Uranium-bearing Coal in the Great Divide Basin Sweetwater County Wyoming

GEOLOGICAL SURVEY BULLETIN 1099

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1962

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

CONTENTS

[The letters in parentheses preceding the titles designate separately published chapters]

Uranium-Bearing Coal in the Central Part of the Great Divide Basin

By GEORGE N. PIPIRINGOS

URANIUM-BEARING COAL IN THE GREAT DIVIDE BASIN, SWEETWATER COUNTY, WYOMING

GEOLOGICAL SURVEY BULLETIN 1099-A

Prepared on behalf of the U.S. Atomic Energy Commission and published with the permission of the Commission

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1961

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

CONTENTS

ILLUSTRATIONS

[All plates in pocket]

TABLES

URANIUM-BEARING COAL IN THE GREAT DIVIDE BASIN, SWEETWATER COUNTY, WYOMING

URANIUM-BEARING COAL IN THE CENTRAL PART OF THE GREAT DIVIDE BASIN

By George N. Pipiringos

ABSTRACT

Nearly 24 townships in the central part of the Great Divide Basin, Sweetwater County, Wyo., were mapped. Fourteen of these townships contain outcrops of uranium-bearing coal. Thirty coal beds were mapped but only seven of them have uranium-bearing coal reserves as defined in this report. Coal beds 2.5 feet or more thick are considered in calculating coal reserves and, of these, only beds containing 0.003 percent or more uranium are considered in calculating the uranium content of coal. The uranium content of coal ash was estimated for those beds 2.5 feet or more thick that contain 0.015 percent or more uranium in coal ash.

Measured and indicated coal reserves in the area total about 730 million short tons and contain about 2,700 short tons of uranium in the coal, or about 2,500 short tons of uranium in the coal ash. Strippable coal (in beds beneath 60 feet or less of overburden) include about 250 million short tons of coal containing about 1,100 short tons of uranium in coal, or about 650 tons of uranium in coal ash.

The thickest coal beds underlie a relatively narrow belt that trends northwestward and coincides approximately with the axis of the Red Desert syncline. The coal beds contain the most uranium on the east flank of the syncline near the southwesternmost edge of the Battle Spring formation. This formation is of early and middle Eocene age and consists predominantly of very coarse-grained arkosic sandstone which is highly permeable. It intertongues southwestward with the less permeable Green River and Wasatch formations. The Green River formation consists of, from youngest to oldest, Laney shale member and the Tipton and Luman tongues. The Wasatch formation interfingers with the Green River formation and consists of, from youngest to oldest, the Cathedral Bluffs, Niland, and Red Desert tongues. The latter two contain all the coal beds in the Wasatch formation. The Laney member of middle Eocene age and Cathedral Bluffs tongue of early or middle Eocene age of the Green River and Wasatch formations, respectively, intertongue and are in part equivalent. The other units are of early Eocene age.

The Bridger formation, which overlies the Laney member of the Green River formation, contains invertebrate fossils of middle Eocene age. The Bridger formation is overlain by the Browns Park(?) formation, whose upper part contains vertebrate fossils of Miocene age.

A broad gentle arch, which is either the eastern extension of the Wamsutter arch or a separate arch en echelon to it, separates the Washakie Basin in the southeastern part of the area from the Red Desert syncline in the northeastern part. The Red Desert syncline plunges gently northwestward into the nearly circular structural Niland basin. The south flank of the Wamsutter(?) arch dips southeastward at an average rate of about 230 feet per mile. The north flank of the arch dips northeastward at an average rate of about 140 feet per mile.

North of the Niland basin, the structure is more complex and is dominated by a northwestward-trending graben which parallels and includes the Cyclone Rim in the northern part of the area. Schroeckingerite deposits in the northeastern part of the area lie within this graben in a sequence of arkosic sandstone and clay shale stratigraphically equivalent to the lower part of the Cathedral Bluffs tongue of the Wasatch formation and to the uppermost part of the Tipton tongue of the Green River formation. Weakly radioactive tuffaceous sandstone beds of the Browns Park(?) formation that probably once blanketed the entire Great Divide Basin are preserved a short distance north and northwest of the schroeckingerite deposits. The geologic settings of the schroeckingerite deposits and uranium-bearing coal beds are similar and their source of uranium is probably the same. The uranium probably was leached from tuffaceous beds in the Browns Park(?) formation and carried to its present site of deposition by ground water whose circulation was guided by structural features and facies changes.

INTRODUCTION

PURPOSE OF THE WORK

Fieldwork, primarily intended to determine distribution of uranium in coal in the central part of the Great Divide Basin, Wyo., was done during the summers of 1951–53 by the U.S. Geological Survey for the Division of Raw Materials of the U.S. Atomic Energy Commission. In addition, the stratigraphy and structure of the coal-bearing rocks, which are of early Eocene age, were studied in detail, and the geology of adjacent or related areas was examined in reconnaissance in order to determine the source of the uranium and how it was deposited.

LOCATION OF THE AREA

The Great Divide Basin is an oval-shaped undrained topographic depression on the Continental Divide embracing about 4,000 square miles in Sweetwater, Carbon, and Fremont Counties, south central Wyoming (fig. 1).

This report is concerned primarly with the central part of the Great Divide Basin, but geologic features of adjacent or related areas are also discussed insofar as they affect the geologic interpretation of the report area.

EARLIER INVESTIGATIONS

Nearly all the Great Divide Basin was mapped in reconnaissance and the main coal-bearing areas delimited by Smith (1909), Ball

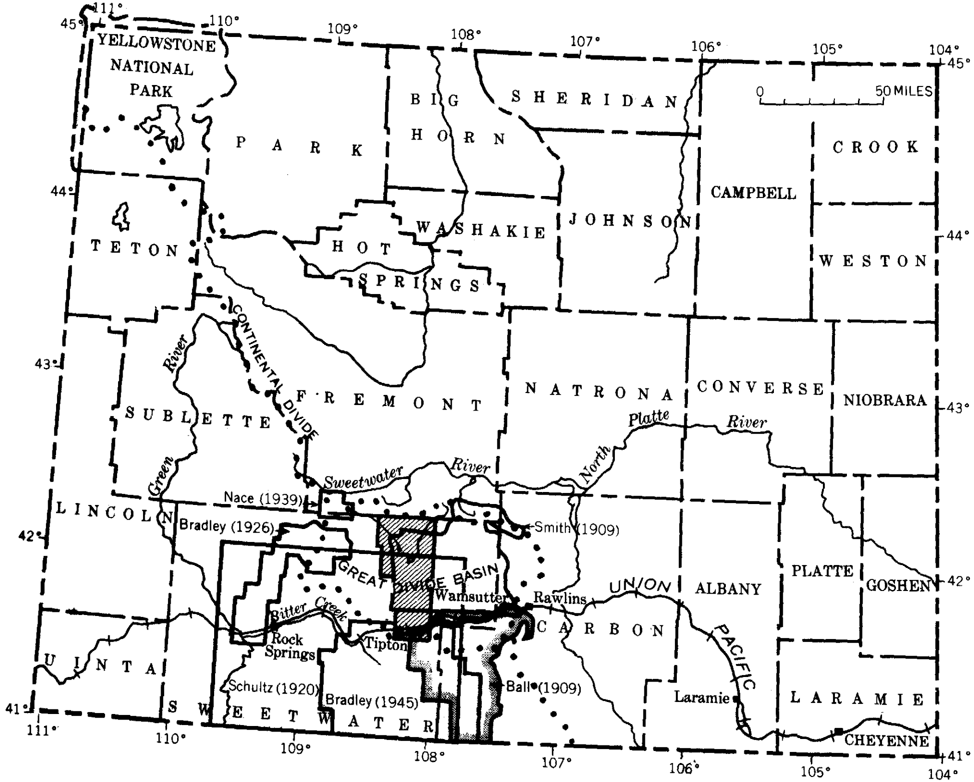

FIGURE 1.—Index map of Wyoming showing location of study area (shaded) in relation to nearby areas described in other reports.

(1909), and Schultz (1909). Schultz (1920) later completed a more comprehensive report in which he defined and described several members of the Green River formation. Sears and Bradley (1924) described intertonguing of the Green River and Wasatch formations in northwestern Colorado and southwestern Wyoming, and later mapping and stratigraphic studies near or related to the central part of the Great Divide Basin by Bradley (1926, 1945), Nightingale (1930), and Nace (1939) have yielded much information concerning the complex stratigraphic relations of the early Tertiary rocks of this region.

Uranium was first discovered in the north-central part of the Great Divide Basin by the late Mrs. Minnie McCormick, resident of Wamsutter, Wyo., who in 1936(?) found a yellow-green mineral, later identified as schroeckingerite, in the east bank of Lost Creek in the NW¼ sec. 31, T. 26 N., R. 94 W. (pl. 1). Radioactive carbonaceous shale and coal were discovered in 1945 by Slaughter and Nelson (written communication, 1946) at Sourdough Butte, a few miles east of the area. Reconnaissance mapping during parts of 1949 and 1950 by Wyant, Sharp, and Sheridan (1956) indicated that very large tonnages of uranium-bearing coal underlie parts of the Great Divide Basin. Results of detailed investigations (1951–53) of the schroeckingerite locality are given in a report by Sheridan, Maxwell, and Collier, 1961.

FIELDWORK

This report gives the results of the geologic mapping, sampling, and auger and core drilling in the western half of a larger area that was studied during the summers of 1951 to 1953. Summaries of some of the principal results of these studies have been published (Pipiringos, 1955, 1956). An area of about 850 square miles (approximately 24 townships or one 30-minute quadrangle) was mapped on aerial photographs at a scale of about 1:36,000 (pl. 1). Information gathered on the distribution and uranium content of the coal beds by mapping and sampling outcrops was augmented by drilling about 120 auger holes and 10 core holes. Many stratigraphic sections were measured and 19 fossil collections were made during the investigation. Some preliminary results of the 1951 and 1952 field seasons have been given in an earlier report (Masursky and Pipiringos, 1959).

ACKNOWLEDGMENTS

The work done during the summers of 1951 and 1952 was under the general supervision of Harold Masursky. A. E. Burford, Howard Gower, and George W. Moore assisted in the mapping during 1952, and J. C. MacLachlan assisted in the mapping during 1953. Gower helped compile the drilling data during the winter of 1952, and

MacLachlan, J. C. Benson, Harold Hyden, R. L. Koogle, and P. E. Soister helped compile the geologic map and the data on coal-reserves at various times during 1953 and 1954. Fossils collected by members of the U.S. Geological Survey were identified by R. W. Brown and T. C. Yen of the Survey, C. L. Gazin of the U.S. National Museum, and R. E. Peck of the Geology Department of the University of Missouri.

Special thanks are extended to N. M. Denson and R. W. Brown of the U.S. Geological Survey whose many helpful suggestions and stimulating discussions in the field were directly responsible for leading the author to two of the more important conclusions of this report: That the distribution of uranium in coal of this area primarily is related to sedimentary facies changes and that the early Tertiary sequence on the east flank of the Rock Springs uplift, formerly mapped as the Wasatch formation of Eocene age, actually consists of both Paleocene and earliest Eocene rocks which are faunally, florally, and lithologically distinct and are separated by an angular unconformity.

W. J. Mapel made many valuable criticisms and suggestions that greatly improved this report.

J. M. Schopf of the Geological Survey described the coal cores and sampled them for analysis.

Proximate and ultimate analyses of coal cores were made by the U.S. Bureau of Mines, Central Experiment Station, Pittsburgh, Pa., under the supervision of Roy F. Abernethy.

Analyses of coal and carbonaceous rocks were made at the U.S. Geological Survey laboratory, Washington, D.C. The radiometric analyses were made by B. A. McCall and E. G. Williams; the chemical analyses by Maryse Delevaux, Carmen Johnson, Shirley Lundine, Ivan Barlow, Harry Levine, W. P. Tucker, Jr., Joseph Budinsky, A. B. Caemmerer, Thomas Farley, J. J. Rowe, and Audrey Smith.

Six analyses of samples of arkosic and tuffaceous sandstone were made at the U.S. Geologic Survey laboratory, Denver, Colo. The radiometric analyses were made by Sylvia Furman, the chemical analyses by Wayne Mountjoy and George Boyes.

One sample of tuffaceous arkosic sandstone was analyzed at the U.S. Geological Survey laboratory, Washington, D.C. The radiometric analysis was made by B. A. McCall and the chemical analysis was made by Roosevelt Moore.

GEOGRAPHY

TOPOGRAPHY

Most of the central part of the Great Divide Basin is nearly flat and featureless. Low hills and ridges range in altitude from 7,300 to 7,500 feet west and north of the Cyclone Rim in the extreme northern part of the area and at Laney Rim in the extreme southern part. These areas of high ground mark the two branches of the Continental Divide. The intermittent lakes and dry flats range from about 6,500 to 6,700 feet in altitude.

Several small buttes in some parts of the area range from 50 to 300 feet above the general level of the terrain. These include Flattop Buttes in the extreme northern part of the area, Bastard Butte and Luman Butte in the northwestern part, Lost Creek Butte in the east-central part, and the Tipton Buttes in the southwestern part. Much of the area is dissected by shallow valleys whose gentle slopes rise to and merge with extensive gravel terraces.

Endlich (1879) applied the name "Red Desert" to the reddish western part of what is now included in the Great Divide Basin. To the nonred area east of the Red Desert he gave the name "Shoshone Basin." The name "Shoshone Basin" has been abandoned, and the name "Red Desert" has been extended to include outcrops of the Cathedral Bluffs tongue of the Wasatch formation southeastward as far as Baggs, Wyo. (Ball, 1909, pl. 13) and is now applied loosely to include much of the area east of Red Desert Flat.

DRAINAGE AND WATER SUPPLY

All the rain that falls in the Great Divide Basin either evaporates, sinks into the ground, or forms intermittent streams that drain into lakes (dry-lake flats), sumps, and reservoirs. The intermittent lakes dry up within a few days following a rain. There is no surface drainage out of the area except in the extreme northern and southern parts of the area, which belong to the Atlantic and Pacific drainages, respectively. There are no permanent lakes or streams in the area other than Grass Lake and Daly Lake, and the upper part of Lost Creek, which is spring fed in the vicinity of the schroeckingerite locality.

Aside from the natural sources previously mentioned, water is obtained from many wells drilled by ranchers, from wells drilled by the Union Pacific Railroad at Tipton, Red Desert, and Frewen, and from the so-called dry hole drilled for oil at the southwest edge of Lost Creek Flat by the Red Desert Oil Co. The "dry" hole yields an artesian flow of warm water at the rate of about 38 gallons per minute, but other wells in the area require the use of pumps to raise the water to the surface. Auger drilling revealed that the water table in the central part of the area is from a few feet to about 25 feet below the surface of the flats.

CLIMATE AND VEGETATION

The Great Divide Basin is semiarid and semiboreal. The average annual precipitation is equivalent to less than 10 inches of rain. The winters are cold and the summers are warm. The temperature rarely exceeds 90° F in the summer, but temperatures below 0° F are common in the winter. Low humidity and continual breezes result in little discomfort from the heat even in the warmest part of the summer; and there is little interruption of fieldwork in the early winter months, inasmuch as snow in October, November, and December is rapidly blown away, melted and evaporated, or sublimated.

The principal types of vegetation are grass, sagebrush, greasewood, salt sage, rabbitbrush, and tumbleweed. No trees grow in the Great Divide Basin, except at some of the railroad stations and locally along the periphery of the basin.

SETTLEMENT AND ROADS

The only communities in the area are Tipton, Red Desert, and Frewen, which are stations along the Union Pacific Railroad, and are inhabited only by employees of the railroad. But Wamsutter, about 4 miles east of Frewen, is a community of 103 inhabitants where food and other supplies can be purchased. Wamsutter includes a fair-sized settlement along U.S. Highway 30 and just north of the highway where the Utah Oil Co. maintains a pumping station. It is also the point where several trucking companies operating between Salt Lake City, Utah, and Denver, Colo., maintain a stop-over station for refueling, vehicle repair, and change of drivers. Rawlins (7,500 population) and Rock Springs (11,000 population) are situated along the railroad 47 miles east and 53 miles west of the map area, respectively.

Most of the Great Divide Basin provides winter grazing for sheep, whose owners maintain several watering places, hay barns, and sheep-shearing pens in the area. From May to October the area does not provide enough water or feed to sustain many; consequently, the sheep are moved to nearby mountains for grazing during that time. A complex network of graded dirt roads, car trails, and wagon trails, which join U.S. Highway 30 at many places, provides easy access by vehicle to nearly all parts of the area except during short periods following heavy rain or snowfall.

LAND SURVEY

HORIZONTAL CONTROL

The central part of the Great Divide Basin was surveyed in the late 1870's and early 1880's. A few of the old notched stone corners still stand, especially along the township lines, but most of them can no longer be found. The external boundaries of the townships south of T. 25 N. were resurveyed in 1936 by the General Land Office and are now well marked by brass-capped steel pipes, many are set alongside the old stone corners. Generally the distances between corners shown on the old plats differ by several chains per mile from those shown on the recent plats. Township tiers 25 and 26 N. were not resurveyed, and only a few of the old stone corners are left to mark the sections. Many of the corners that were found in these northern tiers of townships were made of friable arkosic sandstone, so the chances are that the stones marking the internal corners, which were generally smaller than those marking the external corners, have for the most part completely disintegrated. Only townships 23 and 24 N., R. 97 W., which contain parts of the Luman Ranch homestead, have been resurveyed internally.

The grid for the geologic map (pl. 1) was constructed by plotting the external corners of the townships according to the 1936 plats, and by connecting opposite corners by straight lines, except where some of the old internal corners were recovered. The geologic mapping was transferred from aerial photographs onto the grid by means of a vertical projector.

VERTICAL CONTROL

Vertical control within the map area is limited to U.S. Coast and Geodetic Survey triangulation stations Delaney (altitude 7,445 feet) in sec. 29, T. 19 N., R. 95 W.; Divide (altitude 6,986 feet) in sec. 16, T. 22 N., R. 94 W.; and Red Desert (altitude 6,829 feet) in sec. 8, T. 22 N., R. 95 W. and to several Wyoming State Highway Department bench marks along the north side of U.S. Highway 30 (pl. 1). The altitude above sea level established for Divide, 6,989 feet and Red Desert, 6,832 feet should be 6,986 feet and 6,829 feet, respectively, according to corrections by the U.S. Coast and Geodetic Survey (written communication, 1950). Transit surveys made by private companies (oral communications) indicate that the altitude readings stamped on the Wyoming Highway Department bench marks are about 52 feet too high, and that altitude reading of triangulation station Red Desert (6,829 feet) is about 15 feet too high. Many repeated altimeter traverses made between the bench marks and the triangulation stations and between the triangulation stations Red Desert and Divide showed similar discrepancies.

Altitude readings established by altimeter, shown on plate 1 and those on which the structure contours (pl. 1) are based, are probably accurate to within 15 feet inasmuch as all altimeter loop traverses closed within a few feet, and one linear traverse, more than 30 miles long, between triangulation station Divide and U.S. Geological Survey bench mark Girrard (altitude 7,212 feet, located a few miles north of Flattop Buttes) closed within 10 feet.

No trace was found of the U.S. Geological Survey triangulation station "Tipton" established in the late 1880's on the highest part of Tipton Butte. The Geological Survey bench mark (Z–2) at Red Desert station on the Union Pacific Railroad could not be located.

STRATIGRAPHY

SUMMARY STATEMENT

The sedimentary rocks exposed in the central part of the Great Divide Basin consist mostly of lake, swamp, and stream deposits of early Tertiary age, and have an aggregate thickness of about 5,000 feet. The distribution of the various rock units is shown on the geologic map and the general lithology of the rocks is shown in the composite stratigraphic sections (pl. 2).

The Fort Union formation of Paleocene age is the oldest formation exposed in the area. It consists of sandstone, siltstone, clay shale, and coal beds, and a few miles north of the area it is about 1,000 feet thick and rests unconformably on Cretaceous rocks (Bell, 1954). The upper 50 feet of the formation crops out in a small area north of Cyclone Rim; elsewhere, the Fort Union formation is covered by younger sedimentary rocks.

Unconformably overlying the Fort Union formation is a sequence of beds of early and middle Eocene age about 3,400 feet thick consisting of sandstone, siltstone, oil shale, clay shale, limestone, conglomerate, and coal beds. Six stratigraphic units can be recognized in this sequence. Three are made up predominantly of variegated claystone, or sandstone and siltstone, with subordinate limestone conglomerate, shale, and coal. They are, from youngest to oldest, the Cathedral Bluffs, Niland, and Red Desert tongues of the Wasatch formation. Alternating and intertonguing with these units are three stratigraphic units consisting predominantly of oil shale with subordinate sandstone, siltstone, and limestone. They are, from youngest to oldest, the Laney shale member and the Tipton and Luman tongues of the Green River formation.

In the northern part of the area, the various tongues and members of the Wasatch and Green River formations grade laterally into and intertongue with coarse-grained to conglomeratic arkosic sandstone beds of the Battle Spring formation.

Rocks of Tertiary age, younger than the Laney shale member of the Green River formation, are exposed at Cyclone Rim. They include the Bridger formation of middle Eocene age, which is as much as 250 feet thick and consists of claystone and shale with several thin beds of limestone, and the Browns Park(?) formation of Miocene age, which is at least 400 feet thick and consists of tuffaceous fine-grained to conglomeratic sandstone. An angular unconformity at the base of the Browns Park(?) formation truncates the Bridger formation.

Surficial deposits of Quaternary age cover large areas in the west-central part of the Great Divide Basin. The deposits include alluvium on the bottoms of dry lakes and in the valleys of some of the streams, delta and fan deposits along the margins of some of the dry lakes, sand dunes, and gravel deposits on some of the buttes and mesas.

The general stratigraphic relations of the various formations and members is shown by the restored section on plate 1, and the stratigraphic nomenclature used in this and other published reports on the Great Divide Basin and adjacent areas is shown by table 1. Fossils found in the Tertiary rocks during the investigations are given in table 2, and, except for no. 16, fossil localities are shown on plate 1.

TERTIARY ROCKS

FORT UNION FORMATION

The Fort Union formation has been applied to a sequence of sandstone, siltstone, clay shale, and coal beds near Flattop Buttes at the north edge of the area (Pipiringos, 1955; pls. 1 and 2, this report). Only the upper 50 feet of the formation crops out in the area, but its thickness directly north of Flattop Buttes in the south flank of Bison Basin is about 1,000 feet (Bell, 1954). Vertebrate fossils of late Paleocene (Tiffanian) age were collected in July 1952 by R. W. Brown, H. R. Christner, and Harold Masursky of the Survey from within 300 feet of the top of the formation of the SE¼ sec. 28, T. 27 N., R. 95 W., about 1.5 miles north of Flattop Buttes. A recent report (Gazin, 1956, p. 6 and 7) describes this fauna in detail. Because of similar lithologic character and stratigraphic position, this sequence is correlated with the Fort Union formation west of the Rawlins uplift (Brown, 1949) and with the Fort Union formation of the Wind River Basin of central Wyoming (Yenne and Pipiringos, 1954).

The Fort Union formation, in Bison Basin north of Flattop Buttes, rests unconformably on rocks of Late Cretaceous age, and is uncon-

591964 O—61——2

TABLE 1.—*Correlation of Paleocene and Eocene rocks of the central part of the Great Divide Basin with similar rocks in adjacent areas*

Schultz, 1920		Bradley, 1926	Nightingale, 1930	Bradley, 1945	This report		Age
Rock Springs uplift, Sweetwater County, Wyo.		Northern Sweetwater County, Wyo.	Vermillion Creek gas area, northwestern Colorado and southwestern Wyoming	Washakie Basin, Sweetwater and Carbon Counties, Wyo.	Central part of the Great Divide Basin, Sweetwater County, Wyo.		
					Southern part	Northern part	
Bridger formation		Bridger formation	Bridger formation	Bridger formation	Bridger formation	Bridger formation	Middle Eocene
Green River formation	Plant beds and Tower sandstone of Powell	Morrow Creek member of Green River formation	Green River formation	Morrow Creek[1] member of Green River formation	Laney shale member of Green River formation	Laney shale member of Green River formation	
	Laney shale member	Laney shale member of Green River formation		Laney shale member of Green River formation		Battle Spring formation[2]	
	Cathedral Bluffs red beds member	Cathedral Bluffs tongue of Wasatch formation	Cathedral Bluffs tongue of Wasatch formation	Cathedral Bluffs tongue of Wasatch formation	Cathedral Bluffs tongue of Wasatch formation		
	Tipton shale member	Tipton tongue of Green River formation	Tipton tongue of Green River formation	Tipton tongue of Green River formation	Tipton tongue of Green River formation		?
Wasatch formation		Main body of Wasatch formation (base not exposed in area)	? Hiawatha member of Wasatch formation (lower 3,500 feet known only from drill cuttings)	Main body of Wasatch formation (base not exposed in area)	Niland tongue[2] of Wasatch formation		Early Eocene
					Luman tongue[2] of Green River formation		
					Red Desert tongue[2] of Wasatch formation		
					Unconformity Fort Union formation (not exposed)	Unconformity Fort Union formation	Paleocene
Unconformity Cretaceous			Fault contact Cretaceous		Unconformity (?) Cretaceous (not exposed)	Unconformity Cretaceous (not exposed)	

[1] The name Morrow Creek was abandoned in favor of the name Laney shale by Bradley (1959, p. 1074).
[2] New names proposed by Pipiringos (1955).

TABLE 2.—*Fossils collected in the central and western parts of the Great Divide Basin, Sweetwater County, Wyo.*

[Localities shown on plate 1 (except loc. 16)]

Locality	Age	Identifications	Stratigraphic position
		Browns Park(?) formation	
1. NW¼ sec. 13, T. 26 N., R. 95 W.	Miocene [1]	*Blastometrix* sp.	More than 200 ft. above base.
		Laney shale member of the Green River formation	
2. SE¼NE¼ sec. 18, T. 26 N., R. 95 W.	Middle Eocene [2]	*Unio* cf. *U. haydeni* Meek *Goniobasis* cf. *G. tenera* (Hall).	About 40 ft. above base.
		Cathedral Bluffs tongue of the Wasatch formation	
3. SE¼SE¼ sec. 33, T. 19 N., R. 95 W.	Indeterminate [3]	*Hyopsodus*? sp.	About 500 ft. above base.
		Niland tongue of the Wasatch formation	
4. SE¼NW¼SW¼ sec. 24, T. 24 N., R. 96 W.	Earlier half of the Eocene.[4]	*Salvinia preauriculata* Berry. *Lygodium kaulfussi* Heer *Lemna scutata* Dawson *Equisetum* sp.	30 ft below top (2 ft. below Bush No. 2 coal bed).
5. NW¼SW¼ sec. 21, T. 24 N., R. 95 W.	Eocene [4]	*Aralia* sp. *Mimosites* sp.	90 ft below top (30 ft. above Hay No. 2 coal bed).
6. SE¼NW¼ sec. 28, T. 24 N., R. 95 W.	Eocene [4]	*Typha* sp.	185 ft below top (3 ft. below Luman No. 2 coal bed).
7. SW¼NE¼NE¼ sec. 22, T. 24 N., R. 97 W.	Probably early Eocene age.[2]	*Goniobasis carterii* Conrad. *Valvata* sp.	50 ft below top (25 ft. above Hay No. 2 coal bed).
8. Core hole 4 [5]	Paleocene or early Eocene.	*Cypridea arvardensis* (Swain). *Candona pageii* Swain *Candona* sp.	85 and 50 ft above base (at depths 140–143, 172–176 ft.).
		Luman tongue of the Green River formation	
9. SW¼SW¼ sec. 15, T. 22 N., R. 94 W.	Early Eocene [2]	*Unio* sp. *Valvata* sp. *Viviparus* cf. *V. Paludinaeformis* (Hall) *Goniobasis* cf. *G. tenera* (Hall) *Gyraulus* cf. *G. militaris* (White)	41 ft. above base.
10. SE¼SE¼ sec. 21, T. 22 N., R. 94 W.	Probably Early Eocene.[2]	*Valvata* sp. *Viviparus* sp. *Goniobasis* cf. *G. tenera* (Hall)	38 ft. above base.
11. Core hole 4	Paleocene or Early Eocene.[5]	*Cypridea arvardensis* (Swain). *Candona pageii* Swain *Candona* sp.	23 ft. above base (at depths 458–463 ft).
12. NE¼SW¼SE¼ sec. 36, T. 23 N., R. 95 W.	Early Eocene [2]	*Unio* sp. *Sphaerium* sp. *Viviparus* sp. *Valvata* sp. *Gyraulus* sp. *Goniobasis nodulifera* (Meek) *Goniobasis* cf. *G. tenera* (Hall)	5 ft. above base.
13. NE¼NE¼ sec. 27, T. 20 N., R. 96 W.	Indeterminate [2]	*Unio* sp. *Goniobasis* sp.	At base ("wormy" sandstone).

TABLE 2.—*Fossils collected in the central and western parts of the Great Divide Basin, Sweetwater County, Wyo.*—Continued

Red Desert tongue of the Wasatch formation

Locality	Age	Identifications	Stratigraphic position
14. NE¼NW¼SW¼ sec. 4, T. 19 N., R. 96 W.	Indeterminate [3]	*Hyopsodus*(?) sp	50 ft. below top.
15. SE¼NW¼SW¼ sec. 23, T. 20 N., R. 96 W.	Early Eocene [3] (Lysite or Lost Cabin).	*Paramys* sp *Esthonyx* sp. *Hyopsodus* sp. *Hyracotherium* sp. *Meniscotherium* sp. *Pelycodus* or *Notharctus* sp. Creodont Tapiroid	280 ft. below top.
16. Sec. 12, T. 23 N., R. 100 W.[6]	Early Eocene [3] (Gray Bull, Sand Coulee).	*Pelycodus*(?) sp *Diacodexis* sp. *Hyracotherium* sp. *Esthonyx* cf. *bisulcatus* *Haplomylus* cf. *speirianus* *Meniscotherium*, possible *M. priscum*	Estimated 200 ft. above base.
17. NE¼NE¼ sec. 27, T. 20 N., R. 96 W.	Probably Early Eocene.[2]	*Unio* sp *Valvata* sp. *Gyraulus* sp. *Sphaerium* sp. *Goniobasis* sp.	40 ft. below top.
18. NE¼NE¼ sec. 27, T. 20 N., R. 96 W.	Early Eocene	*Valvata* sp *Viviparus* sp. *Physa* cf. *P. bullatula* White.[2] *Physa* cf. *P. pleromatis* White [2] *Gyraulus* cf. *G. militaris* (White) *Hydrobia* cf. *H. utahensis* (White) "*Planorbis*" cf. *P. convolutus* Meek and Hayden	205 ft. below top ("holey" limestone).
19. SW¼SW¼ sec. 4, T. 21 N., R. 94 W. (Map locality 78).	Eocene [4]	*Salvinia preauriculata* *Sparganium antiquum* (Newberry) *Platanus raynoldsi* Newberry Insect wings	About 190 ft. below top (directly over Tierney No. 4 coal bed).

[1] Fossils collected and identified by W. G. Bell, Geology Dept., Wyoming Univ.
[2] Fossils identified by T. C. Yen, U.S. Natl. Mus.
[3] Fossils identified by C. L. Gazin, Curator Vertebrate Paleontology, U.S. Natl. Mus.
[4] Fossils identified by R. W. Brown, U.S. Geol. Survey.
[5] Fossils identified by R. E. Peck, Geology Dept., Missouri Univ.
[6] The exact location is uncertain. From the fossil locality, the compass bearing to the south end of Steamboat Mountain is S. 85° W., and to Black Rock Butte it is S. 40° W.

formably overlain by arkosic sandstone beds of Eocene age. Coal beds, iron oxide concretions, and bands of purple, yellow, and white are characteristic of the Paleocene rocks of this and adjacent areas.

The lower part of the Wasatch formation as used by Schultz (1920) is here correlated with the Fort Union formation (table 1). It is discussed, together with the upper part of Schultz' Wasatch, near the end of the description of the Niland tongue of the Wasatch formation.

WASATCH AND GREEN RIVER FORMATIONS

The restored sections (pl. 1, figs. 2–6), whose orientation is shown on plate 1, and the photographs (figs. 7–17) depict details of the stratigraphic units described below. The restored sections were constructed by plotting more than 100 measured sections and drawing correlation lines between them. In these restored sections either the algal ball zone at the base of the upper part of the Tipton or the "pastel limestone marker bed" at the base of the Luman tongue is the datum above and below which the measured sections are plotted in their true relative stratigraphic positions. The restored sections are intended to take the place of graphically plotted or written measured sections, which ordinarily are part of a stratigraphic report, and at the same time present the author's concept of the stratigraphic relations of those parts of the Tertiary sequence that are now missing by erosion throughout much of the area or are concealed by younger rocks.

RED DESERT TONGUE OF THE WASATCH FORMATION

The name "Red Desert tongue of the Wasatch formation" has been applied to the sequence of clay shale, siltstone, low-grade oil shale, biotitic sandstone, and coal beds that overlies the Fort Union formation and underlies the Luman tongue of the Green River formation (Pipiringos, 1955). Most of the coal in the area is contained in the Red Desert tongue. This tongue was named from typical exposures of coal-bearing gray-white shale, siltstone, and sandstone that crop out southwest of Red Desert Flat at Tipton Buttes (pl. 1, figs. 5 and 17) and northeast of Red Desert Flat in the northwest corner of T. 21 N., R. 94 W., and adjoining parts of T. 21 N., R. 95 W.; T. 22 N., R. 94 W.; and T. 22 N., R. 95 W. Most of the southern part of the area is directly underlain by the Red Desert tongue, and although only the upper 400 feet of this tongue is exposed in the area, similar rocks on the east flank of the Rock Springs uplift are about 1,000 feet thick, rest unconformably on the Fort Union formation, and conformably underlie the Luman tongue of the Green River formation.

A peculiarly perforate sandstone and a gray-black limestone (fig. 9) were useful in correlating the rocks in the southeastern part of the area with those in the Tipton Buttes area west of Red Desert Flat. These key beds are described on page A–58.

Beds near the top of the Red Desert tongue yielded vertebrate fossils of early Eocene (Lysite or Lost Cabin) age near Tipton Buttes in the SW¼ sec. 23, T. 20 N., R. 96 W., and beds near the base of the tongue yielded vertebrate fossils of earliest Eocene (Graybull and Sand Coulee) age about 14 miles east of Steamboat Mountain in sec. 12, T. 23 N., R. 100 W. (table 2, loc. 16 and 17).

LUMAN TONGUE OF THE GREEN RIVER FORMATION

The name Luman tongue of the Green River formation has been applied to a sequence of oil shale, fossiliferous muscovitic calcareous

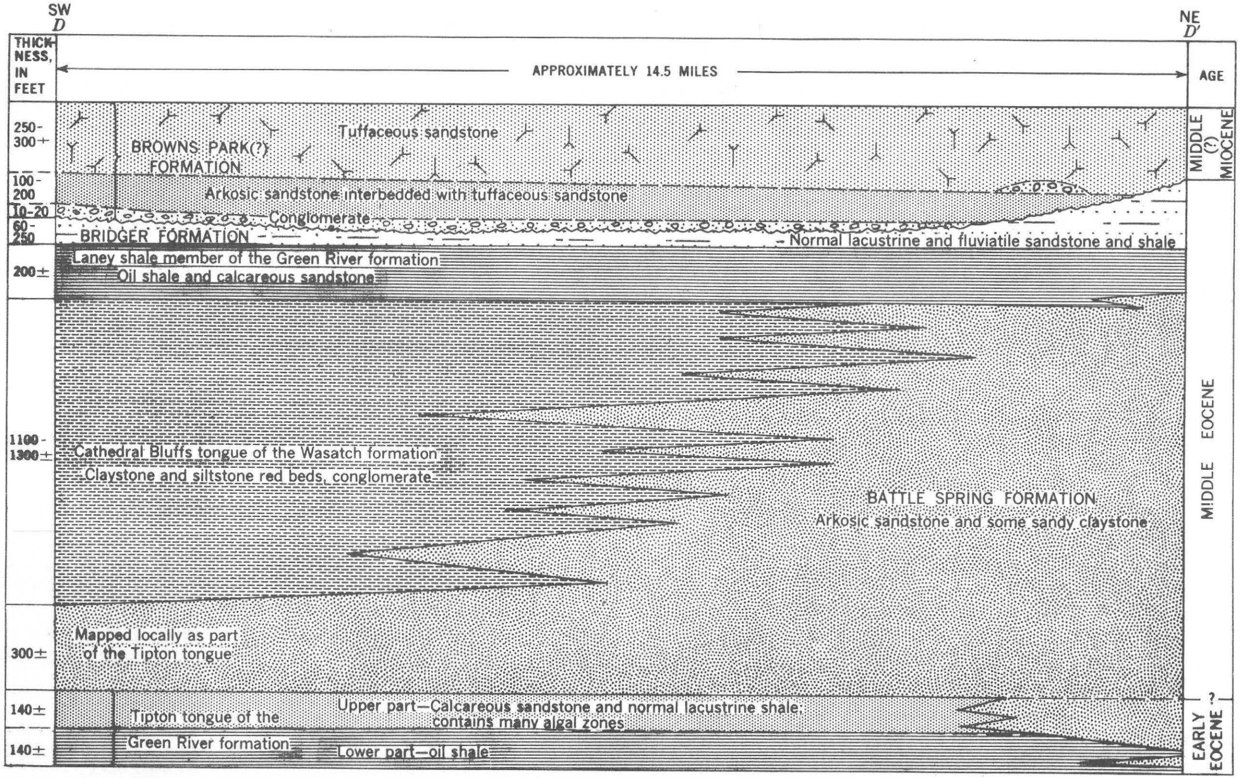

FIGURE 2.—Diagram of the stratigraphic relations of Tertiary rocks from Bastard Butte northeastward to Soda Lake. (See geologic map, pl.1.)

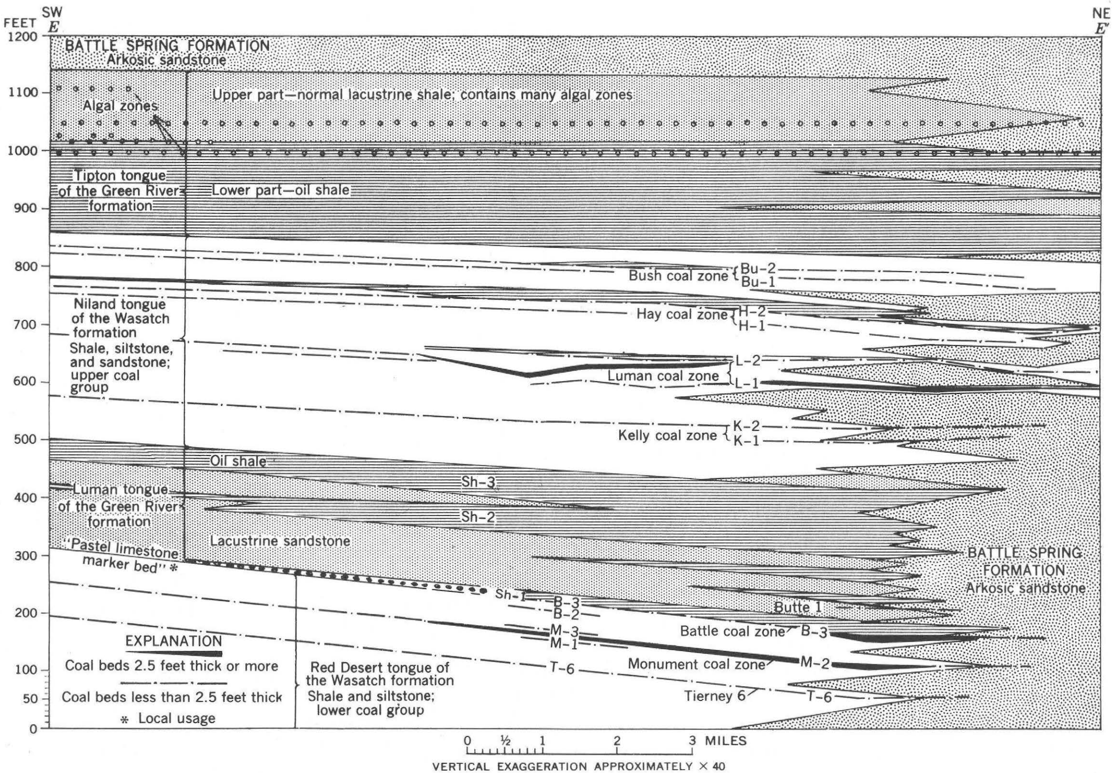

FIGURE 3.—Restored section of lower Tertiary rock from Luman Butte northeastward to Eagles Net Ranch. (See geologic map, pl. 1.)

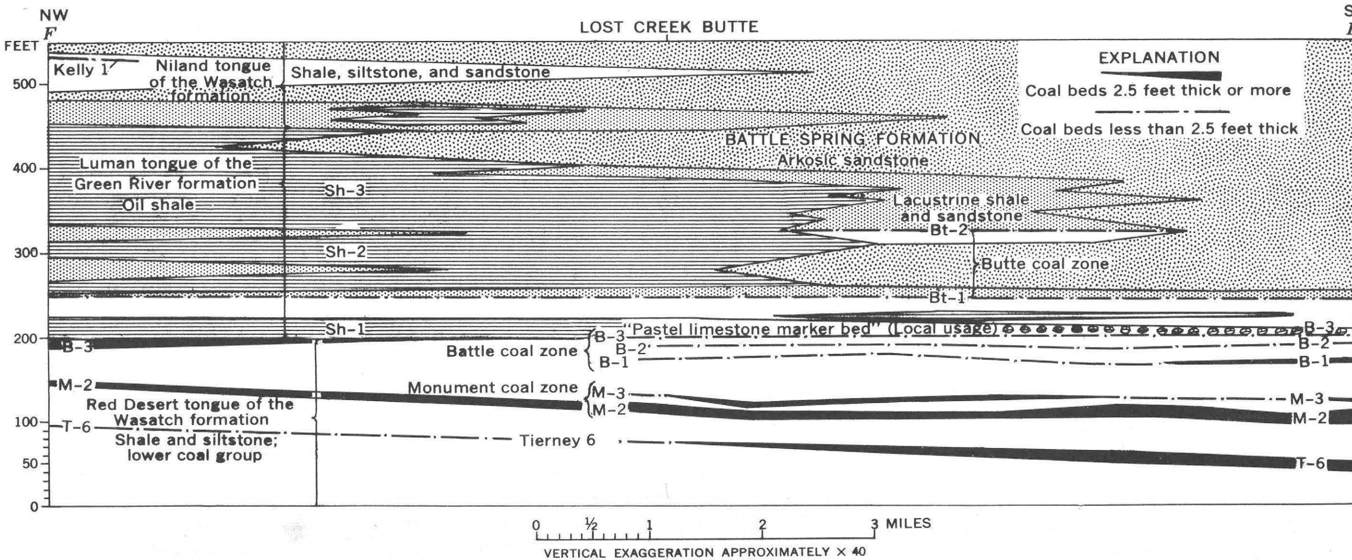

FIGURE 4.—Restored section of lower Eocene rocks from the north shore of Lost Creek Flat southeastward to the vicinity of triangulation station Divide. (See geologic map, pl. 1.)

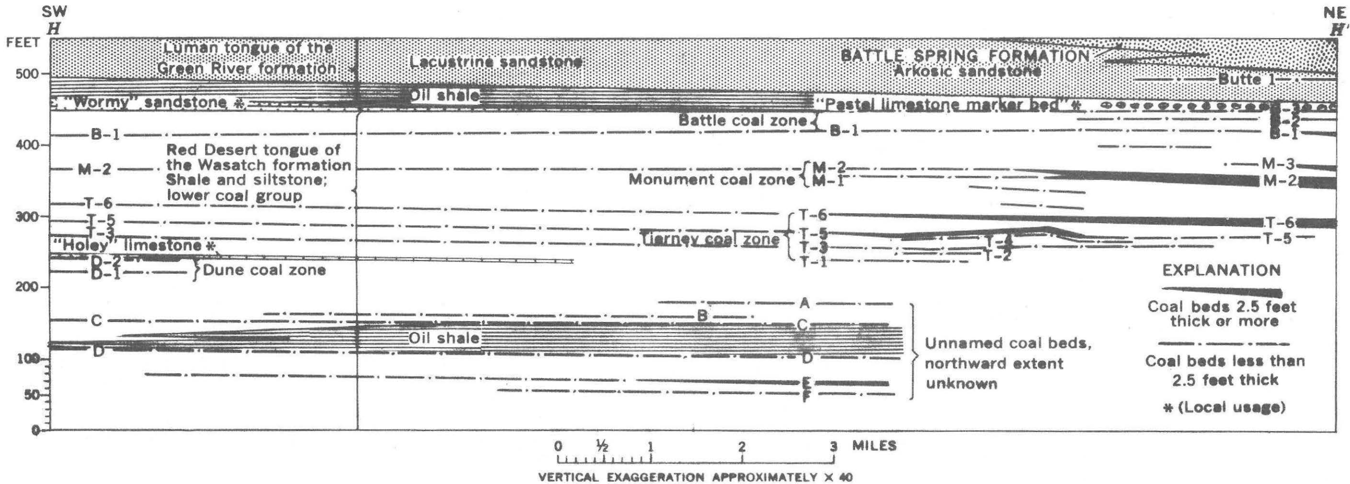

FIGURE 5.—Restored section of lower Eocene rocks from the Tipton Buttes area northeastward to the vicinity of triangulation station Divide. (See geologic map, pl.1.)

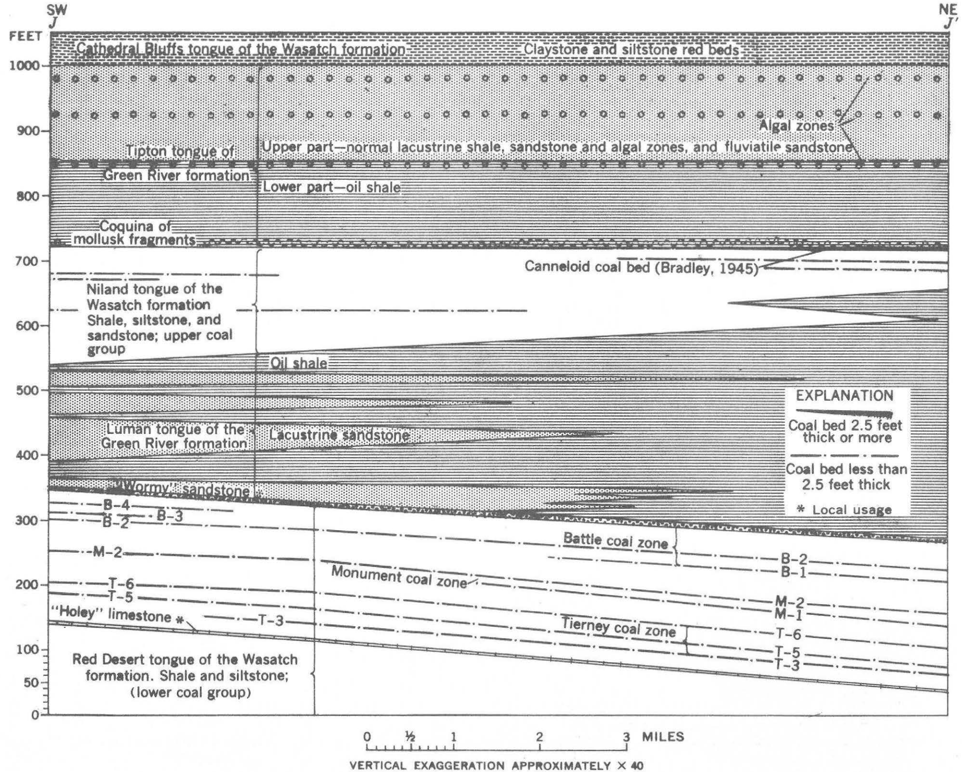

FIGURE 6.—Restored section of lower Eocene rocks from Tipton Station northeastward to Frewen Lake. (See geologic map, pl. 1.)

FIGURE 7.—Crossbedded arkosic sandstone beds in the Battle Spring formation about 10 miles west of Rawlins, Wyo.

sandstone, varved siltstone, clay shale, and a few thin coal beds (Pipiringos, 1955) that is excellently exposed on the south slope of Luman Butte (sec. 34, T. 24 N., R. 97 W.) in the northwest part of the area. These rocks have been mapped as part of the Wasatch formation in the area to the east (Masursky, in press). The Luman tongue overlies the Red Desert tongue of the Wasatch formation and underlies the Niland tongue of the Wasatch formation (figs. 3, 12, 13, and 21). The Luman tongue crops out in two belts; one extends from the vicinity of Luman Butte southeastward to the center of T. 22 N., R. 94 W., and the other extends across the southern part of the area, parallel to U.S. Highway 30. The Luman tongue has been eroded from the central part of the area. It is about 180 feet thick at Luman Butte but thickens eastward to about 270 feet in the vicinity of Lost Creek Butte (figs. 3, 4). It also thickens eastward in the southern part of the area, from about 200 feet at Tipton to about 390 feet at Frewen (fig. 6).

The Luman tongue contains several constituent tongues of low-grade oil shale separated by sandstone and siltstone beds. The three most conspicuous and persistent tongues were mapped separately, and are designated from bottom to top, shale tongues 1, 2, and 3. Shale 1 in the northern part of the area is characterized by gray-black silty

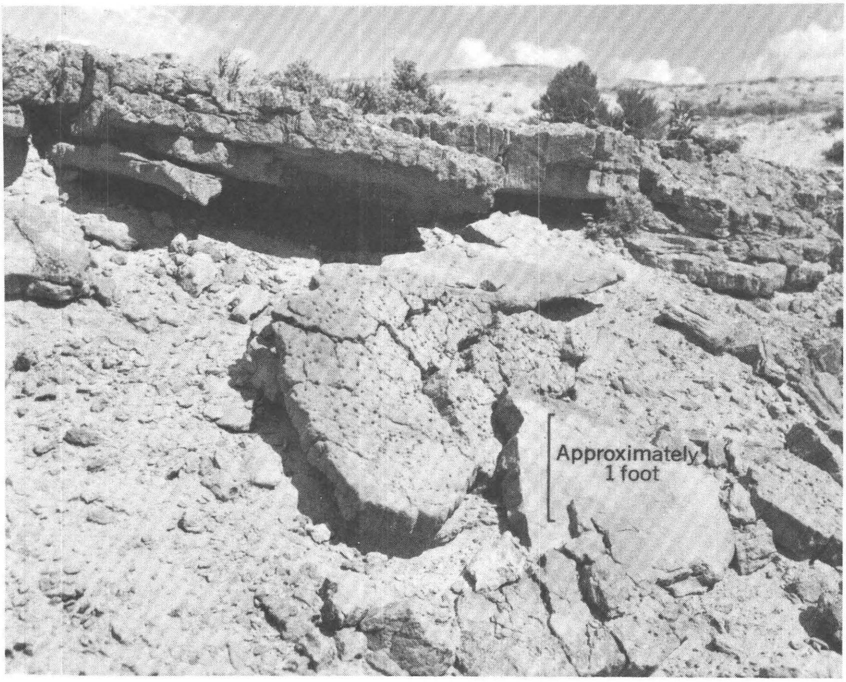

FIGURE 8.—The "wormy" sandstone bed at the base of the Luman tongue of the Green River formation in the NE¼NE¼ sec. 8, T. 19 N., R. 96 W.

limestone concretions which average 1 foot in diameter (the "pastel limestone marker bed") and which have a splintery fracture and weather purple, pink, yellow, buff, and brown; and, except in the vicinity of Luman Butte, shale 1 rests directly on the highest coal bed of the Red Desert tongue of the Wasatch formation (figs. 3, 4, 12, 13, 21, 22). The stratigraphic association of coal overlain by low-grade oil shale containing the "pastel limestone marker bed" is unmistakable and constitutes one of the most useful horizons for correlating and structure contouring in the area. Shale tongues 2 and 3 thicken eastward from Luman Butte at the expense of the intervening siltstone and sandstone; and in the vicinity of Lost Creek Butte, they coalesce into one body of oil shale 120 feet thick (core hole 4, pls. 1 and 4, figs. 3 and 4). In the southern part of the area, shale tongues 1, 2, and 3 thicken eastward from Tipton. In the vicinity of Frewen they coalesce into one body of oil shale about 390 feet thick (fig. 6).

The Luman tongue contains several prominent beds of fossiliferous, calcareous, muscovite-bearing fine-grained sandstone southeast of the Luman ranch in the low bluffs that extend across the sand dune belt in the northwest part of T. 23 N., R. 96 W. One of these sandstone beds (figs. 10, 11), about 40 feet above the base of the tongue, is

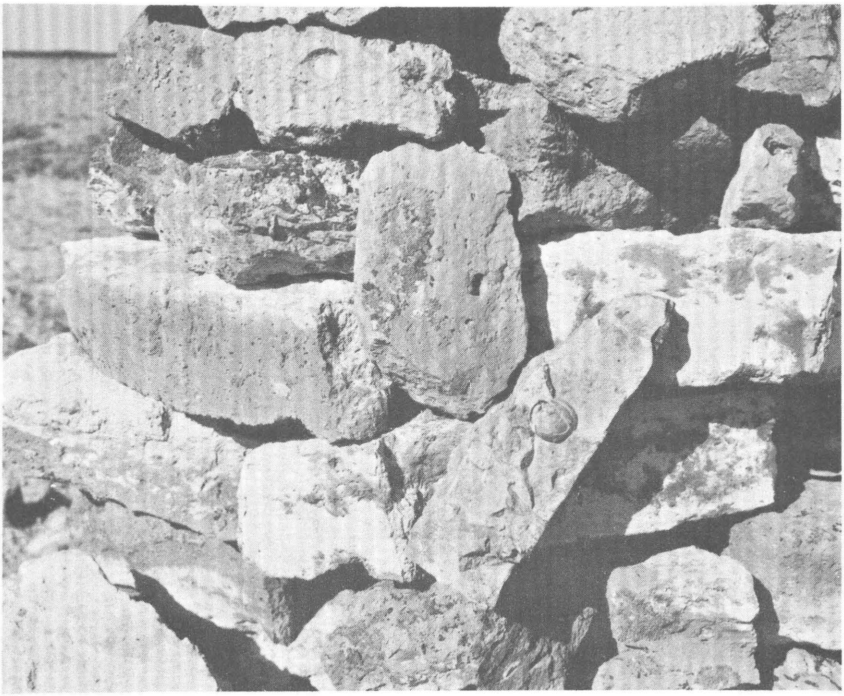

FIGURE 9.—Monument made from blocks of the "holey" limestone about 200 feet below the top of the Red Desert tongue of the Wasatch formation in the NE¼SE¼ sec. 22, T. 20 N., R. 95 W. The gastropod at the lower right is about 2 inches in diameter.

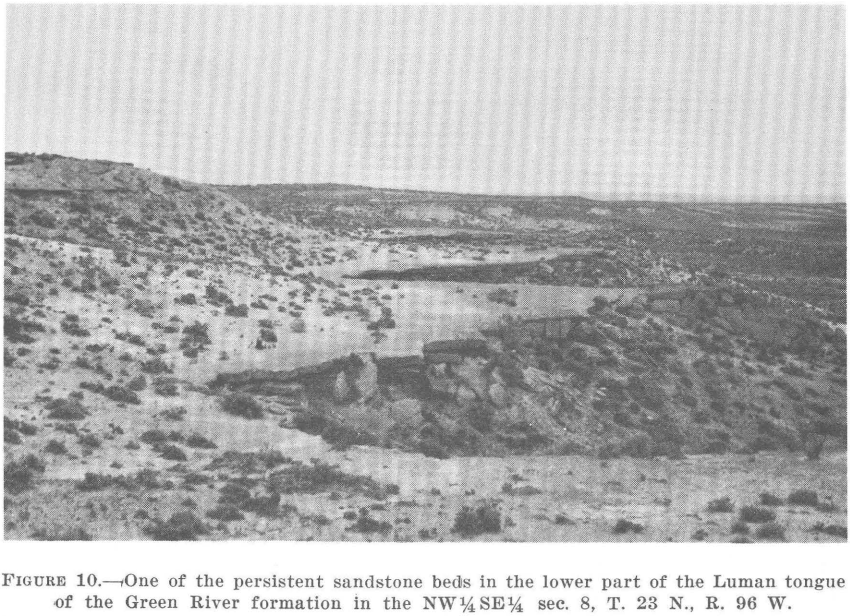

FIGURE 10.—One of the persistent sandstone beds in the lower part of the Luman tongue of the Green River formation in the NW¼SE¼ sec. 8, T. 23 N., R. 96 W.

FIGURE 11.—Fossil mollusk molds in the sandstone bed shown in figure 10.

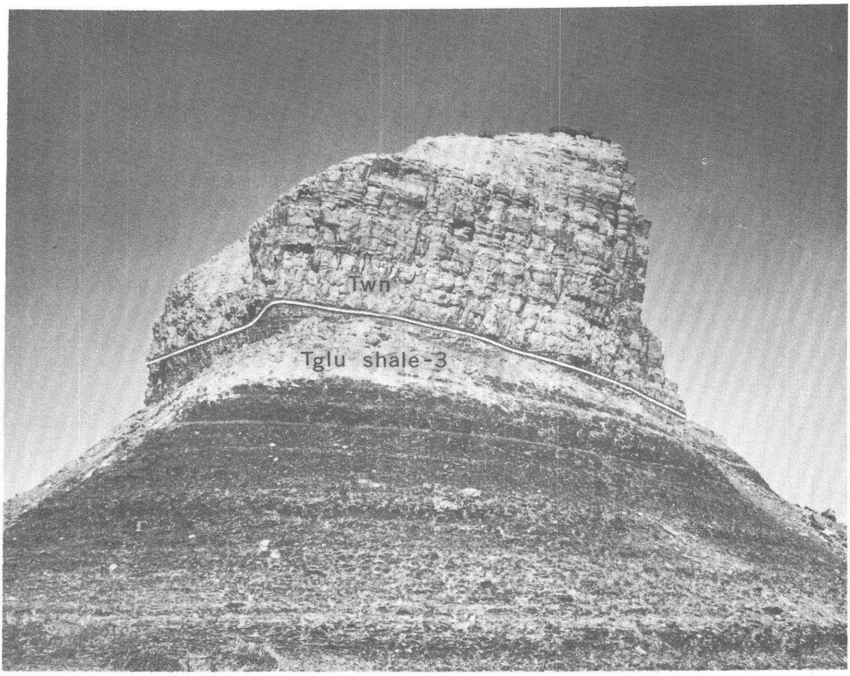

FIGURE 12.—Contact of the Luman tongue of the Green River formation (*Tglu,* shale-3) with the Niland tongue of the Wasatch formation (*Twn*) in the NW¼SW¼ sec. 35, T. 24 N., R. 96 W.

FIGURE 13.—Fragments of a limestone concretion in the "pastel limestone marker bed," a key zone in shale 1 at the base of the Luman tongue in SE¼NW¼ sec. 28, T 22 N., R. 94 W.

about 2 feet thick and persists from Luman Butte southeastward for about 20 miles to fossil locality 9 (pl. 1 and table 2) in sec. 16, T. 22 N., R. 94 W. Another of these beds called the "wormy" sandstone, which was chosen as the base of the Luman tongue in the southern part of the area, is characterized by molluscan impressions and vertical borings possibly made by worms (figs. 6, 8, 9). Mollusk and ostracode remains found at several stratigraphic horizons in the Luman tongue are of early Eocene age (table 2).

NILAND TONGUE OF THE WASATCH FORMATION

The name Niland tongue of the Wasatch formation has been applied to a sequence of coal beds, clay shale, siltstone, sandstone, and low-grade oil shale (Pipiringos, 1955), which crops out at the southern margin of the Niland Basin along the north side of Lost Creek Flat. The name is taken from Niland Spring in sec. 23, T. 25 N., R. 96 W., about 7 miles northwest of the best exposures of the Niland tongue, and the type locality is SW¼ T. 24 N., R. 95 W., and SE¼ T. 24 N., R. 96 W. At this locality the Niland is about 400 feet thick, un-

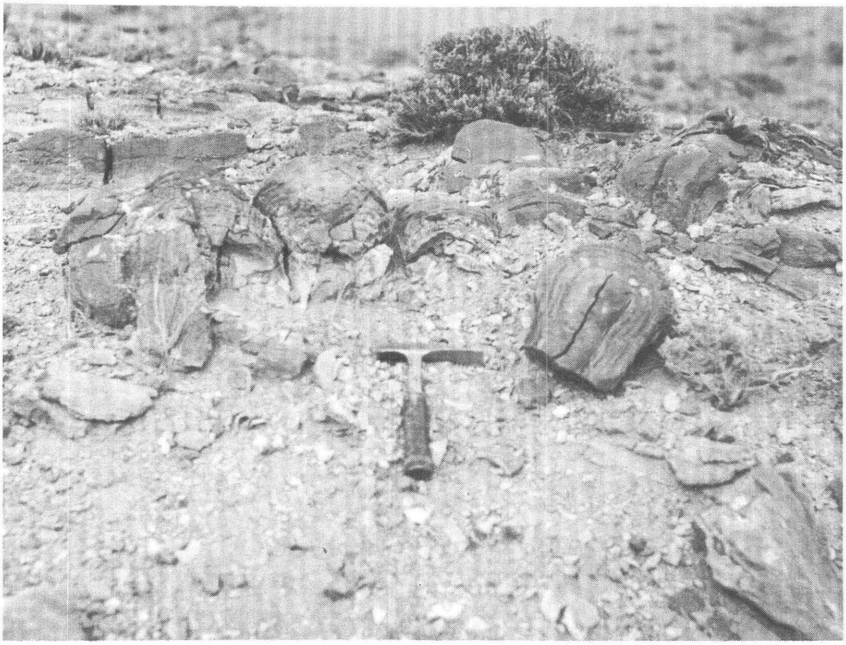

FIGURE 14.—Algal ball zone about 265 feet above the base of the Tipton tongue of the Green River formation in the SE¼SE¼ sec. 18, T. 19 N., R. 94 W.

derlies the Tipton tongue, and rests on the Luman tongue of the Green River formation. The upper and lower contacts are conformable. The Niland tongue thins westward to about 325 feet in the Luman Butte area (fig. 3). It has been removed by erosion over the central part of the area, but crops out in the southern part of the area in a belt parallel to and south of U.S. Highway 30. In the southern part of the area the coal beds of the Niland are for the most part fewer, thinner, and less conspicuous (fig. 6) than in the northern part. An exception is the 5-foot canneloid coal bed at the top of the Niland tongue southeast of Frewen that was mapped by Bradley (1945) along the northeast flank of the Washakie Basin. In its type area, the Niland tongue contains four coal zones that constitute the upper coal group mentioned in this report. Each of these four coal zones is overlain by or interbedded with a low-grade oil-shale tongue (fig. 3, pl. 4). Fossil plants and mollusks collected from the middle of the formation are of early Eocene age (table 2).

As shown in tables 1 and 2, the Red Desert, Luman, and Niland tongues are of early Eocene age and correlate with the upper part of the Wasatch formation as used by Schultz (1920) and with the upper part of the Hiawatha member of the Wasatch formation as used by Nightingale (1930). At Bitter Creek along the Union Pacific Rail-

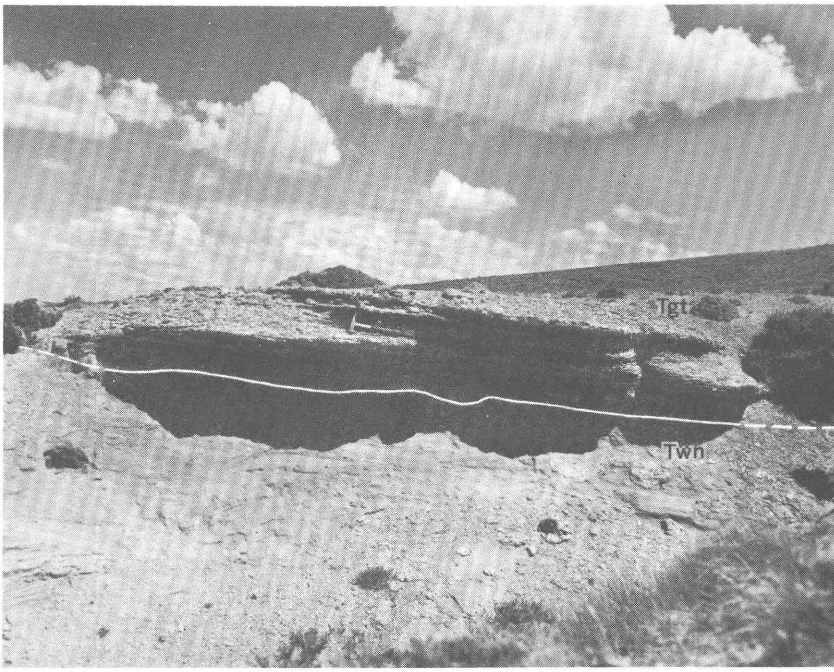

FIGURE 15.—Coquina at the base of the Tipton tongue in the NE¼NE¼ sec. 17, T. 19 N., R. 96 W. Along the Wamsutter Rim, this bed marks the contact between the Tipton (*Tgt*) and the Niland (*Twn*) tongues.

road, about 15 miles west of Tipton, the upper part of Schultz' Wasatch is about 1,400 feet thick and is separated from the lower part by an unconformity. The beds below the unconformity (the lower part of Schultz' Wasatch) are about 1,100 feet thick, contain plants of Paleocene age, and rest unconformably on the Lance formation of Late Cretaceous age. It seems highly probable that the lower part of Schultz' Wasatch is the lithologic continuation of the Fort Union formation of the northern and eastern parts of the Great Divide Basin. The Bitter Creek exposures were examined briefly for fossils and overall thickness, but not critically enough to determine the individual thicknesses of the Niland, Luman, and Red Desert tongues that can be distinguished in the upper part of Schultz' Wasatch formation.

Because of the relationships of the Eocene and Paleocene rocks at Bitter Creek, it seems likely that Nightingale (1930) also included rocks of both Eocene and Paleocene age in his Hiawatha member.

The Luman tongue of the Green River formation presumably pinches out northwestward inasmuch as the Niland and Red Desert tongues of the Wasatch formation cannot be differentiated in the vicinity of Steamboat Mountain, near the north end of the Rock

591964 O—61——3

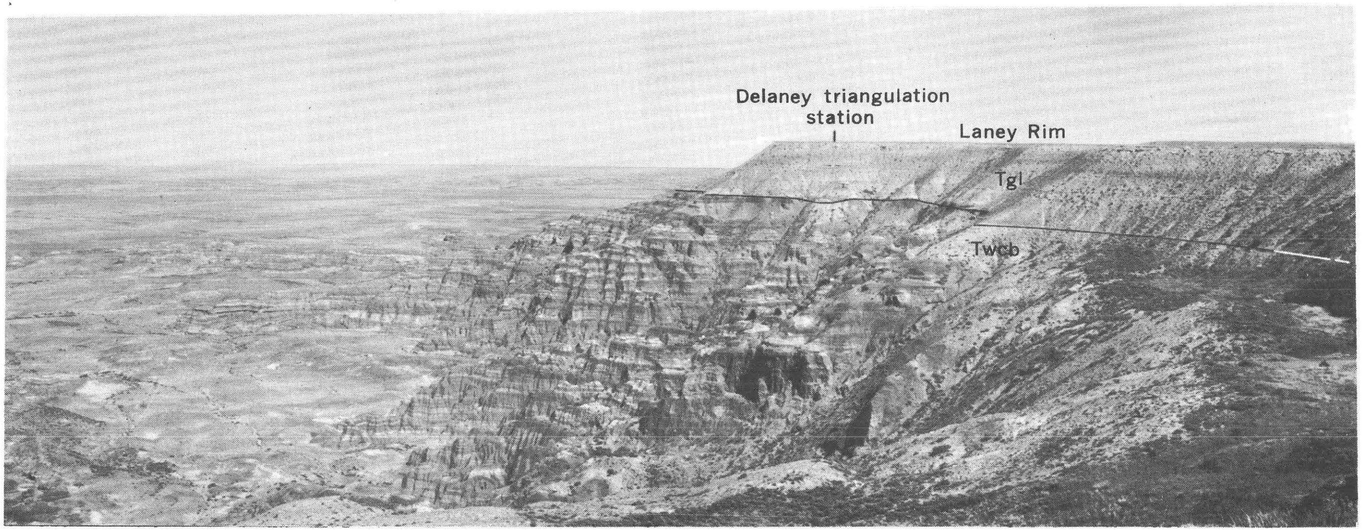

Figure 16.—Contact of the Laney shale member of the Green River formation (*Tgl*) with the Cathedral Bluffs tongue of the Wasatch formation (*Twcb*) in sec. 29, T 19 N., R. 95 W.

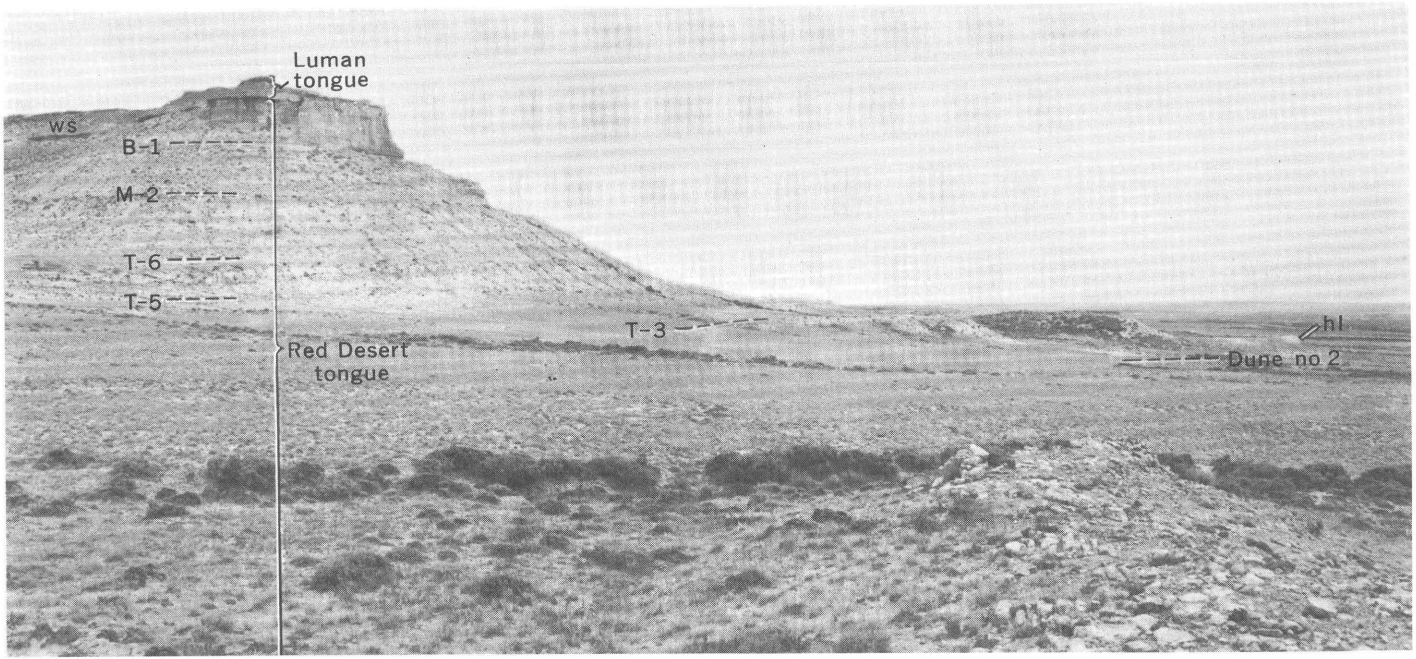

FIGURE 17.—North face of the largest of the Tipton Buttes in the NE¼ sec. 27, T. 20 N., R. 96 W., showing the contact of the Luman tongue of the Green River formation with the Red Desert tongue of the Wasatch formation, the positions of the "wormy" sandstone bed (ws) and the "holey" limestone bed (hl), and the coal beds: Battle No. 1 (B–1), Monument No. 2 (M–2), Tierney No. 6 (T–6), Tierney No. 5 (T–5), Tierney No. 3 (T–3), and Dune No. 2 (D–2).

Springs uplift. The Luman and Niland tongues were traced for at least 6 miles southeast of the area.

Since this study was made, Bradley (1959, p. 1074) has stated that these tongues have been traced

around the west side of Washakie Basin to and around Hiawatha basin. On the west side of Hiawatha basin, just north of Canyon Creek (secs. 7, 8, and 18, T. 12 N., R. 101 W., Sweetwater County, Wyo.), the Niland tongue of the Wasatch thins and loses its identity, thereby establishing the vertical continuity of Luman tongue lithology upward into the base of Tipton tongue of the Green River formation

TIPTON TONGUE OF THE GREEN RIVER FORMATION

The sequence of oil shale, clay shale, and sandstone exposed in the low bluffs south of Tipton was named the Tipton shale member of the Green River formation by Schultz (1920). It was later redesignated the Tipton tongue of the Green River formation by Sears and Bradley (1924). In its type area, the Tipton separates the Niland and the Cathedral Bluffs tongues of the Wasatch formation. The areal distribution of this tongue is about the same as that of the Luman and Niland in the southern part of the area. The tongue has been eroded from the central part of the area; it crops out in the northern part of the area in a wide belt extending from the northwest part of T. 24 N., R. 97 W. and the southwest part of T. 25 N., R. 97 W. eastward to and around the margins of Niland basin. The thickness of the Tipton tongue at Tipton is difficult to measure because much of it underlies a long slope dipping southward from the Wamsutter Rim. Southwest of the settlement of Red Desert in sec. 18, T. 19 N., R. 95 W., the Tipton tongue is well exposed along the east side of a valley that trends from northwest to southeast across sec. 18. At this locality the tongue is about 280 feet thick. The lower part consists of low-grade oil shale containing yellow dolomitic(?) limestone concretions and is about 160 feet thick. The upper part consists of loosely cemented sandstone and lesser amounts of clay shale, fine-grained calcareous sandstone, and algal reefs (figs. 6, 14, 15) and is about 120 feet thick.

The upper part of the Tipton tongue differs strikingly in color and lithologic character from the lower part and from the overlying Cathedral Bluffs tongue of the Wasatch formation (figs. 3, 6, 14, 15), and can be mapped as a separate unit. The contact of the two parts of the Tipton tongue is placed at the top of the lowest algal ball zone. The algal balls consist of spheroidal onion-layered algal deposits of limestone. The occurrence of algal-ball zones is diagnostic of the upper part of the Tipton throughout this and adjacent areas.

The contact of the Tipton with the underlying Niland tongue of the Wasatch is conformable and is marked by a 5-foot bed of coquina of loosely cemented mollusk fragments. In the southeastern part of the area the coquina rests directly on the 5-foot canneloid coal bed at the top of the Niland and in the southwestern part of the area on unfossiliferous massive sandstone beds at the top of the Niland where the 5-foot canneloid coal bed is absent (figs. 6, 15).

The Tipton-Cathedral Bluffs contact is concealed throughout the area, but at the southeast corner of sec. 18, T. 19 N., R. 95 W. on the east side of a small reservoir, the uppermost bed of the Tipton tongue is a calcareous ripple-marked ledge-forming sandstone that is separated from good exposures of red beds in the Cathedral Bluffs tongue by alluvium that seems to conceal not more than 30 feet of section.

At the southeast margin of the Niland basin, in secs. 9 and 16, T. 24 N., R. 95 W., the total exposed thickness of the Tipton tongue is 280 feet. The lower part of the Tipton is 180 feet thick and consists of brown low-grade oil shale and lesser amonts of calcareous fine-grained sandstone and yellow dolomitic(?) limestone concretions. A selected sample of the oil shale (D–2; see U.S. Geol. Survey lab. rept. 130–58 at laboratory in Denver, Colo.) collected from the east bank of Lost Creek (in the SE¼NW¼NW¼ sec. 2, T. 24 N., R. 95 W.) about 60 feet above the base of the Tipton contained 9.7 gallons of petroliferous matter per ton. Analysis was made by R. F. Gantnier, who used the Ruska still method. The contact of the Tipton with the underlying Niland tongue of the Wasatch is conformable and is marked by a 2-foot bed of highly fossiliferous sandstone resting on unfossiliferous massive sandstone beds at the top of the Niland. This contact is generally concealed throughout most of the northern part of the area, but is well exposed south of the road junction shown in sec. 23, T. 24 N., R. 96 W. and in the extreme western part of the area.

The 10-foot algal-ball zone that marks the top of the lower part of the Tipton (fig. 6) can be traced westward into an algal-reef zone reported by Bradley (1926, p. 129, locality 1) to be about 100 feet above the base of the Tipton. The algal-ball zone makes a prominent rim around the eastern side of the Niland basin where it is overlain by a yellow limestone bed ranging from a few inches to a foot in thickness and contains ostracodes of Eocene age.

An arkosic sandstone bed near the top of the lower part of the Tipton, only a few feet thick at the south edge of the Niland Basin, thickens northeastward to more than 25 feet and splits the lower part of the Tipton into two tongues (pl. 1 and fig. 3). This relationship can be seen best in the exposures along Lost Creek at Eagle's Nest Ranch (abandoned) near the southwest corner of sec. 35, T. 25 N., R. 95 W.

Only the lower few feet of the upper part of the Tipton is exposed in most of the northern part of the area, but in the north-central part of sec. 16, T. 24 N., R. 95 W., about 100 feet of the upper part of the Tipton is preserved in a very small tight syncline. There the upper part of the Tipton consists of fine-grained slabby resistant ripple-marked sandstone, minor amounts of greenish paper shale, considerable thicknesses of arkosic sandstone, and contains a zone of algal balls about 50 feet above the lower algal-ball zone that marks the top of the lower part of the Tipton (fig. 3). The lacustrine components of the upper part of the Tipton (such as calcareous sandstone, siltstone, and paper shale) thicken westward at the expense of the fluviatile components (arkosic sandstone and sandy claystone).

The stratigraphically highest fossils of probable early Eocene age were collected from the lower part of the Tipton tongue (D. M. Sheridan, written communication, 1954) about 1 mile west of the schroeckingerite deposits in the northeastern part of the area.

No diagnostic fossils were collected from the upper part of the Tipton tongue, but, inasmuch as the contact with the lower part of the Tipton is gradational, the upper part of the Tipton is probably also of early Eocene age.

CATHEDRAL BLUFFS TONGUE OF THE WASATCH FORMATION

A sequence of red and green claystone exposed in the steep slopes, called the Cathedral Bluffs, below the Laney Rim (fig. 16) along the southern edge of the area, was named the Cathedral Bluffs red beds member of the Green River formation by Schultz (1920). Sears and Bradley (1924) redesignated it the Cathedral Bluffs tongue of the Wasatch formation. Near the U.S. Coast and Geodetic Survey triangulation station Delaney, situated on the Laney Rim, the Cathedral Bluffs tongue is about 900 feet thick and consists almost entirely of red and green banded claystone with a few beds of very coarse grained gray channel sandstone and at least one thin bed of silty limestone near the base. The limestone contains ostracodes similar to those found in the overlying Laney. The contact with the Laney is conformable and intertonguing. The Laney thickens westward at the expense of the Cathedral Bluffs tongue at a rate of about 4 feet per mile.

The Cathedral Bluffs tongue has been eroded in the central part of the area and is not exposed north of the type area except in the vicinity of Bastard Butte. This butte is capped by red beds typical of the Cathedral Bluffs tongue and is an outlier of a thick sequence of red beds that is well exposed northwest of Bastard Butte. This sequence extends northwestward into, and is a part of, the red beds that weather into the badlands southeast of Oregon Buttes known locally as the honeycombs (Nace, 1939). Where the Cathedral Bluffs tongue crops out over a wide area northeast of Bastard Butte, several beds of cobble conglomerate are intercalated with the red and green claystone beds, and where the outcrop pattern narrows eastward, many beds of arkosic sandstone make their appearance (pl. 1, fig. 2). The arkosic sandstone beds thicken eastward at the expense of the red beds and conglomerate. In the vicinity of Lost Creek, arkosic sandstone makes up all but a small part of the formation.

The intertonguing relationship between the Cathedral Bluffs tongue and the Battle Spring formation (fig. 2) was not mapped in detail. The boundary shown in sec. 20, T. 26 N., R. 95 W., is approximate and diagrammatic. The rocks west of the boundary consist predominantly of red and green claystone beds with smaller amounts of arkosic sandstone and sandy claystone beds and are assigned to the Cathedral Bluffs tongue. Eastward, the Cathedral Bluffs tongue is a part of a sequence of rocks consisting predominantly of arkosic sandstone and sandy claystone with smaller amounts of red and green claystone beds. The predominantly arkosic sequence east of the boundary forms a tongue of the Battle Spring formation (pl. 1 and fig. 2), which is described separately on pages A–34 to A–35.

In the Cyclone Rim area west of Lost Creek, the Cathedral Bluffs tongue is estimated to be 1,100 to 1,300 feet thick. It includes a body of arkosic sandstone at the base, 300 feet thick (locally assigned to the upper part of the Tipton, as shown on fig. 2, because it contains some beds of brown low-grade oil shale), and underlies the Laney shale member of the Green River formation. The contact with the Laney is not exposed in the northern part of the area, but it is probably conformable and intertonguing. The thinness of the Laney and the increased thickness of the Cathedral Bluffs tongue suggest that the upper several hundred feet of the Cathedral Bluffs tongue in the Cyclone Rim area are equivalent to the lower part of the Laney (restored section, pl. 1). The physical relationships of the Cathedral Bluffs to the Laney described above suggest that the upper several hundred feet of the Cathedral Bluffs in the northern part of the area is of the same age as the Laney member of the Green River formation, generally considered to be of middle Eocene age.

Fossils are extremely scarce in the Cathedral Bluffs tongue. No diagnostic fossils were found in the area (table 2, loc. 3), but the Cathedral Bluffs in the area mapped by Nace (1939) yielded a single tooth, which G. G. Simpson believed to be of middle Eocene (Bridgerian) age (Nace, 1939, p. 11, 14, 17) and Gazin (1952, p. 12, 14) believed to be of late early Eocene (Lost Cabin) age. Morris (1954) made several small collections of vertebrate remains, which he considers to be of middle Eocene (Bridgerian) age, from the tongue at Cathedral Bluffs and at other localities along the eastern margin of the Washakie Basin. Morris does not show the stratigraphic position from which his collections were taken, but, if the homogeneity of the rocks making up the tongue means that all the Cathedral Bluffs is of the same age, and if Morris' conclusions about the age of his collections are correct, and if the age of the upper part of the Tipton is indeed early Eocene, then the transition from rocks of early Eocene age (Wasatchian) to those of middle Eocene age (Bridgerian) should occur near the Tipton-Cathedral Bluffs contact.

LANEY SHALE MEMBER OF THE GREEN RIVER FORMATION

Schultz (1920) named the Laney shale member from exposures a few miles southwest of the area. In the southern part of the area, the sequence of green and brown oil shale, oolitic sandstone, marl, and cherty algal deposits overlying the Cathedral Bluffs tongue makes up the lower part of the Laney shale member of the Green River formation. These beds are from 100 to 130 feet thick and are capped by the cherty botryoidal algal bed that forms the Laney Rim (fig. 16).

The remainder of the Laney shale of Schultz (1920) overlying the cherty botryoidal algal bed is not exposed in the area. The Laney was not studied in detail, but a superficial examination of the sequence exposed in the Laney Rim area suggests that the thickness of the stratigraphic interval from the cherty botryoidal algal bed up to the base of the Bridger formation, exposed about 10 miles south of the area, is more than 600 feet thick. The beds extending upward from a stratigraphic horizon 50 or 75 feet above the cherty botryoidal algal bed to the base of the Bridger resemble, and presumably are equivalent to, those of the Laney (formerly the Morrow Creek) in the vicinity of Steamboat Mountain at the north end of the Rock Springs uplift. No fossils were collected from the type Laney (but mollusks of middle Eocene age were collected from the stratigraphically higher Laney in the Cyclone Rim area (pl. 1 and table 2, loc. 2).

In the Cyclone Rim area, a sequence of rocks consisting of oil shale, sandy limestone, calcareous sandstone, and arkosic sandstone was assigned to the Morrow Creek member of the Green River formation because of its stratigraphic similarity to the Morrow Creek of the Steamboat Mountain area (Bradley, 1926, Pipiringos, 1955, 1956). The name Morrow Creek has been abondoned in favor of Laney shale member of the Green River formation (Bradley, 1959, p. 1074). The Laney in the Cyclone Rim area contains mollusks of middle Eocene age (table 2). The contact with the underlying Cathedral Bluffs tongue is concealed but probably conformable, and the contact with the overlying Bridger formation also appears to be conformable.

BATTLE SPRING FORMATION

A thick sequence of arkosic sandstone underlies most of the eastern part of the Great Divide Basin. The name Battle Spring formation has been applied to this sequence from typical exposures southwest of Battle Spring Flat and southeast of Lost Creek Butte (Pipiringos, 1955). The Battle Spring formation intertongues with all the subdivisions of the Green River and Wasatch formations described in preceding parts of this report (pl. 1, figs. 2 and 3).

The low structural and topographic relief of the rocks of the Great Divide Basin makes it impossible to determine the thickness of the Battle Spring directly or to designate a compact type locality. The probable minimum thickness of the Battle Spring may be inferred from the thickness of the units with which it intertongues. The inferred thickness is about 3,300 feet but probably is greater because in the northern part of the area tongues of arkosic sandstone in the lower part of the Laney appear to thicken eastward at the expense of the Laney. In the Cyclone Rim area the lithologic character of the Bridger formation is unlike that of the underlying rocks, so the deposition of the Battle Spring formation probably ceased within or at the end of Laney time.

The base of the Battle Spring formation is exposed on the north slope of Flattop Buttes and at a point about 10 miles west of Rawlins, Wyo. (fig. 7), in the northwest part of T. 21 N., R. 89 W.; at both localities the Battle Spring formation overlies the Fort Union formation unconformably.

The Battle Spring formation consists of very coarse grained to pebbly arkosic sandstone and lesser amounts of bright-green claystone that contains abundant large grains of clear angular quartz. Locally, the beds form low rounded bluffs in which the crossbedding of the sandstone is clearly visible; elsewhere, the sandstone weathers to soft slopes littered with spheroidal sandstone concretions that are moderately calcareous and generally contain limonitic centers. The sediments that make up this formation appear to have been deposited in delatic sheets; the source of the sediments appears to have been the Granite Mountains north and northeast of the area.

Where the rivers that carried the sediments spilled into one of the ancient Green River lakes, extensive foreset beds were formed that today dip as much as 15°. Remnants of these foreset beds are preserved and well exposed in the Lost Creek Butte area, especially along the west rim of a small plateaulike highland 3.5 miles northwest of Lost Creek Butte in the southwest part of sec. 31, T. 24 N., R. 95 W. At this locality the foreset beds dip southwestward.

No fossils were found in the Battle Spring formation, but the formations with which the Battle Spring intertongues range in age from earliest Eocene through early middle Eocene. The Battle Spring formation seemingly represents a period of continuous deposition during this time.

In summary, the pre-Bridger Eocene rocks of this area may be thought of as products of three environments. The Green River formation is of lacustrine origin. It interfingers with the Wasatch formation of fluviatile and paludal origin. The Battle Spring formation of deltaic-fluviatile origin interfingers with both. In general, the Laney shale member of the Green River formation thins northeastward, whereas the Tipton and Luman tongues of the Green River formation, the Niland and Red Desert tongues of the Wasatch, and the Battle Spring formation thin southwestward.

BRIDGER FORMATION

Overlying the Laney shale member of the Green River formation is a sequence of gray-green claystone and shale, containing several thin beds of limestone, fossil tree stumps, and cherty limestone algal deposits. The upper part of the formation was eroded before the deposition of the overlying beds; the formation ranges in thickness from 60 to 250 feet in the area, but locally it is absent. The limestone beds of this sequence contain ostracodes of middle Eocene age (D. M. Sheridan, written communication, 1954); and because these rocks occupy the stratigraphic position of the Bridger formation of adjacent areas and are of similar age, they are here correlated with that formation.

BROWNS PARK(?) FORMATION

Unconformably overlying the Bridger formation is a conglomerate, generally ranging from about 10 to 20 feet in thickness, whose constituents locally are as large as boulder size. The conglomerate intertongues with an interbedded sequence of very coarse grained sandstone and fine-grained tuffaceous sandstone. These units are lenticular, but together they are at least 110 feet thick and locally may be as much as 220 feet thick (pl. 2). They can be traced from the extreme northwest corner of the area to a point south of Soda Lake in the NE¼SW¼ sec. 24, T. 26 N., R. 95 W. East of this point the conglomerate and coarse-grained sandstone beds are absent and the overlying homogeneous sequence of fine-grained tuffaceous rocks rests directly on the Bridger formation.

This sequence makes up the lower part of the Browns Park(?) formation and was mapped separately. The contact of the lower part with the upper part of the Browns Park(?) formation is placed at the top of the highest bed of very coarse grained arkosic sandstone. No fossils were found in the lower part of the Browns Park(?) formation.

The basal conglomerate and the interbedded arkosic and tuffaceous sandstone beds in the lower part of the Browns Park(?) formation of this report are believed by some geologists to be of either late Eocene or Oligocene age, or both (Nace, 1939, p. 26; J. D. Love, oral communication, 1951; Wyant, Sharp, and Sheridan, 1956; W. G. Bell, oral communication, 1953).

The interbedded sequence of coarse-grained sandstone and fine-grained tuffaceous sandstone is overlain by a homogeneous sequence of pinkish-white fine-grained tuffaceous sandstone indistinguishable from similar rocks in the underlying sequence. The homogeneous tuffaceous sandstone sequence that composes the upper part of the Browns Park(?) formation is at least 300 feet thick, and crops out throughout most of the northern part of the area.

The rocks in the upper part of the Browns Park(?) formation are lithologically similar to rocks exposed northeast of the area in the vicinity of Split Rock. The latter rocks contain vertebrate fossils of undoubted middle Miocene age (McGrew, 1951). McGrew believes that these rocks near Split Rock are outliers of the Browns Park formation of northern Colorado and southwestern Wyoming. The Miocene rocks in the area likewise may be remnants of the Browns Park formation, which at one time probably blanketed the entire Great Divide Basin. Wallace Bell, Department of Geology, University of Wyoming, (written communication, Feb. 22, 1955) states that vertebrate fossils of Miocene age were found in the upper part of the Browns Park(?) formation in the NW¼ sec. 13, T. 26 N., R. 95 W., a few miles northwest of the schroeckingerite deposits (table 2, loc. 1).

Locally, as in the vicinity of Soda Lake, conglomerate appears to be at the base of the upper part of the Browns Park(?) formation. However, exposures are poor and its presence cannot be certain. If there is conglomerate at this stratigraphic position it is lenticular. Less than 1 mile east of Soda Lake in the SW¼ sec. 19, T. 26 N., R. 94 W., where the contact of the upper part of the Browns Park(?)

formation with the underlying Bridger formation is perfectly exposed, there is no trace of basal conglomerate.

QUATERNARY DEPOSITS

The largest, most conspicuous Quaternary features in the area are the dry-lake flats. Several are scattered throughout the area, the largest of which are Red Desert Flat in the southwestern part and Lost Creek and Battle Spring Flats in the central and eastern parts.

The intermittent streams leading into Red Desert Flat drain areas underlain partly by the red beds of the Cathedral Bluffs tongue and partly by the light-colored beds of the Red Desert tongue of the Wasatch. Consequently, the deposits in the flat consist of red silt, locally overlain by thin smooth white sheets of clayey silt.

The Lost Creek and Battle Spring Flats are underlain by brownish silty clay, whose color is derived from outcrops of brown oil shale of the Luman and Tipton tongues of the Green River exposed locally around their shores. In several places white silt is deposited in deltas along the margins of these flats; and, where deltas have coalesced, as in the southern parts of these two flats, they consist of smooth areas that are white and dotted with clumps of greasewood.

Auger holes in the south end of Red Desert Flat, the northern part of Lost Creek Flat, and in the southern end of Battle Spring Flat indicate that the lake deposits are about 25 feet thick.

The oldest Quaternary features are the isolated sand and gravel terrace deposits, ranging from several square feet to several square miles in area and from 6,750 to 6,900 feet in altitude. These deposits are scattered throughout an area extending from the north boundary of T. 19 N. to the north edge of the Niland basin and seem to be remnants of one preexisting continuous layer.

The deposits south of the middle of T. 21 N. are separated from the underlying bedrock by several feet of red or brown silty clay very similar to that in the floors of the dry-lake flats. Aside from the fact that the lithologic character of the gravel terrace deposits is locally quite unlike that of the Browns Park(?) formation, the general level of the terraces is at least 400 feet lower than can be reasonably assumed for the surface on which the Browns Park(?) was deposited. Likewise the difference in altitude between the terrace level and the level of the lower lying dry-lake flats ranges from about 60 feet in the southern part of the area to more than 300 feet in the northern. For these reasons it seems probable that the sand and gravel deposits are of Pleistocene rather than Recent or Miocene age.

Among the youngest Quaternary features are the sand dunes that have been moved eastward by the wind across the western part of the Great Divide Basin from the vicinity of Steamboat Mountain at the north end of the Rock Springs uplift along a sharply defined belt that terminates in Lost Creek Flat. Some of the active dunes are true barchans and are concave eastward, but most of the active dunes are produced by blowouts and are concave westward. Where the sand dunes have moved across the northern part of the Red Desert Flat, they have repeatedly interrupted and displaced the courses of the intermittent streams draining southward into the Red Desert Flat from the Hay Reservoir.

The lowest parts of the flats south of and parallel to the sand-dune belt decrease in altitude eastward. Apparently in the recent past, when the level of the lakes was high, drainage from the area took place eastward out through Battle Spring Flat.

STRUCTURE

The structure of most of the central part of the Great Divide Basin is shown on plate 1 by contours drawn at intervals of 100 feet on the top of the Tierney No. 5 coal bed in the Red Desert tongue of the Wasatch formation.

The main structural feature is a broad eastward-plunging arch with a poorly defined axis that trends about N. 70° E. across the central part of the area. This arch may be the eastward extension of the Wamsutter arch as mapped by Schultz (1920, pl. 1) or it may be a separate fold en echelon to the Wamsutter arch. Tertiary rocks older than the Browns Park(?) formation dip away from the crest of this fold at angles that average about 2° on the southern limb and slightly less on the northern limb.

Several subsidiary folds are superimposed on the crest of the main arch. The largest of these, here called the Tierney anticline, trends about N. 45° E. at a slight angle to the axis of the larger fold and has about 50 feet of closure in T. 21 N., Rs. 94 and 95 W. Two smaller anticlines in T. 22 N., R. 94 W., with less than 50 feet of closure, are separated from the Tierney anticline by an area containing several minor faults, one of which is shown in figure 18. Surface rocks involved in this folding belong to the Red Desert tongue of the Wasatch formation.

The Red Desert tongue of the Wasatch formation and younger Tertiary rocks exposed on the north limb of the Wamsutter(?) arch are folded in several shallow anticlines and synclines with diverse axial trends. One of these folds is the Red Desert syncline, a broad northwestward-plunging fold that trends about N. 30° W. across the east-central part of the area. The thickest parts of the coal beds in the area, with the exception of Luman No. 2, are near the axis of the Red Desert syncline, whereas the coal beds apparently thin and pinch out in the areas adjacent to the syncline. These relationships suggest that the folding of the syncline, which had probably started in Late Creta-

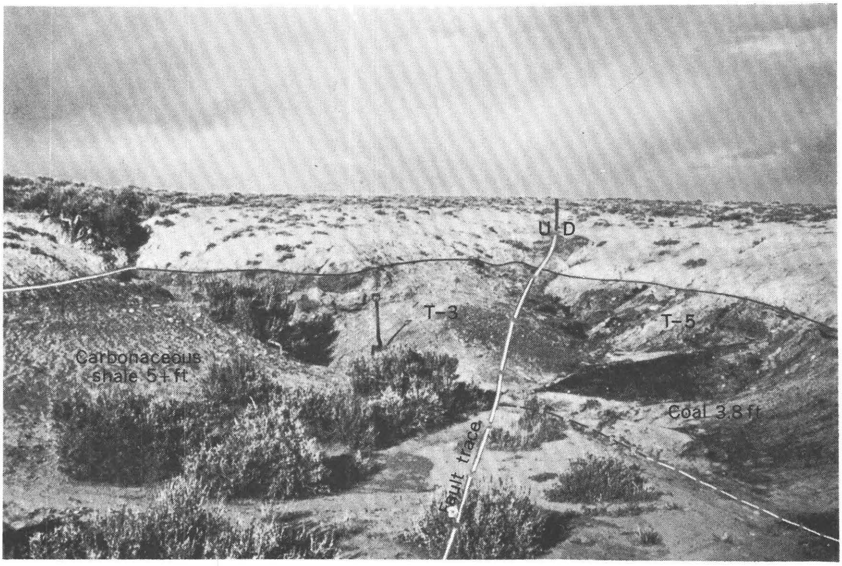

FIGURE 18.—Trace of a vertical normal fault in the SE¼NE¼ sec. 6, T. 21 N., R. 94 W. The top of Tierney No. 5 (T–5) adjoins the top of Tierney No. 3 (T–3), indicating a displacement of about 25 feet. The shovel is 3 feet long.

ceous time, continued to a slight extent during deposition of lower Eocene rocks.

The Red Desert syncline is of primary interest in this area because of its association with the thickest coal beds, the transition from coal beds of relatively high uranium content in the northeast to coal beds of relatively low uranium content in the southwest, and the transition from coarse-grained rocks of good permeability in the northeast to fine-grained rocks of moderate to slight permeability in the southwest. A section across the axis of the syncline in the Lost Creek Butte area is shown in figure 19. The Red Desert syncline plunges northward into a shallow structural depression, here called the Niland basin.

North of the Niland basin, at Cyclone Rim, the Bridger formation and Laney shale member of the Green River formation dip about 22° N. on the flanks of an anticline and parallel syncline that trend about N. 60° W.

The exposed formations are cut by many normal faults that can be traced for several miles. Most of the faults trend northeastward about parallel to the axial trend of the Wamsutter(?) arch; a few, however, trend northwestward at about right angles to the first set of faults and about parallel to the axial trend of the Red Desert syncline.

A normal fault with a displacement of about 3,000 feet, downthrown on the south, may be traced across the northeastern corner of the area in T. 26 N., Rs. 94 and 95 W. This fault, which forms the north side of a graben in the schroeckingerite area, at places brings the basal part

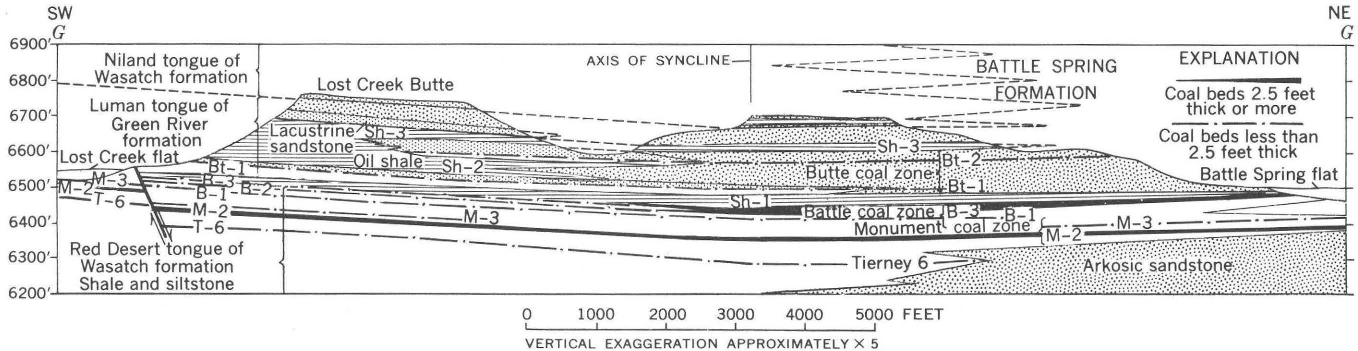

Figure 19.—Diagrammatic structure section across the Lost Creek Butte area. (See geologic map, pl. 1.)

of the Battle Spring formation on the north against the Laney shale member of the Green River formation on the south (pl. 1, figs. 25 and 26). The Browns Park(?) formation which unconformably overlies older rocks on either side of the fault, is downthrown about 100 feet on the south side, thus indicating that most of the fault movement occurred before deposition of the Browns Park(?) formation, but that some movement has occurred since. A second normal fault, which forms the south side of the graben and has a maximum inferred displacement of about 200 to 300 feet, downthrown on the north, parallels the first about 3 miles to the southwest (pl. 1, fig. 16). This fault dies out northwestward, near the center of T. 26 N., R. 95 W. Other faults in the area have displacements of less than 100 feet.

The angular unconformities that separate the Fort Union formation of Paleocene age from both the older and the younger rocks indicate that some folding took place in the Great Divide Basin before and after deposition of the Fort Union formation and that the main structural trends of the area were established in Late Cretaceous time or earlier. Therefore, it seems likely that the degree of the folding discernible in rocks of Eocene age at the surface increases with depth. Certainly it is not logical to assume the opposite: that the folds die out with depth.

Structures trending northwestward appear to be older than those trending northeastward.

COAL

SUMMARY STATEMENT

Coal occurs in beds a few inches to as much as 21 feet thick in the Red Desert and Niland tongues of the Wasatch formation and in the intervening Luman tongue of the Green River formation. Nearly all these coal beds are uraniferous. In general, the coal beds are thickest in a belt about 10 miles wide that extends from the north side of Lost Creek Flat southeastward for about 30 miles to the vicinity of Latham along the Union Pacific Railroad about 13 miles east of Frewen (Smith, 1909; Masursky and Pipiringos, 1959). The coal beds thin both westward and eastward from this belt and little or no coal is present in the western and northeastern parts of the area.

Thirty coal and carbonaceous shale beds were studied. These beds have been grouped into 10 coal zones that from oldest to youngest are: the unnamed coal zone, the Dune, Tierney, Monument, and Battle coal zones in the Red Desert tongue of the Wasatch formation; the Butte coal zone in the Luman tongue of the Green River formation; and the Kelly, Luman, Hay, and Bush coal zones in the Niland tongue of the Wasatch formation (fig. 20). The coal zones in the Niland tongue of the Wasatch formation are referred to collectively as the

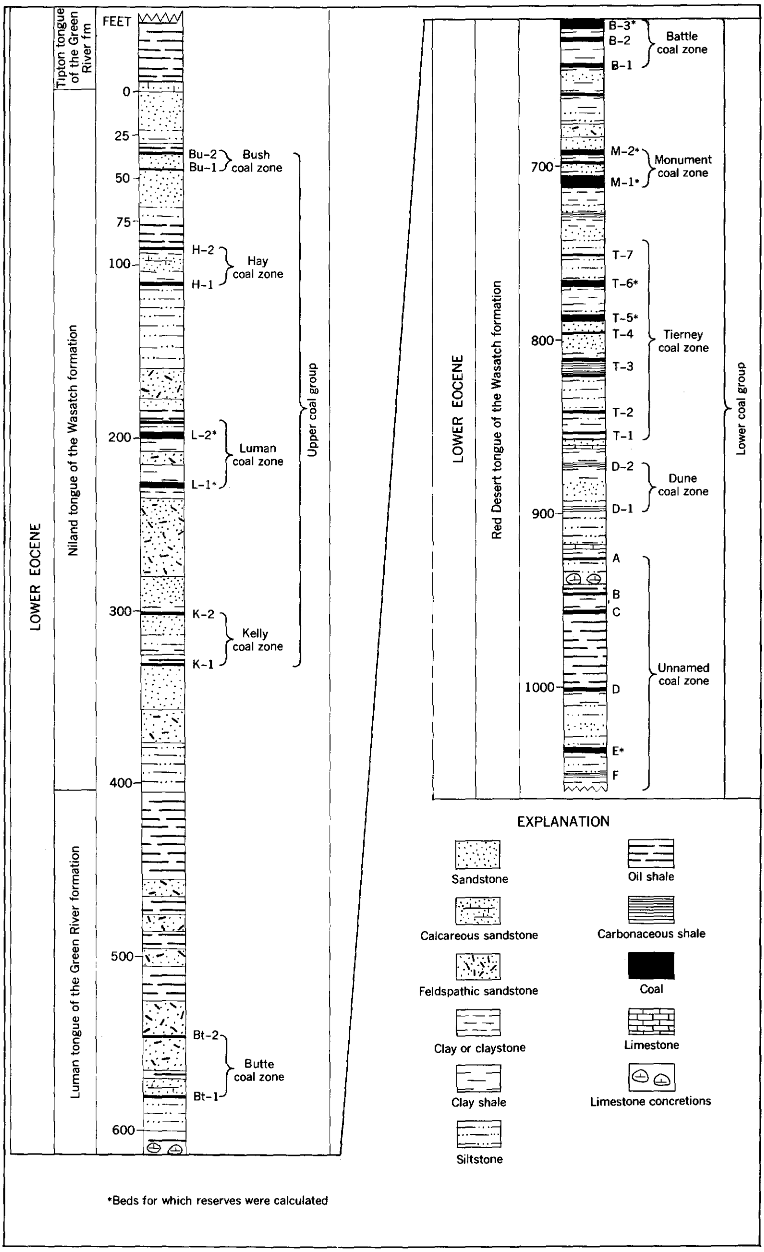

FIGURE 20.—Composite columnar section showing stratigraphic position of the coal zones.

upper coal group, and those in the underlying Red Desert tongue of the Wasatch formation are referred to collectively as the lower coal group. For the most part, the individual coal beds within each zone are numbered consecutively beginning with number 1 for the oldest

TABLE 3.—*Data on core holes, central part of the Great Divide Basin, Sweetwater County, Wyo.*

Core hole	Location			Elevation (feet)	Total depth (feet)	Total thickness of coal beds penetrated [1] (feet)
	Sec.	T. (N)	R. (W)			
1	SW¼SW¼ 24	24	96	6,645	142	6.9
2	SE¼NW¼ 16	24	95	6,630	266	9.5
3	NW¼SW¼ 16	24	95	6,610	173	8.2
4	SE¼NW¼ 28	24	95	6,610	600	26.4
5	SE¼NW¼ 15	24	95	6,580	202	3.7
6	SE¼NE¼ 10	24	95	6,605	263	6.2
7	NW¼SW¼ 20	24	95	6,560	55	5.1
8	NE¼SW¼ 22	24	96	6,715	119	4.7
9	NE¼SW¼ 2	24	95	6,620	206	4.7
10	NE¼SW¼ 17	23	94	6,510	245	26.8
Total					2,271	102.2

[1] General data on all individual coal beds which were penetrated in each hole are shown on plates 4 and 5. Specific information on only those beds of which proximate and ultimate analyses were made is shown on tables 4 and 5.

bed in each zone. The coal beds in the unnamed coal zone in the Red Desert tongue of the Wasatch formation are lettered from *A* to *F* beginning with the youngest bed in the zone.

The principal coal beds in the area, from youngest to oldest, are the Luman No. 2 and No. 1 beds in the upper coal group and the Battle No. 3 bed, the Monument coal zone, the Tierney No. 6 and No. 5 beds, and coal bed *E* in the lower coal group. Coal reserves have been calculated for these beds; the other coal beds in the area are too thin to be considered in calculating the coal reserves and are not shown on the geologic map, except where they are relatively persistent and where they were used for stratigraphic and structural control.

Calcareous sandstone beds that make resistant ledges and zones of limestone concretions are common in the sequences between coal zones, especially in the Red Desert tongue of the Wasatch formation.

The relative stratigraphic position of the coal beds is shown on figures 3–6, and 20 and the thickness and correlation of the principal beds are shown graphically on plates 3–5. The location and data on core holes drilled in the area during the 1952 field season are shown on plates 1, 4, and 5, and table 3.

The coal found in the central part of the Great Divide Basin ranges in rank from subbituminous B to subbituminous C according to the classification of the American Society for Testing Materials (1938). Proximate and ultimate analyses of 17 coal samples recovered in drill cores are shown in table 4, and the rank classification of the various samples is given in table 5.

Lithologic descriptions of coal cores made by J. M. Schopf (Masursky and Pipiringos, 1959, p. 198–211) of the Geological Survey coal geology laboratory at Columbus, Ohio, were used to construct plate 5.

591964 O—61——4

TABLE 4.—*Analyses of coal cores*

[Condition: 1, as received; 2, moisture-free; 3, moisture- and ash-free. Volatile matter: determined by the modified method. Analyses by the U.S. Bureau of Mines, Central Experiment Station, Pittsburgh, Pa., Roy F. Abernethy, chemist in charge. Stratigraphic position of samples shown in plate 5]

Core hole	Sample			Specific gravity	Heating value (Btu)	Ash softening temperature (° F.)	Analyses, in percent											
							Proximate			Ultimate						Forms of sulfur		
	Laboratory No.	Thickness of coal (feet)	Condition				Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Sulfatic	Pyritic	Organic
1	D-97526	1.1	1				22.8	33.5	31.5	12.2								
			2					43.5	40.6	15.9								
			3					51.6	48.4									
	D-97527	4.5	1	1.51	8,430	2,260	22.9	32.4	31.0	13.7	6.3	46.5	1.4	29.9	2.2	0.07	1.39	0.78
			2		10,930			42.0	40.3	17.7	4.9	60.3	1.8	12.4	2.9	.09	1.80	1.01
			3		13,280			51.1	48.9		5.9	73.3	2.2	15.1	3.5	.10	2.19	1.23
2	D-96784	1.2	1	1.55	8,200		23.8	29.7	34.2	12.3					1.7			
			2		10,770			39.0	44.9	16.1					2.3			
			3		12,840			46.5	53.5						2.7			
	D-96785	.6	1	1.57	7,770		22.7	30.7	28.2	18.4					1.9			
			2		10,060			39.7	36.5	23.8					2.5			
			3		13,200			52.1	47.9						3.2			
	D-96786	1.7	1	1.52	8,480		24.3	31.5	32.2	12.0					2.6	.05	1.74	.80
			2		11,210			41.6	42.5	15.9					3.4	.07	2.30	1.06
			3		13,320			49.5	50.5						4.1	.09	2.73	1.26
	D-96787	.7	1	1.46	8,860		23.1	32.2	34.1	10.6					.8			
			2		11,520			41.9	44.3	13.8					1.0			
			3		13,360			48.7	51.3						1.2			
	D-96788	2.7	1	1.54	7,990	2,630	22.3	30.3	30.6	16.8	6.1	42.4	1.2	32.4	1.1	.03	.39	.71
			2		10,280			39.0	39.3	21.7	4.6	54.6	1.5	16.2	1.4	.04	.50	.91
			3		13,120			49.8	50.2		5.9	69.7	1.9	20.7	1.8	.05	.64	1.17
3	D-96781	1.7	1	1.54	8,190		23.0	31.1	31.7	14.2					2.4			
			2		10,640			40.3	41.3	18.4					3.2			
			3		13,040			49.4	50.6						3.9			
	D-96782	.7	1	1.56	7,890		21.2	30.6	30.0	18.2					1.2			
			2		10,010			38.8	38.1	23.1					1.6			
			3		13,010			50.4	49.6						2.0			
	D-96783	3.9	1	1.53	8,330	2,580	20.3	32.4	30.5	16.8	6.1	46.3	1.2	28.2	1.4	.02	.62	.72
			2		10,450			40.7	38.2	21.1	4.8	58.1	1.6	12.7	1.7	.03	.78	.91
			3		13,240			51.5	48.5		6.0	73.6	2.0	16.2	2.2	.04	.98	1.15
4	D-96789	4.1	1	1.56	7,840		19.7	31.7	28.1	20.5	5.8	46.4	1.2	24.7	1.4	.04	.66	.67
			2		9,750			39.5	35.0	25.5	4.5	57.8	1.5	9.0	1.7	.05	.82	.84
			3		13,100			53.0	47.0		6.0	77.6	2.0	12.1	2.3	.06	1.10	1.12
	D-97235	9.2	1	1.47	9,240	2,140	21.7	33.6	36.0	8.7	6.2	52.1	1.4	29.8	1.8	.06	1.10	.61
			2		11,800			42.8	46.1	11.1	4.8	66.6	1.7	13.5	2.3	.08	1.40	.77
			3		13,270			48.2	51.8		5.4	74.9	1.9	15.3	2.5	.09	1.58	.87

	D-97236	1.4	1				23.4	30.3	30.7	15.6								
			2					39.5	40.1	20.4								
			3					49.6	50.4									
	D-97237	5.7	1	1.48	8,860	2,150	24.2	29.1	37.8	8.9	6.3	50.1	1.3	31.8	1.6	.04	1.02	.59
			2		11,690			38.3	49.9	11.8	4.7	66.0	1.8	13.5	2.2	.05	1.34	.78
			3		13,250			43.5	56.5		5.4	74.9	2.0	15.2	2.5	.06	1.52	.89
5	D-96790	2.6	1	1.69	6,560		18.9	26.8	24.7	29.6	5.3	36.7	.9	26.8	.7	.01	.18	.54
			2		8,090			33.0	30.5	36.5	3.9	45.3	1.2	12.2	.9	.02	.22	.67
			3		12,740			52.0	48.0		6.1	71.4	1.8	19.3	1.4	.02	.34	1.05
6	D-96791	4.0	1	1.91	4,600	2,800	14.1	23.1	16.0	46.8	4.2	25.8	.6	21.9	.7	.02	.30	.38
			2		5,350			26.9	18.6	54.5	3.1	30.0	.7	10.9	.8	.02	.35	.45
			3		11,750			59.1	40.9		6.8	65.9	1.6	23.9	1.8	.05	.78	.98
7	D-97233	4.8	1	1.48	8,710	2,440	22.1	33.3	40.4	4.2	6.3	48.5	1.5	38.4	1.1	.02	.37	.70
			2		11,190			42.8	51.9	5.3	5.0	62.3	1.9	24.1	1.4	.03	.48	.90
			3		11,820			45.2	54.8		5.2	65.8	2.0	25.5	1.5	.03	.50	.95
8	D-97528	4.0	1	1.54	8,100		25.9	31.0	30.8	12.3					4.0			
			2		10,930			41.9	41.6	16.5					5.4			
			3		13,100			50.2	49.8						6.4			
9	D-97530	1.1	1		6,590		15.1	26.3	27.1	31.5					3.9			
			2		7,750			30.9	32.0	37.1					4.5			
			3		12,320			49.1	50.9						7.2			
10	D-98226	6.9	1	1.49	9,180		20.7	32.8	37.0	9.5					1.2			
			2		11,570			41.3	46.7	12.0					1.5			
			3		13,150			47.0	53.0						1.8			
	D-98227	2.5	1	1.56	8,660		18.3	30.9	35.8	15.0	5.6	49.0	.9	26.6	2.9	.10	2.10	.70
			2		10,590			37.8	43.9	18.3	4.4	60.0	1.1	12.7	3.5	.13	2.57	.85
			3		12,970			46.3	53.7		5.3	73.4	1.3	15.7	4.3	.15	3.14	1.04
	D-98228	2.2	1	1.55	8,500		18.4	31.1	34.3	16.2					1.6			
			2		10,420			38.2	42.0	19.8					1.9			
			3		13,000			47.6	52.4						2.4			
	D-98229	2.8	1	1.53	8,650		21.9	29.9	37.0	11.2					1.9			
			2		11,080			38.3	47.3	14.4					2.5			
			3		12,930			44.7	55.3						2.9			
	D-98230	2.5	1	1.52	9,190		20.8	31.1	38.8	9.3					1.6			
			2		11,600			39.2	49.0	11.8					2.0			
			3		13,150			44.5	55.5						2.2			
	D-98231	5.4	1	1.48	9,290		20.2	32.4	37.6	9.8	6.1	52.5	1.1	29.1	1.4	.03	.65	.71
			2		11,650			40.6	47.1	12.3	4.8	65.9	1.4	13.9	1.7	.04	.82	.89
			3		13,280			46.3	53.7		5.4	75.1	1.6	15.9	2.0	.04	.93	1.01

TABLE 5.—*Rank of the three principal coal beds in the central part of the Great Divide Basin, Sweetwater County, Wyo.*

[Analyses given in table 4; sample interval and depth to coal beds shown on plate 5. Locations shown on plate 1]

Sample [1]	Core hole [2]	Classification: Subbituminous group	Classification: ASTM symbol [3]	Overburden (feet)
Luman No. 2 coal bed				
D-97528	8	C	(52-93)	90
D-97527	1	B	(50-99)	69
Luman No. 1 coal bed				
D-97233	7	C	(57-91)	41
D-96788	2	C	(51-91)	256
D-96783	3	B	(50-102)	134
D-96789	4	B	(48-100)	44
D-96790	5	C	(50-93)	102
D-96791	6	C	(51-93)	195
D-97530	9	B	(55-100)	194
Battle No. 3 coal bed				
D-97235	4	B	(53-102)	481
D-98226	10	B	(54-102)	55
D-98227	10	B	(55-104)	65
D-98228	10	B	(54-103)	69
D-98229	10	B	(57-99)	73
Monument No. 2 coal bed				
D-97237	4	B	(59-98)	530
D-98230	10	B	(56-102)	144
D-98231	10	B	(55-104)	148

[1] Proximate and ultimate coal analyses made by the U.S. Bureau of Mines are listed in table 4. The sample interval is shown on plate 5.

[2] Location of core holes shown on plate 1; depths to coal beds shown on plate 5.

[3] This classification of coals is described in the standard specifications adopted in 1937 by the American Society for Testing Materials, as revised in 1938 (p. 652–657). Coals having less than 69 percent fixed carbon on the dry, mineral-matter-free basis is classified according to Btu on the moist mineral-matter-free basis (p. 652). Subbituminous B coal is defined as coal containing 9,500 or more and less than 11,000 Btu on the moist, mineral-matter-free basis, and Subbituminous C coal is defined as coal containing 8,300 or more and less than 9,500 Btu on the moist, mineral-matter-free basis. The symbols in column 2 express the classification "in condensed form as in the following example: (62–146) in which the parenthesis signifies that the contained numbers are on the mineral-matter-free basis. The first number represents fixed carbon on the dry basis, reported to the nearest whole percent. The second number represents Btu on the moist basis, expressed as hundreds of Btu (to the nearest hundred); for example, 14,580 Btu would be represented as 146" (p. 653).

UPPER COAL GROUP

The coal beds that crop out north and northwest of Lost Creek Flat occur in the Niland tongue of the Wasatch formation. These beds occur in the Kelly, Luman, Hay, and Bush coal zones, each containing two coal beds. The Niland tongue overlies the Luman tongue of the Green River formation. Thus, the lowest coal zone (Kelly) of the upper coal group is separated from the highest coal zone (Battle) of the lower coal group by about 300 feet of virtually non-coal-bearing rocks (figs. 3, 4, and 20, pl. 4). Calculations based on several analyses of samples of coal in the Luman coal zone taken from core holes indicate that the coal of the upper group ranges from subbituminous B to C in rank (table 5).

The Kelly, Hay, and Bush coal zones of the upper coal group were mapped and sampled throughout the area, but because the beds in these zones are less than 2.5 feet thick, except in a few scattered localities, no reserves were computed for them. The more persistent beds in the zones are shown on plate 1. Their general character is described on figures 3 and 20, and on plates 4 and 5 of this report. Lithologic details are shown by Masursky and Pipiringos (1959, pl. 39).

LUMAN COAL ZONE

The two beds of the Luman zone that contain reserves in the northern part of the area have approximately the same outcrop pattern, and the interval between them is small.

LUMAN NO. 2

The Luman No. 2 coal bed is well exposed and is typically overlain by a bed of brown papery-fissile low-grade oil shale 10 feet or less thick. The coal attains a maximum thickness of 4.5 feet in core hole 1 and thins eastward and westward from this locality. The Luman No. 2 is best exposed near the base of a low bluff that trends westward for several miles in the southeast corner of T. 24 N., R. 96 W. (loc. 2–7, pl. 1). At these localities it consists of an upper bed, too thin to be considered in computing reserves, and a lower bed that contains all the coal estimated in the Luman No. 2 reserves (pl. 3). The upper bed continues eastward from locality 7 for 3 miles to locality 18, where it consists of about 2 feet of coal and black shale. Beyond this point the Luman No. 2 coal grades into shale (pls. 1, 4). The area underlain by the Luman No. 2 where it is 2.5 feet or more thick is shown on figure 27. Throughout this area it averages 3.6 feet in thickness.

The interval from the top of the Luman No. 2 coal bed to the top of the underlying Luman No. 1 coal bed ranges from 30 to 50 feet and averages 33 feet (pls. 3–5, figs. 3, 20).

LUMAN NO. 1

The Luman No. 1 coal bed is 4.7 feet thick at locality 15 (pls. 1, 3) at the tip of the "peninsula" that juts southward into Lost Creek Flat. The area underlain by the Luman No. 1, where it is 2.5 or more feet thick as determined by drilling (figs. 5, 7, 8), is shown on figure 28. Within that area, the Luman No. 1 is as much as 5 feet thick at locality 17 and averages about 3.8 feet.

The Luman No. 1 is thickest along the axis of the Red Desert syncline and in the area adjacent on the west. It thins abruptly westward from core hole 7, but thins only gradually eastward from the axis of the syncline (pls. 1, 4, and 5). Locally, the Luman No. 1 has two or more thin shale or siltstone partings near the top.

A 5-foot bed of carbonaceous shale crops out at locality 19, sec. 4, T. 24 N., R. 94 W. (pls. 1, 3). The inferred outcrop of the Luman No. 1 bed predicted on the basis of preliminary structure contours (Masursky and Pipiringos, 1959, pls. 36 and 45) coincides within about 500 feet of the actual outcrop, as mapped by the author in the summer of 1953. The Luman No. 1 bed is much thicker than the nearest overlying or underlying coal beds, and should extend the farthest. Thus, it is logical to assume that the 5-foot bed of carbonaceous shale at locality 19 is an extension of the Luman No. 1 coal bed.

BUTTE COAL ZONE

The Luman tongue of the Green River formation, which separates the upper from the lower coal group, contains a few thin coal beds assigned to the Butte coal zone. This zone was named from good exposures in the vicinity of Lost Creek Butte, where it contains two coal beds named from bottom to top Butte No. 1 and Butte No. 2. A few lenticular coal stringers, a few inches thick, in the Luman tongue in the vicinity of Luman Butte may be part of this zone but cannot be correlated with the named beds in the Lost Creek Butte area. The coal beds in the Butte zone are too thin to be of interest as a source of coal but can be used locally for stratigraphic and structural interpretations.

BUTTE NO. 2

The Butte No. 2 bed consists of a few feet of carbonaceous shale containing a few inches of coal at the base and is known only from outcrops east of Lost Creek Butte and southwest of Battle Spring Flat. It is well exposed in the SE¼ sec. 7, NW¼ sec. 17, SE¼ sec. 18, N½ sec. 29, and SE¼ sec. 30, T. 23 N., R. 94 W. It was mapped and sampled because its relatively high uranium content (0.016 percent) appears to be related to its proximity to permeable beds of the Battle Spring formation (figs. 4, 19). Near core hole 10, the interval from Butte No. 2 and the overlying shale tongue 3 is about 40 feet.

BUTTE NO. 1

The Butte No. 1 bed, which is generally less than 1 foot thick, is about 75 feet below Butte No. 2 and about 50 feet above the top of Battle No. 3. It is well exposed at the base of the southwest slope of Lost Creek Butte in sec. 23, T. 23 N., R. 95 W., and near the top of the north slope of a butte in sec. 36, T. 23 N., R. 95 W. At the latter locality, it is of interest because its high uranium content (0.013 percent in the upper part) appears to be related to the overlying sand and gravel deposit that caps the butte. (See p. A–62.) The Butte No. 1 bed extends as far as core hole 4 (pl. 5) where it is a few inches thick and about 49 feet above the top of Battle No. 3, and southward as far as the SE¼ sec. 23, T. 22 N., R. 94 W., about one-half mile south of triangulation station Divide.

LOWER COAL GROUP

The coal beds that crop out in the area south of a line extending from Lost Creek Butte to Luman Butte and north of U.S. Highway 30 are in the Red Desert tongue of the Wasatch formation (figs. 4, 5, 20, and pl. 1). For convenience of discussion these coal beds are referred to in this report as the lower coal group.

The coal beds of the lower coal group are more numerous, thicker, and contain more coal reserves than those of the upper coal group. The coal beds range from a few inches to 21 feet in thickness (core hole 10, pls. 4 and 5) and commonly are 5 feet or more thick (pls. 3–5).

Analyses of eight samples from coal beds in the Battle and Monument zones indicate that coal in the lower group is subbituminous B in rank (table 5).

BATTLE COAL ZONE

The Battle coal zone was named from exposures at the south end of Battle Spring Flat near locality 31. Inasmuch as only the Battle No. 3 bed is exposed there, and only Battle No. 1 and No. 3 beds are present at the nearest locality to the south (loc. 32), a more typical locality is in the small valley south of the nearest approach of the dirt road to the base of shale tongue 1 in sec. 36, T. 23 N., R. 95 W. (Masursky and Pipiringos, 1959, pl. 40, loc. 49). There Battle No. 3 is about 0.5 feet thick and lies about 10 feet above the top of Battle No. 2. The latter bed is about 2 feet thick and the interval from the top of Battle No. 2 to the top of the underlying Battle No. 1 is about 15.5 feet. Battle No. 1 is about 1.6 feet thick. The thickest beds of the Battle coal zone occur in a belt that extends from core hole 4 southeastward to the east boundary of the area near auger hole 35 (pls. 3 and 5, figs. 29 and 33). The trend of the belt is nearly parallel to that of the Red Desert syncline and to that of the normal faults mapped in Tps. 22, 23 N., Rs. 94, 95 W.

The Battle No. 3 is the thickest coal bed in the Battle coal zone, and the only bed in the zone for which reserves were calculated. The Battle

No. 3 coal bed averages 7.5 feet thick (table 5) beneath huge areas and locally is as much as 21 feet thick (core hole 10). Locally, as in auger hole 29, Battle No. 3 is split into two distinct beds. The lowermost bed of the Battle zone is designated Battle No. 1. Westward, Battle No. 3 splits into two distinct beds, as happens a few hundred feet west of the southeast corner of T. 23 N., R. 95 W. There the beds are designated from top to bottom Battle No. 3, No. 2, and No. 1.

The base of shale tongue 1 of the Luman tongue of the Green River formation rests directly on Battle No. 3 (fig. 21) throughout the area

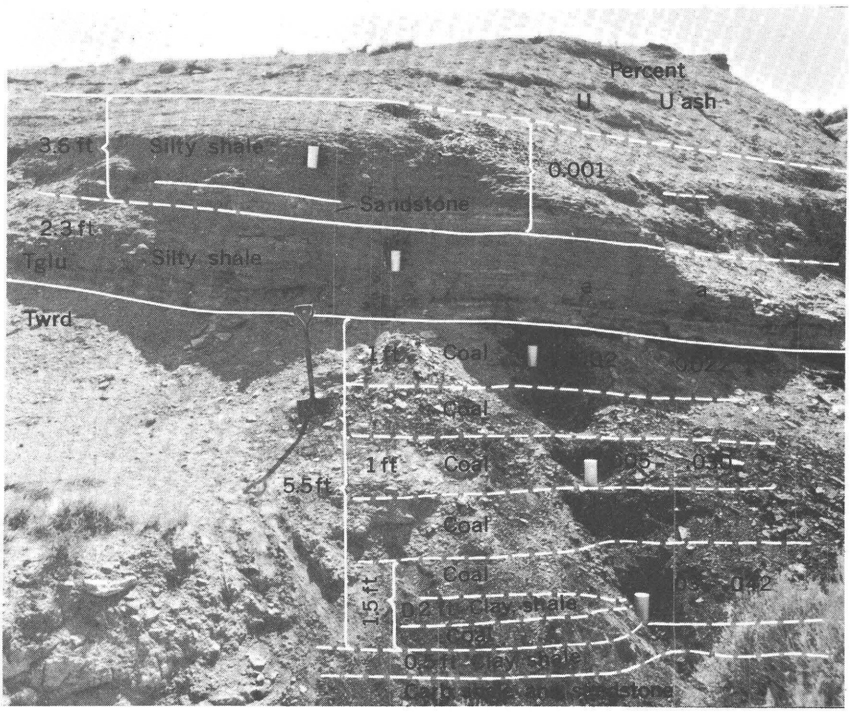

FIGURE 21.—Battle No. 3 coal bed at geologic map locality 31, south of Battle Spring Flat, showing percentage uranium (U) and percentage uranium in ash (U ash) of sampled intervals. Tglu: Luman tongue of the Green River formation; Twrd: Red Desert tongue of the Wasatch formation; *a* indicates less than 0.001 percent uranium.

that extends from about 1 mile south of triangulation station Divide as far north as core hole 4 (fig. 4) and as far west as sec. 8, T. 23 N., R. 96 W. (fig. 3). Westward, beyond this point, no trace remains of the Battle coal beds; and shale tongue 1 thins to less than 2 feet thick and cannot be shown separately at the scale used on the geologic map.

The interval between the top of Battle No. 3 (base of the shale tongue) and the top of the Monument coal zone ranges from 87 feet (core hole 10) at the southwest edge of Battle Spring Flat to 57 feet (loc. 22) near the southwest margin of Lost Creek Flat. The interval is about 87 feet at map localities 62 and 68 and about 60 feet at locality 32. This difference of interval from place to place is caused partly by the fact that the Monument No. 3 bed is lenticular and does not everywhere mark the top of the Monument zone. Aside from the effect the lenticularity of Monument No. 3 has on it, the interval from the base of shale tongue 1 to the top of the Monument zone is constant if measured in a direction parallel to the trend of the Red Desert syncline, but decreases if measured westward at an angle to the syncline. Most of the decrease in interval is due to thinning of the noncoaly rocks between the coal beds.

West of the northwestward-trending normal faults south of the Lost Creek Butte, the coal beds in the Battle coal zone are 2.5 feet or less thick. East of the faults, coal beds in the Battle zone are much thicker, which suggest that minor movements along these faults occurred during early Eocene time.

MONUMENT COAL ZONE

The Monument coal zone at some places consists of about 20 feet of coal and carbonaceous shale (locs. 33 and 34, pl. 3) and at other places it consists of 2 or 3 coal beds separated by clay shale, siltstone, and fine-grained sandstone, all in an interval ranging in thickness from 11 to 29 feet (locs. 46 and 60). Monument No. 2, which splits into Monument No. 1 and No. 2 in the northwestern part of the coal-bearing area, is considerably thicker and more persistent than the overlying Monument No. 3. Because of the small vertical interval and the small horizontal distance between the outcrops of these beds, the Monument zone is shown by a single line on the geologic map drawn at the top of Monument No. 2, except in T. 23 N., R. 94 W. and north of the fault that passes between localities 59 and 60, where it is drawn at the top of Monument No. 3.

The Monument coal zone contains coal beds 2.5 feet or more thick that underlie much of T. 22 N., Rs. 94 and 95 W.; T. 23 N., Rs. 94 and 95 W.; and T. 24 N., R. 95 W.; and coal beds in the zone probably underlie most of Lost Creek Flat, as indicated by surface sections south and southwest of the flat (locs. 20, 21, 22, 41 and 28) and in core holes 10 and 4.

Monument No. 2 was named from good exposures of this bed about a mile west of Monument Lake (dry) just beyond the east edge of the area in the SE¼ sec. 27, T. 22 N., R. 94 W. Monument No. 2 is magnificently exposed at locality 67 (fig. 22), where the bed is about 9 feet thick and crops out on the sides of a small low oval butte. The coal, which once was continuous from the butte to the exposures about 50 feet south of the butte, has been swept away and scattered by the

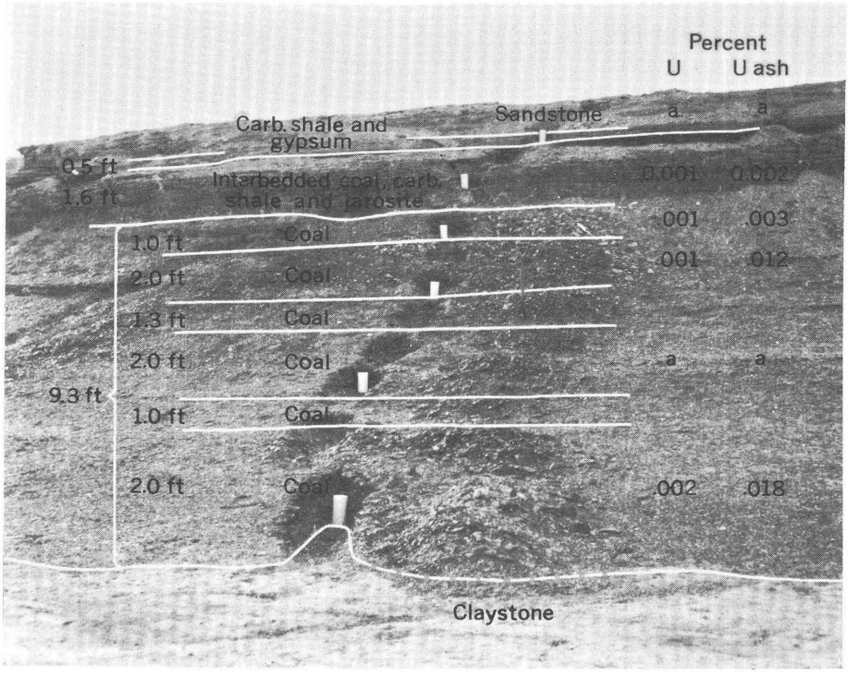

FIGURE 22.—Monument No. 2 coal bed, Red Desert tongue, about 1.5 miles southwest of triangulation station Divide, at geologic map locality 67, showing percentage uranium (U) and percentage uranium in ash (U ash) of sampled intervals; *a* indicates less than 0.001 percent uranium.

wind over the sparse grass, sagebrush, and greasewood directly east of the butte. The butte is capped by gleaming white beds of micaceous siltstone and fine-grained sandstone. It is too low to be seen from the trail, which passes close by, but the effect is startling and spectacular as one leaves the trail and suddenly catches sight of the outcrop. The brilliant white cap of the butte contrasts with the black sides and with the bright-orange and yellow pieces of jarosite and sparkling selenite crystals, which are scattered in profusion on the hollowed-out floor of the depression south of the butte.

This bed is also well exposed at locality 59, where all but the bottom 2 feet of coal crops out. The bed can be traced from locality 59 northeastward across a fault of small displacement to locality 60 (pl. 3) where it underlies Monument No. 3, which is about 3.5 feet thick. An auger hole at locality 60 starting at the base of Monument No. 3 penetrated the top of Monument No. 2 at a depth of about 11 feet and showed Monument No. 2 to be about 14 feet thick. The thickest bed of coal (15 feet) in the Monument zone was penetrated in an auger hole at locality 34 (pl. 3). The average thickness of coal in the reserve area of the Monument zone (figs. 30, 31, 34, 36, 39) is about 7.5 feet.

The interval between the top of Monument No. 2 and the underlying Tierney coal zone ranges about 57 to 76 feet in core holes 4 and 10, and the interval is about 65 feet at four surface localities (47, 48, 66, 67) where surface and augered sections were combined. The increase of interval between these two zones in core hole 10 coincides with the presence of a coarse-grained sandstone tongue of the Battle Spring formation intercalated between the fine-grained rocks that separate the two coal zones.

TIERNEY COAL ZONE

The Tierney coal zone was named from excellent exposures about 2.5 miles northeast of the Tierney shearing pens at localities 78–80 in the NW¼ of T. 21 N., R. 94 W. (pls. 1, 3, and figs. 23, 24). At least seven distinct beds of coal and (or) carbonaceous shale occupy a stratigraphic interval of about 100 feet in the Tierney zone. These

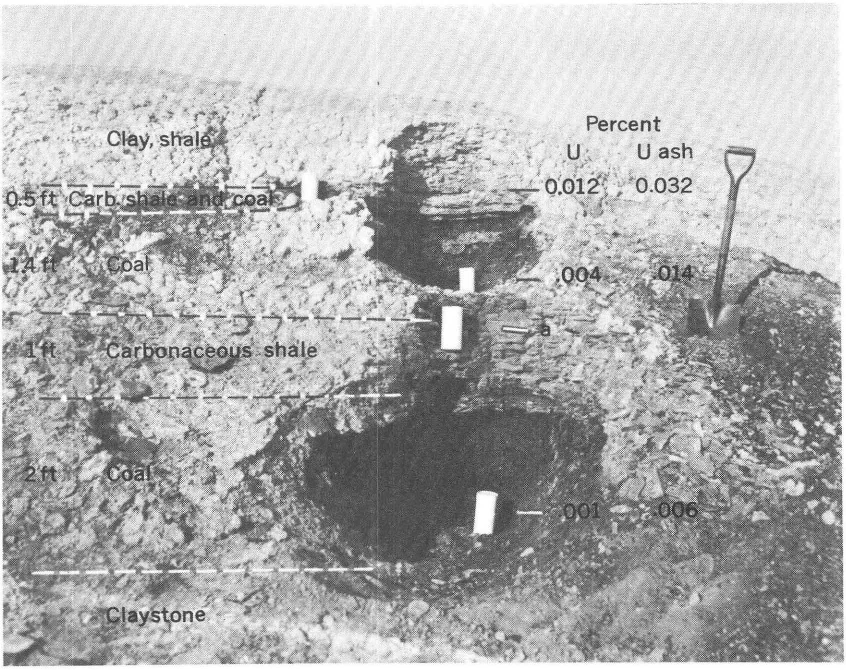

FIGURE 23.—Tierney No. 6 coal bed, Red Desert tongue, about 1.5 miles southwest of Twelve-mile hole at geologic map locality 79, showing percentage uranium (U) and percentage uranium in ash (U ash) of sampled intervals; *a* indicates less than 0.001 percent uranium.

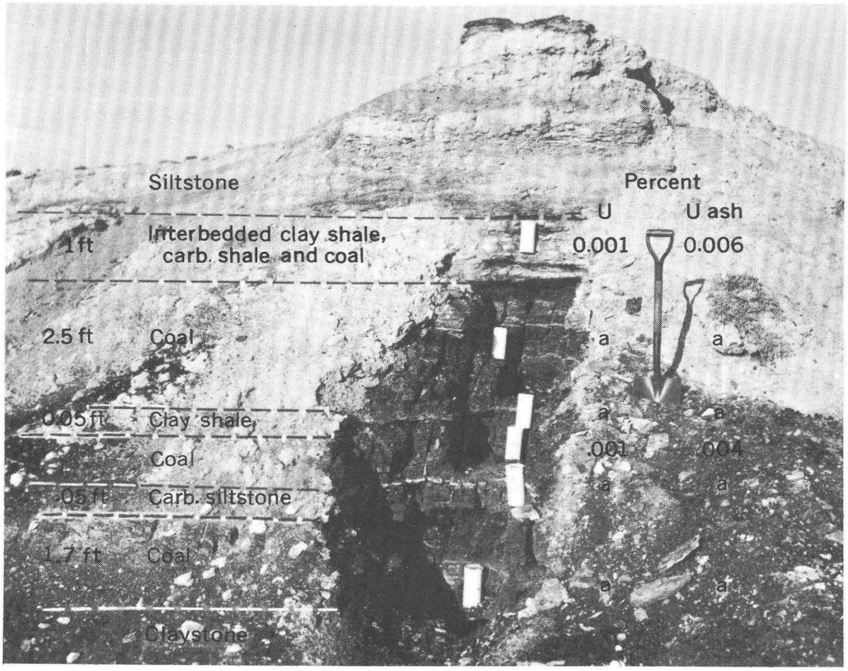

FIGURE 24.—Tierney No. 5 coal bed, Red Desert tongue, about 1.75 miles southwest of Twelve-mile hole at geologic map locality 80, showing percentage uranium (U) and percentage uranium in ash (U ash) of sampled intervals; *a* indicates less than 0.001 percent uranium.

have been numbered 1 to 7 from bottom to top (fig. 20), but only Tierney Nos. 5 and 6 are thick enough (2.5 feet or more) to be considered in estimating the coal reserves.

The rank of the Tierney and underlying coal zones of the lower coal group is not known in this area but presumably is comparable to that of the overlying Monument and Battle zones.

TIERNEY NO. 7

The Tierney No. 7 bed is known only from the headward part of the valley passing between localities 47 and 48, where it consists of carbonaceous shale and coal. Although the total thickness of the bed locally is as much as 5 feet, the coaly lower part does not exceed 1.5 feet.

TIERNEY NO. 6

The Tierney No. 6 bed underlies parts of T. 23 N., R. 94 W., T. 22 N., Rs. 94 and 95 W., and T. 21 N., R. 94 W. Within this area Tierney No. 6 is as much as 13 feet thick (loc. 56, pl. 3) and averages about 6 feet.

The Tierney No. 6 bed is well exposed and typical at locality 79 (fig. 23) where it contains a silty carbonaceous shale parting, locally diagnostic of this bed, which is about 1 foot thick and remarkably persistent. Exposures of this bed lying within a northwestward-trending belt, bounded on the east by an imaginary line extending from locality 70 to 66, and on the west by an imaginary line extending from locality 79 to 48, all contain the diagnostic silty carbonaceous shale parting (pl. 3, locs. 47, 48, 64, 66, 70, 71, 75 and 79). East of this belt, Tierney No. 6 is generally much thicker and relatively free of partings as at localities 55, 56, and 69. West of the belt, the carbonaceous shale parting has entirely replaced the coal in the upper part of the bed (locs. 24, 26, 27, 37, 38, 43, and 44 shown on pl. 3). Thus sections of Tierney No. 6 measured in a northwestern direction are of similar thickness and appearance, whereas sections measured in a southwestern direction change in thickness and appearance from thick relatively pure coal, to coal containing a thick carbonaceous shale parting, to thin coal overlain by an equal or greater thickness of carbonaceous shale. No. 6 bed retains the latter character as far west as the southern part of Lost Creek Flat. From there westward, it is covered by surficial Quaternary deposits. A thin carbonaceous shale that crops out in sec. 5, T. 23 N., R. 97 W. at approximately the stratigraphic position of the Tierney No. 6 may possibly be the wedge edge of this bed.

TIERNEY NO. 5

The Tierney No. 5 bed, which has been mapped as the Sourdough No. 2 bed or as the Sourdough-Monument zone in the eastern part of the Red Desert area, (Masursky and Pipiringos, 1959; Masursky, in press) underlies parts of Tps. 21, 22, and 23 N., R. 95 W., and Tps. 21 and 22 N., R. 94 W. (figs. 32, 38, 41, 42, 44). Tierney No. 5 attains a maximum thickness of 5.5 feet in the extreme southeast corner of the reserve area at locality 76 (pl. 3). The average thickness for the combined reserve areas is about 3.3 feet.

Tierney No. 5 is well exposed and typical at locality 80 (fig. 24) where it is about 4.5 feet thick and contains a brownish-white carbonaceous siltstone parting half an inch thick about 2 feet above the base. This parting is locally persistent and diagnostic of Tierney No. 5. The parting occurs also at localities 48, 72, 74, 76, 77, and 78 (pl. 3).

The interval between the top of Tierney No. 6 and the top of Tierney No. 5 ranges from 12 feet at locality 75 to 26.5 feet at locality 79, and averages 21 feet. Where the sequence between these two coal beds contains a bed of soft, slope-forming sandstone capped by a ledge-forming calcareous sandstone, the interval invariably ranges from 23.5 to 26.5 feet; where the sandstone beds are missing, the interval ranges from 12 to 19 feet in thickness.

At localities 48 and 76, the Tierney No. 5 bed contains minute clear crystals of tschermigite, ammonia alum-$(NH_4)Al(SO_4)_2$.

LOWER BEDS IN TIERNEY COAL ZONE

The remaining beds in the Tierney coal zone are of no economic interest but are useful for correlating locally and in determining, at least, the displacement on one fault in the southern half of sec. 6, T. 21 N., R. 94 W. (fig. 18). There Tierney No. 5 is faulted down against Tierney No. 3, which indicates a 25-foot downward displacement on the south side. The average intervals between the lower Tierney beds are shown on figures 5 and 20.

Locally, Tierney No. 4 consists of coal overlying carbonaceous shale, as at locality 80 where it lies 10.5 feet below the top of Tierney No. 5; elsewhere, as at locality 78, it consists of coal overlain by clay shale, which contains impressions of the floating fern *Salvinia preauriculata* Berry, an Eocene species (loc. 19, table 2). The interval from the top of Tierney No. 4 to the top of Tierney No. 3 ranges from 13 to 17.5 feet.

Tierney No. 3 consists of about 10 feet of carbonaceous shale, which locally contains thin layers of coal. Along the hills south of the closed depression in sec. 4, T. 21 N., R. 94 W. (known locally as Twelvemile hole), it consists of a thin bed of coal overlain by soft dark-green shale containing many selenite crystals. In the vicinity of locality 80, it contains ostracodes and resembles low-grade oil shale.

Tierney No. 2 crops out only in the northern part of sec. 7, T. 21 N., R. 94 W., and was penetrated in an auger hole at locality 78, which started at the base of Tierney No. 3 and reached the top of Tierney No. 2 at a depth of about 13 feet. In sec. 7 it is 2 feet thick and lies about 13 feet above Tierney No. 1, as determined by auger drilling.

DUNE COAL ZONE

The Dune coal zone contains two beds consisting mostly of carbonaceous shale, which were mapped locally for stratigraphic and structural control. These beds are designated from bottom to top Dune No. 1 and Dune No. 2. The zone was named from exposures (fig. 17) south of the sand-dune belt that occupies a strip of land a few miles north of Tipton Buttes.

The zone is best exposed on the north side of a small isolated hill in the SW¼ NE¼ sec. 8, T. 21 N., R. 94 W., where each of the Dune beds consist of a few inches of coal and are about 26 feet apart. The interval down to the next coal zone (fig. 20) was determined by a series of auger holes drilled in the area between localities 78 and 81, supplemented by mapping of locally persistent calcareous sandstone beds and zones of limestone concretions.

UNNAMED COAL ZONE

There are six mappable coal beds in the unnamed zone which underlie large areas of very few coal outcrops. These beds are called from top to bottom beds A, B, C, D, E, and F. Correlation with thicker beds having similar stratigraphic position, which were penetrated in core holes drilled in the area adjacent to the east (Masursky, in press) in uncertain. The stratigraphic position of these coal beds is shown on figure 4 and in plate 5.

Between the latitude passing through locality 80 and south to about the latitude of the middle of T. 20 N. there are less than six localities where outcrops of coal beds A–E can be examined (F does not crop out). Fortunately, most of these coal beds as well as some of the intervening rocks are distinctive and can be identified by careful examination of the rock fragments from animal burrows, which generally are more helpful than auger cuttings because the spill piles are dry and show how the concealed coal and the associated rocks would weather in outcrop. Bed B is characterized by brown fossil wood and by white fossil wood. It underlies a bed of low-grade oil shale, which contains at or near the top a thin zone of limestone concretions that weather bright yellow buff. The interval between beds B and C is made up of greenish shale and siltstone. Bed C does not contain fossil wood and rests directly on brown papery low-grade oil shale. The oil shale is about 50 feet thick and rests on coal bed D. This bed contains a moderate amount of fossil wood that weathers brown. It rests on a gray-green shale and siltstone sequence, about 40 feet thick, which in turn rests on coal bed E. The latter contains a layer of fossil wood that weathers brown, generally 2 inches or more thick and in a few places contains also a moderate amount of fossil wood that weathers white. Thus the position of a coal bed can be inferred from spill piles and the identity of the bed can be determined by the presence or absence of the brown low-grade oil shale and by the types, thickness, and amount of fossil wood in the spill piles. With the exception of coal bed E, auger holes indicate that these unnamed coal beds generally are less than 2.5 feet thick.

Although coal bed E is thin at locality 82, it is slightly more than 2.5 feet thick at locality 81. The area for which coal reserves in this bed were calculated is shown in figure 45. Coal bed F is about 15 feet below E and is known only from examination of animal burrow tailings.

The discussion of the coal beds to this point has been limited to outcrops in the area between the axes of the Red Desert syncline and the Tierney anticline. The rest of this discussion concerns coal in the area south and southwest of the Tierney anticline.

South of the circular outcrop pattern that coal bed E makes along the crest of the Tierney anticline, the section is repeated with successively younger rocks exposed as the southern part of the area is approached. In the southern part of the area the Tierney, Monument, and Battle zones of the lower coal group have slightly different stratigraphic intervals from those in the northern part of the area. All the coal beds in the southern part of the area are thinner than the minimum of 2.5 feet used in calculating coal reserves.

Two key beds were useful in correlating the beds in the lower coal group in the southeastern part of the area with those in the Tipton Buttes area west of Red Desert Flat. These key beds are not present in the northern part of the area. One of the key beds occurs at the base of the Luman tongue (pls. 5 and 6). It consists of a thin (2 feet or less) fossiliferous sandstone bed, which contains numerous fossil worm(?) burrows whose long axes are normal to the bedding. The sandstone filling the burrows is softer than the surrounding rock and the weathered surface of this bed is covered with circular pits averaging about a quarter of an inch in diameter (fig. 8). This peculiarity led to nicknaming the bed the "wormy" sandstone. The "wormy" sandstone is generally 35 to 40 feet above Battle No. 1 in the southern part of the area.

The second key bed consists of gray-black limestone, which occurs about 200 feet below the top of the Red Desert tongue, a few feet below Tierney No. 1 (figs. 5, 6, and 20), and which contains abundant mollusk fragments. Locally the fossils have been leached out giving the limestone bed a perforate appearance, which gave rise to the nickname "holey" limestone. The limestone is about 1 foot thick in the east central part of sec. 22, T. 20 N., R. 95 W (fig. 9). This limestone is thin but prominent and well exposed around the base of the largest of the Tipton Buttes (fig. 17) in sec. 27, T. 20 N., R. 96 W., where it is about 7 feet above the Dune No. 2 coal bed (pl. 13). The Tierney, Monument, and Battle coal zones above the "holey" limestone and below the "wormy" sandstone crop out in an east-west belt throughout the southern part of the area.

The upper coal group crops out south of U.S. Highway 30 where it is represented by thin coal and carbonaceous beds, except near the southeast corner of the area in the NE¼ sec. 7, T. 19 N., R. 94 W. where a 5-foot canneloid coal bed crops out directly beneath the molluscan coquina at the base of the Tipton. The westward continuation of the coquina is shown in figure 15. The coal bed thins abruptly westward but maintains a 5-foot thickness for several miles eastward and southeastward before thinning to less than 2.5 feet. Thus, this bed makes a lenticular outcrop around the northeast corner of the Washakie Basin. In some places it is mined by the local ranchers (Bradley, 1945).

URANIUM IN COAL

Nearly all the coal beds that crop out in the central part of the Great Divide Basin contain from 0.001 to 0.003 percent uranium. In some places, parts of these beds apparently contain no uranium and in other places parts of these beds contain as much as 0.026 percent uranium (pl. 3, localities 15 and 27).

In general, the least uraniferous coal beds are those in the western and southern parts of the area and the most uraniferous are those in the central and northeastern parts. The higher concentrations of uranium (defined as 0.003 percent or more uranium) are found in the coal beds that underlie an area a few miles wide that extends southeastward from the "peninsula" on the northwest side of Lost Creek Flat for an undetermined distance beyond the south edge of Battle Spring Flat. This area of higher concentration of uranium in coal coincides approximately with the east side of the trough of the Red Desert syncline and with the zone of intertonguing of the permeable arkosic sandstone beds of the Battle Spring formation with the less permeable and impermeable sandstone, siltstone, clay shale, and papery-shale beds of the Wasatch and Green River formations.

The areal distribution of uranium in coal beds may be described in various ways. The uranium content decreases westward with distance from the Battle Spring formation, the trough of the Red Desert syncline, and the zone of intertonguing (facies changes). And inasmuch as the thickest coal beds, which lie on the west side of the trough of the Red Desert syncline, contain far less uranium than the thinner beds on the east side, it may be stated that the uranium content decreases as the thickness of the coal beds increases. Thick coal beds and high uranium content are in effect mutually exclusive.

Figure 25 (sections *B–B′*) shows the apparent relationship of uranium content in the Luman coal zone to southwest-northeast facies changes across the Red Desert syncline. The geologic setting of the Luman coal zone is very similar to that of all the coal zones in this area. The average uranium and ash content shown in the graphs for each locality is the weighted average of the coal bed exclusive of clay shale and carbonaceous shale partings.

As shown in figure 25 the uranium content of the Luman No. 2 coal bed ranges from about 0.002 percent at the left or west side of the diagram to about 0.012 percent in the middle, near the axis of the syncline. From locality 1 to locality 4, about 1.8 miles apart, the uranium content ranges from 0.0023 to 0.0055, an increase of 0.0032 percent. From locality 4 to locality 5, about 0.7 mile apart the uranium content rises to 0.009 percent, an increase of 0.0035 percent in less than half the distance between localities 1 and 4. From locality 5 the uranium content increases eastward to a maximum of 0.012 percent at locality 7 and then decreases again at locality 8. Eastward beyond this point the Luman No. 2 coal bed grades completely into a carbonaceous shale and then pinches out. At locality 15, the Luman No. 2 bed consists of a few inches of carbonaceous shale and contains 0.002 percent uranium.

Data used to construct figure 25 are taken from surface and auger samples (pl. 3) and core samples (pls. 4 and 5). The ash content of the auger samples is estimated. Comparison of weighted ash contents of 5 auger samples and nearby core samples from the same coal bed indicates that the ash content of an auger sample ranges from 43 to 69 percent and averages 55 percent too high. The sample localities shown by an arbitrary series of numbers on figure 25 correspond to the geologic map localities (pl. 1) as follows:

Locality No. (fig. 25)	Locality No. (pl. 1)	Sample from—	Locality No. (fig. 25)	Locality No. (pl. 1)	Sample from—
1	1	Core hole.	9	1	Core hole.
2	7	Surface section.	10	7	Do.
3	8	Do.	11	4	Do.
4	9	Do.	12	17	Auger hole.
5	11, 12	Auger holes, average.	13	5	Core hole.
6	14	Surface section.	14	6	Do.
7	16	Do.	15	9	Do.
8	18	Do.			

The relatively sharp rise in uranium content of Luman No. 2 between localities 4 and 5 coincides with the first appearance in the section of coarse-grained permeable rocks, and all the localities (5–8) with the relatively higher concentrations of uranium are in or near the lowest part of the syncline.

The graph of Luman No. 1 (fig. 25) also shows a rise in uranium content northeastward. The uranium content rises from 0.002 percent at locality 9 to 0.004 percent at locality 11. It reaches a maximum of 0.008 percent at locality 13 and gradually diminishes to 0.006 percent uranium at locality 15. About 3 miles east of locality 15, near the east edge of the area, Luman No. 1 consists of about 5 feet of

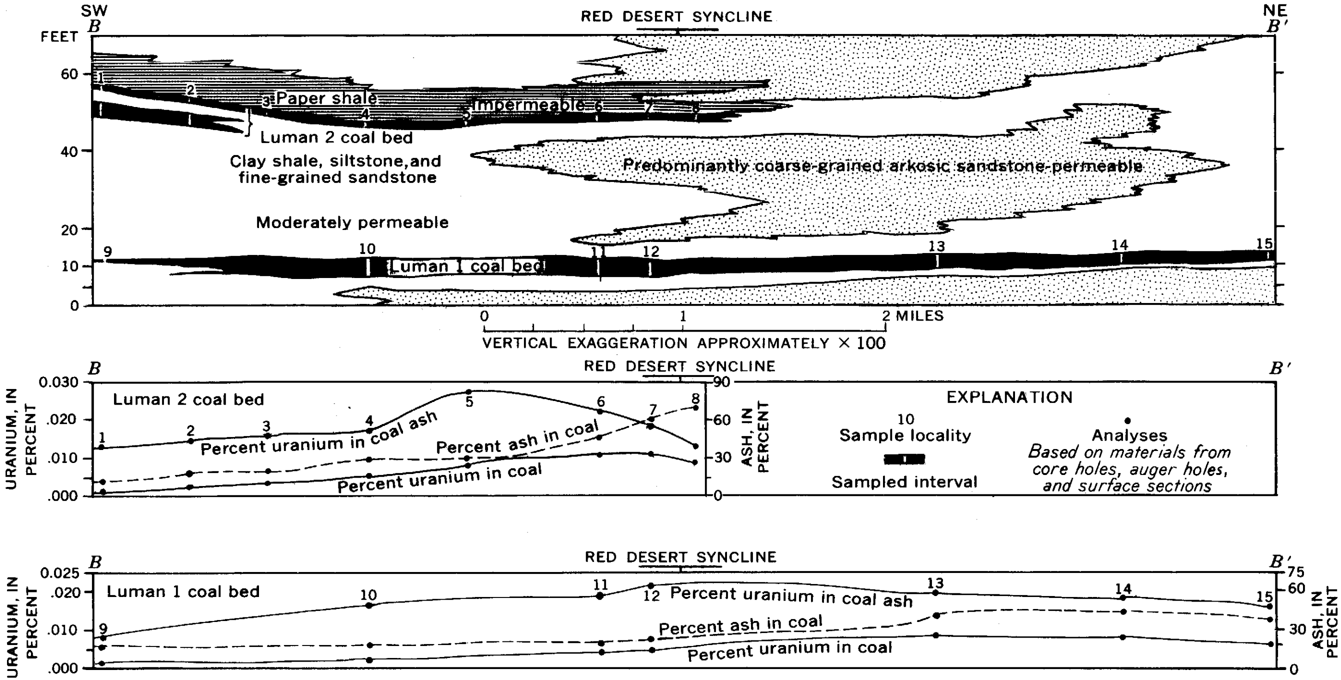

FIGURE 25.—Correlation of distribution of uranium in coal to facies changes. (See geologic map, pl. 1.)

carbonaceous shale and has a uranium content of 0.002 percent. The greatest concentration of uranium in coal coincides with that part of the section containing the largest amounts of coarse-grained permeable rocks. The maximum concentration is in the first locality east of the axis of the syncline. At locality 15 where there is a local decrease of permeable rocks in the section, the uranium content likewise decreases. These two examples of the dependence of the amount of uranium in the coal beds on the degree of permeability of the overlying and underlying rocks and on the syncline, taken alone, are not conclusive, but inasmuch as the same general relationships can be observed in all the coal beds of this area, it seems highly probable that the uranium entered the coal beds from ground water moving down-structure along permeable beds of the Battle Spring formation.

The apparent relationship of the ash content with the uranium content in the coal beds, shown in figure 25, is believed to be almost entirely fortuitous. The margins of the swamps in which the Luman No. 1 and No. 2 coal beds were formed were near the northeast edge of the area, north of Battle Spring Flat, so that an increase in ash content of these beds eastward was to be expected even if the coal beds of this area had never been subjected to uranium mineralization. Mineralogic and chemical studies by Breger, Deul, and Meyrowitz (1955) showed that in a sample from the Luman No. 1 coal bed (loc. 15, pls. 1 and 3) the organic components contained 98 percent of the uranium. Petrologic studies by Schopf and Gray (written communication) of an 8-inch core sample of the Luman No. 1 coal bed taken from a core hole drilled near core hole 5 (pls. 1 and 5) showed similar results.

In view of the foregoing, the only effect that impurities in coal might have on the distribution of uranium in coal is probably to make the impure coal slightly more permeable and thus slightly more accessible to uranium-bearing ground water. The observations of Schopf and Gray that "highly uraniferous layers usually have a considerable amount of amorphous waxy and clayey mineral matter and commonly lie adjacent to a layer of greater mineral content," might be explained in that way.

Locally, relatively high uranium concentrations in coal beds seem related to sand and gravel deposits of probable Pleistocene age. At a locality about 2 miles southeast of Lost Creek Butte, in the NE¼ sec. 31, T. 23 N., R. 94 W., a layer of sand and gravel about 20 feet thick rests on a 10-foot sequence of coarse-grained sandstone that directly overlies a 10-inch coal bed (Butte No. 1). The average uranium content of the coal bed is 0.009 percent. Another thin coal bed (Battle No. 3), about 45 feet lower in the section, is overlain directly by a 20-foot bed of waxy papery-fissile oil shale (shale 1 of the Luman tongue) and contains only 0.0015 percent uranium. Two other samples of the Butte No. 1 coal bed collected from outcrops 500 and 1,000 feet east of the first locality contain 0.005 and less than 0.001 percent uranium, respectively. The eastward decrease in uranium content of the Butte No. 1 coal bed is local and is associated with an increase in interval between Butte No. 1 and the sand and gravel layer, and also is associated with a gradation from coarse-grained sandstone to clay shale in the beds directly above Butte No. 1.

In the SE¼ sec. 25, T. 22 N., R. 95 W., about 8 miles south of Lost Creek Butte, the uranium content of five coal beds distributed through 80 feet of section ranges from 0.014 percent in the highest (Monument No. 1; Masursky and Pipiringos, 1959, pl. 42, loc. 135) to none in the lowest (Tierney No. 5; loc. 48, pl. 3). The highest coal bed is directly overlain by a 20-foot sequence of medium-grained sandstone beds which is capped by a layer of sand and gravel about 10 feet thick. The four lower coal beds are interbedded with clay shale, siltstone, and fine-grained sandstone. Chemical analyses of sand and gravel samples from both localities showed 0.003 percent or less equivalent uranium and less than 0.001 percent uranium. Presumably the water in which the sand and gravel were deposited was uranium bearing, and most of the uranium that may have been deposited with the sand and gravel has since been leached and redeposited in the first coal bed beneath it.

SCHROECKINGERITE DEPOSITS

Schroeckingerite [$NaCa_3(UO_2)(CO_3)_3(SO_4)F \cdot 10H_2O$] is a yellow-green secondary mineral containing 26.8 percent uranium (Frondel and Fleischer, 1955) which was discovered in the Red Desert area by the late Mrs. Minnie McCormick of Wamsutter, Wyo., before February 1937. The mineral was believed to be new and was named dakeite by Larsen (1937). Later Novacek (1939) showed that dakeite was a synonym for schroeckingerite, which had been named many years previously. Consequently the name dakeite has been abandoned.

The schroeckingerite locality is in the northeast corner of the area in secs. 30 and 31 of T. 26 N., R. 94 W., not far from the structurally lowest part of the area (pl. 1). The Geological Survey made brief intermittent reconnaissance investigations of the locality from 1944 to 1950 and detailed investigations from 1951 to 1953. The results of these investigations are described in detail by Wyant, Sharp, and Sheridan (1956) and by Sheridan, Maxwell, and Collier (1961).

The deposits are calichelike and are found only in the alluvium and the upper several feet of the underlying bedrock. The schroeckingerite was formed so recently that the uranium and its disintegration products have not attained radioactive equilibrium (Wyant, Sharp, and Sheridan, 1956). Reconnaissance mapping and stratigraphic studies by the author indicate that, although most of the bedrock deposits occur in a sequence of arkosic sandstone and clay shale stratigraphically equivalent to the lower part of the Cathedral Bluffs tongue of the Wasatch formation, at least part of the bedrock of the schroeckingerite locality is in the Tipton tongue of the Green River formation. The presence of low-grade oil shale suggests, furthermore, that some of these beds are in the upper part of the lower Tipton. (See p. A–29 to A–31 and pl. 1.)

ORIGIN OF THE URANIUM DEPOSITS

Wyant, Sharp, and Sheridan (1956) consider two ways in which the uranium may have accumulated in the coal beds of the Red Desert area: Syngenetic—the uranium was introduced by ground and surface water into swamps where coal was forming and was fixed before coalification by biogenetic processes or by carbon fixation; and epigenetic—the uranium was leached from overlying source rocks, such as volcanic ash, by ground and surface water and carried down to precipitate in, or be adsorbed by, lignite. They expressed a preference for the first explanation—a syngenetic or at least precoalification origin for the uraniferous liginite beds in the Red Desert area.

Because of the much greater amount of information now available for this area the suggested explanations outlined above can be refined and amplified as follows:

1. *Syngenetic*—the uranium accumulated while the coal was forming (early Eocene time). It was introduced into the swamps by ground and surface water or by direct uranium-bearing ash falls.

   Possible sources of uranium are the Granite Moutains, the Battle Spring formation, a deep-seated hydrothermal source emplaced during or shortly before early Eocene time, and volcanic eruptions during early Eocene time.
2. *Diagenetic*—the uranium accumulated during or shortly after the formation of the coal, but before hardening of the coal and the surrounding sediments.

   The Eocene rocks were folded before the deposition of younger rocks (Browns Park (?) of this report). Inasmuch as none of the Eocene rocks show signs of having been folded while still in an unconsolidated state lithification of the coal-bearing rocks must have occurred no later than the closing stages of Eocene time. Thus the time of mineralization was confined to the Eocene. The uranium was introduced primarily by ground water and, to some extent, by surface water and direct volcanic-ash falls.

Possible sources of uranium are the younger parts of the Wasatch and Green River formations, the Bridger formation, and the sources given under the syngenetic explanation above. Hydrothermal sources could have come into existence any time during the Eocene.

3. *Epigenetic*—the uranium accumulated after the coal beds and surrounding rocks were formed, hardened, folded, and eroded. Mineralization occurred after the close of the Eocene. Uranium was introduced into the coal by circulating ground water.

   Possible sources of uranium: are the Battle Spring formation, the Granite Mountains, post-Eocene sedimentary rocks, post-Eocene deep-seated hydrothermal sources, and post-Eocene volcanic-ash falls. The first two sources are possible post-Eocene sources because it is conceivable that ground water might not have been able to transfer uranium from these sources to the coal beds until post-Eocene folding created favorable artesian conditions.

   It is doubtful that upper Eocene and Oligocene rocks ever covered the area. The only identifiable post-Eocene Tertiary rocks in the area are in the north edge and belong to the Browns Parks(?) formation of Miocene and Miocene(?) age. Pliocene(?) rocks overlie Miocene rocks in the Granite Mountains (J. D. Love, 1952, written communication) and quite possibly at one time had overlain the Browns Park(?) of the area.

4. A combination of all three methods could have accounted for the present-day distribution of uranium in coal.

The author believes that the following explanation (one of the possibilities listed under 3) is more likely to be closer to the true explanation than any of the others.

The uranium accumulated after the coal-bearing Eocene rocks were formed, hardened, folded, and eroded, and after the Eocene rocks were buried by uranium-bearing post-Eocene rocks. The uranium was introduced almost entirely by ground water moving downward and then laterally for considerable distances guided by structural conditions and stratigraphic facies changes.

The source of the uranium was the Browns Park(?) formation. The uranium in this formation, undoubtedly contained in volcanic constituents, such as glass shards, presumably would not be released until the shards were devitrified (Waters and Granger, 1953, p. 21). The process of transferring uranium from the Browns Park(?) formation to underlying rocks began as soon as that formation came into existence, but probably the transfer of the bulk of the uranium took place after deposition and lithification of the Browns Park(?)

formation and overlying Pliocene rocks, if any, and after post-Pliocene uplift giving surface and ground water a chance to percolate through these rocks and leach the uranium. Devitrification likewise would not be rapid until after lithification and uplift of the post-Eocene Tertiary rocks.

Objections to a syngenetic or diagenetic origin for uranium occurrences in coal are: The distribution of uranium apparently is influenced by regional structure and the vertical and lateral distribution of uranium in coal is considerably less uniform than would reasonably be expected if the uranium had accumulated at the time the coal was formed or shortly thereafter.

Larsen (1937, p. 7) believes that the final steps in the formation of the schroeckingerite deposits are the rising of water solutions to the surface by capillarity, evaporation of the water, and deposition of dissolved minerals. Wyant, Sharp, and Sheridan (1956) agree and further note that the deposits are confined to the Cyclone Rim fault zone and are apparently related to iron-stained solution zones. The south limit of this fault zone is shown south of the schroeckingerite locality on plate 1 of the present report. They concluded that the zone of faulting is a major control for the localization of the schroeckingerite deposits.

To the information, so far mentioned, on factors controlling ground-water movement, the following is added.

Figure 26, section *C–C′*, is a diagrammatic south-north structure section across the graben along whose south border the schroeckingerite deposits are located. The section shows only major stratigraphic units and structural features. The Miocene rocks have been projected into the plane of section. Many small east-west trending normal faults that dip southward occur in the schroeckingerite locality (Wyant, Sharp, and Sheridan, 1956; Sheridan, Maxwell, and Collier, 1961) but are not shown. A structure section drawn eastward nearly normal to section *C–C′* and along the axis of the syncline in the graben, would show that the syncline plunges eastward, flattens out in the area northwest of the schroeckingerite deposits, and rises again east of the deposits. The structural setting is such that ground water north of the schroeckingerite deposits is under hydrostatic pressure from the west, north, and east. Lost Creek flows south across the structurally lowest part of the garben. If the fault extending northeastward across the northwest margin of the Niland basin (pl. 1) provides a pathway for ground-water movement, much of the ground water moving down dip along the axis of the Red Desert syncline into the Niland basin might leave the Niland basin along this fault, enter the graben, and also contribute its uranium to the formation of the schroeckingerite deposits.

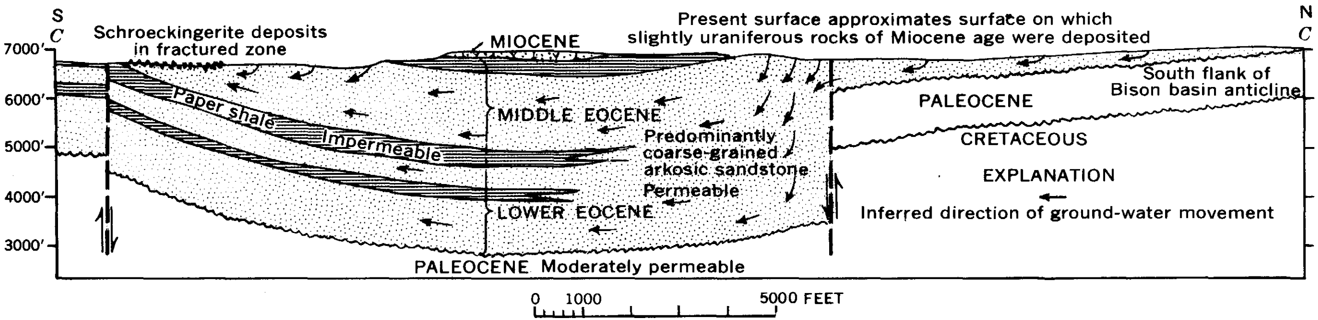

FIGURE. 26.—Diagrammatic section across the schroeckingerite locality, Great Divide Basin. (See geologic map, pl. 1.)

The asymmetric distribution of the deposits with respect to Lost Creek (nearly all the deposits lie east of Lost Creek) may be due to the fact that the graben is structurally higher in the west causing the area of hydrostatic equilibrium to be displaced slightly eastward, up-structure from the lowest part of the syncline in the graben.

The stratigraphic and structural circumstances and the calichelike nature of the schroeckingerite make it highly probable that the deposits are made by evaporation of uranium-charged ground water brought to the surface by a combination of artesian conditions and capillary action.

SOURCE OF THE URANIUM

Determination of the source of the uranium in these two types of deposits is considerably more difficult inasmuch as it has proved impossible to tell from an examination of the deposits themselves anything about the source of the uranium. Conclusions as to the source must depend on indirect or negative evidence, regional considerations, and purely theoretical considerations.

In connection with the schroeckingerite deposits, Wyant, Sharp, and Sheridan (1956) favored the possibility that the uranium was leached by ground water from uranium-bearing coal beds, which were inferred to underlie the schroeckingerite deposits, and carried to the surface along the Cyclone Rim fault zone. Subsequent work has rendered this possibility highly improbable because the coal beds that Wyant, Sharp, and Sheridan (1956) had reference to (upper coal group of the present report) probably do not extend northward as far as the schroeckingerite locality and the ground water is practically incapable of leaching uranium from coal.

In discussing the results of laboratory experiments demonstrating the facility with which low rank coals can extract uranium from aqueous solution, Moore (1954) states, "The uranium is apparently retained in the coal by an irreversible process."

Wyant, Sharp, and Sheridan assumed that uranium could be leached from coal by ground water because most of the nine surface samples of coal and carbonaceous shale which they collected apparently contained an insufficient amount of uranium (uranium, determined by chemical analyses) to account for the radioactivity (equivalent uranium, determined by radiometric analyses).

Chemical and radiometric analyses of 485 samples of coal, carbonaceous shale, carbonaceous siltstone, black shale, and coaly shale taken from the cores shown on plates 4 and 5 show that only 6 samples (none of which were coal) contain an excess of equivalent uranium over uranium of more than 0.003 percent (maximum analytical error), indicating that the uranium in the coal beds of this area is not subject to leaching by the present ground water.

Breger, Deul, and Meyrowitz (1955, p. 620–621) point out that the presence of schroeckingerite in this area suggests that the ground water contains uranium in the form of soluble alkaline or alkaline-earth uranyl carbonate. Alkaline uranium-bearing ground water not only is incapable of leaching uranium from coal, but would most probably surrender its uranium to the coal upon contact. Thus the possibility that the uranium in the schroeckingerite deposits came from underlying uranium-bearing coal beds is practically ruled out.

The ground water and (or) surface water which carried the uranium now in the coal beds and in the schroeckingerite deposits could have acquired the uranium from a deep-seated hydrothermal source, from granite-derived uranium minerals in the arkose of the Battle Spring formation, or from the weakly uraniferous tuffaceous Browns Park (?) formation.

No known conclusive evidence exists to support the first possibility in this area. Iron staining, carbonate veins (Lincoln R. Page, oral communication), and iron oxide cement in the rocks associated with the schroeckingerite deposits cannot be considered as unequivocal evidence of the presence of a hydrothermal source beneath the schroeckingerite locality or surrounding areas inasmuch as these features can also be formed by action of ground water that has not come in contact with hydrothermal solutions.

The lava flows capping the Leucite Hills, some 50 miles southwest of the schroeckingerite locality, are too far away to be cited as evidence of a deep-seated hydrothermal source that might have contributed uranium directly to the schroeckingerite deposits. The suggestion that such a hydrothermal body might have contributed uranium to ground water, which then carried the uranium eastward to the schroeckingerite deposits and to the coal beds, is contradicted by the distribution of the uranium deposits. Contrary to what might be expected under such a hypothesis the uranium content of the coal beds increases eastward with distance from the Leucite Hills, and the deposits, both in the coal and in the schroeckingerite deposits, are situated adversely with respect to structural and stratigraphic controls of hypothetical ground-water movement from the Leucite Hills eastward.

The possibility that the Battle Spring formation was the source of the uranium is improbable. The arkosic sandstone beds were clearly derived from the Granite Mountains north and northeast of the area. Inasmuch as the uranium in minerals that withstand transportation well, such as monazite, is not leachable under normal ground-water conditions, consideration must be given to interstitial uranium that may be present in the granite of the Granite Mountains. Such interstitial uranium from granite elsewhere is said to be readily leachable (Larsen and Phair, 1954, p. 80). But whether the interstitial uranium is readily leachable under field conditions is uncertain.

The Granite Mountains are overlapped by a minimum of 900 feet of weakly uraniferous tuffaceous rocks (Love, written communication, 1952) that almost certainly at one time completely covered them, and it may be difficult to determine how much of the interstitial uranium that may be present in the granite was derived from magma and how much from overlying uranium-bearing tuffaceous rocks.

The suggestion that the overlying tuffaceous rocks may have supplied the interstitial uranium that may be present in the granite of the Granite Mountains is virtually the same as that made by Hurley (1950, p. 5) to explain discrepancies in helium age determinations of igneous rocks: "If it is true that supergene alterations have effected these changes in igneous rocks, the cause of low helium-ages in igneous rocks may be due to modification of the radioactivity late in the rocks' history rather than the losses of helium."

From previous discussions it seems certain that structure played an important role in determining the distribution of the uranium in this area. If so, it is difficult to explain the widespread occurrence of uranium in coal far removed from the Battle Spring formation and in structurally unfavorable positions if that formation were the source of the uranium.

The coal beds in the Tipton Buttes area locally contain as much as 0.005 percent uranium (Tierney No. 5 at the locality shown in fig. 3), yet they are many miles from the Battle Spring formation and are separated from it by the Wamsutter(?) arch.

A sample from a coal bed in the Fort Union formation many miles west of the area on the east flank of the Rock Springs uplift contained 0.025 percent uranium. Obviously because of the structural and stratigraphic conditions, ground water could not have carried uranium upstructure from the Battle Spring formation to these localities. Such widespread sporadic distribution of uranium occurrences in an area that locally contains smaller well-defined areas of relatively higher concentrations, as along the Red Desert syncline, seems to require a widespread source of uranium.

In contrast to the real or apparent lack of evidence in favor of the two possibilities discussed thus far, remnants of the weakly radioactive tuffaceous sandstone beds of the Browns Park(?) formation of Miocene age crop out less than a mile from the schroeckingerite deposits. Remnants of this formation are also preserved at the Rawlins uplift and at least as far south as Baggs, Wyo., and at Aspen

Mountain and other areas in the southern part of the Rock Springs uplift southwest of the Great Divide Basin. Similar rocks (the Chadron formation of Nace, 1939) cap the Oregon Buttes in the northwest corner of the Great Divide Basin. Thus at one time these tuffaceous rocks quite likely covered the entire Great Divide Basin. These tuffaceous rocks are weakly radioactive and the following analyses of tuffaceous sandstone (table 6) are typical of the Browns Park(?) formation in the northern part of the area.

TABLE 6.—*Analyses of weakly radioactive tuffaceous sandstone*

Sample	Locality	Percent equivalent uranium	Percent uranium
58387	SE¼ sec. 24, T. 26 N., R. 95 W	0.003	
56751	NE¼ sec. 9, T. 26 N., R. 95 W	.001	0.001
56752	do	.001	.001
56864	do	.002	
56865	SE¼ sec. 31, T. 27 N., R. 95 W	.002	
56866	do	.001	
148080 [1]	SW¼NE¼ sec. 22, T. 26 N., R. 95 W	.005	.004

[1] Radiometric analysis by B. A. McCall and chemical analysis by Roosevelt Moore, Washington, D.C., 1956. All other radiometric analyses by Sylvia Furman, and all other chemical analyses by Wayne Mountjoy and George Boyes, Denver, Colo., 1952.

An additional 21 samples of this formation were collected by the author for detailed analyses and study. Unfortunately all but one (sample 148080 in table 6) were lost in shipment. These few analyses are admittedly inadequate to support the contention that the Browns Park(?) formation was the source of the uranium in this area.

Nevertheless, the analyses available suggest that at one time the Browns Park(?) formation locally contained at least 0.005 percent uranium, which has since been subjected to leaching. The upper part of the Bridger formation directly below the Browns Park(?) contains many beds of silicified claystone and limestone, white and brown chalcedony layers, and black, completely silica-replaced, fossil tree stumps and trunk segments. The silica in the upper part of the Bridger is interpreted to have been derived from the devitrification of volcanic glass shards in the overlying Browns Park(?). Such a process would facilitate the oxidation, removal, and transport of the uranium in the shards. This possibility was suggested by Waters and Granger (1953, p. 20–21).

Miocene and Pliocene(?) rocks northeast, southeast, and south of the central part of the Great Divide Basin are known to contain uranium. Pliocene(?) rocks of the Split Mountain area (part of the Granite Mountains) contain as much as 0.005 percent uranium and 0.016 percent equivalent uranium (J. D. Love, written communication, 1952). Miocene(?) and Miocene rocks of the Miller Hill and Baggs areas, which generally contain similar quantities of uranium, locally contain concentrations of more than 0.1 percent uranium (Love, 1953, p. 7; Vine and Prichard, 1954, p. 4). These findings also suggest indirectly that the source of the uranium in the central part of the Great Divide Basin probably was the Browns Park(?) formation.

Though the uranium content of the Browns Park(?) is low, such a source can adequately account for the large tonnages of uranium in the coal beds of this area as well as its widespread areal distribution.

Leaching of the uranium from tuffaceous beds stratigraphically high in the section by percolating ground water and the redeposition of the uranium in coal beds lower in the section was advanced in 1950 as an explanation of the uranium occurrences in the coal beds of northwestern South Dakota by Denson, Bachman, and Zeller (1959). There, the proximity of highly uraniferous coal to the tuffaceous beds of the Oligocene White River and the Miocene Arikaree formations capping the buttes served to demonstrate the effect of ground water percolating downward; there is no necessity to postulate lateral movements of any appreciable magnitude.

Because of many thick tongues of impermeable low-grade oil shale throughout most of the coal-bearing area of the central part of the Great Divide Basin, the distribution of uranium cannot be explained primarily by downward movement of uranium-bearing ground water and necessitates the supposition that lateral movements of water played the dominant role in the emplacement of the uranium in the coal beds.

The most probable source of uranium in the coal beds and schroeckingerite deposits of this area was and is the weakly uraniferous tuffaceous sandstone beds of the Browns Park (?) formation. Transfer of the uranium from the source rocks directly downward was prevented throughout most of the coal-bearing area by intervening thick sequences of nearly impermeable beds of the Green River formation. Where these impermeable beds were absent and the source rocks rested on the permeable Battle Spring formation, uranium-bearing water percolated downward and laterally for several miles in response to structural and permeability controls such as the Red Desert syncline and the zone of facies changes described previously.

Absorption of uranium by coal from ground water is a process that generally seems irreversible in nature. The coal beds nearest the permeable tongues of the Battle Spring formation accumulated higher concentrations of uranium than did the coal beds farther away.

Leaching and transport of uranium from the Browns Park(?) formation to its present sites of deposition presumably commenced as soon as that formation came into existence, probably reached a climax in the wet periods of the Pleistocene, and continues at a greatly diminished rate today. The vast areas once underlain by the Browns Park(?) formation are now represented by relatively small remnants, and in their vicinity, as at the schroeckingerite locality, the process of leaching, transport, and deposition of uranium still continues.

SUGGESTIONS FOR PROSPECTING

URANIUM IN COAL

The east flank and the trough of the Red Desert syncline offer the best possibilities for developing uranium-bearing coal if such an operation becomes economically feasible. No uranium minerals have been found as yet in the coarse-grained rocks that crop out in the coal-bearing part of the area, but it seems reasonable to suppose that prospecting might disclose occurrences of uranium minerals in the coarse sandstone associated with coal beds within this area and in the sandstone beds in the area adjacent to the northeast.

SCHROECKINGERITE

In prospecting for other schroeckingerite deposits all areas should be examined that are underlain by coarse-grained rocks whose structure would favor channeling and restricting the flow of ground water which in turn would enhance the possibility of caliche-type uranium deposits. The most favorable such locality (because of its nearness to tuffaceous rocks, the hypothetical source of the uranium) in the area lies in the vicinity of Grass and Daly Lakes in the extreme northwest corner where the Browns Park(?), the Bridger, and the Laney shale all contain coarse-grained beds. In the two latter formations, impermeable shale beds act as stratigraphic traps that could be mineralized. The second and less favorable area lies along the fault zone in the vicinity of Niland Spring in T. 25 N., R. 96 W.

OTHER URANIUM MINERALS

J. D. Love (written communication, 1955) has reported the discovery by prospectors of metaautunite in conglomeratic beds in sec. 15, T. 26 N., R. 96 W. Love believes that the conglomerate in which the mineral occurs is in place. If so, the mineral occurs in the Cathedral Bluffs tongue of the Wasatch. This occurrence is near one of the topographically highest parts of the area and could not have been separated by any appreciable thickness of sediments from the Miocene tuffaceous rocks, remnants of which are still preserved in this part of the area. Inasmuch as conglomeratic beds are numerous in the Cathedral Bluffs tongue from about the middle of R. 97. W. and eastward, and considerable parts of this area lie at relatively high altitudes, it seems probable that other finds will be made there.

OIL AND GAS

Since the days of Hayden (1868, p. 252) the area now known as the Great Divide Basin has been considered to be a structural as well as a topographic basin, and has received scant attention from oil geologists. The Great Divide Basin probably is synclinal in east-west cross section, but it is anticlinal in north-south cross section (pl. 1). The resultant structure is saddle-shaped. The Rock Springs uplift forms the west side and the Rawlins uplift forms the east side of the structurally high, broad open parts of the "saddle"; the Washakie Basin forms the structurally low, relatively narrow south side of the "saddle"; and the structurally complex area, consisting of en echelon folds and faults and extending from the Green Mountains westward to Oregon Buttes, forms the north side.

The broad, gentle Wamsutter(?) arch contains several structural highs on its crest, the largest of which is the Tierney anticline. It seems probable that the folds increase in amplitude with depth. The arch, which may be a continuation of the Wamsutter arch of Schultz (1920) or may be independent of it and en echelon to it, presumably was folded penecontemporaneously with the Rock Springs uplift and the Rawlins uplift. In both these uplifts angular unconformities exist between Cretaceous and Paleocene rocks and between Paleocene and Eocene rocks. Even though the Wamsutter(?) arch might not have been as severely affected as these uplifts, it doubtless was affected to some extent; and therefore, the effects of deformation resulting in any small fold, such as those shown in plate 1, should be more pronounced at depth, as is demonstrated along the flanks of the previously mentioned uplifts. Certainly it seems unreasonable to assume that they die out with depth. There are several producing oil and (or) gas fields peripheral to the Great Divide Basin so that it seems probable that other oil or gas accumulations may be present within the basin itself.

Townships 25 and 26 N., which were mapped in reconnaissance without sufficient vertical control to draw a complete structure-contour map, apparently also contain some geologic features of interest for oil prospecting. Several inferred anticlinal axes are shown (pl. 1) and, in addition, the southwest part of T. 26 N., R. 96 W., and the southeastern part of T. 26 N., R. 97 W., may be underlain by a broad fold or by a structural terrace. This possibility is suggested by the broadening of the outcrop pattern of the Cathedral Bluffs tongue in these areas and by the distinct change in the strike of the beds from northwest to northeast, as shown by the outcrop pattern of the overlying Laney shale member and the Bridger formation in the northern parts of these two townships.

COAL RESERVES AND URANIUM CONTENT

COMPUTATION OF TONNAGE AND URANIUM CONTENT

The following table shows the cutoff limits used in calculating tonnage and uranium content of coal shown by the maps on figures 27–45. In these figures, faults are shown only where they affect calculation of coal reserves.

Thickness of measured and indicated coal reserves (feet)	Approximate uranium content	
	Uranium in coal (percent)	Uranium in coal ash (percent)
≥10	≥0.010	≥0.050
5–10	0.005–0.010	0.020–0.050
2.5–5	.003–.005	.015–.020

Coal beds that are less than 2.5 feet thick or that might be present more than 2 miles from the nearest surface section, auger hole, or core hole are not included in computation of reserves shown on figures 27–45. Also excluded are coal beds whose ash content exceeds 33 percent or that contain partings whose combined thickness is more than half the total thickness of the bed.

Coal beds containing less than 0.003 percent uranium are excluded from computation of the uranium in the coal, but their uranium content is shown on figures 27–45 if the coal beds are 2.5 feet or more thick. Similarly, coal beds whose ash contains less than 0.015 percent uranium are excluded from computation of the uranium in coal ash, but their uranium content is shown if the coal bed is 2.5 or more feet thick. (See block 1, fig. 27.)

Measured coal reserves are those within a ½-mile radius of the nearest control point (surface section, auger hole, core hole). Indicated coal reserves are those ½ to 2 miles from the nearest control point. Measured and indicated reserves are combined into one category for the purposes of this report. About ¼ to ⅓ of the total coal reserves (table 7) is measured coal.

The tonnage of coal contained in each bed was computed as follows: An isopach map of each coal bed was prepared for each township. It was impractical to consider the three main beds of the Monument zone separately and the coal tonnages shown for this zone are based on the combined thickness of Monument No. 1, No. 2, and No. 3, except where otherwise indicated.

The isopach interval used on the work sheets was as small as one-half foot locally, but only the 2.5-, 5-, and 10-foot isopachs are shown on the maps in figures 27–45. The areas bounded by the isopach

591964 O—61——6

lines, by the outcrop line, and by the 2-mile-limit line are designated by numbers, such as "block 1," and "block 2." The tonnage and uranium content of coal in each block are given in the tables that accompany the maps. Areas containing strippable reserves of coal are shown by a gray overprint (representing the 60-foot maximum overburden limit). Where the average uranium content of the strippable coal is the same as the average for the total area included in the block, the same block number is used to designate both the total area and that part of the total that is strippable (see figure 45).

However, letter subscripts (1a, 1b, and so on) are used where the average uranium content for the strippable areas differs from that of the total area (fig. 33, block 1a), or where strippable coal reserves were calculated separately (fig. 39, blocks 2a and 2b).

The area, in acres, of each coal-reserve block was determined by planimeter. The factor of 1,770 short tons of subbituminous coal per acre-foot used in this report may be conservative for the area as a whole.

The coal beds were sampled at the localities shown on plates 1 and 3–5 in vertical intervals ranging from 2 feet to less than 0.1 foot. The samples were ashed and analyzed chemically and radiometrically and the percentage of coal ash, uranium in coal ash, and equivalent uranium was determined. Most of these analyses are shown graphically in figures 3–5. The percentage of uranium in coal is the product of the percentage of ash and the percentage of uranium in ash, rounded off to the nearest thousandth. For example, block 1 in figure 28 is shown to contain 910 tons of uranium in coal. This figure is the product of tons of coal per acre-foot, acres, thickness, percent ash, and percent uranium in ash ($1{,}770 \times 3{,}542 \times 3.8 \times 0.2 \times 0.00019$) and not the product of tons of coal and percent uranium in coal, which would yield a figure of 960 tons of uranium in coal ($24{,}000{,}000 \times 0.00004$). Thickness measurements of the coal beds are significant only to 2 figures and inasmuch as these measurements enter in all calculations, all estimates and totals are rounded to 2 significant figures.

The uranium content of the coal at each locality was determined by adding the products of the percentage of uranium and the thickness sampled and dividing by the total thickness. Lines connecting points of equal uranium content were drawn at intervals of 0.0005 percent, and the average percentage of uranium for each block was determined by adding the products of the areas and their uranium content and dividing by the total area. "Isopercentage" lines are not shown, except where parts of a coal-reserve block contain 0.003 percent or more uranium if considered separately rather than as part of the whole block. (See figs. 31, 34–36, and 40.)

An analogous procedure is used to determine the average ash and the average percentage of uranium in ash for coal-reserve block. Inasmuch as no appreciable amount of uranium is lost when the coal is ashed, the number of tons of uranium in the coal ash is equal to the number of tons of uranium in coal. In some places the ash content of a given coal-reserve exceeds the cutoff limit (33 percent) and no estimate of total uranium in ash is shown. (See block 3, fig. 33 and block 2, fig. 34.)

In summary, the basic calculations used in this report to determine the tons of coal and uranium contained in a given block are

$$\text{Tons of coal} = 1{,}770 \times A \times T$$

where

$1{,}770$ = tons subbituminous coal per acre-foot
A = area, in acres
T = average thickness of coal, in feet

$$\text{Percent U in coal} = PA \times PUA$$

where

PA = percent ash
PUA = percent uranium in ash

$$\text{Tons U in coal or in coal ash} = 1{,}770 \times A \times T \times PA \times PUA$$

The values of T and PA contain only two significant figures. Inasmuch as either T or PA enters into all computations, all the estimates and totals are rounded off to two significant figures.

SUMMARY OF TONNAGE AND URANIUM CONTENT

COAL

The Luman, Battle, Monument, and Tierney coal zones and coal bed E are estimated to contain about 720 million short tons of measured and indicated coal (table 7), 250 million tons of which is covered by 60 feet or less of overburden. From one-fourth to one-third of this tonnage is measured coal. The reserves in each bed for each township are shown on the maps and tables in figures 27–45. All tonnage estimates of coal, uranium in ash, and uranium in coal given in the tables below (figs. 27–45) are rounded to two significant figures. (See section "Computation of tonnage and uranium content" for formulas used to obtain these estimates, and for cutoff limits.) The percentage of ash and the percentage of uranium in ash were determined by the U.S. Geological Survey laboratory, Washington, D.C. The percentage of uranium in coal was calculated from the percentage of ash (column 5) and the percentage of uranium in ash.

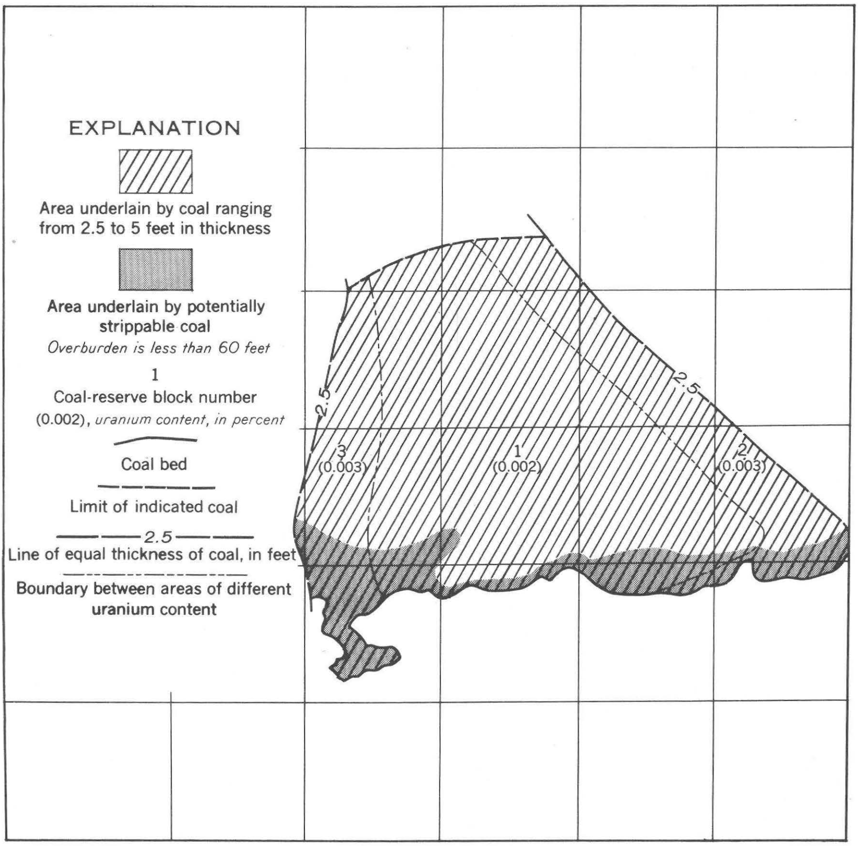

FIGURE 27.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Luman No. 2 bed in T. 24 N., R. 96 W.

Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Percent ash	Uranium in ash: Percent	Uranium in ash: Short tons	Uranium in coal: Percent	Uranium in coal: Short tons
Coal reserves and uranium content								
1	2,980	3.8	20,000	17.0	0.013	----------	0.002	----------
2	956	3.8	6,400	17.0	.016	170	.003	170
3	750	2.8	3,700	17.2	.016	100	.003	100
Total	----------	----------	30,000	----------	----------	270	----------	270
Potentially strippable coal (included in above blocks)								
1	331	4.0	2,300	20.0	0.013	----------	0.002	----------
2	125	3.5	770	17.0	.016	20	.003	20
3	261	2.7	1,200	17.2	.016	30	.003	30
Total	----------	----------	4,300	----------	----------	50	----------	50

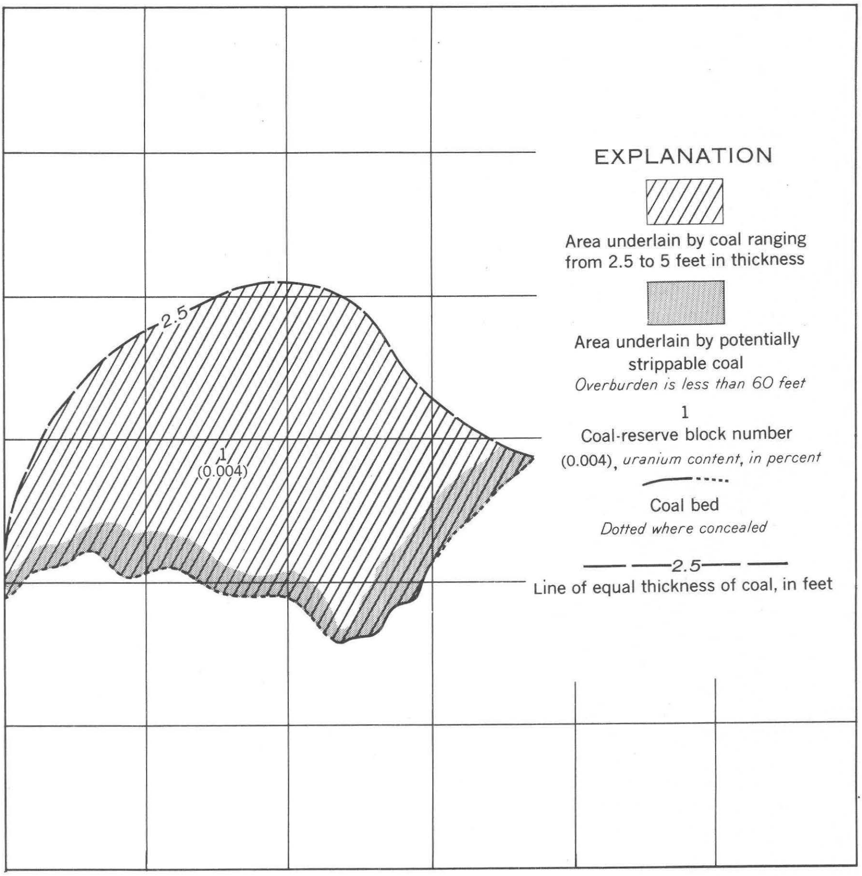

FIGURE 28.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Luman No. 1 bed in T. 24 N., R. 95 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	3,542	3.8	24,000	20.0	0.019	910	0.004	910
Potentially strippable coal (included in above blocks)								
1	607	3.8	4,100	26.0	0.017	180	0.004	180

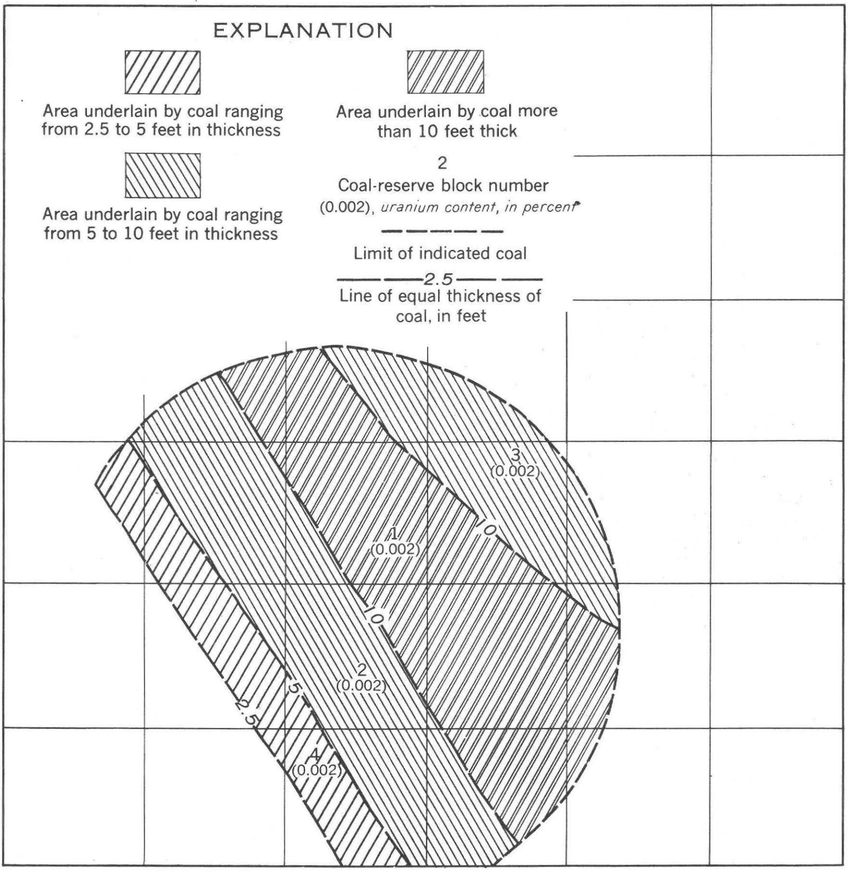

FIGURE 29.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Battle No. 3 bed in T. 24 N., R. 95 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Uranium in ash		Uranium in coal	
					Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	2,353	11.0	46,000	11.5	0.013		0.002	
2	1,765	7.5	23,000	11.5	.013		.002	
3	950	8.0	14,000	11.5	.013		.002	
4	790	3.8	5,300	11.5	.013		.002	
Total			87,000					

FIGURE 30.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Monument No. 2 bed in T. 23 N., R. 96 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	1,459	3.0	7,800	22.0	0.003	----------	0.001	----------
Potentially strippable coal (included in above blocks)								
1	1,117	3.3	6,500	15.0	0.003	----------	0.001	----------

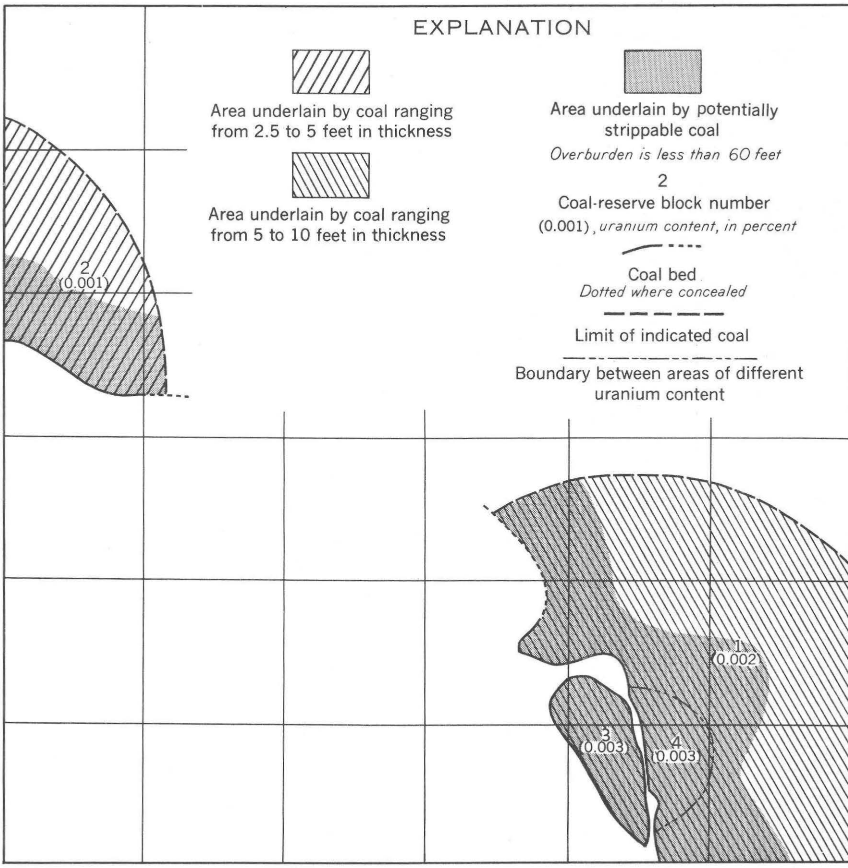

FIGURE 31.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Monument No. 2 bed in T. 23 N., R. 95 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	2,833	7.0	35,000	17.7	0.012		0.002	
2	950	3.4	5,700	21.0	.007		.001	
3	271	5.5	2,600	12.0	.022	70	.003	70
4	226	6.4	2,600	12.0	.022	70	.003	70
Total			46,000			140		140
Potentially strippable coal (included in above blocks)								
1	1,168	6.0	12,000	17.7	0.012		0.002	
2	442	3.1	2,400	21.0	.007		.001	
3	271	5.5	2,600	12.0	.022	70	.003	70
4	226	6.4	2,600	12.0	.022	70	.003	70
Total			20,000			140		140

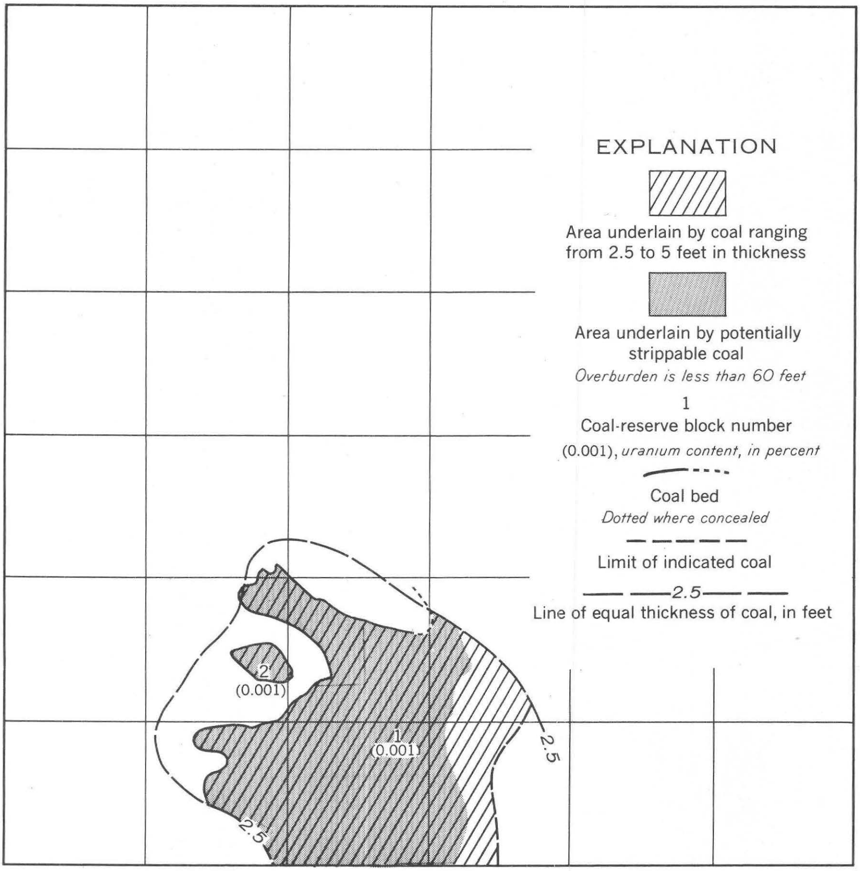

FIGURE 32.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Tierney No. 5 bed in T. 23 N., R. 95 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	1,905	3.5	12,000	15.0	0.007		0.001	
2	41	2.8	200	15.0	.007		.001	
Total			12,000					
Potentially strippable coal (included in above blocks)								
1	1,575	3.6	10,000	15.0	0.007		0.001	
2	41	2.8	200	15.0	.007		.001	
Total			10,000					

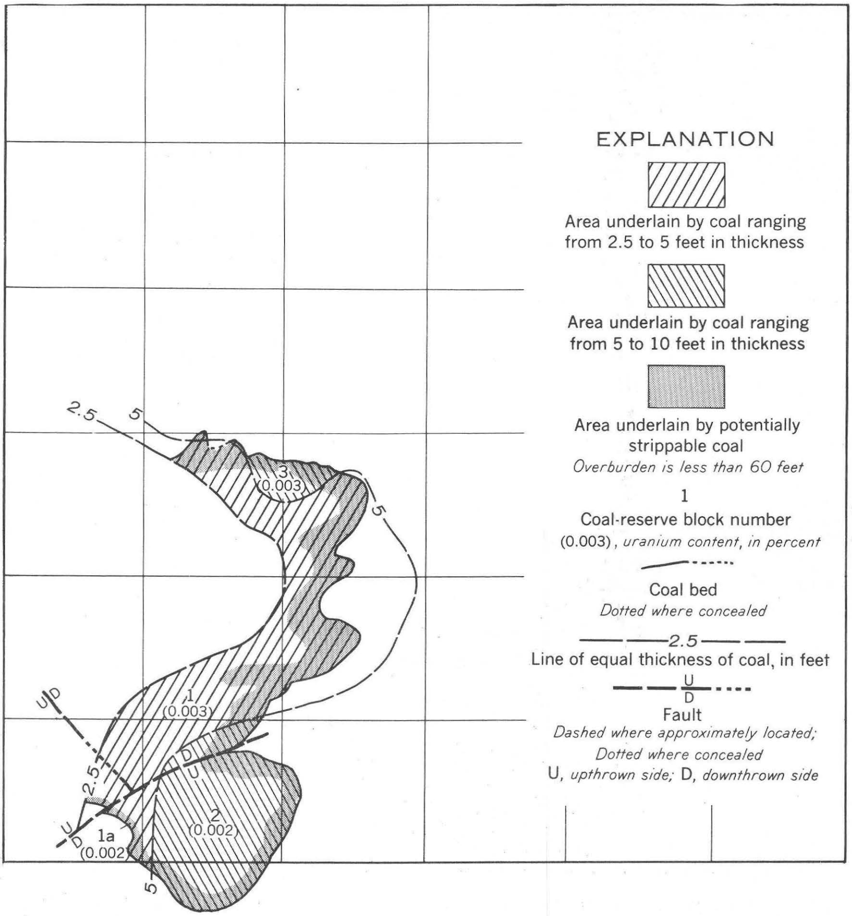

Figure 33.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Battle No. 3 bed in T. 23 N., R. 94 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	1,070	3.2	6,100	18.9	0.018	210	0.003	210
2	552	6.8	6,600	33.0	.005		.002	
3	92	6.9	1,100	33.0	.008		.003	30
Total			14,000			210		240
Potentially strippable coal (included in above blocks)								
1	591	3.6	3,800	15.0	0.018	100	0.003	100
1a	37	4.0	260	33.0	.005		.002	
2	184	6.9	2,200	33.0	.005		.002	
3	40	8.5	600	33.0	.010		.003	20
Total			6,900			100		120

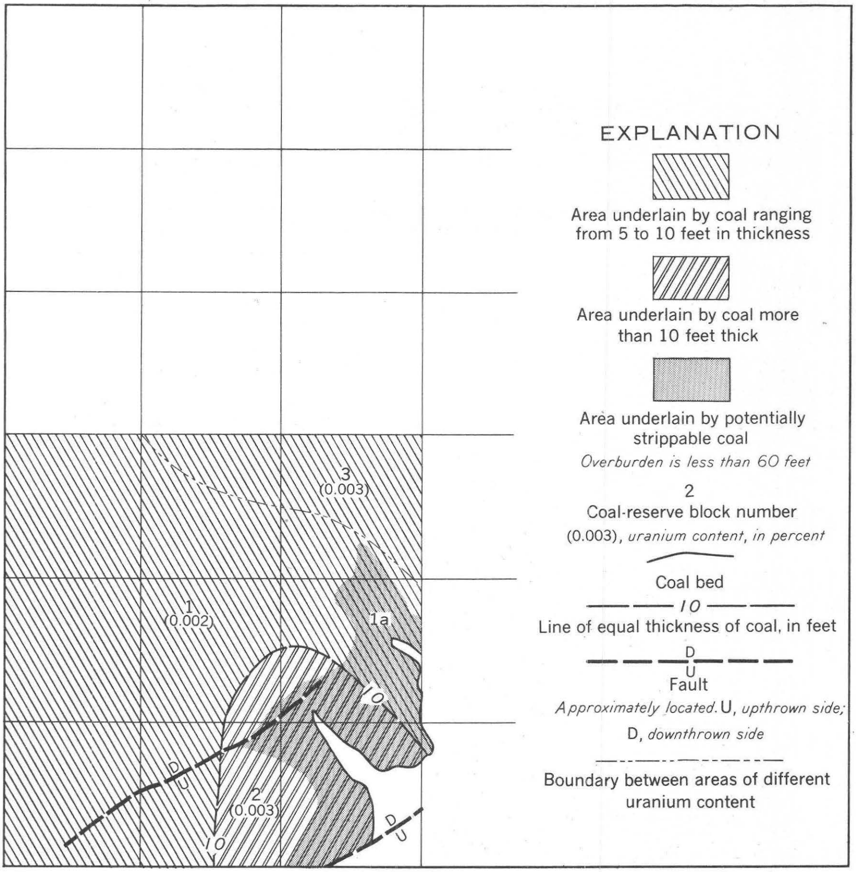

FIGURE 34.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Monument zone in T. 23 N., R. 94 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	3,850	8.5	58,000	30.0	0.007		0.002	
2	951	12.5	21,000	31.0	.009		.003	590
3	630	7.9	8,800	20.0	.017	300	.003	300
Total			88,000			300		890
Potentially strippable coal (included in above blocks)								
1a	269	8.9	4,200	31.2	0.011		0.003	150
2	482	13.0	11,000	30.0	.010		.003	330
Total			15,000					480

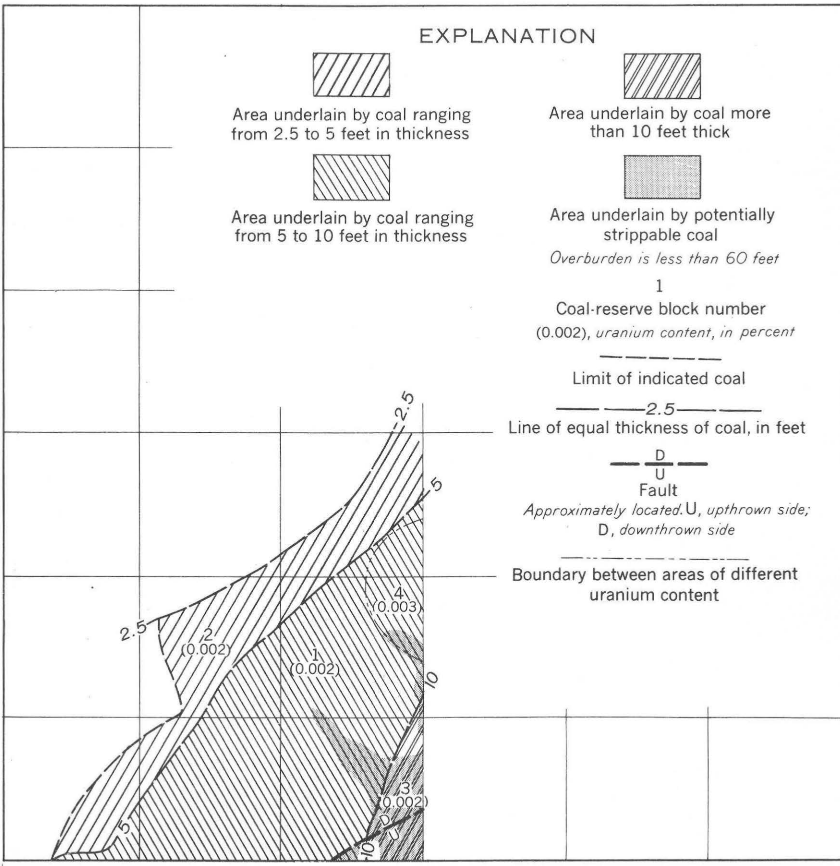

FIGURE 35.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Tierney No. 6 bed in T. 23 N., R. 94 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Uranium in ash		Uranium in coal	
					Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	1,695	7.4	22,000	25.0	0.008		0.002	
2	871	3.8	5,900	21.0	.009		.002	
3	189	10.1	3,400	17.1	.010		.002	
4	181	7.0	2,200	14.4	.021	70	.003	70
Total			34,000			70		70
Potentially strippable coal (included in above blocks)								
1	88	9.7	1,600	19.0	0.013		0.002	
3	157	10.2	2,800	19.0	.013		.002	
4	23	8.0	330	15.2	.018	10	.003	10
Total			4,700			10		10

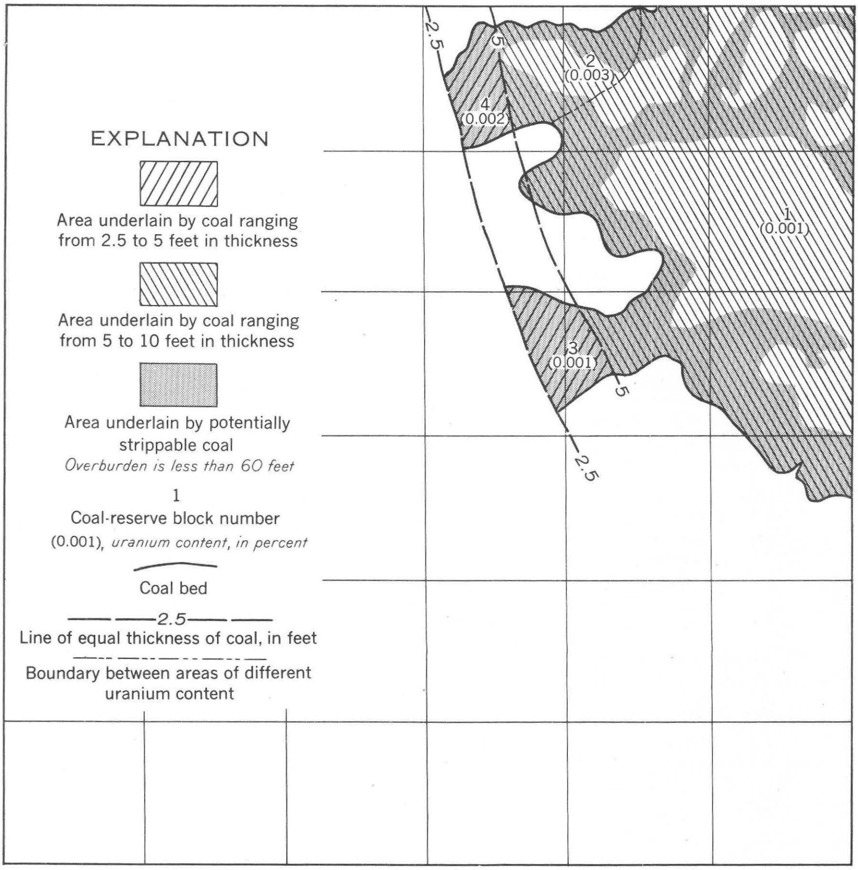

FIGURE 36.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Monument zone in T. 22 N., R. 95 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	3,750	7.7	51,000	21.0	0.007		0.001	
2 [1]	357	4.2	2,700	13.0	.023	80	.003	80
3	215	3.7	1,400	21.0	.007		.001	
4	170	3.8		45.0	.004		.002	
Total			55,000			80		80
Potentially strippable coal (included in above blocks)								
1	2,020	7.1	25,000	21.0	0.007		0.001	
2 [1]	225	4.2	1,700	13.0	.023	50	.003	50
3	215	3.7	1,400	21.0	.007		.001	
4	170	3.8		45.0	.004		.002	
Total			28,000			50		50

[1] Monument No. 2 only.

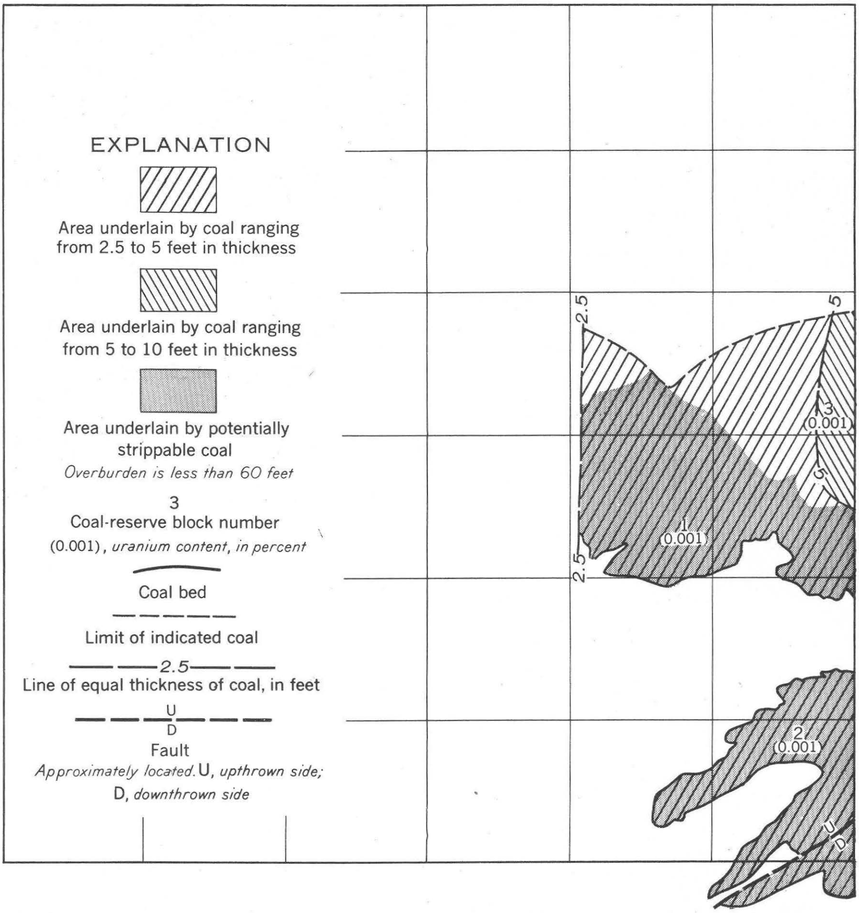

FIGURE 37.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Tierney No. 6 bed in T. 22 N., R. 95 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	1,774	3.7	12,000	12.0	0.008	----------	0.001	----------
2	697	2.9	3,600	19.0	.007	----------	.001	----------
3	198	5.1	1,800	10.0	.008	----------	.001	----------
Total	----------	----------	17,000	----------	----------	----------	----------	----------
Potentially strippable coal (included in above blocks)								
1	1,291	3.5	8,000	12.0	0.010	----------	0.001	----------
2	697	2.9	3,600	19.0	.007	----------	.001	----------
Total	----------	----------	12,000	----------	----------	----------	----------	----------

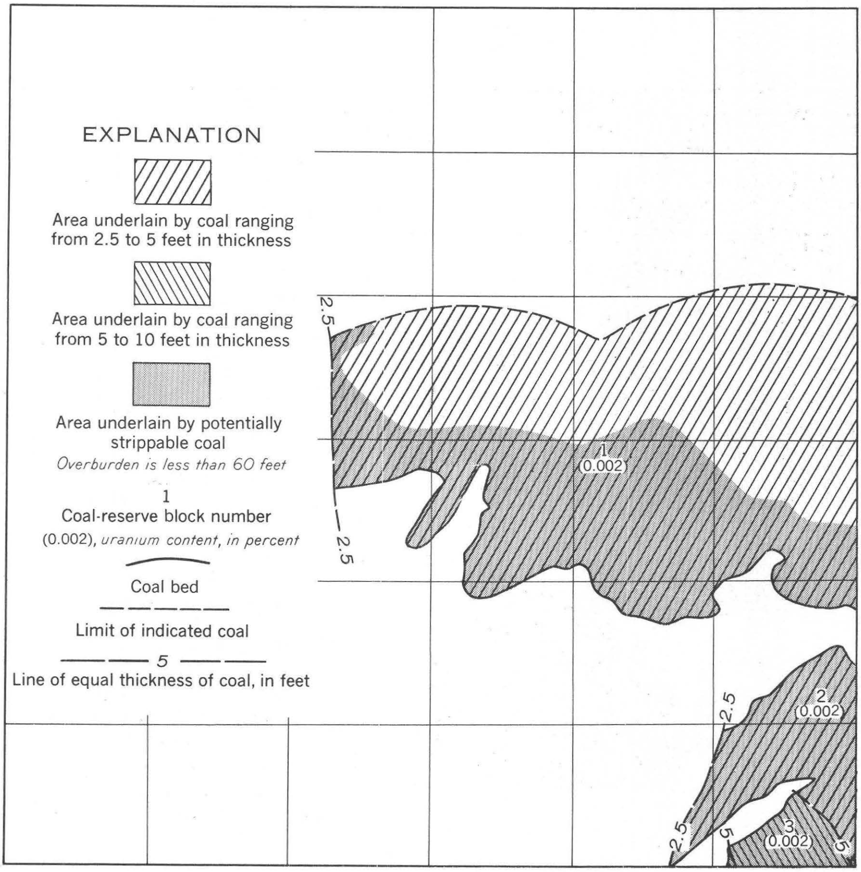

FIGURE 38.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Tierney No. 5 bed in T. 22 N., R. 95 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Uranium in ash		Uranium in coal	
					Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	4,261	3.3	25,000	19.7	0.009		0.002	
2	614	3.2	3,500	23.5	.007		.002	
3	162	5.1	1,500	26.0	.008		.002	
Total			30,000					
Potentially strippable coal (included in above blocks)								
1	1,985	3.9	14,000	20.5	0.009		0.002	
2	614	3.2	3,500	23.5	.007		.002	
3	162	5.1	1,500	26.0	.008		.002	
Total			19,000					

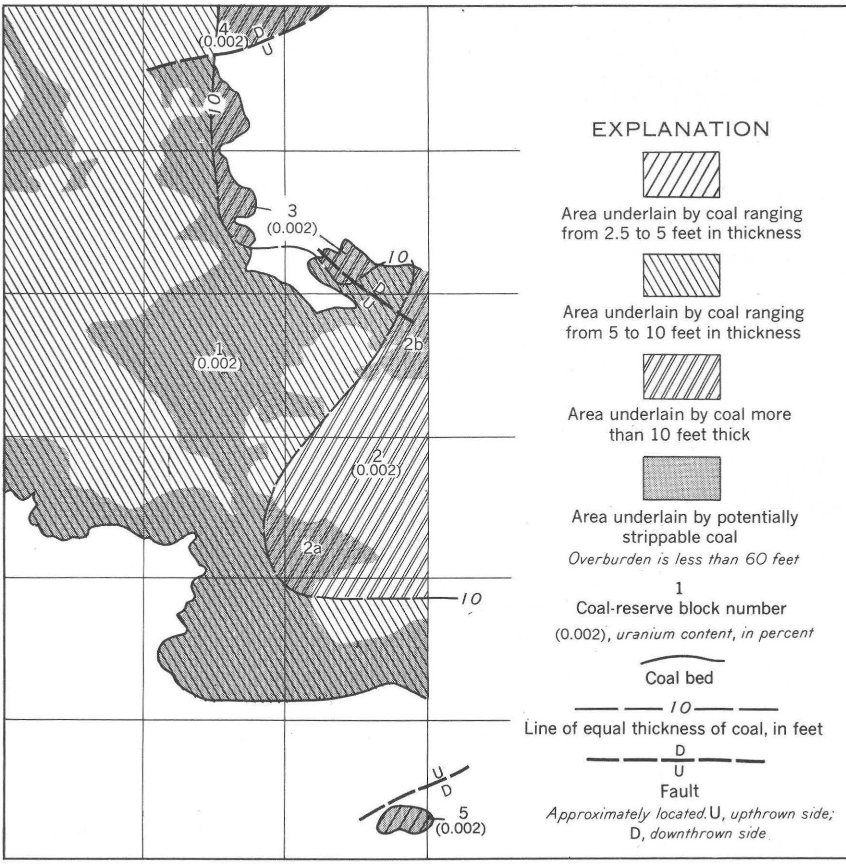

FIGURE 39.—Map and table (following) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Monument zone in T. 22 N., R. 94 W. Strippable reserves were not calculated for secs. 6 and 7.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	5, 524	9. 2	90, 000	22. 7	0. 007	----------	0. 002	----------
2	1, 226	10. 4	23, 000	13. 0	. 016	470	. 002	----------
3	159	10. 3	2, 900	16. 0	. 009	----------	. 002	----------
4	104	10. 8	2, 000	18. 0	. 012	----------	. 002	----------
5	52	4. 0	370	32. 0	. 007	----------	. 002	----------
Total	----------	----------	120, 000	----------	----------	470	----------	----------
Potentially strippable coal (included in above blocks)								
1	2, 472	9. 6	42, 000	24. 0	0. 007	----------	0. 002	----------
2a	188	10. 7	3, 600	14. 0	. 016	80	. 002	----------
2b	103	10. 3	1, 900	15. 1	. 011	----------	. 002	----------
3	159	10. 3	2, 900	16. 0	. 009	----------	. 002	----------
4	104	10. 8	2, 000	18. 0	. 012	----------	. 002	----------
5	52	4. 0	370	32. 0	. 007	----------	. 002	----------
Total	----------	----------	51, 000	----------	----------	80	----------	----------

591964—61——7

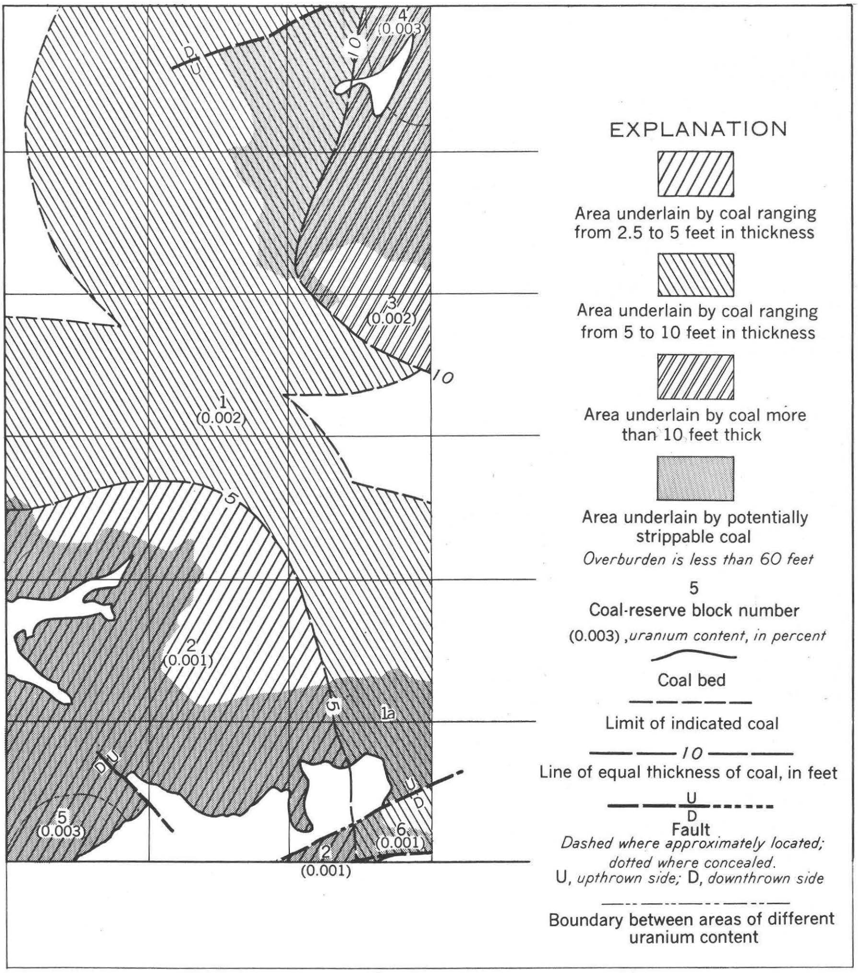

FIGURE 40.—Map and table (following) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Tierney No. 6 bed in T. 22 N., R. 94 W.

Measured and indicated coal reserves					Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Percent ash	Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	5,702	7.5	76,000	29.0	0.007		0.002	
2	2,886	3.7	19,000	17.0	.010		.001	
3	795	11.0	15,000	27.0	.008		.002	
4	125	12.0	2,700	22.0	.012		.003	70
5	180	2.6	830	19.0	.016	30	.003	30
6	140	6.0	1,500	16.0	.008		.001	
Total			120,000			30		100
Potentially strippable coal (included in above blocks)								
1	662	9.2	11,000	32.0	0.007		0.002	
1a	300	5.7	3,000	32.0	.007		.002	
2	1,880	2.7	9,000	15.3	.010		.002	
3	515	11.0	10,000	27.5	.008		.002	
4	125	12.0	2,700	22.0	.012		.003	70
5	180	2.6	830	19.0	.016	30	.003	30
6	70	6.0	740	16.0	.008		.001	
Total			37,000			30		100

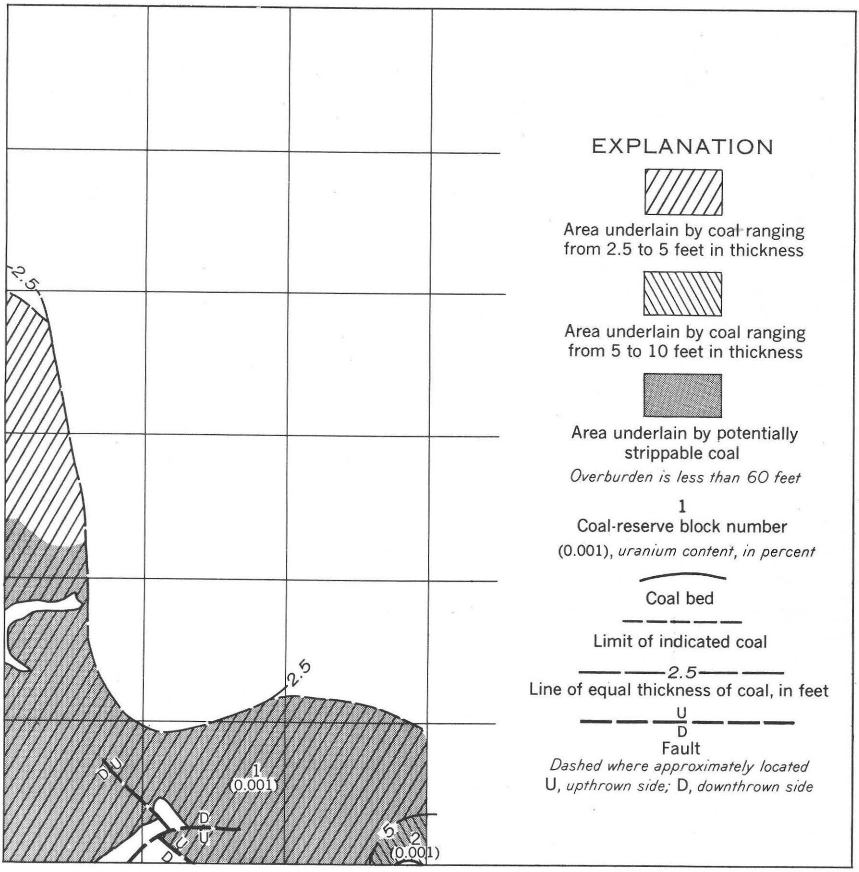

FIGURE 41.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Tierney No. 5 bed in T. 22 N., R. 94 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	2,760	3.0	15,000	15.0	0.006		0.001	
2	74	5.1	670	16.0	.005		.001	
Total			16,000					
Potentially strippable coal (included in above blocks)								
1	2,340	3.1	13,000	15.5	0.006		0.001	
2	74	5.1	670	16.0	.005		.001	
Total			14,000					

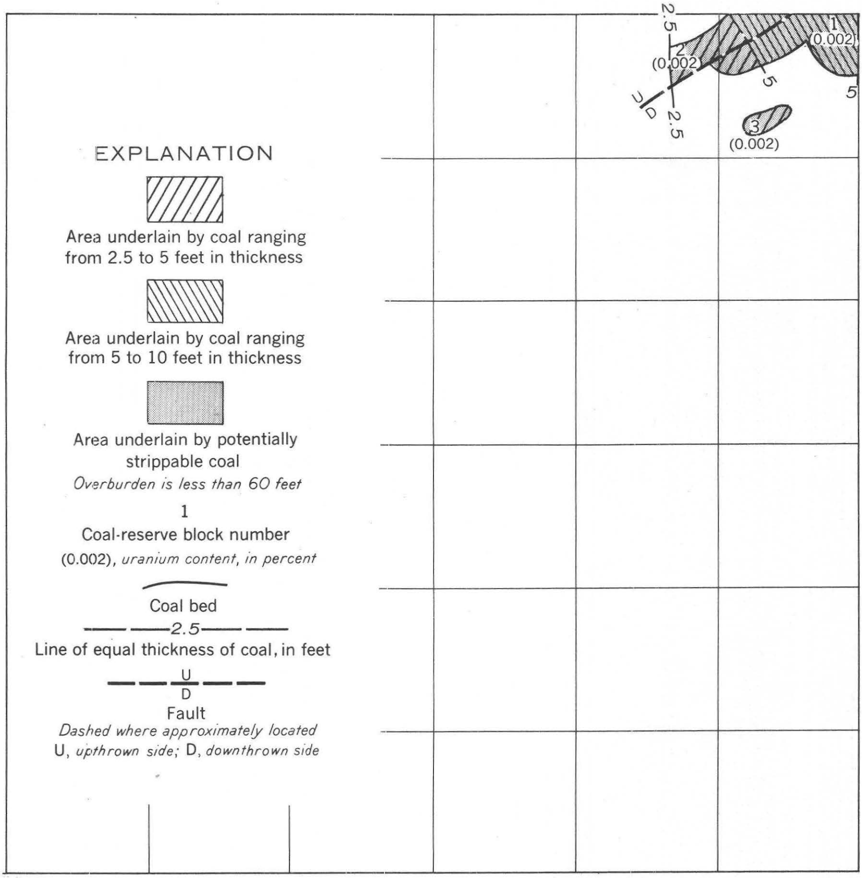

FIGURE 42.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Tierney No. 5 bed in T. 21 N., R. 95 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	177	5.2	1,600	25.2	0.006		0.002	
2	107	3.7	700	32.0	.006		.002	
3	22	4.0	160	27.0	.007		.002	
Total			2,500					
Potentially strippable coal (included in above blocks)								
1	177	5.2	1,600	25.2	0.006		0.002	
2	107	3.7	700	32.0	.006		.002	
3	22	4.0	160	27.0	.007		.002	
Total			2,500					

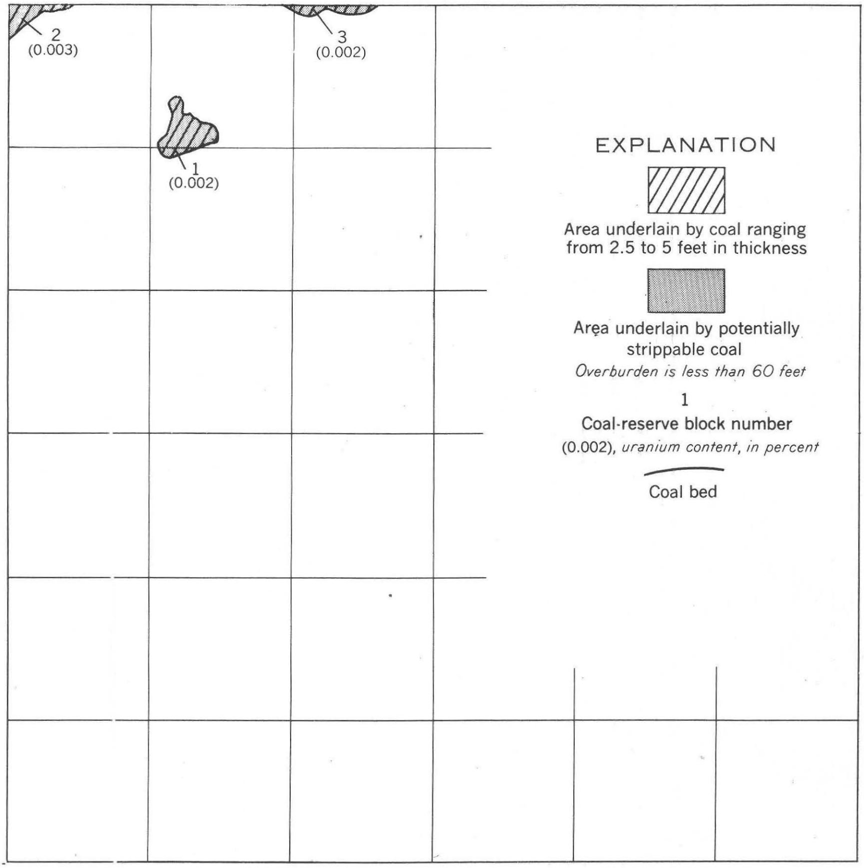

FIGURE 43.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Tierney No. 6 bed in T. 21 N., R. 94 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	53	3.3	310	24.0	0.010		0.002	
2	39	2.6	180	16.0	.016	5	.003	5
3	13	4.6	110	15.0	.008		.001	
Total			600			5		5
Potentially strippable coal (included in above blocks)								
1	53	3.3	310	24.0	0.010		0.002	
2	39	2.6	180	16.0	.016	5	.003	5
3	13	4.6	110	15.0	.008		.001	
Total			600			5		5

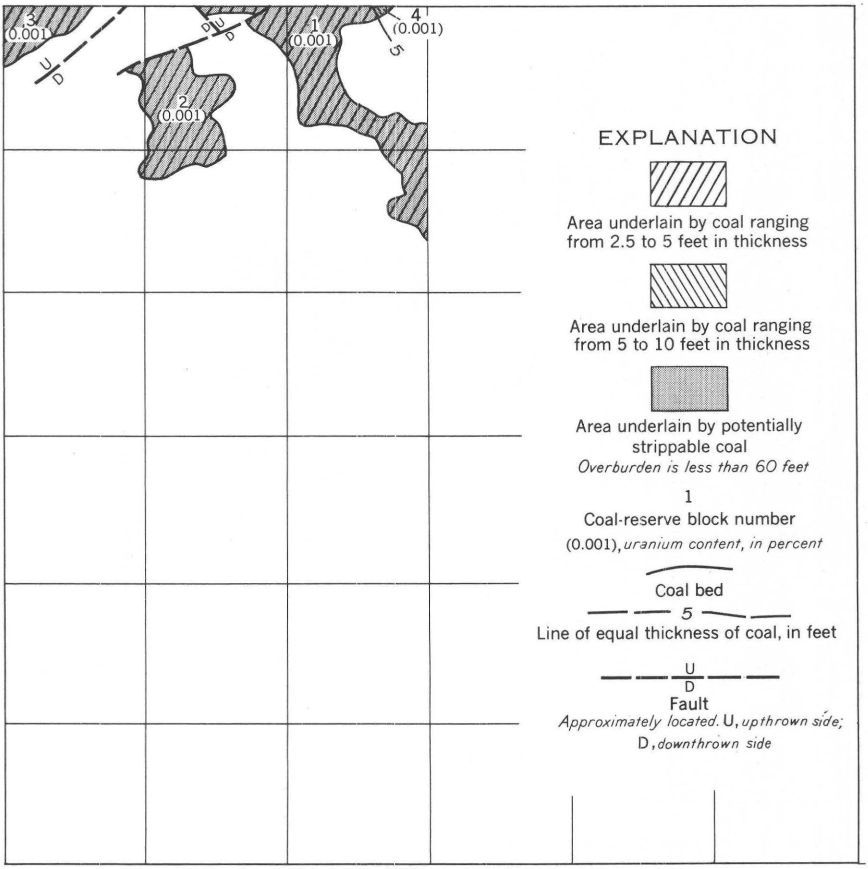

FIGURE 44.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Tierney No. 5 bed in T. 21 N., R. 94 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
					Uranium in ash		Uranium in coal	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	422	4.0	3,000	15.0	0.007	--	0.001	--
2	261	3.9	1,800	15.0	.004	--	.001	--
3	110	4.5	880	21.8	.004	--	.001	--
4	11	5.2	100	16.0	.005	--	.001	--
Total	--	--	5,800	--	--	--	--	--
Potentially strippable coal (included in above blocks)								
1	422	4.0	3,000	15.0	0.007	--	0.001	--
2	261	3.9	1,800	15.0	.004	--	.001	--
3	110	4.5	880	21.8	.004	--	.001	--
4	11	5.2	100	16.0	.005	--	.001	--
Total	--	--	5,800	--	--	--	--	--

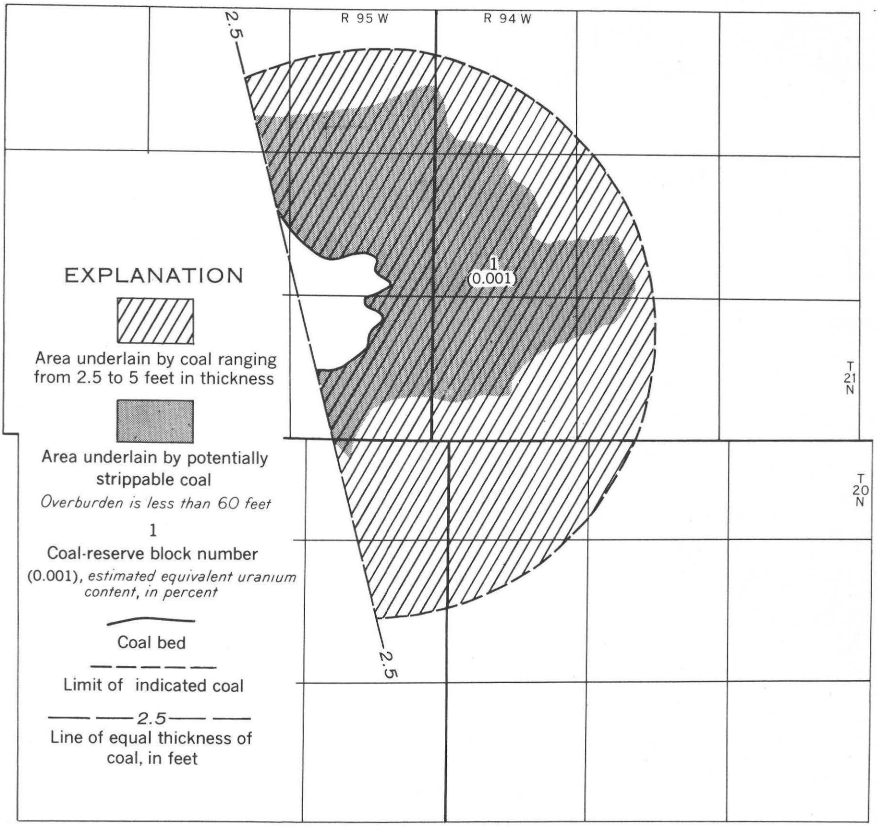

FIGURE 45.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in coal bed E in Tps. 20 and 21 N., Rs. 94 and 95 W.

Measured and indicated coal reserves				Percent ash	Approximate uranium content			
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Uranium in ash		Uranium in coal	
					Percent	Short tons	Percent	Short tons
Coal reserves and uranium content								
1	4,800	2.6	22,000	----------	----------	----------	[1] 0.001	----------
Potentially strippable coal (included in above blocks)								
1	2,152	2.6	9,900	----------	----------	----------	[1] 0.001	----------

[1] Estimated equivalent uranium.

TABLE 7.—*Summary of tonnage and uranium content of coal in the central part of the Great Divide Basin, Sweetwater County, Wyo.*

Measured and indicated coal reserves				Approximate uranium content				
				Uranium in ash			Uranium in coal	
Coal bed or zone	Area (acres)	Average thickness (feet)	Coal [1] (thousands of short tons)	Ash [2] (percent)	Average uranium content [2] (percent)	Uranium [1] (short tons)	Average uranium content [3] (percent)	Uranium [1] (short tons)
Coal reserves and uranium content								
Luman No. 2	4,686	3.6	30,000	17.0	0.013	270	0.002	270
Luman No. 1	3,542	3.8	24,000	20.0	.019	910	.004	910
Battle No. 3	7,572	7.6	100,000	14.5	.013	210	.002	240
Monument Zone	22,557	7.9	320,000	22.8	.008	990	.002	1,100
Tierney No. 6	15,538	6.0	170,000	22.1	.008	100	.002	170
Tierney No. 5	10,927	3.4	66,000	18.0	.007	----------	.002	----------
Coal bed E	4,800	2.6	22,000	----------	----------	----------	.001	----------
Total [1]	----------	----------	730,000	----------	----------	2,500	----------	2,700
Coal (included above) covered by 60 feet or less of overburden								
Luman No. 2	717	3.4	4,300	18.4	0.015	50	0.003	50
Luman No. 1	607	3.8	4,100	26.0	.017	180	.004	180
Battle No. 3	852	4.6	6,900	20.5	.014	100	.003	120
Monument Zone	9,409	7.3	120,000	20.9	.008	270	.002	670
Tierney No. 6	6,093	5.0	54,000	19.2	.010	45	.002	120
Tierney No. 5	7,901	3.6	51,000	18.9	.007	----------	.001	----------
Coal bed E	2,152	2.6	9,900	----------	----------	----------	[4] .001	----------
Total [1]	----------	----------	250,000	----------	----------	650	----------	1,100

[1] All tonnage estimates rounded to two significant figures. See pages A–75 to A–77 for formulas used to obtain these estimates and for cutoff limits.
[2] Analyses by U.S. Geological Survey.
[3] Calculated from percentage of ash and percentage of uranium in ash.
[4] Estimated equivalent uranium.

URANIUM IN COAL

About 85 million tons of the coal contains 0.003 percent or more uranium, or about 2,700 tons of uranium. About 1,100 tons of the uranium is contained in about 37 million tons of coal covered by 60 feet or less overburden.

URANIUM IN COAL ASH

About 83 million tons of the coal contains 0.015 percent or more uranium in the coal ash, or about 2,500 tons of uranium in the coal ash. About 650 tons of this uranium is contained in coal beds covered by 60 feet or less overburden totaling about 22 million tons.

The cutoff 0.003 percent or more uranium used in this report serves to emphasize the areas containing the most uranium per unit area. It is interesting to note, however, that if 0.002 percent or more uranium is used as the cutoff, the uranium content of coal in the areas shown in figures 9–27 would total about 15,000 tons.

LITERATURE CITED

American Society for Testing Materials, 1938, Standard specifications for classification of coals by rank: D 388–38, p. 652–657.

Ball, M. W., 1909, The western part of the Little Snake River coal field, Wyoming: U.S. Geol. Survey Bull. 341, p. 243–255.

Bell, W. G., 1954, Stratigraphy and geologic history of Paleocene rocks in the vicinity of Bison Basin, Wyoming [abs.]: Geol. Soc. America Bull., v. 65, p. 1371.

Bradley, W. H., 1926, Shore phases of the Green River formation in northern Sweetwater County, Wyoming: U.S. Geol. Survey Prof. Paper 140, p. 121–131.

——— 1945, Geology of the Washakie Basin, Sweetwater and Carbon Counties, Wyo., and Moffat County, Colo.: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 32.

——— 1959, Revision of stratigraphic nomenclaure of Green River formation of Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 43, p. 1072–1075.

Breger, I. A., Deul, Maurice, and Meyrowitz, Robert, 1955, Geochemistry and mineralogy of a uraniferous sub-bituminous coal: Econ. Geology, v. 50, no. 6, p. 610–624.

Brown, R. W., 1949, Paleocene deposits of the Rocky Mountains and Plains: U.S. Geol. Survey Prelim. Map (with descriptive notes), scale 1:1,000,000.

Deonson, N. M., Bachman, G. O., and Zeller, H. D., 1959, Uranium-bearing lignite in northwestern South Dakota and adjacent States: U.S. Geol. Survey Bull. 1055–B, p. 11–57 [1960].

Endlich, F. M., 1879, Report on the geology of the Sweetwater district: U.S. Geol. and Geographical Survey Terr., 11th Ann. Rept., p. 3–158.

Frondel, J. W., and Fleischer, Michael, 1955, Glossary of uranium and thorium-bearing minerals, 3rd ed.: U.S. Geol. Survey Bull. 1009–F, p. 169–209.

Gazin, C. L., 1952, The lower Eocene Knight formation of western Wyoming and its mammalian faunas: Smithsonian Misc. Coll., v. 117, no. 18, 82 p.

——— 1956, Paleocene mammalian faunas of the Bison Basin in south-central Wyoming: Smithsonian Misc. Coll., v. 131, no. 6, 57 p.

Hayden, F. V., 1868, Second annual report of the U.S. Geological Survey of the Territories embracing Wyoming, *in* U.S. Gen. Land Off. Rept., 1868: p. 220–255.

Hurley, P. M., 1950, Distribution of radioactivity in granites and possible relation to helium age measurement: Geol. Soc. America Bull., v. 61, no. 1, p. 1–7.

Larsen, E. S., Jr., 1937, Dakeite—a new uranium mineral from Wyoming: The Mineralogist, v. 5, no. 2, p. 7.

Larsen, E. S., Jr., and Phair, George, 1954, The distribution of uranium and thorium in igneous rocks, *in* Faul, Henry, ed., Nuclear geology: New York, John Wiley and Sons, Inc., p. 75–89.

Love, J. D., 1953, Preliminary report on uranium deposits in the Miller Hill area, Carbon County, Wyo.: U.S. Geol. Survey Circ. 278, 10 p.

McGrew, P.O., 1951, Tertiary stratigraphy and paleontology of southcentral Wyoming, *in* Wyoming Geol. Assoc. Guidebook, 6th Ann. Field Conf., 1951: p. 54–57.

Masursky, Harold, in press, Uranium-bearing coal in the eastern part of the Red Desert area, Great Divide Basin, Sweetwater County, Wyoming: U.S. Geol. Survey Bull. 1099–B.

Masursky, Harold, and Pipiringos, G. N., 1959, Uranium-bearing coal in the Red Desert area, Sweetwater County, Wyo.: U.S. Geol. Survey Bull. 1055-G, p. 181-215 [1960].

Moore, G. W., 1954, Extraction of uranium from aqueous solution by coal and some other materials: Econ. Geology, v. 49, p. 652-658.

Morris, W. J., 1954, An Eocene fauna from the Cathedral Bluffs tongue of the Washakie Basin, Wyoming: Jour. Paleontology, v. 28, no. 2, p. 195-203.

Nace, R. L., 1939, Geology of the northwest part of the Red Desert, Sweetwater and Fremont Counties, Wyoming: Wyoming Geol. Survey Bull. 27, 51 p.

Nightingale, W. T., 1930, Geology of the Vermillion Creek gas area in southwest Wyoming and northwest Colorado: Am. Assoc. Petroleum Geologists Bull., v. 14, p. 1013-1040.

Novacek, Radim, 1939, The identity of dakeite and schroeckingerite: Am. Mineralogist, v. 24, no. 5, p. 317-323.

Pipiringos, G. N., 1955, Tertiary rocks in the central part of the Great Divide Basin, Sweetwater County, Wyo., *in* Wyoming Geol. Assoc. Guidebook, 10th Ann. Field Conf., 1955: p. 100-104.

——— 1956, Uranium-bearing coal in the central part of the Great Divide Basin, Sweetwater County, Wyoming, *in* Contributions on the geology of uranium and thorium by the U.S. Geological Survey and Atomic Energy Commission to the United Nations international conference on peaceful uses of atomic energy, Geneva, Switzerland, 1955: U.S. Geol. Survey Prof. Paper 300, p. 433-438.

Schultz, A. R., 1909, The northern part of the Rock Springs coal field, Sweetwater County, Wyo.: U.S. Geol. Survey Bull. 341, p. 256-282.

——— 1920, Oil possibilities in and around Baxter Basin, in the Rock Springs uplift, Sweetwater County, Wyo.: U.S. Geol. Survey Bull. 702, 107 p.

Sears, J. D., and Bradley, W. H., 1924, Relations of the Wasatch and Green River formations in northwestern Colorado and southern Wyoming, with notes on oil shales in the Green River formation: U.S. Geol. Survey Prof. Paper 132-F, p. 93-107.

Sheridan, D. M., Maxwell, C. H., and Collier, J. T., 1961, Geology of the Lost Creek schroeckingerite deposits, Sweetwater County, Wyo.: U.S. Geol. Survey Bull. 1087-J (in press).

Smith, E. E., 1909, The eastern part of the Great Divide Basin coal field, Wyo.: U.S. Geol. Survey Bull. 341, p. 220-242.

Vine, J. D., and Prichard, G. E., 1954, Uranium in the Poison Basin area, Carbon County, Wyo.: U.S. Geol. Survey Circ. 344, 8 p.

Waters, A. C., and Granger, H. C., 1953, Volcanic debris in uraniferous sandstones, and its possible bearing on the origin and precipitation of uranium: U.S. Geol. Survey Circ. 224, 26 p.

Wyant, D. G., Sharp, W. N., and Sheridan, D. M., 1956, Reconnaissance study of uranium deposits in the Red Desert, Sweetwater County, Wyo.: U.S. Geol. Survey Bull. 1031-I, p. 237-308 [1957].

Yenne, K. A., and Pipiringos, G. N., 1954, Stratigraphic sections of Cody shale and younger Cretaceous and Paleocene rocks in the Wind River Basin, Fremont County, Wyo.: U.S. Geol. Survey Oil and Gal Inv. Chart OC-49.

INDEX