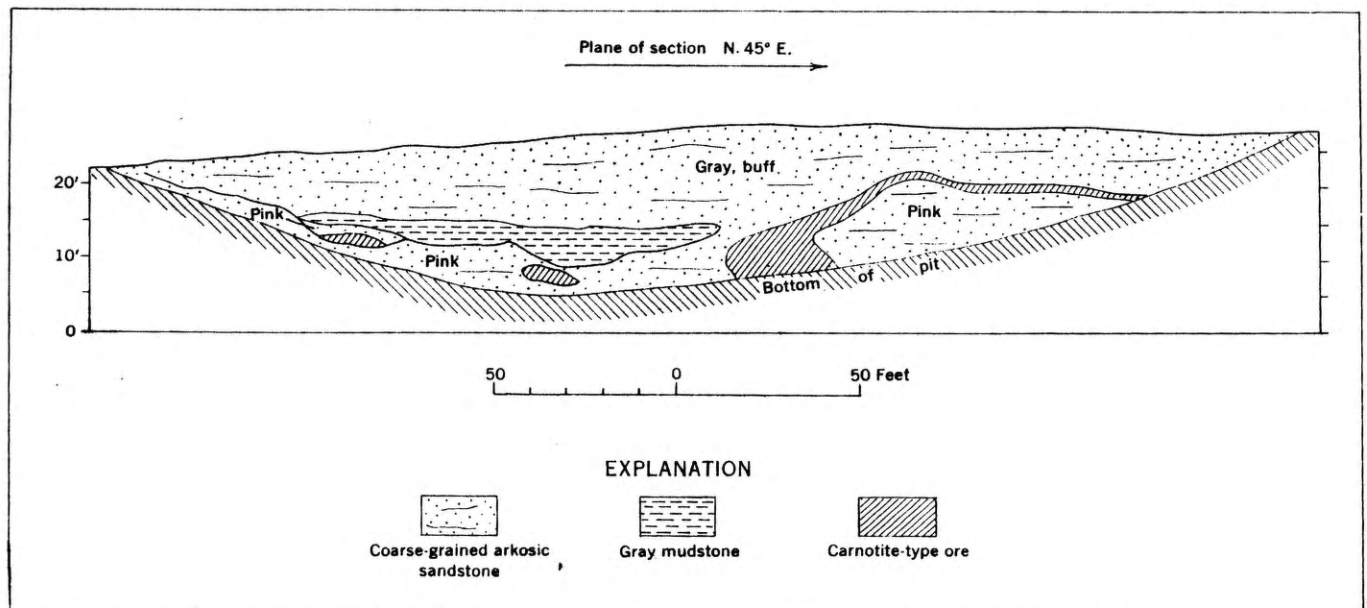


FIGURE 123.—Vertical section through pit, Anomaly 119, sec. 11, T. 45 N., R. 75 W., Campbell County, Wyo.

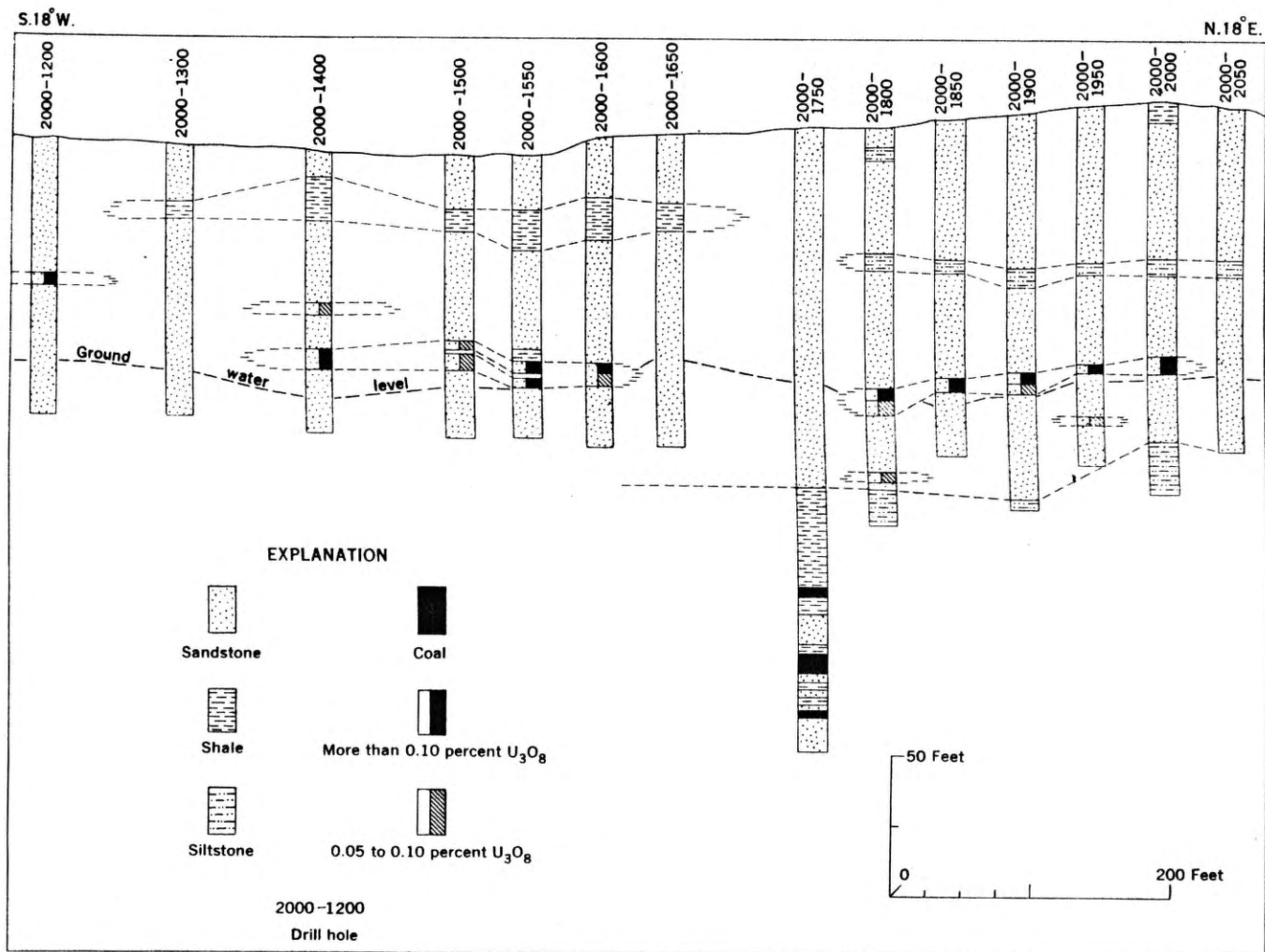


FIGURE 124.—Vertical section through uranium ore bodies, Pat claim, sec. 3, T. 37 N., R. 73 W., Converse County, Wyo.

R. 92 W., Fremont County, Wyo., about 65 miles north of Rawlins (fig. 120).

The region exhibits complex structural features and has an equally complex geologic history. The northwestward-trending Green Mountains are locally more than 8,000 feet in altitude and are underlain mostly by strata of Eocene age. A prominent northward-dipping thrust fault bounds the range on the north, and the Great Divide Basin is the topographic boundary to the south. The thrust fault, which was active during much of the Tertiary period, probably influenced sedimentation during the Eocene period by continually rejuvenating source highlands (Gooldy, 1947; Whalen and Norton, 1955). The Fort Union formation (Paleocene) and older rocks were strongly folded before deposition of the Wasatch formation (Eocene), but continued movement also caused folding in the strata of Wasatch age, which overlies the older rocks with an angular discordance. Sedimentary rocks present range in age from Cambrian to Miocene.

Most of the uranium deposits are in the Wasatch

formation, which averages over 800 feet in thickness and is composed of an alternating series of lenticular boulder beds, arkosic conglomerates, fine- to coarse-grained arkosic sandstones, siltstones, and carbonaceous shales.

At the Sno-Ball mine mineral concentration is confined to the lower beds of the Wasatch, in lenses of very coarse-grained angular arkosic sandstone and conglomerates of granite cobbles. Extreme irregularity of bedding is accompanied by torrential crossbedding. Thin dark carbonaceous mudstone layers are intercalated in the section. The mineralized zones are irregular and often sporadic in distribution.

Most ore mined in the open pit has come from the top of a persistent carbonaceous mudstone layer, which dips approximately 15° east. This ore zone attains a thickness of several feet, swells and pinches in direction of dip, and is irregular in shape along the strike. Uranium is disseminated as grain coatings and as interstitial or cementing material in lenticular beds of coarse-grained poorly sorted arkosic sandstone and in

upper parts of the carbonaceous mudstone immediately underlying or imbedded with the sandstone ore.

Abundant carbonaceous fossil plant fragments are present throughout the ore zones and in many places are associated with the highest grade ore. A few small steeply dipping faults and fractures have been mineralized, but in general bedding planes seem to contain more uranium than fractures do.

A white, seemingly bleached sandstone zone of different thicknesses in the basal part of the Wasatch formation is apparent for over 1,000 feet along the strike and is especially conspicuous in the mine area. This band is localized in the more permeable layers and may be the result of alteration accompanying mineral deposition.

The dominant ore mineral is uranophane in earthy yellow grains and as paintlike smears along fractures in granite cobbles and boulders. Minor amounts of phosphuranylite occur with the uranophane. Uraninite from dark carbonaceous mudstone has been identified in minor amounts. Limonite, the dominant associate mineral, is present as earthy interstitial fillings and as stain in and around mineralized zones. Lenses of permeable sandstone and layers of carbonaceous mudstone or sooty fossil carbonaceous material facilitated ore deposition (fig. 125).

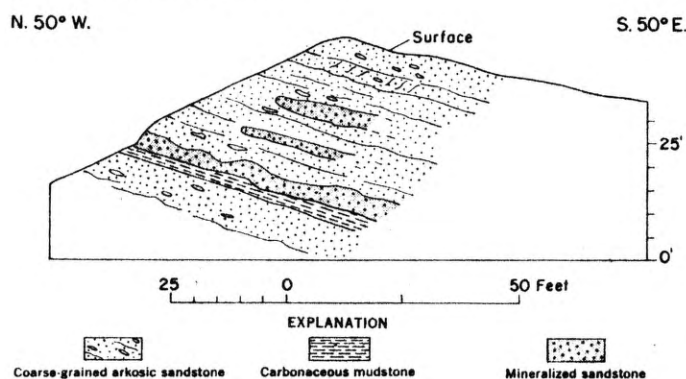


FIGURE 125.—Vertical section, generalized, through outcrops on Sno-Ball claim, sec. 28, T. 28 N., R. 92 W., Fremont County, Wyo.

BAGGS AND MAYBELL AREAS

The Washakie basin of southern Wyoming and northern Colorado also contains economically significant deposits, principally of uranophane, in the Browns Park formation of Miocene(?) age. The basin is an area of about 1,500 square miles. The Browns Park formation comprises sandstones, shales, and tuffaceous beds unconformably overlying older strata. Two uranium deposits, similar in many respects, are the Poison Basin claims in sec. 4, T. 12 N., R. 92 W., 6 miles west of Baggs, Wyo., and the Gertrude claims in sec. 17, T. 7 N., R. 94 W., northeast of Maybell, Moffat County, Colo. (fig. 120).

Uranophane with meta-autunite and schroeckingerite are the common secondary minerals and are disseminated

in lenticular bedded deposits in fine- to medium-grained sandstones, which are often highly cross-bedded. Small quantities of uraninite associated with gypsum, calcium carbonate, and limonite have been identified in the Poison Basin claims.

Drilling has disclosed gray unoxidized ore in both areas, but the identify of the uranium mineral has not been determined. Finely divided pyrite is a common gangue mineral in this ore. Assays in which the chemical content exceeds radiometrically equivalent uranium are common.

Fracturing and faulting are known to be important controls in localization of these deposits. Visible quantities of carbonaceous materials are conspicuously lacking.

CONCLUSIONS

The study of uranium occurrences in clastic rocks of Tertiary age is new, and extensive geologic information is not yet available. A marked resemblance exists between the many Wyoming deposits, however, and those of the more thoroughly studied Colorado Plateau. Wyoming uranium deposits are distinct in the abundance of such compounds as phosphates and arsenates and are characterized by radiometric disequilibrium in most ores.

Widespread unconformities which separate strata of Tertiary age from older sedimentary rocks are common. Uranium deposits occur near such surfaces in several Wyoming areas. These surfaces are boundaries of marked lithologic and structural change which must have influenced the lateral flow of migrating solutions.

Wyoming represents a new uranium province that is defined almost entirely by occurrences in clastic sediments. As prospecting and exploration progress, it is likely that the areas of known ore deposits will be increased and that significant deposits will be found in sedimentary rocks older than Tertiary.

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