Uranium-bearing Coal in the Eastern Part of the Red Desert Area Wyoming

By HAROLD MASURSKY

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

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

URANIUM-BEARING COAL IN THE EASTERN PART OF THE RED DESERT AREA, WYOMING

By Harold Masursky

ABSTRACT

Uranium-bearing coal underlies approximately 300 square miles of the Red Desert in the east-central part of the Great Divide Basin, a large topographic and structural basin of interior drainage along the Continental Divide in south-central Wyoming.

Coal-bearing rocks of the Wasatch formation were cyclically deposited in swamps marginal to the lakes formed in Green River time and are interbedded with coarse-grained fluviatile arkose of the Battle Spring formation to the northeast and organic lacustrine shale of the Green River formation to the southwest. The coal-bearing sequence is about 700 feet thick and is of early Eocene age. The axis of maximum coal deposition trends northwestward; the coal beds are lenticular and grade into shale to the east and west. The strata are inclined at angles of 1° to 2° so that the outcropping coal beds, which are as much as 40 feet thick, are potentially strippable over large areas.

The highest concentrations of uranium are localized in the carbonaceous rocks unconformably overlain by gravel of possible Miocene age, as at Creston Ridge where the uppermost coal bed contains as much as 0.051 percent uranium near the top of the bed in contrast to a coal bed 40 feet lower which contains less than 0.001 percent.

Widespread lower concentrations of uranium in the coal, ranging from 0.0004 percent in the southwest to 0.010 percent in the northeast and averaging about 0.003 percent, are apparently related to the permeability of the rocks enclosing the coal beds. The uranium content of the coal beds increases toward the northeast as the intercalated lithologies change and become coarser grained and more permeable. In the cyclically deposited sequence, several coal beds in vertical succession are enriched in uranium adjacent to the intercalated beds of coarse-grained sandstone that generally underlie the coal seams. The close relationship between the uranium content of the coal and the permeability of the surrounding rocks indicates that the uranium was probably epigenetically emplaced.

Semiquantitative spectrographic analyses show that in the carbonaceous rocks gallium, germanium, iron, molybdenum, lead, vanadium, and the rare earths

have a distribution pattern similar to that of uranium and may have been similarly emplaced.

Three possible modes of origin for the uranium and other trace elements, partly supported by available evidence, are derivation from hydrothermal solutions rising along faults; leaching from the granite of the Granite Mountains during its weathering and erosion; leaching from the overlying tuffaceous rocks.

Laboratory experiments on the solubility of uranium demonstrate that coal of the Great Divide Basin will extract uranium effectively from natural water. Investigation of the sedimentary rocks included studies of mineralolgic composition, grain size and shape, and porosity and permeability.

Coal reserves and uranium content were calculated for the nine principal coal beds, which range in thickness from a few inches to 42 feet and average about 7 feet. Estimates of uranium content are based on uranium analyses of 1,700 core and auger samples and 500 surface samples obtained in 60 core holes, 140 auger holes, and 79 surface sections. About 24,000 short tons of uranium is contained in 690 million short tons of coal at a grade of 0.003 percent or more uranium. An additional 1,600 million tons of measured and indicated coal contains less than 0.003 percent uranium. About 20 percent of the estimated coal is potentially strippable.

In Battle Spring flat, the area of highest uranium concentration, the Sourdough No. 2 bed averages 2.8 feet in thickness, underlies 428 acres, and contains 2 million tons of coal with an average uranium content of 0.010 percent; the coal ash averages 0.030 percent uranium. Locally, thin splits of this bed contain as much as 0.047 percent uranium and 0.140 percent uranium in the coal ash. The 103 proximate and 16 ultimate analyses of cores show that the coal contains an average of about 16 percent ash, 2.5 percent sulfur, and 21 percent moisture and has an average heating value of about 7,900 Btu on an as-received basis. The coal is subbituminous B in rank.

Results of the investigation indicate that the large reserves of coal in the Red Desert are of interest primarily as a fuel resource and that uranium probably can be produced only as a byproduct. However, thin carbonaceous shale in the coarse-grained clastic facies to the northeast of the principal coal area may be the site of higher grade uranium deposits similar to those at Crooks Gap.

INTRODUCTION

A program of geological mapping and exploratory core drilling was carried out from 1951 to 1953 by the U.S. Geological Survey on behalf of the U.S. Atomic Energy Commission to determine the areal distribution, thickness, and uranium content of coal in the eastern part of the Red Desert area, Sweetwater County, Wyo. Results of the field and laboratory studies of the distribution of uranium and other trace metals and hypotheses concerning the origin and mode of emplacement of the trace elements in the coal are presented in this report.

GEOGRAPHY

The area investigated includes about 300 square miles in the eastern part of the Red Desert, a loosely defined area surrounding the Red Desert playa, which lies in the east-central part of the Great Divide Basin. The Great Divide Basin is an area of internal drainage along the Continental Divide with an altitude ranging from 6,500 to 7,200 feet. It is bounded on the north by the Green Mountains, on the east by the Rawlins uplift, on the west by the Rock Springs uplift, and on the south by the Laney Rim of the Washakie Basin (fig. 1). The sparse rainfall supports scattered vegetation of sagebrush, greasewood, and rabbitbrush. All streams and lakes within the area are intermittent. Wamsutter (population about 100) is on the Union Pacific Railroad and the Lincoln Highway (U.S. 30) both of which extend across the southern part of the area. Many graded dirt roads and trails make most of the area easily accessible by automobile. Sheep grazing is the only local industry.

FIELD AND LABORATORY WORK AND ACKNOWLEDGMENTS

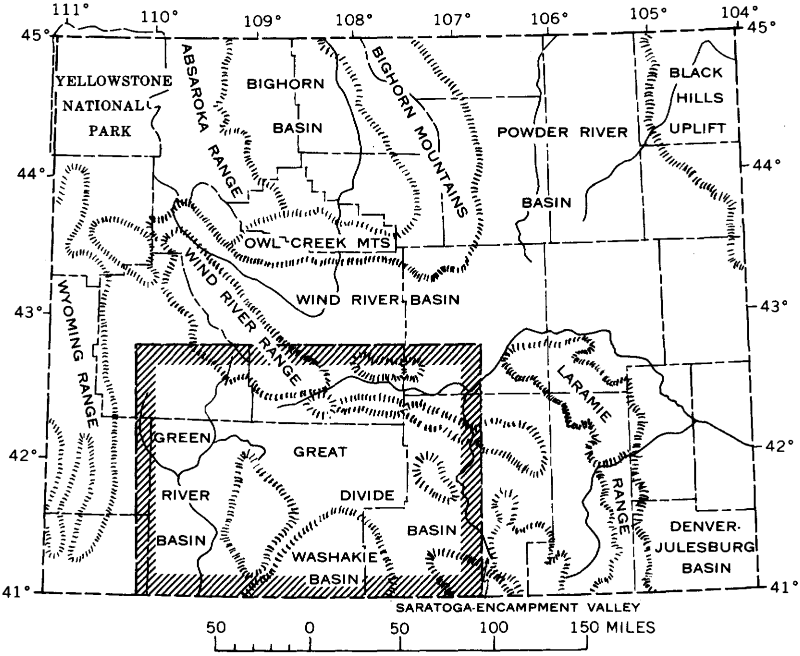
Fieldwork was done in the eastern Red Desert area from 1951 to 1953. Geologic mapping and sampling of coal outcrops were carried out during the summer of 1951; the following two field seasons were spent primarily in core and auger drilling. The geologic contacts, drill hole locations, and section corners were plotted on aerial photographs at a scale of about 1:48,000, and the data subsequently were compiled on a base map prepared from township plats of the U.S. Bureau of Land Management. Sixty core holes, 140 power-auger holes, and 79 surface sections were dug and sampled during the course of the fieldwork. J. R. Pierson, Jr., assisted during the summer of 1952; H. D. Gower and G. W. Moore assisted during the core drilling in the fall of 1952, and Gower continued work on compilation of data during part of the winter of 1952–53. J. G. Stephens and R. F. Gantnier assisted during 1953–54, both in the field and in the office, by compiling drill-core data. R. L. Sutton assisted during part of 1953–54. J. H. Sindelar drilled and logged power-auger holes during the summers of 1952 and 1953. J. M. Schopf processed coal cores and provided detailed descriptions of the coal from 21 drill holes. The core drilling was done by a private company under contract to the U.S. Geological Survey.

Chemical, spectrographic, and sedimentation work was done in the U.S. Geological Survey laboratories. Fuel analyses of coal and assays of oil shale were made by the U.S. Bureau of Mines. R. F. Gantnier was responsible for the sedimentation studies; Wayne Mountjoy performed the chemical work on the leaching and extraction of uranium.

Thanks are due Raymond Larsen for making available the facilities of his ranch during the course of the field investigation.

PREVIOUS WORK

Early geological exploration in south-central Wyoming was carried out by Hayden (1869, 1883), Powell (1876), and King (1878). The most detailed published report on the area is Smith's study (1909) of



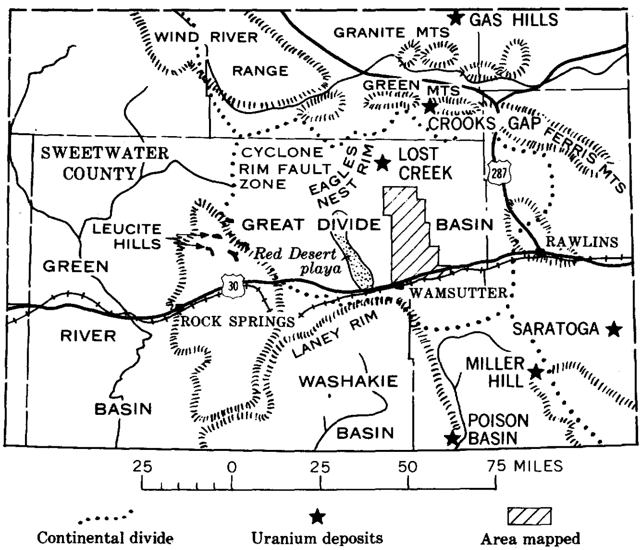


FIGURE 1.—Index map of Wyoming showing major physiographic features and location of inset map, which shows location of mapped area and adjacent uranium deposits.

the eastern Great Divide Basin coal field, which was part of a program to classify coal lands of the Rocky Mountain area. Geologic investigations in adjacent coal fields were made by Veatch (1907), Schultz (1909), Ball (1909), and Ball and Stebinger (1910).

Occurrences of oil shale were investigated by Sears and Bradley (1925) and Bradley (1926; 1931; 1945; 1948). Contributions on the oil and gas possibilities of the surrounding area have been made by Schultz (1920), Fath and Moulton (1924), Dobbin and others (1928), Pott and DeVore (1951), Helmke (1951), and Krampert (1951). Stratigraphic and structural studies have been made by Bauer (1934), Nace (1939), and Knight (1951).

Uranium was discovered about 1935 at Lost Creek in the northern part of the Great Divide Basin by a local prospector, the late Mrs. Minnie McCormick. The uranium mineral, now known as schroeckingerite, was described by Larsen (1937). Uranium-bearing coal was discovered in the Great Divide Basin in 1945 by A. M. Slaughter and J. M. Nelson (written communication) and was further investigated by Wyant, Sharp, and Sheridan (1956). An airborne radioactivity reconnaissance was made by Nelson, Sharp, and Stead (1951). Detailed studies of the Lost Creek schroeckingerite deposits were made by Sheridan, Collier, and Sears (written communication), by Sheridan, Maxwell, and Collier (written communication). Preliminary reports have been issued on nearby, recently discovered sandstone-type uranium deposits at Miller Hill (Love, 1953), Gas Hills (Love, 1954), and Poison Basin (Vine and Prichard, 1954).

Preliminary results of the present investigation have been summarized by Masursky and Pipiringos (1959). Uranium-bearing coal to the west of the area discussed in this report is described by Pipiringos (in press).

STRATIGRAPHY

The rocks exposed in the eastern Red Desert area of the Great Divide Basin are nonmarine sedimentary deposits. They comprise an older fluviatile, lacustrine, and paludal sequence of sandstone, shale, and coal beds, included in the Wasatch and Battle Spring formations, and are overlain locally by younger deposits of alluvium, colluvium, lakebeds, sand dunes, and gravel on high erosion surfaces. The older rocks have an exposed thickness of about 700 feet and are early Eocene in age. They are correlated on the basis of age and stratigraphic position with the upper part of the stratigraphic unit that Sears and Bradley (1925) refer to the main body of the Wasatch formation in parts of southwestern Wyoming and adjacent States. Some of the gravel deposits on high surfaces may belong to the Browns Park formation of Miocene(?) age or they may be younger stream terraces. Surficial deposits at other places in the eastern Red Desert area are Pleistocene or Recent in age.

The main body of the Wasatch formation and the Battle Spring formation are the oldest stratigraphic units in the intertonguing sequence of lacustrine and fluviatile rocks of Eocene age and have an exposed thickness of 6,000 feet in the Great Divide Basin. The higher units in the sequence, in ascending order, are: the Tipton tongue of the Green River formation, the Cathedral Bluffs tongue of the Wasatch formation, and the Laney shale and Morrow Creek members of the Green River formation. Along the north margin of the Great Divide Basin, the Battle Spring formation unconformably overlies rocks ranging in age from Paleocene to Precambrian, and at various places it is overlain by nonmarine rocks of the Bridger formation of middle Eocene age and the Continental Peak formation of Nace (1939) of late Eocene age, and by deposits of tuffaceous sandstone, shale, and conglomerate that have been referred to the White River formation of Granger (Van Houten, 1954) of Oligocene age, the Browns Park formation of Miocene(?) age, and the North Park formation of Pliocene(?) age.

A generalized section of the rocks exposed in the Great Divide Basin is shown by table 1. The stratigraphic relation of the coal-bearing rocks in the eastern Red Desert area with coal-bearing rocks exposed in adjacent areas is shown by figure 2. The distribution of the various map units in the eastern Red Desert area is shown by the geologic map (pl. 1).

TABLE 1.—*Generalized section of Tertiary and Quaternary rocks exposed in the Great Divide Basin and adjacent regions*

System	Series	Formation and member	Thickness (feet)	Area where exposed	Description of rocks
Quaternary	Recent and Pleistocene.		0–58	Eastern Red Desert.	Silt and sand deposited in playa lakes; active dunes along northeast shore of dry lakes and discontinuous mantle of transverse dunes.
Tertiary	Pliocene(?)	North Park formation.	0–600 0–1,600	Split Rock; Saratoga Valley.	Yellowish, white, and gray tuff, pumicite, shale, sandstone, and chalcedony; arkosic tuff at base.
	Miocene (?)	Browns Park formation.	0–200	Eastern Red Desert; Powder Wash.	Pinkish-gray laminated tuffaceous sandstone, crossbedded in places. Cobble conglomerate at base, 0–75 ft thick; terraces in Red Desert may be capped by basal conglomerate.
	Oligocene	White River formation of Granger (Van Houten, 1954).	0–260	Beaver Divide.	Grayish-orange tuffaceous siltstone and sandstone; Beaver Divide conglomerate member at base, 60–125 ft thick. Missing by erosion except along north edge of basin.

TABLE 1.—*Generalized section of Tertiary and Quaternary rocks exposed in the Great Divide Basin and adjacent regions*—Continued

System	Series		Formation and member		Thickness (feet)	Area where exposed	Description of rocks
Tertiary	Eocene	Upper	Continental Peak formation of Nace (1939).		145–250	Oregon Buttes.	Reddish-brown fine- to medium-grained tuff and fuffaceous sandstone.
		Middle	Bridger formation.		670–765	Oregon Buttes; Washakie Basin.	Brown, gray, and greenish sandstone; tuff, organic shale; limestone, and clay-pellet conglomerate; lacustrine and fluviatile sediments; grades into underlying unit.
		Middle	Green River formation	Morrow Creek member.	9–300	Laney Rim	Brownish and buff marlstone sandstone, shale, and limestone. Lacustrine and fluviatile sediments.
		Middle	Green River formation	Laney shale member.	0–500	Laney Rim	Buff chalky to muddy marlstone and brown to gray, oil shale weathering blue-white; also contains analcitized tuff. Lacustrine sediments.
		Middle	Green River formation	Cathedral Bluffs tongue.	115–1,750	Cathedral Bluffs.	Gray and pinkish-red mudstone and greenish-gray sandstone. Fluviatile sediments.
		Lower	Green River formation	Tipton tongue	0–388	Wamsutter Rim.	Brown papery varied organic shale, gray flakey marlstone, and brown fossiliferous limy sandstone. Lacustrine sediments.
		Lower	Main body of Wasatch formation and Battle Spring formation.		3,500±	Eastern Red Desert.	Main body of Wasatch formation in central part of basin consists of gray to buff arkose, siltstone, coal, and beds of organic shale and fossiliferous sandstone of lacustrine origin. Battle Spring formation consists of boulder conglomerate at mountain front, grading outward to buff arkose and greenish clayey sandstone, variegated in places.
	Paleocene		Fort Union formation.		1,060±	Bison Basin	Gray to buff siltstone and shale, impure coal, ferruginous sandstone, clay ironstone, and pebble conglomerate.

TERTIARY SYSTEM

FORT UNION FORMATION (PALEOCENE)

The Fort Union formation of Paleocene age is not exposed but underlies the area according to information from oil test wells. The formation crops out to the north at Bison Basin and east along the Rawlins uplift, where its contained coal beds are locally uranium bearing. The Fort Union formation was named for exposures at old Fort Union, now Buford, near the mouth the Yellowstone River in North Dakota by Meek and Hayden (1862, p. 433). These strata

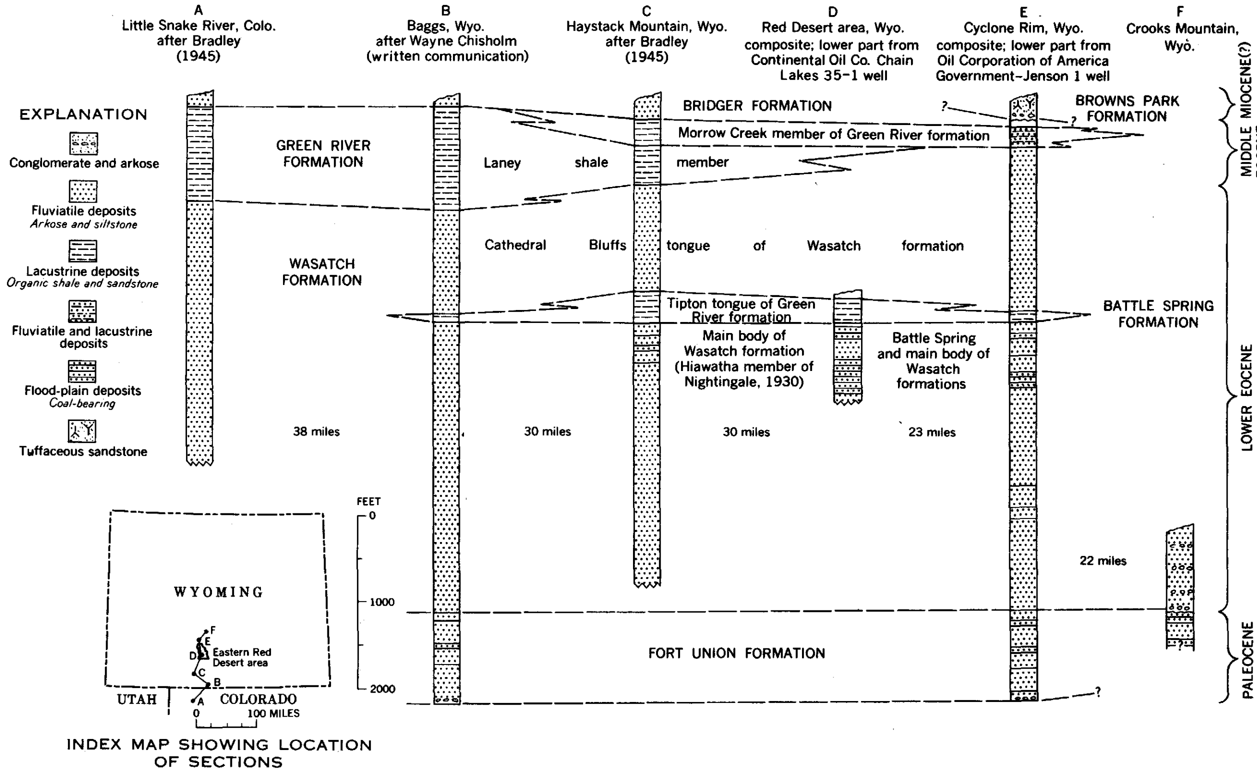


FIGURE 2.—Chart showing relation of coal-bearing rocks in the Red Desert, Wyo., to the Wasatch, Battle Spring, and Green River formations in adjacent regions.

were variously termed "Undifferentiated Tertiary" in the Great Divide Basin (Smith, 1909, p. 224), "Upper Laramie" (Ball and Stebinger, 1910, p. 193), and "Post-Laramie" (Gale, 1909, p. 289) and were separated from the "Laramie" rocks of Cretaceous age because they contained fossils now recognized as Paleocene in age. In the Great Divide Basin these rocks rest unconformably on the older units and are in turn unconformably overlain by younger rocks at the adjacent uplifts. In the central part of the basin, subsurface data indicate that the Fort Union formation is conformable with adjacent formations and is relatively persistent in thickness and character.

Although it is difficult to distinguish the Fort Union formation from the underlying Lance formation of Late Cretaceous age in many places, both Smith (1909) and Ball (1909) reported that in the Great Divide Basin the basal unit of the Fort Union formation is massive sandstone, cross-bedded, ferruginous, and conglomeratic, in places In the South Baggs U.S. Government well 1 (J. Ray McDermott) 44 miles south of Wamsutter in center NE¼NW¼sec. 9, T. 12 N., R. 92 W., a comparable sandstone forms the basal unit of the Fort Union formation, which is 1,060 feet thick (Wayne Chisholm, oral communication). The Fort Union is overlain by coarse-grained arkose of the Wasatch formation. In the Oil Corp. of America U.S. Government-Jenson 1 well, 32 miles north of Wamsutter in SW¼SW¼SW¼sec. 7, T. 25 N., R. 94 W., similar units are identifiable in the sample and electric logs; the Fort Union formation is 1,055 feet thick.

Exposures of the uppermost 300 feet of the Fort Union formation were examined at three localities in the Great Divide Basin. At Crooks Gap and at Bison Basin in Fremont County, from 2 to 24 miles north of the mapped area, the Fort Union formation is unconformably overlain by arkose and boulder conglomerate of the Battle Spring formation of early Eocene age. The upper beds of the Fort Union formation here consists of gray siltstone and shale, which is variegated in places, impure coal beds, ferruginous sandstone containing many plant fossils, clay ironstone, and pebble conglomerate containing many fragments of chert and porcellanite.

A collection of vertebrate fossils from the upper part of the Fort Union formation, along the south rim of Bison Basin in Fremont County (sec. 7, T. 27 N., R. 95 W.), was determined by C. L. Gazin of the U.S. National Museum to be of late Paleocene age.

North of Riner station on the Union Pacific Railroad (sec. 25, T. 21 N., R. 90 W.), about 9 miles east of the mapped area, coal-bearing rocks of the Wasatch formation disconformably overlie the drab, coal-bearing rocks of the Fort Union formation. The basal unit of the Battle Spring formation is a bed of coarse-grained white

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homogeneous arkose, 20 to 30 feet in thickness. This arkose, which weathers into beehive-shaped masses, can be traced northward toward the Green Mountains into a boulder conglomerate—a relationship noted by Smith (1909, p. 234). These rocks were designated by Smith as undifferentiated Tertiary but were considered to be of Fort Union age on the basis of plant-fossil determinations (Smith, 1909, p. 233).

The coal beds of the Fort Union in these localities are thin, impure, and not significantly uranium bearing with the exception of the uppermost beds in the Bison basin area. This occurrence is described on page B–62.

WASATCH AND BATTLE SPRING FORMATIONS (EOCENE)

LITHOLOGIC CHARACTER

The main body of the Wasatch formation, as described by Sears and Bradley (1925), includes rocks of fluviatile, lacustrine, and paludal origin that underlie the Tipton tongue of the Green River formation and overlie the Fort Union formation (table 1). The very coarse grained arkosic sandstone equivalents of the Wasatch formation were named the Battle Spring formation by Pipiringos (in press) for Battle Spring flat in the northwestern part of the area. The Wasatch and Battle Spring formations correlate with the upper part of the Hiawatha member of the Wasatch formation, as defined by Nightingale (1930) at Hiawatha Dome about 55 miles southwest of the eastern Red Desert area. Nightingale, however, apparently included rocks equivalent to the Fort Union formation of Paleocene age in the lower part of his Hiawatha member. As subsequently used by many stratigraphers the Hiawatha member of the Wasatch formation includes the strata above the Fort Union formation and underlying the Tipton tongue of the Green River formation (Wood and others, 1941; McGrew, 1951).

The name Battle Spring formation was proposed by Pipiringos (in press) for nearby rocks in a similar stratigraphic position. Having been formally adopted, the name is used here reluctantly. This name is undesirable on both local and general grounds. First, these thick-bedded coarse-grained rocks are a mountainward fluviatile facies of the main body of the Wasatch formation that grades basinward into a fine-grained thin-bedded coal-shale-sandstone facies deposited in alternating lake, swamp, and stream environments. To assign the sandstone facies formational name and rank de-emphasizes the intimate lateral gradation of the sandstone and coal-bearing facies that in turn weakens recognition of the genetic tie between these lateral changes and uranium distribution.

Second, even if a formation name were appropriate, Battle Spring is not a desirable one. The term is not well defined, largely owing to poor exposures in the type locality. Neither the top nor bottom is present there or exposed nearby and, therefore, the thickness is indefinite. In addition, the age range in the type area is unknown. The lower part of the sequence is presumably of early Eocene (Wasatch) age, but the upper part might be of middle or even late Eocene age. It is, therefore, premature to name these rocks formally. Probably, naming should be reserved, at least, until the sandstone facies can be studied in the northeast part of the Great Divide Basin, where critical relations are likely to be revealed in good and abundant exposures.

The rocks mapped as the main body of the Wasatch formation by Sears and Bradley extend northeast from the Washakie Basin and underlie most of the eastern Red Desert area. The top of the Battle Spring formation is exposed at Eagles Nest, about 2 miles northwest of the area, where it is in contact with the Tipton tongue of the Green River formation. The basal contact of the Wasatch formation with the Fort Union formation is exposed 9 miles east of the area. At the Oil Corp. of America U.S. Government-Jensen 1 well in the Lost Creek area, the Battle Spring formation and main body of the Wasatch formation are about 3,500 feet thick and southward they thin to about 2,000 feet at the South Baggs Government 1 well. The Wasatch and Battle Spring formations exposed in the area are about 700 feet thick and lie about 500 feet stratigraphically below the base of the Tipton tongue.

The Battle Spring and Wasatch formation interfinger complexly along a northwestward-trending zone, about 15 miles wide, that extends across the central part of the area. The stratigraphic relations within the Wasatch formation are shown by the restored section (pl. 1), and the inferred conditions during deposition by the block diagram (fig. 3).

The Battle Spring formation consists of buff, cream, and red friable coarse-grained arkose; gray to green poorly sorted sandy claystone and siltstone; and a few thin beds of black carbonaceous shale that grade laterally northeastward into green sandy claystone containing pyrite nodules (pl. 1). Bedding is irregular and individual units are lenticular, indicating that the facies was probably deposited by aggrading streams in a piedmont environment. The more massive beds of arkose commonly contain spheroidal concretions, cemented with calcium carbonate, which range from a few inches to 6 feet in diameter. In places, the sandstone is thin bedded and finely cross laminated and contains cigar-shaped calcareous concretions as much as 50 feet long and 6 feet in diameter. The rocks of the sandstone facies weather to

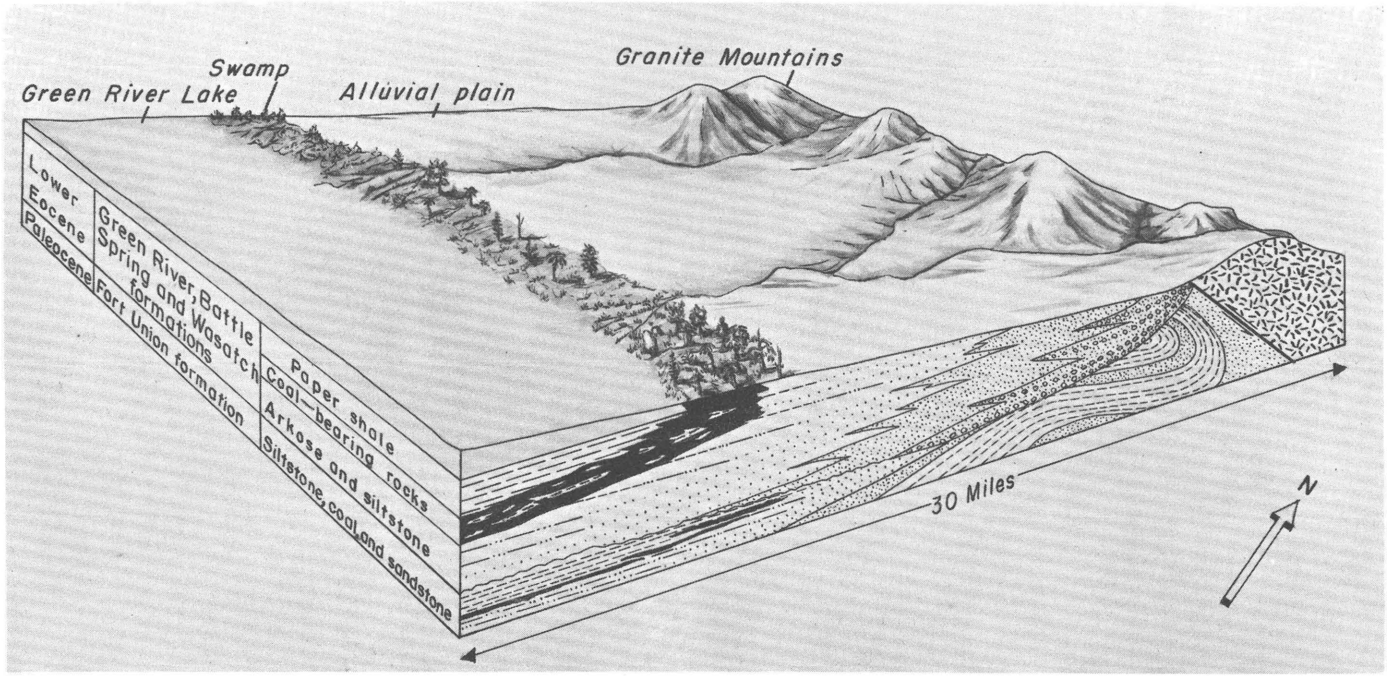

FIGURE 3.—Block diagram showing inferred conditions during deposition of the lower Eocene rocks in the northeastern part of the Great Divide Basin, Sweetwater County, Wyo.

broad flat areas and gentle hills mantled by sand dunes derived from the reworking of the arkose. Fossil turtle bones are common, but other identifiable fossils were not discovered.

The Battle Spring formation grades southwestward into the coal-bearing main body of the Wasatch formation, which consists of cream to gray siltstone, coal, carbonaceous shale, fossiliferous fine-grained sandstone, and sandy limestone. Bedding is even and units are relatively persistent laterally, indicating deposition in a complex environment alternating between flood plain, swamp, and open water (lacustrine) conditions. These rocks weather into rolling hills and flat-topped buttes held up by the lime-cemented sandstone beds. Dark patches of sagebrush characterize the coal outcrops as seen on aerial photographs, forming a polka-dot pattern. In contrast, the organic-shale outcrops show up as smooth gray areas, owing to the cover of low-growing salt sage.

The shale facies of the Wasatch formation consist of beds of organic paper shale with some fossiliferous sandstone and siltstone. These rocks are interbedded with sandstone, siltstone, and coal. The lacustrine shale weathers chocolate brown and separates into paper-thin folia. Bradley (1931, p. 8) has described similar rocks and called them low-grade oil shale, defining low-grade shale as that yielding less than 10 gallons of oil per ton by distillation. The oil yield from the shale in this area is 2.8 gallons or less per ton (see following table).

Analyses of organic-rich paper shale of the Wasatch formation

[Analyses by the modified Fischer methods supplied by Petroleum and Oil-Shale Experiment Station, US. Bureau of Mines, Laramie, Wyo., H. M. Thorne, chief]

Core hole	Interval sampled (feet)	Sample	Yield of product [1]					
			Percent by weight				Gallons per ton	
			Oil	Water	Spent shale	Gas loss	Oil	Water
17	151.5–152.5	SBR53-450	0.2	4.9	94.2	0.7	0.4	11.8
18	66.7– 71.8	451	.1	4.9	94.3	.7	.2	11.7
	88.5– 87.65	452	.2	4.8	94.0	1.0	.2	11.6
	88.8– 92.7	453	.5	5.0	93.3	1.2	1.3	12.0
	93.0– 98.3	454	1.1	3.4	94.5	1.0	2.8	8.2
	98.5–103.7	455	.3	2.7	96.2	.8	.8	6.4
40	31.4– 33.4	462	.0	6.8	92.8	.4	.0	16.3
	37.8– 39.8	463	.0	7.6	91.8	.6	.0	18.2
	47.2– 49.2	464	.2	7.2	91.6	1.0	.5	17.1
	69.7– 73.7	465	.7	6.6	91.8	.9	1.7	15.9

[1] Based on average of two analyses for core holes 17 and 18 and on one analysis for hole 40.

Since the oil yield is so small, these rocks are called organic shale or paper shale in this report. The lithologic characteristics and the fossils of the shale suggest deposition in a lacustrine environment.

The thicker more persistent beds are shown separately on the geologic map. The lacustrine rocks, here included in the main body of the Wasatch formation, are thicker and more persistent to the west, where they have been mapped as tongues of the Green River formation Pipiringos, in press).

The following collections of plant fossils from the main body of the Wasatch formation were identified and designated as early Eocene by R. W. Brown of the U.S. Geological Survey:

Larsen No. 3 coal bed, map locality 83, sec. 22, T. 21 N., R. 94 W.

Salvinia preauriculata
Equisetum sp.
Lygodium kaulfussi
Ficus sp.
Chaetopteles sp.
Osmunda sp.
Sassafras sp.
Typha sp.
Zizyphus sp.
Alisma sp.
Insect wings
Lemma scutata
Moss sp.

Sourdough No. 2 coal bed, locality 19, sec. 34, T. 23 N., R. 94 W.

Anemia sp.
Glyptostrotius dakotensis Brown

The following mollusks were collected 32 feet above the Battle No. 3 coal bed from a bed of sandstone capping a small butte in sec. 15, T. 22 N., R. 94 W. They were identified by T. C. Yen of the U.S. Geological Survey and designated as early Eocene:

Unio sp. undet.
Valvata sp. undet.
Viviparus cf. *V. paludinaeformis* (Hall)
Goniobasis cf. *G. tenera* (Hall)
Gyraulus cf. *G. militaris* (White)

Intercalated in the lacustrine organic shale sequences are a few beds of ostracod coquina, but the species represented are long ranging and are not useful for critically dating the rocks.

Following are two detailed core descriptions of equivalent stratigraphic sections in the main body of the Wasatch formation and the sandstone of the Battle Spring formation. The core holes are about 5 miles apart.

Section of part of Battle coal zone, core hole 18, sec. 8, T. 23 N., R. 94 W.

	Thickness (feet)
Main body of the Wasatch formation:	
Siltstone, greenish-gray, laminated	1.4
Shale, light-olive-gray; silty clay, calcareous; few plant fossils; abundant fragments of pelecypods and gastropods	2.2
Sandstone, greenish-gray, medium- to coarse-grained, subangular, clayey	1.1
Shale, light-olive-gray; abundant triturated invertebrate fossils	9.5
Dolomite, light-olive-gray, clayey, fossiliferous	.2
Shale, light-olive-gray; abundant pelecypods parallel to bedding	3.0
Sandstone, light-gray, very fine grained; contorted lamination	.6
Shale, light-gray, fossiliferous	1.7
Shale, carbonaceous, coaly streaks	.3
Coal, clean; conchoidal fracture; composed of vitrain	.9
Coal, impure	.4
Coal, clean, contains pyrite	.2
Coal, shaly, impure; contains pyrite	.7
Coal, clean, laminated, cleated; contains pyrite	.7
Coal, clean	2.4
Shale, coaly streaks	.2
Coal, clean, banded	1.1
Shale, carbonaceous	1.2
Coal, clean	.6
Shale, carbonaceous	1.0
Coal, clean	.4
Shale, carbonaceous; clay pellets	.3
Coal, clean	2.0
Claystone, dark-gray, slickensided	.2
Core loss	.8
Claystone, slickensided	.4
Coal, laminated	.3
Shale, carbonaceous	.4
Shale; clay; plant fossils	1.0
Coal, clean	.5
Shale, carbonaceous	1.1
Coal, laminated	.2
Claystone, slickensided	.4
Coal, clean	1.0
Shale, carbonaceous	.8
Coal, clean	1.5
Claystone, gray, slickensided	.2
Core loss	.4
Coal, clean, friable; carbonaceous shale partings	1.7
Shale, carbonaceous	.3
Coal, clean	2.2
Shale, carbonaceous	.4
Siltstone, light-gray	1.0
Claystone, gray	1.2
Siltstone, gray, laminated	.7
Total	48.8

Section of part of lateral equivalent of Battle coal zone, core hole 26, sec. 16, T. 24 N., R. 94 W.

	Thickness (feet)
Battle Spring formation:	
Sandstone, dark greenish gray, fine- to coarse-grained, poorly sorted, subangular	3.0
Claystone, dark-greenish gray, slickensided	1.3
Sandstone, buff, coarse-grained to very coarse grained, granular, clayey, subangular to subround, arkosic	2.6
Sandstone, medium-light-gray, fine-grained to very fine grained, clayey, micaceous, friable	6.6
Claystone, dark-greenish-gray, slickensided	.7
Sandstone, light-gray, fine-grained, well-sorted, angular, calcareous, micaceous	2.0
Siltstone, greenish-gray, sandy	1.0
Sandstone, light-gray, fine-grained, angular, well-sorted, laminated, micaceous	5.5
Siltstone, dark-gray; fossil plant fragments	.5
Sandstone, medium-light-gray, fine-grained, micaceous	5.2
Sandstone, light-gray, coarse-grained to very coarse grained; granules, clayey, micaceous	4.1
Sandstone, light-gray, fine- to medium-grained, calcareous, micaceous	2.2
Sandstone, medium-light-gray, coarse-grained to very coarse grained, micaceous, arkosic; few carbonaceous streaks	10.4
Total	45.1

CYCLIC SEDIMENTATION

The outstanding characteristic of the coal bearing part of the main body of the Wasatch formation in the Red Desert is the rhythmic repetition of similar rock types in vertical sequence. The cyclic nature of the deposits, which acted as one of the controls for the distribution of uranium in the coal, complicates the correlation of coal beds and, therefore, the estimation of coal reserves. An early description of this type of rhythmic sedimentation was given by Udden (1912, p. 47), who recognized that the coal measures of Pennsylvanian age in Illinois were cyclically deposited. Wanless and Weller (1932, p. 1003) proposed the term "cyclothem" for the beds deposited during each of these sedimentary cycles. Moore (1935) applied the term "megacyclothem" to the complex sedimentary deposits in the Pennsylvanian rocks of Kansas, which consist of several cyclothems occurring in a definite pattern.

A comparison between the cyclic deposits of the Red Desert and those of Kansas (Moore, 1935) is shown in figure 4. The ideal Red Desert cyclothem is one in which the lithologic units, in ascending order, are sandstone, siltstone, claystone, coal, paper shale, coal, siltstone, and sandstone. These rock types represent the transgression of sedimentary environments from fluviatile to lacustrine and back

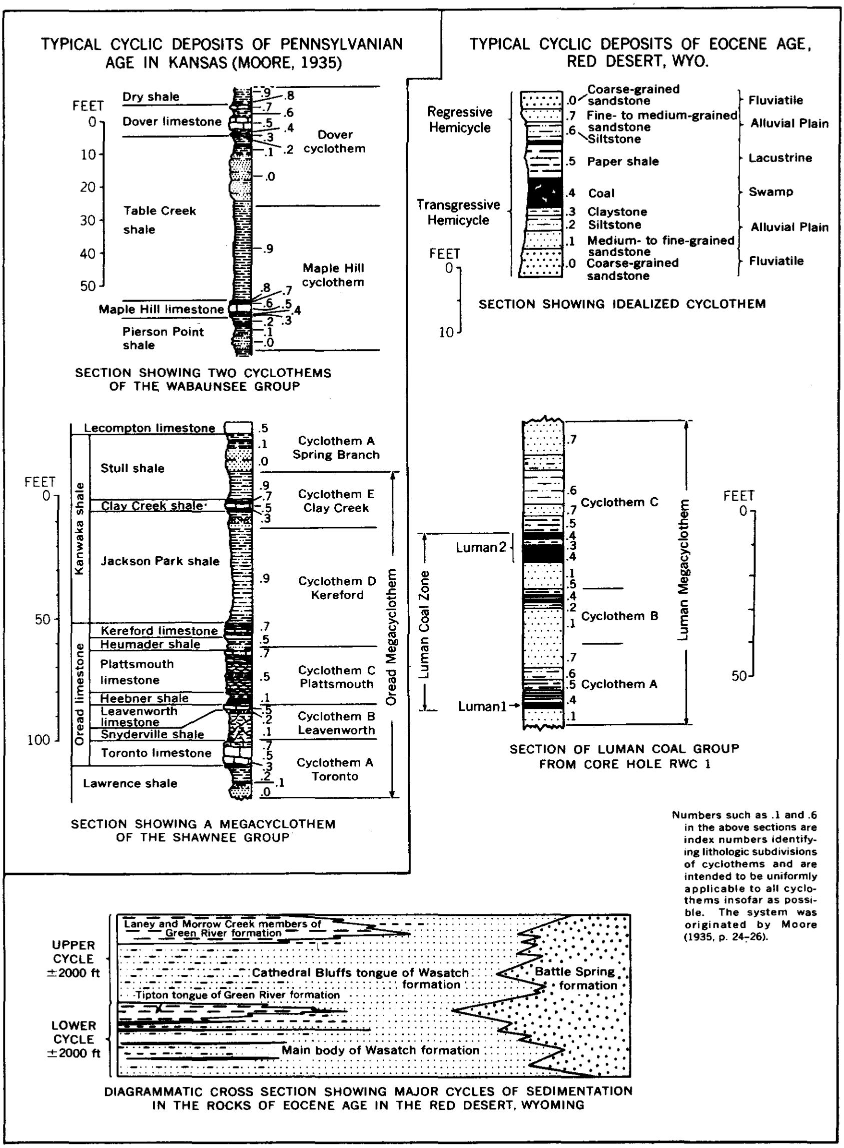

FIGURE 4.—Diagram showing cyclic deposits of Eocene age in the Red Desert, Wyoming, and of Pennsylvanian age in eastern Kansas.

to fluviatile. The cyclothems of the Wabaunsee group of Kansas described by Moore represent a similar alternation of fluviatile and marine environments. In most of the cyclothems observed in the Red Desert, the regressive phase (hemicycle) of the cycle is suppressed, and the rock types, in ascending order, are sandstone, coal, and shale.

The cyclothems occur in related groups: in the lower cyclothem of a group, the most conspicuous rock type is the initial one, the sandstone; in the upper cyclothem, the most abundant rock type is the upper one, the paper shale. This cycle of cyclothems is similar to Moore's megacyclothem. In this report the coal beds are grouped into coal zones that are equivalent to megacyclothems. The Luman coal zone, considered as a megacyclothem, is shown in figure 4 and is compared to a megacyclothem of the Shawnee group of Kansas. The diagrammatic section in figure 4 shows that the intertongued fluviatile, paludal, and lacustrine rocks of the Wasatch and Green River formations fit into a similar gross cyclic pattern. The influence of the rythmically deposited sediments on the distribution of uranium is discussed in the section on uranium deposits.

Sharp disagreement exists as to whether cyclic deposits are due to tectonic control or some other cause. In the Red Desert, the cyclical sedimentation was apparently due to periodic subsidence of the basin of deposition and uplift of the source areas. This mechanism was proposed by Weller (1930, 1931) for the coal measures of Pennsylvanian age in Illinois and reaffirmed for European coal measures by Rutten (1952). The interbedded boulder conglomerate and arkose of the Battle Spring formation at the north margin of the basin suggest that the uplift was intermittent. The thick sequence of interbedded fluviatile and lacustrine beds deposited in the basin shows that the basin remained almost filled with sediment during subsidence. Although the initial lacustrine deposits are small and patchy, the higher lacustrine beds are very widespread and uniform, indicating that most of the basin floor subsided evenly.

At places, fluviatile coarse-grained sandstone rests disconformably on organic shale; commonly the bottom part of the sandstone beds is gray, evenly bedded, calcareous, and fossiliferous, suggesting deposition in a lacustrine environment. Upward, however, the sandstone generally becomes red, cross laminated, and unfossiliferous, indicating a transition to a fluviatile environment. The arkose, which contains lacustrine fossils in the basal few feet, was evidently deposited rapidly in a shallow lake. The upper part of these arkose units is made up of stream-channel deposits. This sudden influx of sandy material into the lacustrine environment was probably due to uplift in the source area.

Many European geologists reject the intermittent subsidence hypothesis of Weller to explain the cyclic nature of coal measures. Robertson (1948) proposed that rhythmic, intermittent sedimentation can occur in a steadily subsiding basin. He stated that the vegetation growing along the shore will filter out clastic sediments. When the vegetation is overwhelmed by sea water, marine deposits will form on the top of the vegetation. The greater compaction of the vegetation compared to the clastic rocks will allow continued marine deposition in the area of former lagoonal accumulation. The sudden incursion of sea water is due to the breakdown of an offshore bar, behind which the peat deposits form. The breakdown is caused by the inability of the upbuilding of the bar to keep pace with the steady subsidence of the basin. After the breakdown of the bar and deposition of marine rocks, clastic sediments again build out from the shore across the marine area, another bar forms, and vegetation again accumulates behind the new bar. This so-called plant-controlled sequence or vegetation compaction during uniform subsidence is believed to be taking place along the Dutch coast today and to have been an important factor in the rhythmic deposition in the Limburg and Anatolia basins (Van der Heide, 1950).

The evidence for intermittent movement along the thrust faults bounding the Great Divide Basin, which results in the periodic deposition of boulder conglomerate, does not seem compatible with the hypothesis that there may have been a steady subsidence of the basin floor. Nevertheless the plant-controlled sequence may have accentuated the cyclic aspect of the sedimentation, which was due primarily to intermittent subsidence.

TERTIARY OR QUATERNARY SYSTEM

Deposits of poorly consolidated sandstone and cobble conglomerate of questionable age cap flat-topped topographic highs in the southeastern part of the area. The deposits are 5 to 20 feet thick, dip about 60 feet per mile to the east, and lie unconformably upon the virtually flat-lying Wasatch formation. The cobbles in the conglomerate are as much as 4 inches in diameter and are composed of granite, chert, gray limestone, and red sandstone. These deposits may be the correlative of the basal conglomerate of the Browns Park formation of Miocene(?) age.

Similar conglomerate caps terraces at the Rawlins uplift, 20 miles east of the area, and passes under the tuffaceous sandstone of the Browns Park formation (J. Barlow, oral communication). In the Saratoga basin, southeast of Rawlins, rocks described and referred to the Browns Park formation by McGrew (1951, p. 56) comprise a basal conglomerate as much as 100 feet thick and an upper sandy unit 750 feet thick. A mammalian fauna from these beds in the Saratoga area is believed to be middle Miocene (Hemingfordian) in age.

About 9 miles north of the area, an eastward-trending ridge, the Cyclone Rim, is underlain by a cobble conglomerate, as much as 50 feet thick, which rests unconformably on rocks of middle Eocene age.

In the basin north of the river the conglomerate grades upward into coarse-grained sandstone with pipelike, calcareous concretions, which in turn grades upward into well-sorted medium-grained tuffaceous sandstone. At some places the sandstone is highly calcareous and even bedded; in others, it is marked by large sweeping cross bedding, excellent sorting, and rounded frosted sand grains, which probably indicate an eolian origin. Glassy shards in the tuffaceous sandstone have an index of refraction ranging from 1.502 to 1.516. The pinkish-gray color and castellate weathering form make it a very distinctive unit in outcrop. Near Split Rock in Fremont County, fossils collected from these beds were dated as middle Miocene by McGrew (1951, p. 56), who correlates the rocks with the Browns Park formation. A discontinuous mantle of this unit, designated the Chadron formation by Nace (1939), is traceable for 30 miles westward from the Cyclone Rim to Oregon Buttes, where it comprises a thin conglomerate at the base, overlain by coarse-grained sandstone with prominent pipelike concretions, and a few thin beds of interbedded tuff. The tuff beds are composed almost entirely of glass shards with an index of refraction of 1.485 to 1.495 (fig. 5).

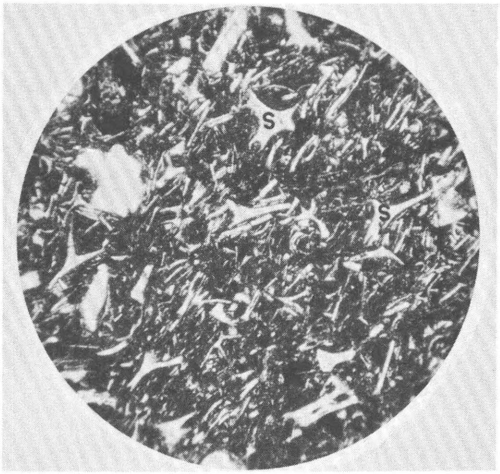

FIGURE 5.—Photomicrograph of thin section showing tuff from the Browns Park formation of Miocene(?) age at Oregon Buttes, Sweetwater County, Wyo. Shards, *S*, of glass have an index of refraction ranging from 1.485 to 1.495. Devitrification of the abundant glass during weathering releases uranium to the ground water. × 30. Ordinary light.

The tuffaceous rocks just described to the north, east, and west of the area are similar in lithologic character and fossil content to the Browns Park formation of Miocene(?) age, as described by Bradley

(1936), to the south along the south side of the Washakie Basin and at the type locality in Browns Park, Colo. (Powell, 1876). However, the correlation of the isolated remnants of conglomerate within the area with the Browns Park formation is uncertain, because Oligocene, Pliocene, and Pleistocene rock units in the Great Divide Basin also contain conglomerate. Until vertebrate fossils are found in the conglomerate at Creston Ridge, or a detailed study is made of all the conglomerate to establish lithologic distinctions, the age of the rocks at Creston Ridge will remain in doubt.

QUATERNARY SYSTEM

The principal surficial deposits are lacustrine sand and silt in the dry-lake basins. A maximum thickness of 58 feet of surficial lake sediment was observed in drill holes in the northwestern part of Battle Spring flat. In this area, the lower 40 to 50 feet of the deposit appears to consist of well-sorted coarse-grained arkose, and the upper 10 to 20 feet, of gray silt. The lakes were more extensive during the Pleistocene pluvial cycles, when they entirely filled the shallow depressions, as indicated by shore features still visible at the margins. The floors of the dry lakes are being dissected by the streams that empty into the centrally located playas. Delta-fan deposits marginal to the lake flats are being laid down by the principal streams.

Dunes of sand and silt are distributed along the northeast margins (the leeward side) of the flats. A discontinuous mantle of transverse dunes has formed in parts of the area where the bedrock is unconsolidated coarse-grained arkose. The dunes were formed from the directly subjacent material and are now largely fixed by vegetation.

SEDIMENTATION

Studies of size-grade distribution, grain shape, and mineral composition were made of the coal-bearing rocks to determine the validity of the field descriptions of cores, to describe the rocks accurately, and to determine lithologic variations in relation to environments of deposition. The work on grain size and grain shape was done by Robert F. Gantnier. Gantnier and James G. Stephens made the mineral identifications.

GRAIN SIZE

Seventy-two representative lithologic samples were selected from 12 core holes for detailed study of grain sizes. Histograms showing size-grade distributions are shown in figures 6–17.

Grains range in size from small pebbles to clay; however, most of the clastic particles are medium-grained sand to fine-grained silt. Clay-sized particles are least common; even the lacustrine shale consists predominantly of silt-sized particles in an organically rich matrix

SIZE, IN MILLIMETERS	SIZE CLASSIFICATION	SAMPLES FROM CORE HOLE 17, IN PERCENT BY WEIGHT								
		22.3–22.5 ft Sandy siltstone	36.0–36.4 ft Calcareous, coarse sandstone	55.3–55.5 ft Medium-fine, sandstone	57.0–57.2 ft Calcareous, medium-coarse sandstone	182.5–182.7 ft Sandy siltstone	185.6–185.8 ft Silty, fine sandstone	198.5–198.7 ft Sandy siltstone	228.2–228.4 ft Calcareous, clayey siltstone	347.0–347.2 ft Coarse-very coarse sandstone
	Pebble		0.5							1.5
4	Granule		6.5							14
2	Very coarse sand		20	1.5	2.5		4			28
1	Coarse sand	0.5	25	8	30.5		10			29
0.5	Medium sand	6.5	16	44.5	44.5	0.5	12.5	12		15
0.25	Fine sand	18	17	35.5	16.5	10.5	20	17		6
0.125	Very fine sand	21	9	6.5	3	25.5	26.5	17		2.5
0.062	Silt					61.5			76	
0.005	Silt	53	6	4	2	1	27	54	4	4
0.002	Clay					1			20	
	Percent carbonate	0	17.2	0	26.3	9.2	0	0	35.9	0

EXPLANATION

0 50 100

44.5

Percent by weight

20

Percent of specimen <0.062 mm yielding sample too small for wet analysis

17.2

Percent carbonate by weight in original sample

R. F. Gantnier, analyst

FIGURE 6.—Histogram showing grain-size distribution in samples from core hole 17.

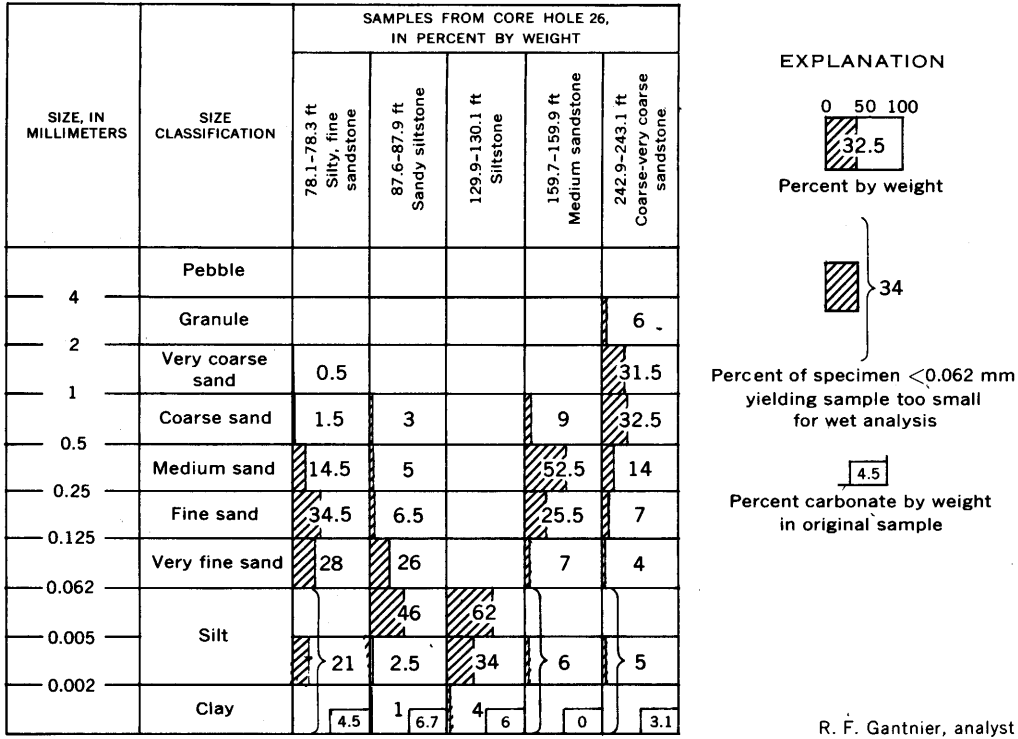

FIGURE 7.—Histogram showing grain-size distribution in samples from core hole 26.

SIZE, IN MILLIMETERS	SIZE CLASSIFICATION	SAMPLES FROM CORE HOLE 28, IN PERCENT BY WEIGHT					
		27.9–28.1 ft Fine-medium sandstone	34.1–34.3 ft Sandy siltstone	48.2–48.4 ft Medium-coarse sandstone	116.3–116.5 ft Calcareous sandy siltstone	141.5–141.7 ft Sandy shale	183.3–183.5 ft Fine-medium sandstone
	Pebble			0.5			
4							
	Granule			8			0.5
2							
	Very coarse sand	2.5		14			3
1							
	Coarse sand	10	9	25			16.5
0.5							
	Medium sand	28	18.5	24			35.5
0.25							
	Fine sand	40.5	11.5	19.5			27.5
0.125							
	Very fine sand	12.5	12.5	5.5	26	22	10
0.062							
	Silt	6.5 (<0.062 mm)	41	3.5 (<0.062 mm)	53.5	18	7 (<0.062 mm)
0.005							
	Silt		1		4.5	8	
0.002							
	Clay		6.5		16	60	
	Percent carbonate	5.6	0	0	11.7	7.2	0

EXPLANATION

0 50 100

35.5

Percent by weight

6.5

Percent of specimen <0.062 mm yielding sample too small for wet analysis

5.6

Percent carbonate by weight in original sample

R. F. Gantnier, analyst

FIGURE 8.—Histogram showing grain-size distribution in samples from core hole 28.

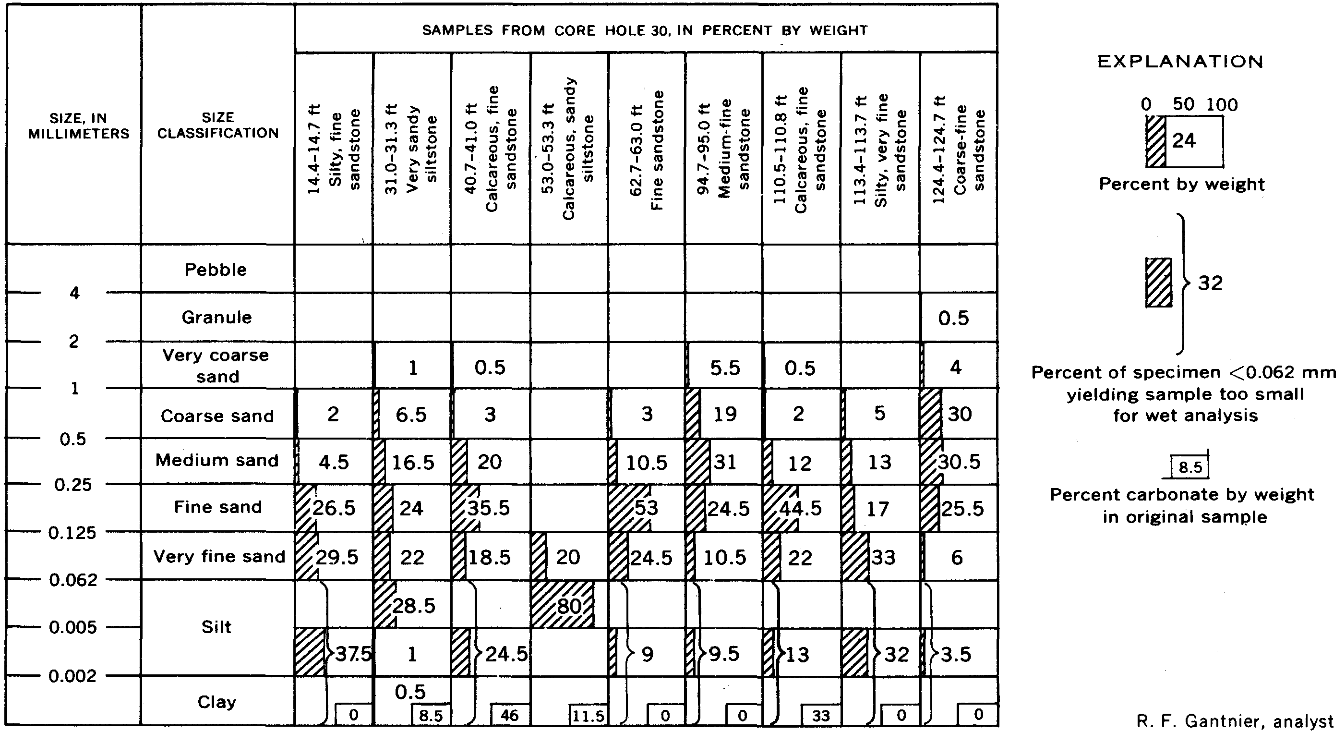

FIGURE 9.—Histogram showing grain-size distribution in samples from core hole 30.

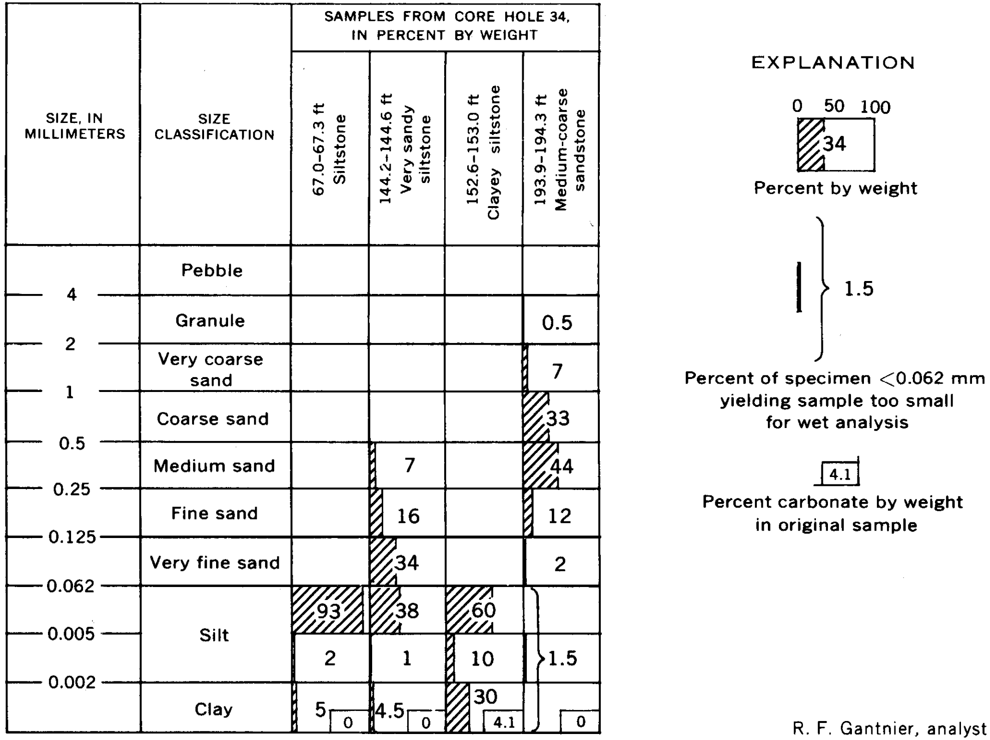

FIGURE 10.—Histogram showing grain-size distribution in samples from core hole 34.

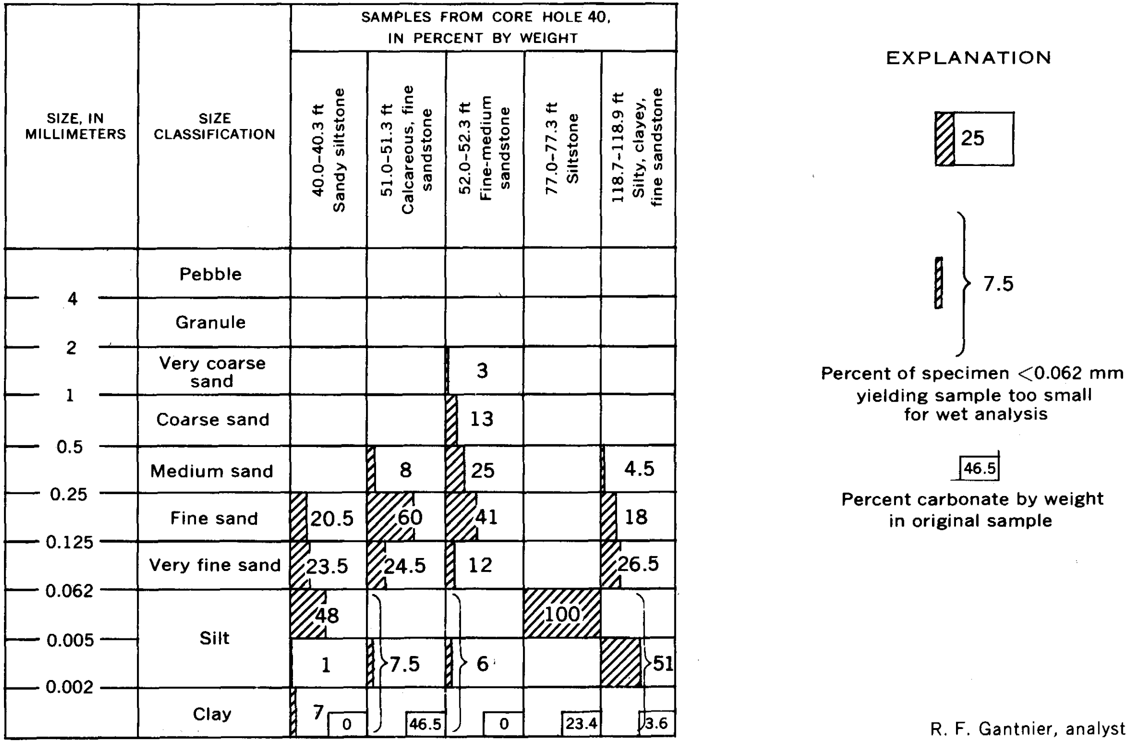

FIGURE 11.—Histogram showing grain-size distribution in samples from core hole 40.

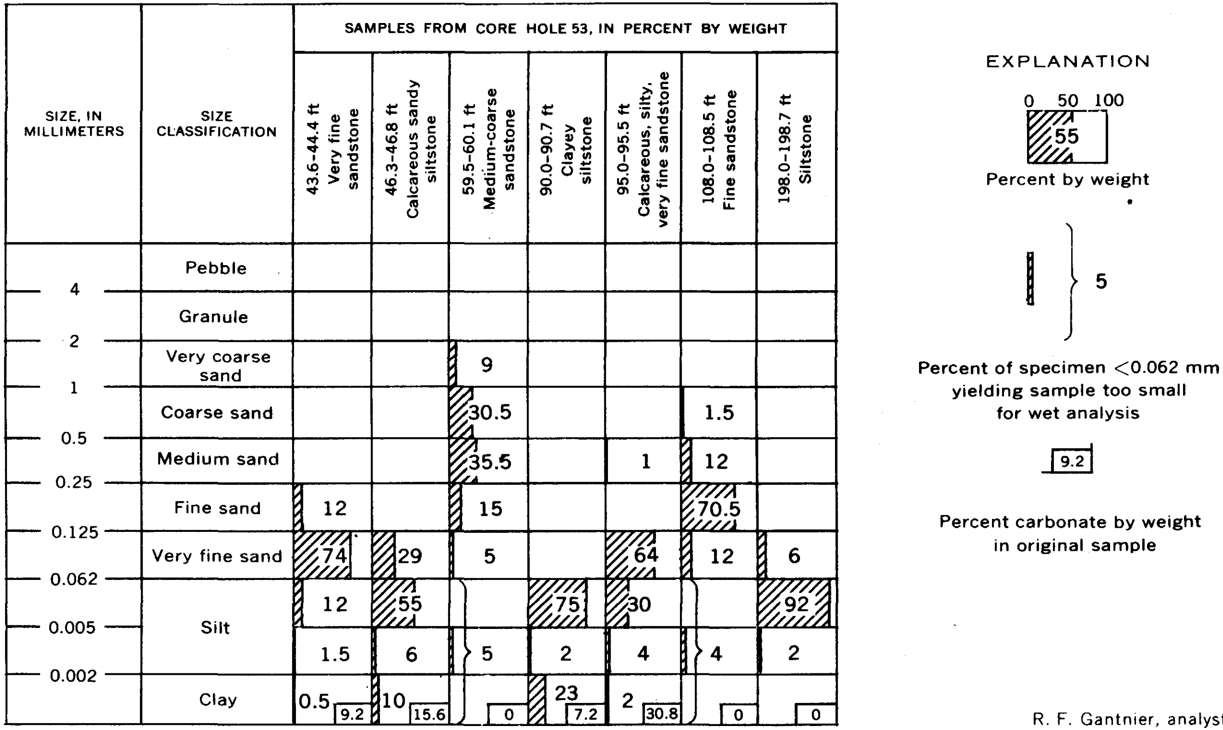

FIGURE 12.—Histogram showing grain-size distribution in samples from core hole 53.

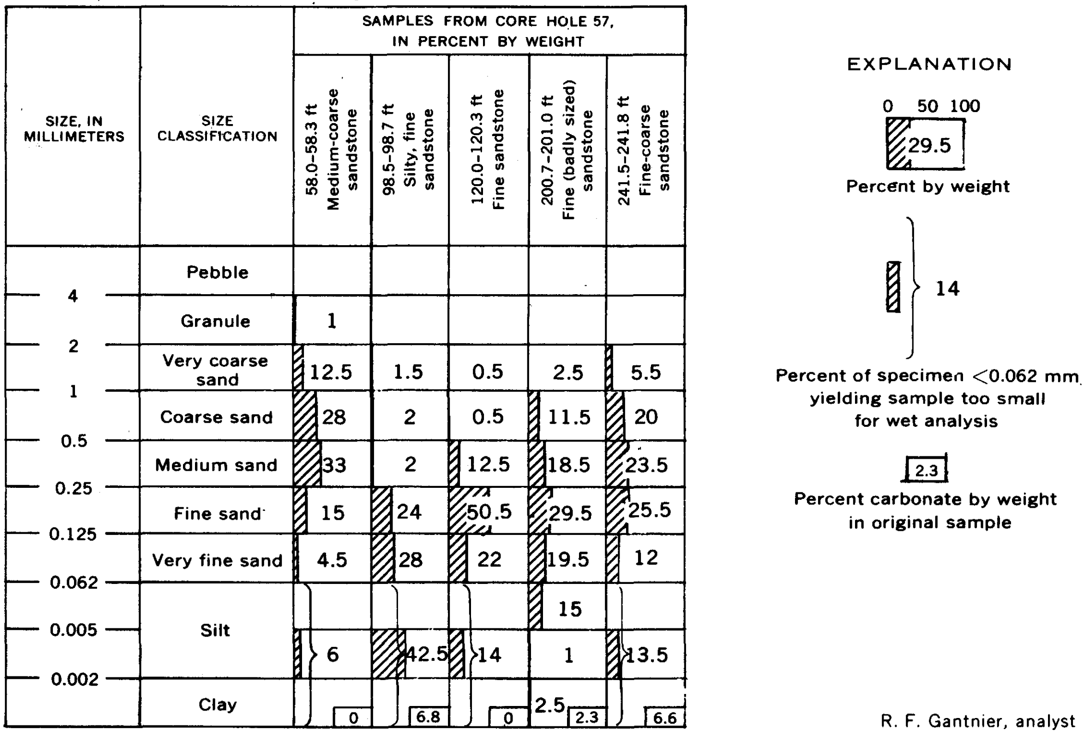

FIGURE 13.—Histogram showing grain-size distribution in samples from core hole 57.

SIZE, IN MILLIMETERS	SIZE CLASSIFICATION	SAMPLES FROM CORE HOLE 59, IN PERCENT BY WEIGHT						
		30.0–31.7 ft Silty, very fine-fine sandstone	32.7–33.3 ft Silty limestone	74.4–75.0 ft Fine-medium sandstone	99.5–101.0 ft Calcareous siltstone	115.0–115.8 ft Calcareous, silty, very fine-fine sandstone	190.0–192.5 ft Calcareous, silty, very fine-fine sandstone	262.7–264.7 ft Fine-medium, sandstone
	Pebble							
4								
	Granule							
2								
	Very coarse sand							0.5
1								
	Coarse sand			5		0.5		5
0.5								
	Medium sand			29.5		1.5		28
0.25								
	Fine sand	29.5		50		30	11	57
0.125								
	Very fine sand	39.5		8.5		42	62	6
0.062								
	Silt		62		100	25.5		
0.005								
	Silt	31	34	7		0.5	27	3.5
0.002								
	Clay		4					
	Percent carbonate	0	78	0	17.5	22.6	30.5	1.6

EXPLANATION

0 50 100

27

Percent by weight

7

Percent of specimen <0.062 mm yielding sample too small for wet analysis

30.5

Percent carbonate by weight in original sample

R. F. Gantnier, analyst

FIGURE 14.—Histogram showing grain-size distribution in samples from core hole 59.

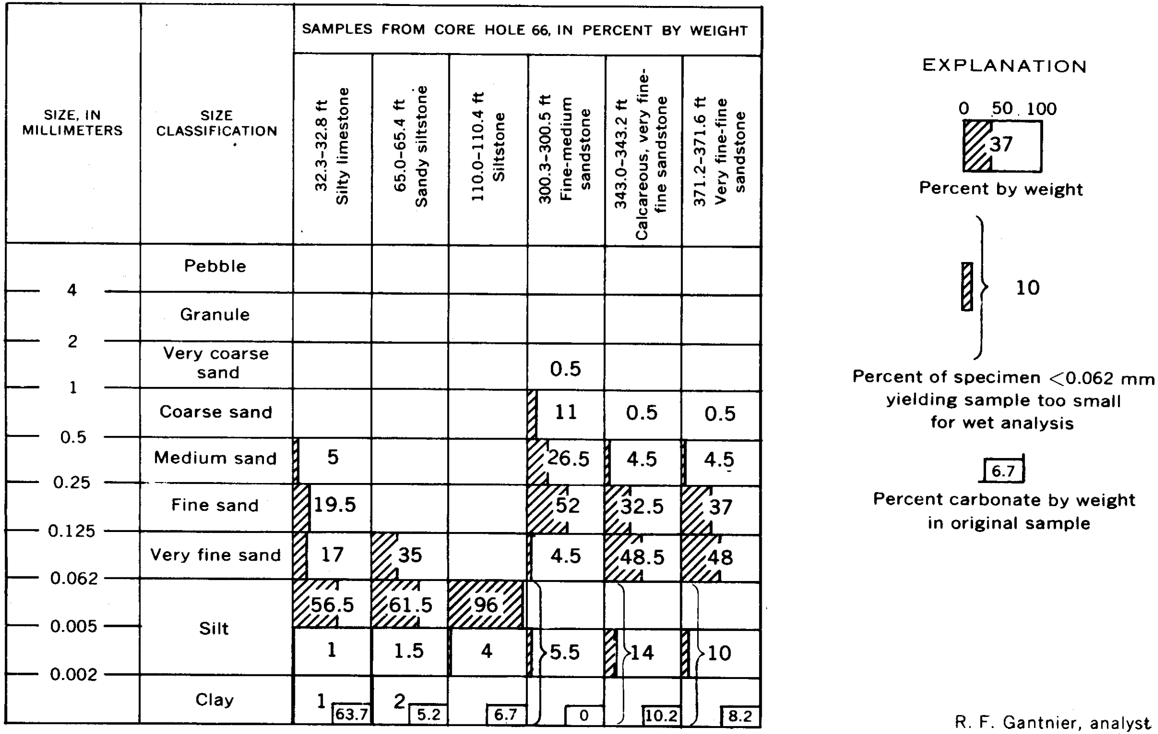

FIGURE 15.—Histogram showing grain-size distribution in samples from core hole 66.

SIZE, IN MILLIMETERS	SIZE CLASSIFICATION	SAMPLES FROM CORE HOLE 68 IN PERCENT BY WEIGHT: 29.0–29.8 ft Silty, sandy limestone	70.0–70.6 ft Silty, very fine sandstone	95.5–96.1 ft Calcareous, fine sandstone	190.5–191.0 ft Siltstone	196.0–196.6 ft Silty limestone
	Pebble					
4						
	Granule					
2						
	Very coarse sand			0.5		
1						
	Coarse sand	2.5		0.5		
0.5						
	Medium sand	14.5		5		
0.25						
	Fine sand	14.5	20	76		
0.125						
	Very fine sand	21.5	56.5	17		
0.062						
	Silt	45	21.5		98	86
0.005						
	Silt	1	1	1	2	10
0.002						
	Clay	1 [45.4]	1 [3.6]	[13.2]	[0]	4 [68.1]

EXPLANATION

0 50 100

14.5

Percent by weight

1

Percent of specimen <0.062 mm yielding sample too small for wet analysis

13.2

Percent carbonate by weight in original sample

R. F. Gantnier, analyst

FIGURE 16.—Histogram showing grain-size distribution in samples from core hole 68.

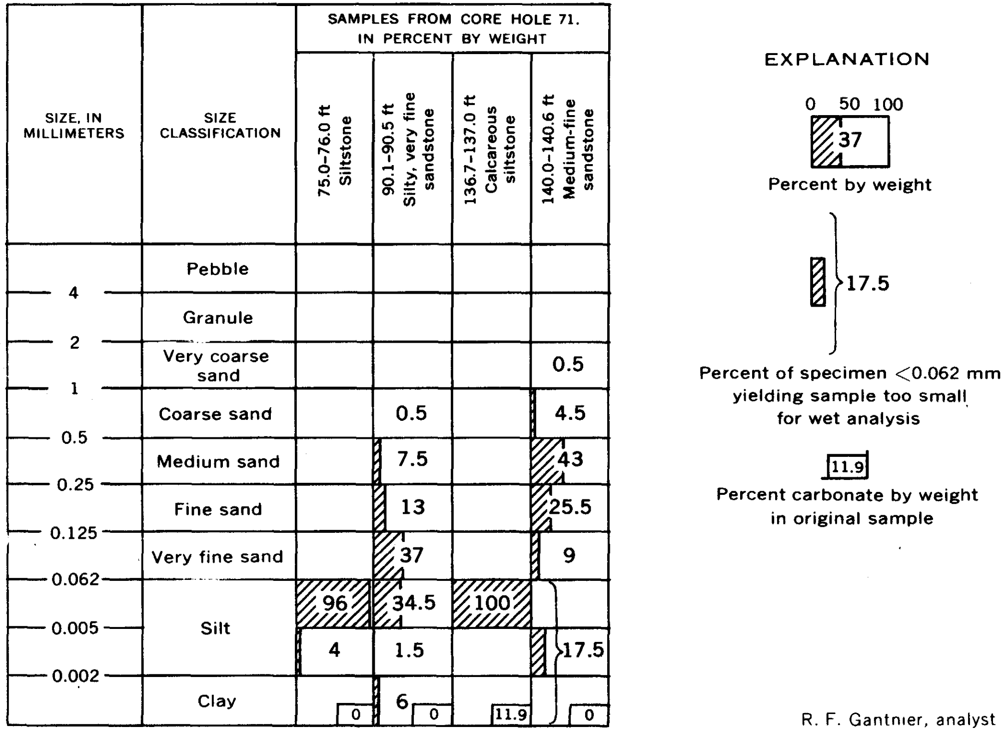

FIGURE 17.—Histogram showing grain-size distribution in samples from core hole 71.

similar to the shale in the Green River formation, in the Uinta Basin described by Hunt and others (1954). The siltstone shows the best sorting; several samples contained from 75 to 100 percent coarse-grained silt particles. The coarser grained rocks are not as well sorted, but some arkose contains as much as 65 percent very coarse grained to coarse-grained sand. The contrast between the size-grade distribution in a channel sandstone and a channel-marginal sandy claystone is shown in figure 28.

GRAIN SHAPE

Spericity and roundness were visually estimated using a binocular microscope. At least 90 percent of the sand-sized grains are angular to subangular. Sphericity and roundness according to Wadell's method (Krumbein and Pettijohn, 1938, p. 295) are $\frac{0.25}{0.50}$ for the quartz, $\frac{0.35}{0.75}$ for the feldspar, and $\frac{0.80}{0.90}$ for the hypersthene. The angularity of the grains suggests a short distance of transport, and this is confirmed by the geologic relations, which show that the granite source area lies about 25 miles north of the area. Most of the sand grains have a dull luster, but only a few have impact rings, indicating that the dull luster probably resulted from chemical action rather than from abrasion. The slight alkalinity of the ground water and the presence of flourine, as shown by the analyses in table 7, may have caused this frosting of the grains.

MINERALOGY

Grain counts of 233 sized fractions were made with the binocular microscope to determine the mineral composition. In the greater-than-4-mm-size fraction, feldspar makes up as much as 60 percent of the sample; in all other size fractions, quartz is the dominant mineral, amounting to 60 to 80 percent. The types of feldspar present in size fractions greater than 0.062 mm, in order of decreasing abundance, are: microline, albite, orthoclase, oligoclase, perthite, labradorite, and andesine. Microcline is the only feldspar present in the greater-than-2-mm-size fraction and is dominant in the finer fractions. The feldspar content decreases from a maximum of 60 percent in very coarse sand to 7 percent in silt, whereas the quartz content increases roughly in an inverse ratio. The average feldspar content ranges from 20 to 30 percent. According to the classification by Krynine (1948, p. 149), the sandstone would be called arkose, and the finer grained rock, micaceous-chlorite siltstone.

Heavy minerals are more abundant in the finer grain sizes than in the coarser grain sizes; they range from about 1.0 percent in silt to a trace in medium-grained sand. Heavy-mineral separations were made of the fine-grained sand fractions. Less than 0.1 percent heavy minerals precipitated in the bromoform. The specific gravities of both mica and hypersthene, the most abundant of the mafic minerals, bracket that of bromoform (2.87), and they are, therefore, found in both the light and heavy fractions. Minerals in the fine-grained-sand fraction in order of decreasing abundance are:

Light fraction	*Heavy fraction*
Quartz	Chlorite
Microline	Hypersthene
Albite	Zircon
Orthoclase	Muscovite
Oligoclase	Brown biotite
Perthite	Black biotite
Labradorite	Copper-red biotite
Andesine	Tourmaline
Chlorite	Pyrophyllite
Muscovite	Garnet
Clinochlore	Pyrite
Selenite	Epidote
Copper-red biotite	Hornblende
Rose quartz	Biotite with garnet
Brown biotite	Magnetite
Black biotite	
Hypersthene	
Pyrite in quartz	
Stilpnomelane	

The rocks are locally consolidated by cement of several types. The most common cement is calcite, which makes up about 2 to 78 percent of the rocks and averages 6 to 12 percent. The organic paper shale is composed of silt-sized detritus cemented with organic matter. Pyrite-cemented sandstone concretions are common, and the pyrite amounts to as much as 44 percent by weight of the nodules. A pebble conglomerate capping Barren Butte, 14 miles north of the area, was the only silica-cemented rock observed.

Most samples contain only a trace of clay, although clay amounts to 60 percent of one sample and is abundant in four other samples. X-ray determinations (see following table) show that the most common clay mineral in both the fluviatile and lacustrine lower Eocene rocks is illite (hydromica). Kaolinite is also present, as is a minor amount of montmorillonite along the Cyclone Rim, north of the area. A flood of montomorillonite appears in the Morrow Creek member of the Green River formation and in the overlying Bridger formation, both of middle Eocene age. The montmorillonite probably originated from the decomposition of abundant volcanic material in the

X-ray determinations of clay minerals from the Red Desert area, Wyoming, and adjacent regions

[Analysts: A. J. Gude, 3d, and W. F. Outerbridge, both of U.S. Geological Survey]

Formation	Member	Age	Locality	Rock type	Clay mineral
Bridger		Middle Eocene.	Washakie basin.	Tuff	Montmorillonite.
Green River.	Morrow Creek.	do	do	Organic shale	Montmorillonite and illite.
Wasatch	Main body	Early Eocene.	Eagles Nest	do	Illite and kaolinite.
Do	do	do	Painted Bluff.	Fluviatile silty claystone.	Kaolinite, montmorillonite, and illite.
Do	do	do	Eastern Red Desert area.	Weathered albite grains from seven core samples.	Illite.

middle Eocene units. Intensive volcanism also started at this time in the Rattlesnake Hills (Carey, 1954) and in the Absaroka Mountains (Love, 1939) north and west of this area. The potassium feldspar appears unweathered even under the microscope, whereas the plagioclase is apparently altered. The partially altered plagioclase grains were determined by X-ray analyses to be albite and illite.

SOURCE OF SEDIMENTS

The granite of the Granite Mountains and associated basic dikes, which crop out 25 miles north of the area, were examined in thin section to determine their mineralogic composition which was compared with the mineral composition of the sedimentary rocks in the Wasatch and Battle Spring formations derived from them. The samples were from outcrops of the granite or from boulders blasted in mining and were all somewhat weathered. The granite is hypidiomorphic to allotriomorphic granular and has been somewhat sheared, as shown by the undulatory extinction in the quartz and by the cataclastic grain boundaries (fig. 18). Mineralogic composition of the granite is contrasted with arkose by grain counts in thin sections as follows:

Granite of the Granite Mountains

Minerals identified	*Percent*
Microcline (including perthite)	44. 1
Quartz	29. 6
Plagioclase (albite)	22. 9
Chlorite	1. 5
Biotite	. 7
Magnetite	. 6
Muscovite	. 5
Apatite	. 1
Total	100. 0

Battle Spring arkose

Minerals identified	*Percent*
Quartz	50. 7
Microcline (including orthoclase)	37. 0
Plagioclase (albite)	12. 0
Mafic minerals	. 3
Total	100. 0

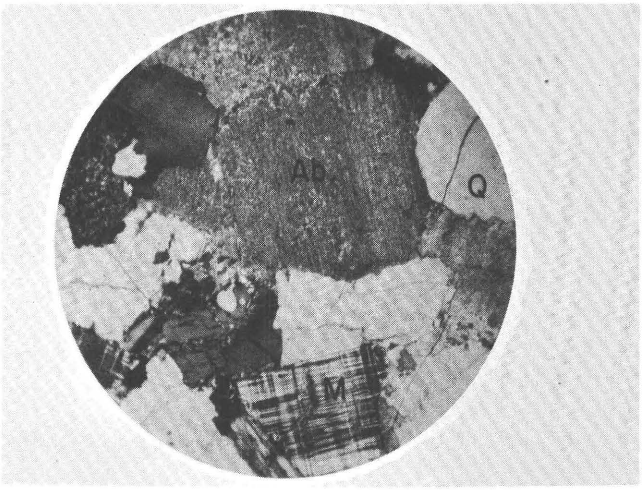

FIGURE 18.—Photomicrograph showing thin section of granite from the Granite Mountains of Precambrian age, the parent rock of the Wasatch and Battle Spring formation. Specimen is from north of Crooks Gap, Fremont County, Wyo. Microcline, *M;* albite, *Ab;* and quartz, *Q*, are dominant. Albite is partly altered to illite(?). × 16. Crossed nicols.

In the granite, phenocrysts of microcline as much as 30 mm in diameter are common, and some are as much as 50 mm in diameter. The albite (An_7) is riddled with well-defined flakelets of sericite. The biotite is partly altered to chlorite. Epidote, zoisite, sphene, leucoxene and allanite are present in small amounts.

The basic dikes were probably basaltic but are so highly altered that the original texture and composition are problematical. They now consist principally of chlorite, epidote, and zoisite with minor magnetite and sphene. The scattered identifiable plagioclase is andesine or labradorite.

SUMMARY OF CHANGES FROM THE GRANITIC SOURCE ROCKS TO ARKOSIC SEDIMENTS

Thin sections of the arkose from near the mountain front are distinguishable from those of the granite only by their noninterlocking texture and by a pasty matrix surrounding the detrital grains (fig. 19). The mineral composition is almost the same as that of the granite, except that several types of calcic plagioclase feldspar, probably derived from the basic dikes, are present. A decrease in grain size accompanies a decrease in the abundance of feldspar—albite diminishes first, then microcline. Heavy minerals increase in abundance in the fine-grained rocks. Clay minerals are not abundant; the finest grained rocks consist dominantly of highly angular quartz and feldspar of silt size.

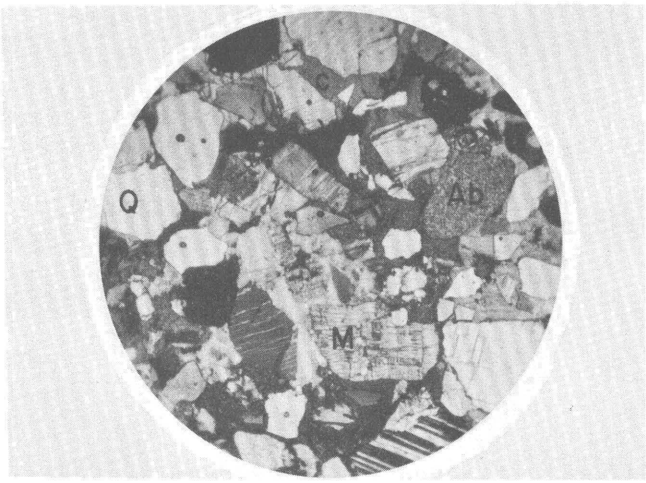

FIGURE 19.—Photomicrograph showing thin section of arkose from the Battle Spring formation of Eocene age south of Crooks Gap, Fremont County, Wyo. The arkose was derived from the granite of the Granite Mountains and shows the similarity in mineralogy to the source rock. Calcite cement, *C*. × 16. Crossed nicols. See figure 18 for explanation of symbols.

The clay minerals—dominantly illite with minor amounts of kaolinite—suggest conditions of weathering and erosion in the source area similar to those proposed by Hooks and Ingram (1955) for the North Carolina arkosic red beds of Triassic age. In those deposits, the predominant illite and clays of the montmorillonite group were derived from deeply dissected, partially weathered bedrock and the less abundant kaolin from more thoroughly weathered parts of the residual mantle. Bradley (1948, p. 641) states that the average rainfall in the Great Divide Basin area during Eocene time may have been 30 to 40 inches and the average temperature about 65° F., as determined from study of the fossil flora.

PERMEABILITY

Permeability studies (see table, p. B–40) were made to investigate the suspected relationship between the uranium content of the coal and related carbonaceous materials and the permeability of the associated clastic rocks. By use of the graph by Krumbein and Sloss (1951), the degree of permeability was computed for 22 of the most common lithotypes from their grain-size distribution. Permeability determined in this manner ranges from 390 to 1.5 millidarcys. Aqueous permeability of 10 clastic rocks and 7 coal samples was determined directly with a permeameter. The permeability of these samples ranges from 3,020 millidarcys for coarse- to medium-grained sandstone to 0.003 millidarcys for silty limestone. Siltstone and limestone were consolidated enough to allow a ¾-inch-diameter core to be cut for insertion into the permeameter. The other clastic rocks were disaggregated and repacked into the permeameter by means of a Johnson shaking table. Because the natural rock texture is broken down when the rock is crushed, the permeability of the disaggregated samples may not be the same as that of the original sample. Permeability of coal, which ranges from 4.93 to 0.022 millidarcys, was determined by using the more sensitive falling-head method. It is difficult to measure permeability of coal because the permeability is low and coal is friable and has a tendency to slake. The higher degrees of permeability probably represent transmission of fluid through desiccation cracks.

Porosity and gas permeability of 13 additional clastic rocks are given in the following table. Effective porosity was determined with a gas-extraction porosimeter and ranges from 7.4 to 29.0 percent. Gas permeability for blocks cut from the undisturbed rock was determined in a permeameter using compressed nitrogen, and ranges from 267 to less than 0.1 millidarcys.

These studies show that the coarse-grained well-sorted arkose is several thousand times as permeable as organic shale and calcareous siltstone and that a small amount of clay or calcareous cement will markedly decrease the permeabillity. The close relaton between uranium content and the permeability of the enclosing sedimentary rocks, both vertically and areally, is discussed in the section on distribution of uranium, pp. B–64 to B–67.

STRUCTURE

The eastern Red Desert area is located in the central part of the Great Divide Basin, which is a structural as well as topographic basin (fig. 1). The Great Divide Basin is separated from the Hanna basin on the east by the Rawlins uplift that extends northward from Rawlins, from the Wind River Basin on the north by the Green and Granite Mountains, from the Green River basin on the west by the Rock Springs uplift that surrounds Rock Springs, and from the Washakie Basin on the south by the eastward-trending Wamsutter arch (pl. 1). The Rawlins and Rocks Springs uplifts are asymmetric folds with the steep limb on the west. Along the north margin of the basin at the Green Mountains, Precambrian granite is thrust to the south across overturned Paleozoic rocks. A series of en echelon folds in the Mesozoic and Tertiary rocks trend N. 50° W. and are truncated by the east-west thrust faults. The folding decreases southward, and the strata in the area are nearly flat lying. In general, the rocks dip about 100 feet per mile, except along faults where drag has produced dips of as much as 25°.

Permeability and porosity of clastic sediments and coal, eastern Red Desert area, Sweetwater County, Wyo.

Computed average permability of 22 lithotypes

[Values computed from graph by Krumbein and Sloss (1951); R. F. Gantnier, analyst]

Description of sample	Permeability (millidarcys)
Sandstone, coarse-grained to very coarse grained	390
Sandstone, calcareous coarse-grained	253
Sandstone, medium- to coarse-grained	148
Sandstone, fine- to coarse-grained	87
Sandstone, calcareous medium- to coarse-grained	68
Sandstone, fine- to medium-grained	54
Sandstone, medium-grained	50
Sandstone, fine-grained, poorly sorted	45
Sandstone, fine-grained	22
Sandstone, silty, fine-grained	21
Sandstone, calcareous fine-grained	16
Sandstone, silty, very fine grained to medium-grained	14
Sandstone, silty, very fine grained	14
Sandstone, very fine grained to fine-grained	14
Sandstone, calcareous, poorly sorted	12
Sandstone, calcareous very fine grained to fine-grained	11
Sandstone, silty, very fine grained to fine-grained	8
Sandstone, very fine grained	8
Sandstone, calcareous silty very fine grained	6
Limestone, silty, sandy	6
Sandy siltstone, calcareous	3
Shale, sandy	1.5

Aqueous permeability of clastic sediments and coal

[Aqueous permeability at 68 °F determined by I. S. McQueen, analyst, U.S. Geological Survey]

Core hole (see geologic map)	Sampled interval (feet)	Description of sample	Permeability (millidarcys)
34	193.9 –194.3	Sandstone, coarse- to medium-grained	3,020
57	120.0 –120.3	Sandstone, well-sorted fine-grained	1,371
53	59.5 – 60.1	Sandstone, coarse-grained	148
17	347.0 –347.2	Sandstone, coarse-grained	121
68	95.5– 96.1	Sandstone, calcareous fine-grained	55
53	198.0– 198.7	Siltstone	33
71	140.0 –140.6	Sandstone, silty clayey medium-grained	10
34	152.6 –153.0	Siltstone, clayey	[1] 8
66	110.0 –110.4	Siltstone, calcareous	[1] .2
59	32.7 –33.3	Limestone, silty	[1] .003
72	103.88–103.98	Coal	[2] 4.93
	102.65–102.74	do	[2] 1.3
	103.98–104.07	do	[2] .55
	104.47–104.58	do	[2] .38
	103.77–103.88	do	[2] .27
	100.50–100.63	do	[2] .27
	101.44–101.54	do	[2] .022

Porosity and gas permeability of clastic sediments

[Determinations supplied by R. F. Gantnier, analyst, U.S. Geological Survey]

Core hole (see geologic map)	Sampled interval (feet)	Description of sample	Porosity (percent) [3]	Permeability (millidarcys) [4]
17	57.0– 57.2	Sandstone, coarse-grained	22.1	267
34	193.9–194.3	Sandstone, medium- to coarse-grained	26.1	106
40	52.0– 52.3	Sandstone, medium-grained	19.3	83
17	22.3– 22.5	Sandstone, fine- to medium-grained	22.1	45.8
30	31.0– 31.3	Sandstone, silty, medium-grained	19.0	41
71	90–1– 90.6	Sandstone, fine-grained	29.0	19.6
26	78.1– 78.3	Sandstone, clayey medium-grained	17.0	19
71	75.6– 76.0	Sandstone, silty, fine-grained	13.0	5
	75.6– 76.0	Sandstone, silty, fine-grained		[5] .9
17	36.0– 36.2	Sandstone, clayey, coarse-grained	7.4	.9
	59.4– 59.5	Shale, organic	15.8	[5] .1
68	29.0– 29.8	Siltstone, calcareous		.1
28	116.3–116.5	Siltstone, clayey	18.8	[5] .1

[1] Permeability determined from sample cut parallel to bedding; other samples of clastic rocks disaggregated and repacked in permeameter using Johnson shaking table.
[2] Permeability of coal samples determined by falling-head method; all other samples determined by constant-head method.
[3] Effective porosities determined in gas-extraction porosimeter.
[4] Gas permeabilities determined in permeameter using compressed nitrogen.
[5] Permeability determined perpendicular to bedding; all other samples determined parallel to bedding.

The Laney Rim (fig. 1), just southwest of the area (Bradley, 1945), and the Eagles Nest Rim to the northwest mark the edges of two basins connected by a shallow trough known as the Red Desert syncline (Schultz, 1920, p. 40). The Red Desert syncline flattens and loses identity where it crosses the broad poorly defined eastward-trending structural high in T. 21 N., named the Wamsutter arch by Schultz (1920, p. 41).

Structure contours on top of a coal bed (Sourdough No. 2), approximately 500 feet below the base of the Tipton tongue of the Green River formation, are shown on plate 1. Two U.S. Geological Survey triangulation stations, four State highway bench marks, and approximately 150 elevation stakes, set by transit during a geophysical survey, furnished basic vertical control. Elevations of the Sourdough coal bed in core and augerholes and on the outcrop were determined by using an altimeter. Along the east and west edges of the area, where the coal beds grade into shale, the contours are less reliable than in the central part.

Two sets of normal faults of small displacement, one trending N. 70° E., the other, N. 45° W., cut the Wasatch and Battle Springs formations. Maximum observed displacement on each set of faults is about 70 feet.

Episodes in the Tertiary structural history of the area are:

1. Thrust faulting in early Eocene time. The Wasatch and Battle Springs formations of early Eocene age apparently were derived from the rising mass of Precambrian grantite involved in the thrust faulting in the Crooks Gap area.
2. Folding in post-middle Eocene and pre-Miocene time. The lower and middle Eocene rocks are affected by the gentle folding that formed the Wamsutter arch, Red Desert syncline, and the Washakie and Niland basins.
3. Large-scale high-angle faulting in post-Miocene or post-Pliocene time. The Miocene rocks, which were deposited across the eroded edges of the older rocks, are dropped to the north along the eastward-trending Cyclone Rim fault zone (fig. 1). Rocks of Miocene and questionable Pliocene age are preserved in the large graben north of the Green Mountains (fig. 1). Post-Pliocene faulting has been reported also in the Saratoga Encampment Valley (fig. 1), southeast of the Red Desert.
4. Small-scale high-angle faulting in Pleistocene and Recent time. The high-angle faults of small displacement within the area seem to cut Recent alluvium and playa deposits in places.

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COAL

OCCURRENCE AND DISTRIBUTION

Coal beds occur throughout the 700-foot thickness of the main body of the Wasatch formation exposed in the eastern Red Desert area. The coal was formed in shore-marginal swamps of the Green River Lake that occupied this area intermittently during Eocene time (Lake Gosiute of Bradley, 1948, p. 640). The coal beds are lenticular, grading into shale within a short distance eastward and more gradually westward. The axis of maximum coal deposition trends northwestward and passes between Creston and Latham stations on the Union Pacific Railroad along the south boundary of the area. The axis of maximum coal deposition gradually shifted basinward (southwestward) with the passage of time. The thickest parts of the younger coals, therefore, lie southwestward from the thickest parts of the older coals. (See restored section, pl. 1.) The beds range in thickness from a few inches to 42 feet and average about 7 feet. They have been grouped into seven principal coal zones, which have been named, from oldest to youngest, Latham, Creston, Hadsell, Larsen, Sourdough, Monument, and Battle. The zones contain from 2 to 5 coal beds in each; the beds are numbered serially starting with number 1 for the oldest bed in each zone. The relative stratigraphic position of the principal coal beds and zones is shown graphically by figure 20. An eighth coal zone, the Luman zone, occurs 440 feet stratigraphically above the Battle coal zone and crops out in the northwest corner of the area.

The thickness and correlation of the principal coal beds penetrated by drill holes are shown in plates 2 to 5, and the beds sampled in outcrop and auger holes shown in plates 6 to 10. Each correlation chart shows drill holes or surface sections and auger holes plotted in lines from west to east across a tier of townships. Plate 2 shows drill holes in Tps. 23 and 24 N., R. 94 W.; plate 3 shows drill holes in T. 22 N., Rs. 92, 93, and 94 W.; plate 4 shows drill holes in Tps. 21 and 22 N., Rs. 92, 93, and 94 W., and so forth. The areal distribution of the principal coal beds is shown on the geologic map (pl. 1). Reserves of coal in each township are shown on maps in figures 36 to 70 and reserves of carbonaceous shale in figures 71 and 72.

DESCRIPTION OF COAL ZONES

The thickest coal bed in the area, the Creston No. 2 bed, is 42 feet thick in drill hole 64 (pls. 1, 5). The bed extends for about 5 miles to the west, maintaining a thickness of about 20 feet. Individual beds in the other coal zones are as thick as 20 feet at several places in the area. Brief descriptions of the distribution of coal in the principal zones follow:

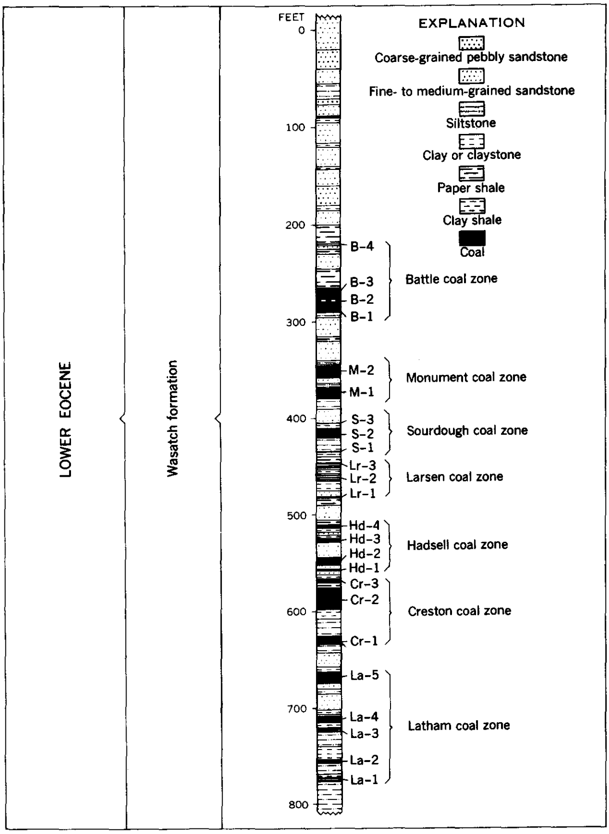

FIGURE 20.—Composite columnar section showing stratigraphic position (pl. 1) of principal coal zones.

LATHAM COAL ZONE

The stratigraphically lowest coal zone in the main body of the Wasatch formation exposed in the area is the Latham zone. It crops out in T. 20 N., Rs. 92 and 93 W., near Latham station on the Union Pacific Railroad. As exposures are few, only two surface sections of beds were measured. Auger and core holes penetrate the zone in an area extending about 6 miles north of the outcrop. The Latham zone comprises five beds of coal within a stratigraphic interval of about 120 feet. The correlation of the lenticular coal beds depends largely on establishing their stratigraphic intervals below the persistent Creston No. 2 coal bed. Latham No. 3 bed and No. 4 bed were grouped together in calculating reserves. Both beds are lenticular, but only one or the other is present in the individual drill holes penetrating the zone. The maximum thickness of the coal is about 20 feet, as measured in core hole 49. The combined beds maintain a thickness of 2.5 feet to 5 feet for an east-west distance of about 12 miles along U.S. Highway 30. Latham No. 5 coal bed is 5 feet thick in core hole 62, but it is not present in adjacent drill holes. Heating values of coal in the Latham zone range from 6,270 to 8,870 Btu (as received).

CRESTON COAL ZONE

The thick and persistent coal beds of the Creston zone overlie the Latham zone and crop out extensively in T. 20 N., Rs. 92 and 93 W., west of Creston Ridge. The Creston No. 2 bed and No. 3 bed were grouped together in calculating reserves. The combined coal beds are about 42 feet thick in core hole 64 and maintain a thickness of about 20 feet for 5 miles to the west. To the east, the coal grades into a few thin beds of carbonaceous shale within a distance of about 2 miles. In core hole 49, 5 miles north of the outcrop, the Creston No. 2 coal bed is 31 feet thick. The Creston No. 2 bed has burned at several places and forms prominent masses of red clinker directly north of U.S. Highway 30. Heating values of the coal range from 7,310 to 8,710 Btu (as received). Separate reserves were calculated for the Creston No. 3 bed underlying Creston Ridge, as the impure coal has an unusually high uranium content at locality 209.

HADSELL COAL ZONE

Overlying the Creston zone is the Hadsell zone, which is exposed near the Hadsell Ranch, and crops out at places in Tps. 20 to 24 N., Rs. 93 and 94 W. The Hadsell zone comprises four coal beds within a stratigraphic interval of 60 to 80 feet. For reserve computations the Hadsell No. 1 bed was combined with the No. 2 bed. The combined beds are 2½ to 5 feet thick in most of T. 21 N., R. 93 W., and are about 17 feet thick in the central part of the township. The Hadsell No. 3 bed was combined with the No. 4 bed for computing reserves; the combined thickness of these coal beds is less than 5 feet in the southern half of the area. Beds of impure coal and carbonaceous shale correlated with the Hadsell zone crop out locally in the northern part of the area and are useful for structural control. Heating values of the coal range from 6,900 to 7,700 Btu (as received).

LARSEN COAL ZONE

The Larsen coal zone underlies the area directly south of the Larsen Ranch and crops out at many places in Tps. 20 and 21 N., Rs. 93 and 94 W. The zone includes three beds within a stratigraphic interval of 60 to 90 feet. There is an increase in the thickness of the stratigraphic interval, including the Larsen zone in the core holes along the southern margin of Monument Lake flat (pl. 4). The position of the thicker stratigraphic section coincides with the axis of maximum coal deposition in the overlying Sourdough No. 2 bed.

The coal beds are thin and impure; only two small areas are underlain by a coal bed more than 2½ feet thick. (See locs 140, 142, 144, and 163, pls, 9, 10). The only available heating value for the coal in this zone is 7,760 Btu (as received).

SOURDOUGH COAL ZONE

The exposure of the Sourdough coal zone at Sourdough Butte was the first uranium-bearing coal locality described in the eastern Red Desert area. The Sourdough zone is well exposed at many localities and underlies large parts of the southwestern half of the area. Three coal beds are included in the zone in a stratigraphic interval of about 30 feet. The Sourdough No. 1 and No. 3 beds are thin, impure, and very local in occurrence. The No. 2 bed, which is known as the Tierney No. 5 bed in the western part of the Red Desert area, is as much as 12 feet thick along the axis of maximum deposition and thins to the east and west. In core holes 11, 14, and 23, in T. 23 N., R. 94 W., the stratigraphic interval between the Sourdough No. 2 bed and the overlying Monument No. 1 bed thins from 45 feet to 10 feet. To the south, the Sourdough and Monument zones are distinguishable in core hole 40. Eastward, from hole 40, however, only one bed is present; it represents the coalesced Sourdough and Monument zones. In the southern part of Battle Spring flat the stratigraphic position of the Sourdough zone is occupied by very coarse grained cross-laminated arkose. Small fragments of coal lie along the planes bounding the laminae. This unit may represent stream-channel deposits formed during penecontemporaneous erosion of the carbonaceous sequence. Heating values of the coal range from 7,010 to 9,040 Btu (as received), except in the weathered near-surface coal, which has a value as low as 4,440 Btu (as received).

MONUMENT COAL ZONE

The next higher coal zone underlies the west-central part of the area. The Monument zone comprises two coal beds within a stratigraphic interval of about 40 feet. The Monument No. 1 bed is about 9 feet thick in core hole 11 (sec. 27, T. 23 N., R. 94 W.) and extends northward for 5 miles in an elongate mass about 3 miles wide. The Monument No. 1 bed is separated from the overlying No. 2 bed by 11 feet of sandstone and carbonaceous siltstone in core hole 11. To the northwest, the beds coalesce and include more than 20 feet of coal in core hole 17. The Monument No. 2 bed grades into carbonaceous shale within about 1 mile to the east but persists southward for more than 8 miles and maintains a thickness of about 11 feet. Carbonaceous shale, correlated with the Monument No. 2 bed, is unconformably overlain by conglomerate of Miocene (?) age along Creston

Ridge, north of the microwave station. Heating values for the coal range from 6,970 to 9,590 Btu (as received). Where the bed is weathered the heating value is only 3,830 Btu (as received).

BATTLE COAL ZONE

The stratigraphically highest coal zone for which reserves were calculated is the Battle zone. It underlies the area near triangulation station Divide and the southwest margin of Battle Spring flat. The Battle zone comprises four beds in a stratigraphic interval of about 90 feet. The Battle No. 1 and No. 4 beds are very thin and impure. The Battle No. 2 and No. 3 beds were grouped together in calculating reserves. The combined thickness of the beds in core hole 10 is more than 21 feet, but they grade into a thin carbonaceous shale a short distance to the northeast in core hole 22. The Battle No. 3 bed is about 11 feet thick in core hole 39 and thins to 5 feet in a mile to the southwest. To the east it grades to a few thin beds of carbonaceous shale in about 3 miles. Heating values of the coal range from 8,100 to 9,750 Btu (as received).

LUMAN COAL ZONE

The Luman coal zone lies about 440 feet stratigraphically above the Battle zone. An 8-inch-diameter core of the Luman No. 1 bed from a hole drilled half a mile west of the area was cut for a study of coal utilization and petrographic investigation. The thickness and ash content of the coal from this core are shown in figure 24. Reserves of coal in the Luman zone occur west of the area and are reported by Masursky and Pipiringos (1959). A thin impure coal bed, tentatively correlated with the Luman No. 1 bed, crops out in the northwest corner of the area.

PHYSICAL AND CHEMICAL CHARACTER

The coal in the eastern Red Desert area is black and thick to thin banded; commonly it has conchoidal fracture, vitreous luster, and a brown streak. Upon exposure to air it first checks, then slacks to small chips. If the coal is dried slowly away from direct sunlight, it will check but will not slack. Hand specimens of the coal were relatively coherent 2 years after collection but broke into rectangular blocks, approximately 1.0 by 2.5 by 3.5 inches.

The coal beds are poorly exposed (fig. 21), forming smooth slopes, except where a resistant caprock holds up a near-vertical face or at blowouts where wind keeps the exposure clean. A truck-mounted power auger was used to confirm the presence of coal beds in areas of poor exposure. Cleats and fractures in the coal are commonly filled with gypsum, $CaSO_4 \cdot 2H_2O$, and jarosite, $KFe_3(OH)_6(SO_4)_2$.

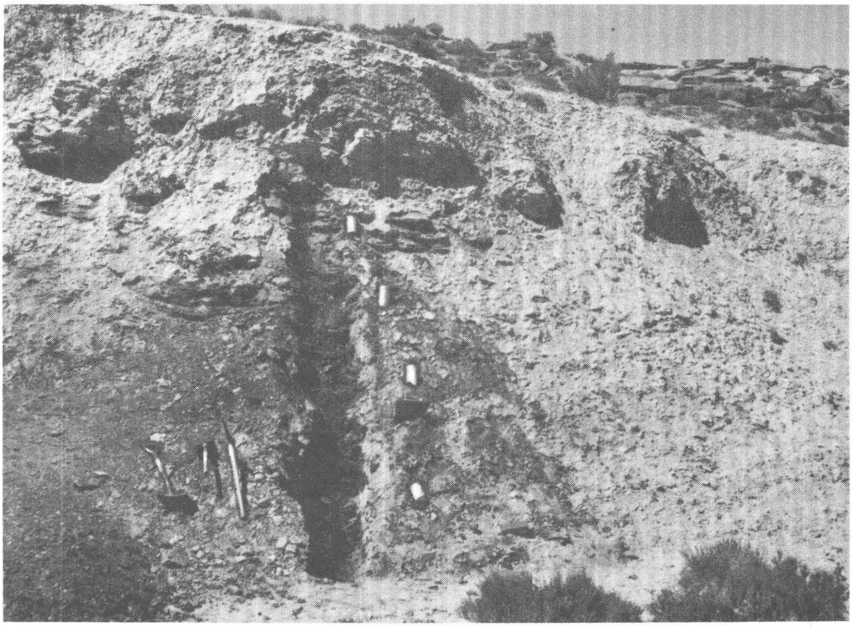

FIGURE 21.—Channel through 16-foot-thick Creston coal bed (loc. 193, pl. 1). Sample intervals are indicated by quart containers.

Tschermigite, $NH_4Al(SO_4)_2 \cdot 12H_2O$, is associated with the Sourdough No. 2 bed along the south side of Twelve Mile Hole and Monument Lake flat. Hydrous magnesium sulphate, some which is epsomite, $MgSO_4 \cdot 7H_2O$, and hexahydrite, $MgSO_4 \cdot 6H_2O$, is associated with the Latham No. 4 bed near U.S. Highway 30. Pyrite, FeS_2, is commonly found in the cores of unweathered coal. On the outcrop the pyrite is generally altered to limonite (hydrous iron oxides) or hematite, Fe_2O_3.

Table 2 lists 103 proximate and 16 ultimate fuel analyses made by the U.S. Bureau of Mines on coal from cores. The average "as received" heating value is about 7,900 Btu, average ash content is 16 percent, average sulfur content is 2.5 percent, and average moisture content is 21 percent. These values vary widely since some of the samples are from impure coal beds and others are from weathered beds. Calculations using the Parr formula (American Society for Testing Materials, 1938) show that the coal is subbituminous B in rank.

Analyses of coal from cores, made by the U.S. Geological Survey Washington laboratory and given in table 3, show that the coal yields from 7.8 to 25.2 gallons of oil per ton by the Fischer assay method.

TABLE 2.—*Analyses of coal from cores, Red Desert area, Sweetwater County, Wyo.*

[Condition: 1, as received; 2, moisture-free; 3, moisture- and ash-free. Volatile matter: determined by modified method. Analyses supplied by U.S. Bureau of Mines, Central Experiment Station, Pittsburgh, Pa., Roy F. Abernathy, chemist in charge]

Core hole	Sample	Specific gravity	Ash-softening temperature (°F)	Thickness of coal (feet)	Condition	Proximate: Moisture	Proximate: Volatile matter	Proximate: Fixed carbon	Proximate: Ash	Ultimate: Hydrogen	Ultimate: Carbon	Ultimate: Nitrogen	Ultimate: Oxygen	Ultimate: Sulfur	Forms of sulfur: Sulfate	Forms of sulfur: Pyritic	Forms of sulfur: Organic	Heating value (Btu)
Battle No. 3 coal bed																		
10	D-98226	1.49	--	6.9	1	20.7	32.8	37.0	9.5	--	--	--	--	1.2	--	--	--	9,180
					2	--	41.3	46.7	12.0	--	--	--	--	1.5	--	--	--	11,570
					3	--	47.0	53.0	--	--	--	--	--	1.8	--	--	--	13,150
	98227	1.56	--	2.5	1	18.3	30.9	35.8	15.0	5.6	49.0	0.9	26.6	2.9	0.10	2.10	0.70	8,660
					2	--	37.8	43.9	18.3	4.4	60.0	1.1	12.7	3.5	.13	2.57	.85	10,590
					3	--	46.3	53.7	--	5.3	73.4	1.3	15.7	4.3	.15	3.14	1.04	12,970
	98228	1.55	--	2.2	1	18.4	31.1	34.3	16.2	--	--	--	--	1.6	--	--	--	8,500
					2	--	38.2	42.0	19.8	--	--	--	--	1.9	--	--	--	10,420
					3	--	47.6	52.4	--	--	--	--	--	2.4	--	--	--	13,000
	98229	1.53	--	2.8	1	21.9	29.9	37.0	11.2	--	--	--	--	1.9	--	--	--	8,650
					2	--	38.3	47.3	14.4	--	--	--	--	2.5	--	--	--	11,080
					3	--	44.7	55.3	--	--	--	--	--	2.9	--	--	--	12,930
Monument No. 2 coal bed																		
10	D-98230	1.52	--	2.5	1	20.8	31.1	38.8	9.3	--	--	--	--	1.6	--	--	--	9,190
					2	--	39.2	49.0	11.8	--	--	--	--	2.0	--	--	--	11,600
					3	--	44.5	55.5	--	--	--	--	--	2.2	--	--	--	13,150
	98231	1.48	--	5.4	1	20.2	32.4	37.6	9.8	6.1	52.5	1.1	29.1	1.4	0.03	0.65	0.71	9,290
					2	--	40.6	47.1	12.3	4.8	65.9	1.4	13.9	1.7	.04	.82	.89	11,650
					3	--	46.3	53.7	--	5.4	75.1	1.6	15.9	2.0	.04	.93	1.01	13,280
Battle No. 3 coal bed																		
11	D-98232	1.57	--	3.4	1	23.2	30.6	33.4	12.8	--	--	--	--	2.8	--	--	--	8,100
					2	--	39.9	43.5	16.6	--	--	--	--	3.6	--	--	--	10,550
					3	--	47.9	52.1	--	--	--	--	--	4.4	--	--	--	12,660

								Monument No. 2 coal bed										
11	D-98233----	1.53	----------	2.1	1	22.1	30.9	33.9	13.1	--------	--------	--------	--------	1.5	--------	--------	--------	8,450
					2	--------	39.7	43.4	16.9	--------	--------	--------	--------	1.9	--------	--------	--------	10,860
					3	--------	47.7	52.3	--------	--------	--------	--------	--------	2.2	--------	--------	--------	13,060
								Monument No. 1 coal bed										
11	D-98234----	1.68	----------	5.8	1	12.2	27.6	28.8	31.4	--------	--------	--------	--------	1.8	0.06	1.25	0.53	6,970
					2	--------	31.4	32.8	35.8	--------	--------	--------	--------	2.1	.07	1.43	.60	7,940
					3	--------	49.0	51.0	--------	--------	--------	--------	--------	3.3	.10	2.23	.93	12,370
								Sourdough No. 2 coal bed										
11	D-98235----	1.49	----------	1.8	1	22.5	31.6	37.4	8.5	--------	--------	--------	--------	1.8	--------	--------	--------	9,040
					2	--------	40.7	48.4	10.9	--------	--------	--------	--------	2.4	--------	--------	--------	11,660
					3	--------	45.7	54.3	--------	--------	--------	--------	--------	2.7	--------	--------	--------	13,100
	98236----	1.53	----------	4.5	1	10.1	41.6	36.4	11.9	5.8	50.4	1.0	27.9	3.0	0.05	2.25	0.73	8,970
					2	--------	46.2	40.5	13.3	5.2	56.0	1.1	21.0	3.4	.06	2.51	.82	9,980
					3	--------	53.3	46.7	--------	6.0	64.6	1.3	24.2	3.9	.07	2.89	.94	11,510
12	E-19214----	----------	----------	1.3	1	22.0	29.9	37.1	11.0	--------	--------	--------	--------	3.2	--------	--------	--------	8,600
					2	--------	38.4	47.5	14.1	--------	--------	--------	--------	4.1	--------	--------	--------	11,030
					3	--------	44.7	55.3	--------	--------	--------	--------	--------	4.8	--------	--------	--------	12,840
								Monument No. 2 coal bed										
13	E-18649----	----------	2,080	4.9	1	22.2	30.8	38.4	8.6	6.1	52.0	0.7	31.2	1.4	0.15	0.40	0.81	9,020
					2	--------	39.6	49.4	11.0	4.6	66.8	.9	14.9	1.8	.20	.52	1.04	11,580
					3	--------	44.5	55.5	--------	5.2	75.0	1.1	16.7	2.0	.22	.58	1.17	13,010
								Monument No. 1 coal bed										
16	E-22088----	----------	2,320	1.7	1	21.5	29.7	32.3	16.5	--------	--------	--------	--------	2.4	--------	--------	--------	7,640
					2	--------	37.9	41.1	21.0	--------	--------	--------	--------	3.0	--------	--------	--------	9,720
					3	--------	47.9	52.1	--------	--------	--------	--------	--------	3.8	--------	--------	--------	12,300
								Sourdough No. 2 coal bed										
17	E-22089----	----------	----------	2.2	1	19.5	31.6	38.2	10.7	--------	--------	--------	--------	3.3	--------	--------	--------	8,910
					2	--------	39.3	47.4	13.3	--------	--------	--------	--------	4.2	--------	--------	--------	11,070
					3	--------	45.3	54.7	--------	--------	--------	--------	--------	4.8	--------	--------	--------	12,770

TABLE 2.—*Analyses of coal from cores, Red Desert area, Sweetwater County, Wyo.*—Continued

Core hole	Sample	Specific gravity	Ash-softening temperature (°F)	Thickness of coal (feet)	Condition	Proximate				Ultimate					Forms of sulfur			Heating value (Btu)
						Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Sulfate	Pyritic	Organic	
Battle No. 3 coal bed																		
17	E–22090			4.0	1	18.8	31.0	38.7	11.5					2.1				9,080
					2		38.2	47.6	14.2					2.6				11,180
					3		44.5	55.5						3.0				13,030
Monument No. 1 coal bed																		
17	E–22091			5.3	1	18.7	32.1	40.9	8.3					1.2				9,590
					2		39.5	50.3	10.2					1.5				11,790
					3		44.0	56.0						1.7				13,130
	22092		2,310	4.6	1	18.2	32.7	38.3	10.8	6.0	52.9	0.9	27.8	1.6				9,310
					2		40.0	46.8	13.2	4.8	64.7	1.1	14.2	2.0				11,390
					3		46.0	54.0		5.6	74.6	1.2	16.3	2.3				13,120
Battle No. 3 coal bed																		
18	E–18718		2,180	5.3	1	19.1	33.3	40.7	6.9					0.9	0.03	0.19	0.70	9,750
					2		41.2	50.3	8.5					1.1	.04	.23	.87	12,050
					3		45.0	55.0						1.2	.04	.25	.95	13,180
	18719		2,110	1.2	1	19.1	31.8	36.3	12.8					2.8	.20	1.82	.78	8,680
					2		39.3	44.9	15.8					3.5	.24	2.24	.97	10,730
					3		46.6	53.4						4.1	.29	2.67	1.15	12,750
	18720		2,240	2.0	1	18.6	29.8	35.0	16.6					2.3	0.18	1.23	0.98	8,210
					2		36.6	43.0	20.4					2.8	.22	1.51	1.12	10,090
					3		45.9	54.1						3.6	.28	1.89	1.41	12,670
Monument No. 2 coal bed																		
18	E–19972		2,390	8.2	1	16.6	33.3	37.7	12.4					1.3	0.05	0.52	0.73	9,270
					2		39.9	45.2	14.9					1.6	.06	.63	.88	11,110
					3		46.9	53.1						1.8	.07	.74	1.03	13,060

Monument No. 1 coal bed

19	E-19973	--------	2,630	6.4	1	16.8	27.3	25.8	30.1	--------	--------	--------	--------	2.1	0.17	1.23	0.66	6,680
					2	--------	32.8	31.1	36.1	--------	--------	--------	--------	2.5	.21	1.47	.79	8,030
					3	--------	51.3	48.7	--------	--------	--------	--------	--------	3.9	.32	2.31	1.24	12,570

Sourdough No. 2 coal bed

19	E-19974	--------	2,760	3.7	1	15.2	28.7	27.3	28.8	--------	--------	--------	--------	2.0	0.11	1.24	0.69	7,010
					2	--------	33.8	32.3	33.9	--------	--------	--------	--------	2.4	.13	1.46	.81	8,260
					3	--------	51.2	48.8	--------	--------	--------	--------	--------	3.6	.20	2.21	1.23	12,500

Monument No. 2 coal bed

22	E-19975	--------	2,560	4.6	1	17.5	30.5	32.2	19.8	--------	--------	--------	--------	1.6	0.12	0.82	0.64	8,070
					2	--------	37.0	39.0	24.0	--------	--------	--------	--------	1.9	.15	1.00	.77	9,780
					3	--------	48.7	51.3	--------	--------	--------	--------	--------	2.5	.20	1.32	1.01	12,870

Monument No. 1 coal bed

22	E-19976	--------	2,230	6.1	1	18.8	31.6	35.7	13.9	--------	--------	--------	--------	2.0	0.17	1.08	0.72	8,750
					2	--------	38.9	44.0	17.1	--------	--------	--------	--------	2.4	.20	1.33	.88	10,770
					3	--------	46.9	53.1	--------	--------	--------	--------	--------	2.9	.24	1.60	1.07	12,990

Monument No. 2 coal bed

24	E-22093	--------	--------	3.4	1	20.0	31.5	38.0	10.5	6.1	52.2	0.8	28.7	1.7	--------	--------	--------	9,130
					2	--------	39.4	47.5	13.1	4.8	65.3	.9	13.8	2.1	--------	--------	--------	11,410
					3	--------	45.3	54.7	--------	5.5	75.1	1.1	15.9	2.4	--------	--------	--------	13,130

Monument No. 1 coal bed

24	E-22094	--------	2,490	2.0	1	16.7	29.5	31.5	22.3	--------	--------	--------	--------	3.0	--------	--------	--------	7,840
					2	--------	35.4	37.8	26.8	--------	--------	--------	--------	3.6	--------	--------	--------	9,410
					3	--------	48.4	51.6	--------	--------	--------	--------	--------	4.9	--------	--------	--------	12,850

TABLE 2.—*Analyses of coal from cores, Red Desert area, Sweetwater County, Wyo.*—Continued

Core hole	Sample	Specific gravity	Ash-softening temperature (°F)	Thickness of coal (feet)	Condition	Proximate				Ultimate					Forms of sulfur			Heating value (Btu)
						Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Sulfate	Pyritic	Organic	
Sourdough-Monument coal bed																		
29	E-22212		2,340	4.2	1	21.0	29.2	30.8	19.0					1.9	0.77	0.40	0.70	7,370
					2		36.9	39.1	24.0					2.4	.97	.51	.89	9,320
					3		48.6	51.4						3.1	1.28	.67	1.17	12,270
31	22095		2,330	8.9	1	23.8	28.7	28.4	19.1					2.3				7,210
					2		37.7	37.2	25.1					3.1				9,460
					3		50.3	49.7						4.1				12,620
32	23179			3.0	1	23.5	29.1	33.7	13.7					2.8				7,950
					2		38.1	44.0	17.9					3.7				10,390
					3		46.3	53.7						4.5				12,650
	23180		2,200	5.9	1	25.8	31.7	34.0	8.5	6.5	48.3	1.1	33.8	1.8	.04	.87	.85	8,580
					2		42.7	45.8	11.5	4.9	65.0	1.5	14.7	2.4	.05	1.17	1.14	11,570
					3		48.3	51.7		5.5	73.5	1.7	16.6	2.7	.06	1.32	1.29	13,070
Monument No. 2 coal bed																		
34	E-23181			4.2	1	23.8	31.7	35.0	9.5					2.4				8,650
					2		41.6	46.0	12.4					3.1				11,350
					3		47.5	52.5						3.6				12,960
38	22210		2,640	3.0	1	34.0	25.0	16.9	24.1					1.8				3,830
					2		37.9	25.5	36.6					2.7				5,800
					3		59.7	40.3						4.3				9,140
	22211		2,190	4.7	1	25.7	29.7	32.8	11.8					2.0				8,020
					2		40.0	44.1	15.9					2.7				10,810
					3		47.6	52.4						3.2				12,860
Battle No. 3 coal bed																		
40	E-23609			4.0	1	25.3	31.1	35.5	8.1					2.3				8,580
					2		41.7	47.5	10.8					3.1				11,480
					3		46.7	53.3						3.5				12,860

Monument No. 2 coal bed

40	E-23610			9.1	1	20.7	33.1	35.9	10.3					2.7				8,820
					2		41.8	45.2	13.0					3.4				11,120
					3		48.0	52.0						3.9				12,780

Sourdough No. 2 coal bed

40	E-23611			7.3	1	23.2	33.6	33.0	10.2					2.9				8,680
					2		43.7	43.1	13.2					3.8				11,310
					3		50.4	49.6						4.4				13,040

Monument No. 2 coal bed

43	E-24660			10.3	1	24.5	33.0	31.7	10.8					2.8				8,160
					2		43.8	41.9	14.3					3.6				10,820
					3		51.0	49.0						4.3				12,620

Sourdough No. 2 coal bed

43	E-24661	1.53		10.6	1	24.0	32.4	30.5	13.1	6.1	45.8	1.3	30.5	3.2	0.11	2.04	1.01	8,170
					2		42.6	40.2	17.2	4.5	60.3	1.6	12.2	4.2	.15	2.69	1.33	10,750
					3		51.5	48.5		5.5	72.8	2.0	14.7	5.0	.18	3.25	1.61	12,980
45	23466		2,110	2.1	1	27.8	29.7	30.3	12.2					2.3				7,130
					2		41.2	41.8	17.0					3.1				9,880
					3		49.6	50.4						3.8				11,900
	23467		2,110	3.2	1	26.3	32.6	32.5	8.6					1.5				8,630
					2		44.2	44.2	11.6					2.0				11,700
					3		50.1	49.9						2.3				13,250
	23468		2,000	4.1	1	24.3	32.3	31.5	11.9					4.3				8,350
					2		42.6	41.7	15.7					5.7				11,030
					3		50.5	49.5						6.7				13,080

Hadsell No. 4 coal bed

45	E-23469		1,980	3.4	1	23.1	30.4	29.8	16.7					6.0				7,770
					2		39.5	38.9	21.6					7.8				10,100
					3		50.4	49.6						10.0				12,890

TABLE 2.—*Analyses of coal from cores, Red Desert area, Sweetwater County, Wyo.*—Continued

Core hole	Sample	Specific gravity	Ash-softening temperature (°F)	Thickness of coal (feet)	Condition	Proximate: Moisture	Proximate: Volatile matter	Proximate: Fixed carbon	Proximate: Ash	Ultimate: Hydrogen	Ultimate: Carbon	Ultimate: Nitrogen	Ultimate: Oxygen	Ultimate: Sulfur	Forms of sulfur: Sulfate	Forms of sulfur: Pyritic	Forms of sulfur: Organic	Heating value (Btu)
Sourdough No. 2 coal bed																		
47	E-24663		2,050	4.6	1	25.2	31.0	31.1	12.7					4.5				8,000
					2		41.5	41.6	16.9					6.0				10,690
					3		49.9	50.1						7.2				12,860
	24664		2,070	3.8	1	26.5	32.4	30.1	11.0					2.5				8,160
					2		44.1	40.9	15.0					3.3				11,100
					3		51.9	48.1						3.9				13,060
Hadsell No. 4 coal bed																		
47	E-23470		2,020	3.2	1	22.4	27.6	26.6	23.4					5.7				6,900
					2		35.6	34.2	30.2					7.3				8,890
					3		51.1	48.9						10.5				12,740
Hadsell No. 2 coal bed																		
49	E-25610		2,320	3.3	1	35.7	24.2	26.8	13.3					1.3				6,510
					2		37.6	41.7	20.7					2.1				10,120
					3		47.3	52.7						2.6				12,760
Creston No. 2 coal bed																		
49	E-25611			11.5	1	20.7	32.2	34.4	12.7	6.0	49.8	1.1	28.6	1.8				8,710
					2		40.6	43.4	16.0	4.7	62.8	1.3	12.9	2.3				10,980
					3		48.4	51.6		5.6	74.7	1.6	15.4	2.7				13,070
	25612			2.9	1	21.4	30.2	33.9	14.5					2.3				8,170
					2		38.4	43.1	18.5					2.9				10,400
					3		47.1	52.9						3.6				12,750
	25613			1.6	1	20.2	30.0	32.9	16.9									
					2		37.6	41.3	21.1									
					3		47.6	52.4										
	25614			6.2	1	22.4	30.2	35.8	11.6					1.7				8,630
					2		39.0	46.1	14.9					2.1				11,120
					3		45.8	54.2						2.5				13,080

49	E-25615			4.3	1	20.7	32.9	36.1	10.3									
					2		41.5	45.4	13.1									
					3		47.7	52.3										
	25616			10.4	1	19.8	31.8	36.4	12.0					2.0				8,870
					2		39.7	45.4	14.9					2.6				11,060
					3		46.6	53.4						3.0				13,000
Sourdough No. 2 coal bed																		
50	E-26284			2.2	1	27.8	33.6	32.1	6.5					1.8				8,020
					2		46.6	44.4	9.0					2.5				11,110
					3		51.2	48.8						2.8				12,210
Hadsell No. 4 coal bed																		
51	E-24662		2,020	2.8	1	22.5	30.5	28.4	18.6					5.7				7,570
					2		39.3	36.7	24.0					7.3				9,760
					3		51.7	48.3						9.6				12,830
Sourdough No. 2 coal bed																		
51	E-24665		2,190	5.8	1	41.4	27.4	17.6	13.6					1.2				4,440
					2		46.8	30.0	23.2					2.0				7,570
					3		60.9	39.1						2.6				9,860
Hadsell No. 1 coal bed																		
53	E-27439		2,220	2.1	1	18.0	26.5	24.4	31.1					3.8				6,320
					2		32.4	29.7	37.9					4.6				7,710
					3		52.1	47.9						7.4				12,420
Hadsell No. 2 coal bed																		
53	E-27440			2.8	1	23.0	31.0	32.2	13.8					2.7				8,250
					2		40.2	41.9	17.9					3.5				10,720
					3		48.9	51.1						4.3				13,050
Sourdough No. 2 coal bed																		
53	E-27441		2,050	4.8	1	24.0	31.0	32.1	12.9					3.2				7,910
					2		40.7	42.3	17.0					4.2				10,410
					3		49.1	50.9						5.0				12,540

TABLE 2.—*Analyses of coal from cores, Red Desert area, Sweetwater County, Wyo.*—Continued

Core hole	Sample	Specific gravity	Ash-softening temperature (°F)	Thickness of coal (feet)	Condition	Proximate				Ultimate					Forms of sulfur			Heating value (Btu)
						Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Sulfate	Pyritic	Organic	
Hadsell No. 1 coal bed																		
55	E-25607		2,040	3.0	1	26.8	26.2	30.3	16.7					3.1	0.06	1.93	1.09	7,230
					2		35.8	41.4	22.8					4.2	.08	2.63	1.49	9,870
					3		46.4	53.6						5.4	.10	3.41	1.93	12,780
Larsen No. 2 coal bed																		
55	E-25389		2,130	1.0	1	24.6	30.5	28.7	16.2					3.0	0.06	2.28	0.63	7,760
					2		40.4	38.2	21.4					3.9	.08	3.03	.84	10,280
					3		51.5	48.5						5.0	.10	3.85	1.07	13,090
Larsen No. 3 coal bed																		
55	E-25390		2,060	2.0	1	19.4	28.7	25.3	26.6					5.3	0.09	4.49	0.70	6,720
					2		35.6	31.4	33.0					6.5	.11	5.56	.87	8,340
					3		53.1	46.9						9.8	.16	8.30	1.29	12,440
Sourdough No. 2 coal bed																		
55	E-25391		2,870	1.6	1	19.8	16.1	9.0	55.1					1.9	0.63	1.01	0.22	
					2		20.1	11.3	68.1					2.3	.79	1.26	.27	
	25392		2,090	3.4	1	24.6	30.4	29.3	15.7					3.7	0.18	2.75	0.80	7,700
					2		40.3	38.9	20.8					4.9	.23	3.65	1.06	10,210
					3		50.9	49.1						6.2	.30	4.61	1.34	12,890
59	25608		2,040	2.3	1	25.9	30,3	29.1	14.7					4.4	.23	3.07	1.14	7,570
					2		40.9	39.2	19.9					6.0	.31	4.15	1.55	10,220
					3		51.1	48.9						7.5	.39	5.18	1.93	12,760
	25609		2,190	3.0	1	26.4	26.5	25.4	21.7					2.2	.28	1.13	.77	6,200
					2		36.0	34.5	29.5					3.0	.38	1.53	1.05	8,430
					3		51.0	49.0						4.2	.53	2.17	1.48	11,950

Hadsell No. 3 coal bed

59	E-26285	----------	2,060	1.7	1	21.7	28.1	27.1	23.1	--------	--------	--------	--------	7.2	--------	--------	--------	6,810
					2	--------	35.9	34.6	29.5	--------	--------	--------	--------	9.2	--------	--------	--------	8,700
					3	--------	50.9	49.1	--------	--------	--------	--------	--------	13.1	--------	--------	--------	12,340

Hadsell No. 2 coal bed

59	E-26286	----------	2,180	2.0	1	18.8	22.0	19.3	39.9	--------	--------	--------	--------	4.4	--------	--------	--------	4,960
					2	--------	27.1	23.7	49.2	--------	--------	--------	--------	5.4	--------	--------	--------	6,110
					3	--------	53.4	46.6	--------	--------	--------	--------	--------	10.6	--------	--------	--------	12,020

Hadsell No. 1 coal bed

59	E-26287	----------	2,120	3.0	1	21.3	28.5	27.1	23.1	--------	--------	--------	--------	3.9	--------	--------	--------	6,890
					2	--------	36.2	34.5	29.3	--------	--------	--------	--------	5.0	--------	--------	--------	8,760
					3	--------	51.2	48.8	--------	--------	--------	--------	--------	7.0	--------	--------	--------	12,400

Creston No. 3 coal bed

59	E-26288	----------	2,010	4.2	1	31.7	26.8	24.8	16.7	--------	--------	--------	--------	4.5	--------	--------	--------	6,630
					2	--------	39.3	36.3	24.4	--------	--------	--------	--------	6.6	--------	--------	--------	9,700
					3	--------	51.9	48.1	--------	--------	--------	--------	--------	8.7	--------	--------	--------	12,830

Creston No. 2 coal bed

59	E-26289	----------	1,990	5.0	1	24.6	30.8	37.6	7.0	--------	--------	--------	--------	1.3	--------	--------	--------	8,950
					2	--------	40.8	49.9	9.3	--------	--------	--------	--------	1.8	--------	--------	--------	11,860
					3	--------	45.0	55.0	--------	--------	--------	--------	--------	1.9	--------	--------	--------	13,080
	26290	----------	2,170	5.0	1	32.8	28.8	31.2	7.2	--------	--------	--------	--------	1.2	--------	--------	--------	7,840
					2	--------	42.9	46.3	10.8	--------	--------	--------	--------	1.8	--------	--------	--------	11,660
					3	--------	48.0	52.0	--------	--------	--------	--------	--------	2.1	--------	--------	--------	13,060
	26291	----------	2,140	6.0	1	29.1	27.8	28.9	14.2	--------	--------	--------	--------	2.9	--------	--------	--------	7,300
					2	--------	39.2	40.8	20.0	--------	--------	--------	--------	4.0	--------	--------	--------	10,290
					3	--------	49.0	51.0	--------	--------	--------	--------	--------	5.0	--------	--------	--------	12,860
62	26665	----------	2,180	4.5	1	24.4	30.6	33.7	11.3	--------	--------	--------	--------	1.8	--------	--------	--------	8,330
					2	--------	40.5	44.6	14.9	--------	--------	--------	--------	2.4	--------	--------	--------	11,020
					3	--------	47.6	52.4	--------	--------	--------	--------	--------	2.9	--------	--------	--------	12,950
	26666	----------	2,140	8.7	1	22.8	29.6	28.9	18.7	--------	--------	--------	--------	3.4	--------	--------	--------	7,310
					2	--------	38.3	37.5	24.2	--------	--------	--------	--------	4.5	--------	--------	--------	9,460
					3	--------	50.6	49.4	--------	--------	--------	--------	--------	5.9	--------	--------	--------	12,480
	26667	----------	2,160	8.0	1	25.8	30.9	32.9	10.4	--------	--------	--------	--------	2.1	--------	--------	--------	8,130
					2	--------	41.7	44.2	14.1	--------	--------	--------	--------	2.8	--------	--------	--------	10,970
					3	--------	48.5	51.5	--------	--------	--------	--------	--------	3.3	--------	--------	--------	12,760

617853 O—62——5

TABLE 2.—*Analyses of coal from cores, Red Desert area, Sweetwater County, Wyo.*—Continued

Core hole	Sample	Specific gravity	Ash-softening temperature (°F)	Thickness of coal (feet)	Condition	Proximate				Ultimate					Forms of sulfur			Heating value (Btu)
						Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Sulfate	Pyritic	Organic	
									Latham No. 5 coal bed									
62	E-26668	--------	2,200	4.9	1	25.0	28.5	29.9	16.6	--------	--------	--------	--------	2.0	--------	--------	--------	7,420
					2	--------	38.0	39.8	22.2	--------	--------	--------	--------	2.7	--------	--------	--------	9,900
					3	--------	48.8	51.2	--------	--------	--------	--------	--------	3.4	--------	--------	--------	12,710
									Latham No. 4 coal bed									
62	E-26669	--------	2,210	5.7	1	20.8	25.8	24.7	28.7	--------	--------	--------	--------	3.0	--------	--------	--------	6,270
					2	--------	32.5	31.3	36.2	--------	--------	--------	--------	3.8	--------	--------	--------	7,910
					3	--------	51.0	49.0	--------	--------	--------	--------	--------	6.0	--------	--------	--------	12,400
62	26670	--------	2,350	5.9	1	25.6	28.7	30.0	15.7	--------	--------	--------	--------	2.2	--------	--------	--------	7,480
					2	--------	38.5	40.5	21.0	--------	--------	--------	--------	3.0	--------	--------	--------	10,040
					3	--------	48.8	51.2	--------	--------	--------	--------	--------	3.7	--------	--------	--------	12,720
									Creston No. 2 coal bed									
63	E-29373	--------	--------	7.6	1	25.3	30.0	33.5	11.2	6.1	45.6	1.0	33.5	2.6	--------	--------	--------	7,980
					2	--------	40.1	44.9	15.0	4.5	61.1	1.3	14.6	3.5	--------	--------	--------	10,680
					3	--------	47.2	52.8	--------	5.2	17.9	1.5	17.3	4.1	--------	--------	--------	12,570
									Latham No. 3 coal bed									
63	E-29374	--------	--------	3.4	1	25.2	30.4	33.2	11.2	--------	--------	--------	--------	3.0	0.04	1.90	1.05	8,210
					2	--------	40.6	44.4	15.0	--------	--------	--------	--------	4.0	.05	2.54	1.40	10,970
					3	--------	47.8	52.2	--------	--------	--------	--------	--------	4.7	.06	2.99	1.65	12,920

Creston No. 2 coal bed

64	E-30376			2.4	1	23.3	32.2	32.3	12.2					3.6				8,450
					2		42.0	42.1	15.0					4.7				11,020
					3		50.0	50.0						5.6				13,100
	30377			11.6	1	14.5	40.6	33.0	11.9	6.2	46.5	0.9	31.6	2.9				8,330
		1.54			2		47.5	38.6	13.9	5.3	54.4	1.0	22.1	3.3				9,740
					3		55.1	44.9		6.2	63.1	1.2	25.6	3.9				11,310
	30378			2.4	1	25.4	30.4	31.9	12.3									
					2		40.8	42.8	16.4									
					3		48.8	51.2										
	30379			4.5	1	24.1	31.4	31.6	12.9					2.4				8,050
					2		41.3	41.7	17.0					3.1				10,600
					3		49.7	50.3						3.7				12,760
	30380			6.7	1	24.4	31.3	32.1	12.2					2.3				8,070
					2		41.4	42.4	16.2					3.0				10,680
					3		49.4	50.6						3.6				12,740

Creston No. 3 coal bed

65	E-27921		2,180	2.2	1	23.1	25.3	27.5	24.1					2.8				6,530
					2		32.9	35.8	31.3					3.7				8,500
					3		48.0	52.0						5.4				12,380

Latham No. 4 coal bed

66	E-30944			8.0	1	23.8	33.1	31.6	11.5	6.2	46.0	1.2	31.1	4.0				8,500
					2		43.4	41.6	15.0	4.6	60.4	1.6	13.2	5.2				11,150
					3		51.1	48.9		5.4	71.1	1.9	15.5	6.1				13,120

Latham No. 3 coal bed

	E-30945			5.3	1	22.6	30.9	31.2	15.3	5.9	43.6	1.3	28.5	5.4				7,980
					2		39.9	40.3	19.8	4.3	56.3	1.7	11.0	6.9				10,310
					3		49.8	50.2		5.4	70.2	2.2	13.6	8.6				12,850

Creston No. 2 coal bed

70	E-32281	1.489		7.2	1	24.9	31.0	35.1	9.0	6.3	48.5	1.0	32.6	2.6	0.06	1.54	1.00	8,580
					2		41.3	46.8	11.9	4.6	64.6	1.4	14.0	3.5	.08	2.05	1.33	11,430
					3		46.9	53.1		5.3	73.4	1.5	15.9	3.9	.09	2.33	1.51	12,980
	32282	1.505		7.4	1	25.2	31.8	32.8	10.2	6.4	46.5	1.1	32.3	3.5	.05	2.19	1.27	8,370
					2		42.5	43.9	13.6	4.8	62.2	1.5	13.2	4.7	.07	2.93	1.70	11,200
					3		49.2	50.8		5.5	72.0	1.8	15.3	5.4	.08	3.40	1.97	12,970

TABLE 2.—*Analysis of coal from cores, Red Desert area, Sweetwater County, Wyo.*—Continued

Core hole	Sample	Specific gravity	Ash-softening temperature (°F)	Thickness of coal (feet)	Condition	Proximate				Ultimate					Forms of sulfur			Heating value (Btu)
						Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Sulfate	Pyritic	Organic	
Latham No. 3 coal bed																		
70	E-32283	1.523	----	6.4	1	24.6	30.3	32.7	12.4	----	----	----	----	2.9	----	----	----	8,210
					2	----	40.1	43.4	16.5	----	----	----	----	3.9	----	----	----	10,890
					3	----	48.1	51.9	----	----	----	----	----	4.6	----	----	----	13,040
Latham No. 4 coal bed																		
70	E-32284	----	----	2.2	1	26.2	30.8	34.0	9.0	----	----	----	----	----	----	----	----	----
					2	----	41.8	46.0	12.2	----	----	----	----	----	----	----	----	----
					3	----	47.6	52.4	----	----	----	----	----	----	----	----	----	----
Luman No. 1 coal bed																		
72	E-33561	1.91	2,670	0.9	1	17.0	21.4	18.1	43.5	----	----	----	----	1.5	0.04	1.06	0.42	4,680
					2	----	25.8	21.7	52.5	----	----	----	----	1.8	.04	1.28	.51	5,640
					3	----	54.2	45.8	----	----	----	----	----	3.8	.09	2.69	1.06	11,860
	33562	1.54	2,450	0.9	1	22.2	29.0	34.2	14.6	6.0	46.7	1.1	30.2	1.4	.02	.62	.76	8,280
					2	----	37.2	44.0	18.8	4.5	60.0	1.4	13.5	1.8	.02	.80	.97	10,640
					3	----	45.8	54.2	----	5.6	73.9	1.7	16.6	2.2	.03	.98	1.20	13,100
	33563	1.92	----	0.3	1	15.1	21.8	16.4	46.7	----	----	----	----	0.5	----	----	----	4,520
					2	----	25.7	19.3	55.0	----	----	----	----	0.6	----	----	----	5,320
	33564	1.93	----	0.9	1	16.1	21.3	16.7	45.9	----	----	----	----	0.6	----	----	----	4,450
					2	----	25.4	19.9	54.7	----	----	----	----	0.8	----	----	----	5,310
	33565	----	----	0.2	1	19.9	26.6	27.9	25.6	----	----	----	----	0.6	----	----	----	7,030
					2	----	33.2	34.8	32.0	----	----	----	----	0.8	----	----	----	8,770
					3	----	48.9	51.1	----	----	----	----	----	1.1	----	----	----	12,900
	33566	1.69	2,890	----	1	18.9	26.1	25.3	29.7	----	----	----	----	0.8	.01	.20	.57	6,570
					2	----	32.2	31.2	36.6	----	----	----	----	1.0	.02	.24	.70	8,090
					3	----	50.8	49.2	----	----	----	----	----	1.5	.02	.38	1.10	12,760
	33567	1.46	2,450	----	1	23.0	31.5	35.4	10.1	----	----	----	----	1.1	.00	.42	.72	9,130
					2	----	41.0	45.9	13.1	----	----	----	----	1.5	.00	.55	.93	11,860
					3	----	47.1	52.9	----	----	----	----	----	1.7	.00	.63	1.07	13,640
	33568	----	2,790	----	1	17.2	23.4	20.1	39.3	----	----	----	----	1.0	----	----	----	5,280
					2	----	28.3	24.3	47.4	----	----	----	----	1.1	----	----	----	6,380
					3	----	53.9	46.1	----	----	----	----	----	2.2	----	----	----	12,130
	33569	----	2,440	----	1	22.4	30.3	34.4	12.9	----	----	----	----	1.3	----	----	----	8,580
					2	----	39.1	44.2	16.7	----	----	----	----	1.7	----	----	----	11,050
					3	----	46.9	53.1	----	----	----	----	----	2.0	----	----	----	13,260

TABLE 3.—*Fischer assays of subbituminous coal from the eastern Red Desert area, Sweetwater County, Wyo.*

[Analyst: J. Budinsky, U.S. Geological Survey]

Core hole	Coal bed	Sample	Interval sampled				Oil (gallons per ton)	Water (gallons per ton)	Gas plus loss (percent)	Spent coal (percent)
			From—		To—					
			Feet	Inches	Feet	Inches				
40	Battle No. 3	129072	82	8¾	87	2⅛	15.0	63.8	8.00	59.8
	Monument No. 2	129073	146	11¼	157	9⅛	10.5	59.4	8.20	62.4
	Sourdough No. 2	129074	210	7⅛	220	¼	16.3	56.5	8.00	61.6
49	Hadsell No. 2	129075	177	9½	192	⅛	9.2	46.5	5.40	71.2
	Creston No. 2	129076	259	10⅞	272	1½	15.2	59.4	8.00	60.8
		129077	182	7¼	276	7⅜	12.1	51.8	6.40	66.8
		129078	278	0	279	¼	7.76	43.9	13.8	64.6
		129079	288	5¼	296	7½	9.20	56.1	13.4	59.4
	Latham No. 4	129080	348	6⅜	354	5	10.8	55.1	12.6	60.0
		129081	357	4⅜	371	9½	7.76	54.1	12.6	61.6
			Feet		Feet					
72	Luman No. 1	138262	99.36		100.28		8.3	39.3	2.2	--------
		138263	100.28		101.2		14.9	50.3	5.0	--------
		138264	101.12		101.44		9.6	36.0	1.6	--------
		138265	102.07		102.92		12.5	33.6	3.7	--------
		138266	102.92		103.15		15.3	43.1	7.3	--------
		138267	103.15		103.77		14.1	46.3	4.8	--------
		138268	103.77		104.27		25.2	32.0	4.4	--------
		138269	104.27		104.70		23.0	48.0	7.7	--------

Preliminary studies indicate that the coal of the Red Desert is predominantly attrital (J. M. Schopf, oral communication). The lack of carbonized logs, the absence of roots in the underclay, and the dominantly attrital character of the coal suggest that the coal formed from vegetation swept into place. Bradley (1945) reported a 6-foot bed of canneloid coal near Wamsutter. A similar bed occurs at locality 192 (Latham No. 4 bed), near U.S. Highway 30. The coal is unbanded, has a dull luster and low specific gravity, and is probably canneloid.

WEATHERING

The weathered coal of the uppermost bed has a notably lower heating value and higher moisture and ash content than the underlying unweathered coal. In core hole 51, a bed under 30 feet of cover, has 4,400 Btu, 41.4 percent moisture, and 13.6 percent ash—all on the "as received" basis. In contrast, the same bed under 70 feet of cover has 8,080 Btu, 25.9 percent moisture, and 12.4 percent ash. A similar relationship was noted by Gill, Zeller, and Schopf (1959) at Slim Buttes, S. Dak., by comparing the heating values and ash content of lignite from bulldozer pits with those of the same beds penetrated in core holes. Weathering in the Red Desert extends to widely varying depths and seems partly dependent upon the permeability of the overlying strata. The lower heating value of the near-surface beds decreases the quality of the coal that might be mined by stripping.

CLINKER

In many places the coal beds are burned, producing prominent beds of red clinkers, formed from the sintering of the roof rocks. Auger holes and core holes indicate that the burning rarely extends more than 10 feet laterally into the bed. Apparently, the fires were smothered by caving and collapse of the roof rocks, which at most places consist of poorly consolidated siltstone and sandstone. The clinker is resistant to weathering and forms small ridges flanking many of the best coal outcrops. In a few places, the upper split of a coal bed above a thick parting has burned, leaving the lower split relatively unaltered.

URANIUM

OCCURRENCE AND DISTRIBUTION

Local concentrations of uranium in the coal and carbonaceous shale in the Wasatch formation of the eastern Red Desert area amount to as much as 0.051 percent in the coal and 0.080 percent in the coal ash. Widespread lower concentrations of uranium amount to as much as 0.020 percent in the coal and 0.130 in the coal ash but average about 0.003 percent in the coal and 0.015 percent in the coal ash. The occurrences and distribution of uranium in the principal coal beds penetrated in the drill holes are shown in plates 2 to 5; the uranium content of beds sampled at the outcrop is shown in plates 6 to 10. Uranium minerals have not been identified in the coal. The uranium is associated with the organic fraction of the coal and may occur as an organometallic compound or complex according to Breger, Deul, and Rubinstein (1955). Although the concentration of uranium is too low to make direct recovery feasible, uranium might be recovered as a byproduct after using the coal as fuel.

PRE-MIOCENE(?) UNCONFORMITY

The greatest concentrations of uranium are in the topographically highest coal beds unconformably overlain by conglomerate of possible Miocene age. At Creston Ridge, in the southeastern part of the area, an impure coal bed, 7 feet thick and unconformably overlain by the conglomerate, contains as much as 0.051 percent uranium in its upper part, whereas a coal bed 40 feet below the unconformity contains 0.001 to 0.003 percent uranium (fig. 22*A*). At Bison Basin, a breached anticline 20 miles north of the area, siltstone, claystone, and uranium-bearing impure coal of the Fort Union formation of Paleocene age are disconformably overlain by coarse-grained arkose of the Battle Spring formation. Isolated remnants of conglomerate that may be the basal unit of the Browns Park formation of Miocene(?) age occur along the south rim of the basin near the Battle Spring-

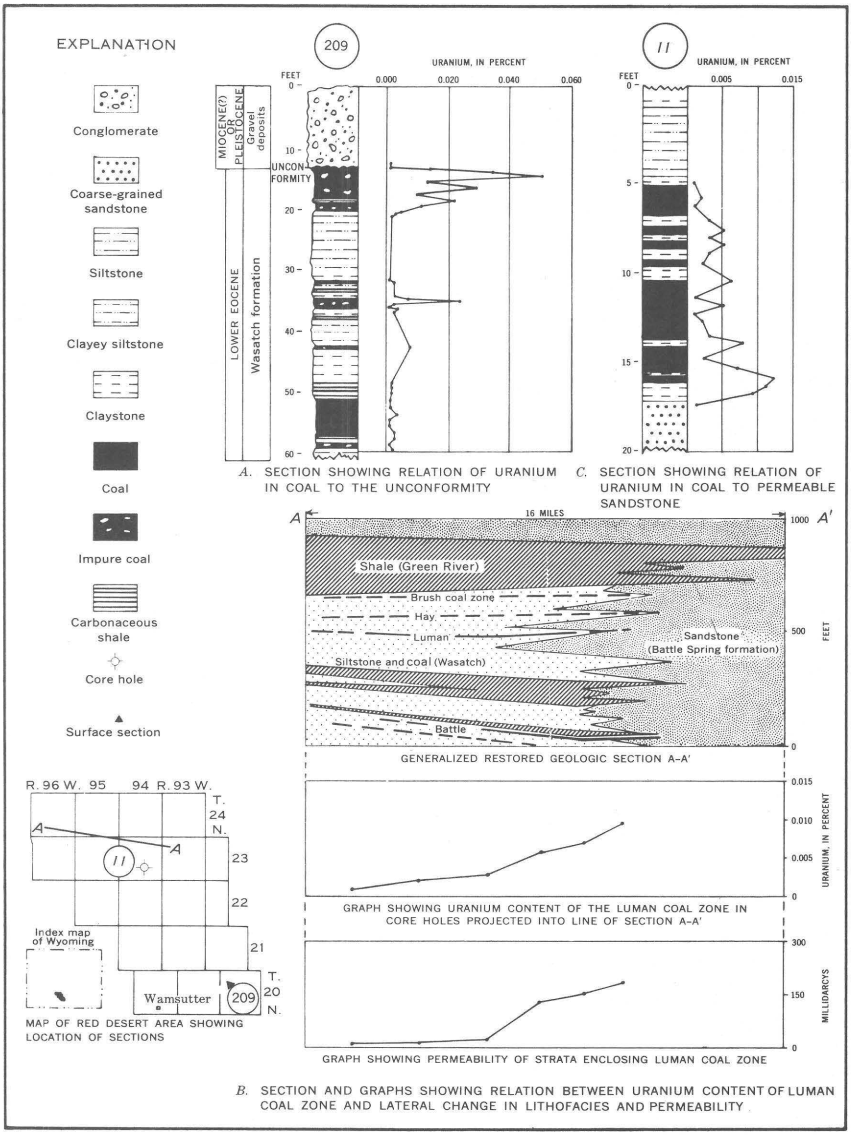

FIGURE 22.—Diagram showing three controls for epigenetic emplacement of uranium in the coal.

Fort Union contact. The uppermost impure coal bed in the Fort Union formation contains 0.056 percent uranium, where it is directly overlain by the conglomerate, whereas a coal bed 12 feet stratigraphically lower contains only 0.005 percent uranium, and a bed 40 feet lower contains 0.001 percent. These relations suggest the emplacement of the uranium by downward migrating solutions.

LATERAL CHANGE IN LITHOFACIES

Widespread lower concentrations of uranium in coal are related to the permeability of the enclosing rocks. In the central part of the area the coal is interbedded with impermeable siltstone and shale and has a uranium content of about 0.001 percent. To the northeast, where the rocks grade laterally into sandstone of the Battle Spring formation, the coal beds are thin, impure, and interbedded with permeable, coarse-grained arkose; the uranium content of the coal increases to about 0.010 percent. Data from six core holes show that the uranium content of the Luman coal zone and the average permeability of the strata, 20 feet thick, enclosing the coal increase eastward as the lithofacies change and the rocks become coarser grained (fig. 22*B*). In this setting the thick pure coal beds, most suitable for fuel, contain low concentrations of uranium, whereas at the margin of the Wasatch formation the coal beds are thin and impure and contain higher concentrations of uranium.

INTERCALATED PERMEABLE BEDS IN THE CYCLIC SEQUENCE

Coal beds adjacent to permeable coarse-grained sandstone contain the most uranium. As the sandstone commonly underlies the coal in the cyclothems, the uranium content of the coal is highest at the bottom of the bed and decreases irregularly upward (fig. 22*C*). A similar pattern of distribution of uranium occurs in each of several coal beds in the cyclic sequence, where the coal beds are in contact with permeable sandstone (fig. 23). According to laboratory determinations, the aqueous permeability of the sandstone underlying the coal is about 390 millidarcy, whereas the permeability of the overlying shale is less than 0.1 millidarcys. At many places in the Red Desert area, several uranium-bearing coal beds, each related to a permeable sandstone, can be penetrated in one drill hole. This occurrence contrasts with the occurrence at Creston Ridge, which is similar to that of the uranium-bearing lignite in the Dakotas (Denson, Bachman, and Zeller, 1959), where only the uppermost coal bed in a sequence overlain by tuffaceous rocks is uranium bearing.

PARTINGS WITHIN COAL BEDS

The distribution of uranium within the coal beds is highly irregular. The highest uranium content occurs in impure coal layers adjacent to partings or layers of high ash content (samples 24 and 41, fig. 24). The lowest uranium content occurs in the middle of pure-coal intervals (fig. 24, samples 16 and 46). The aqueous permeability of the high-ash

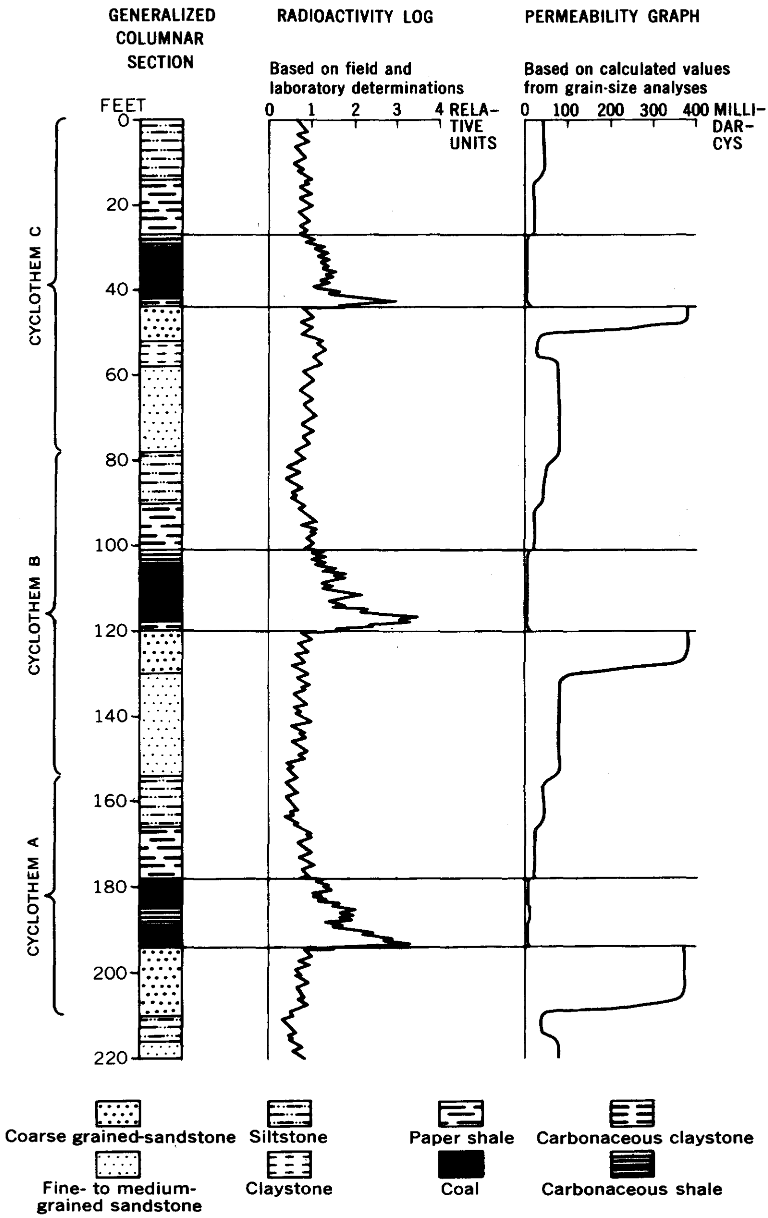

FIGURE 23.—Idealized diagram showing relation between uranium content of coal beds and the permeability of the enclosing cyclically deposited strata.

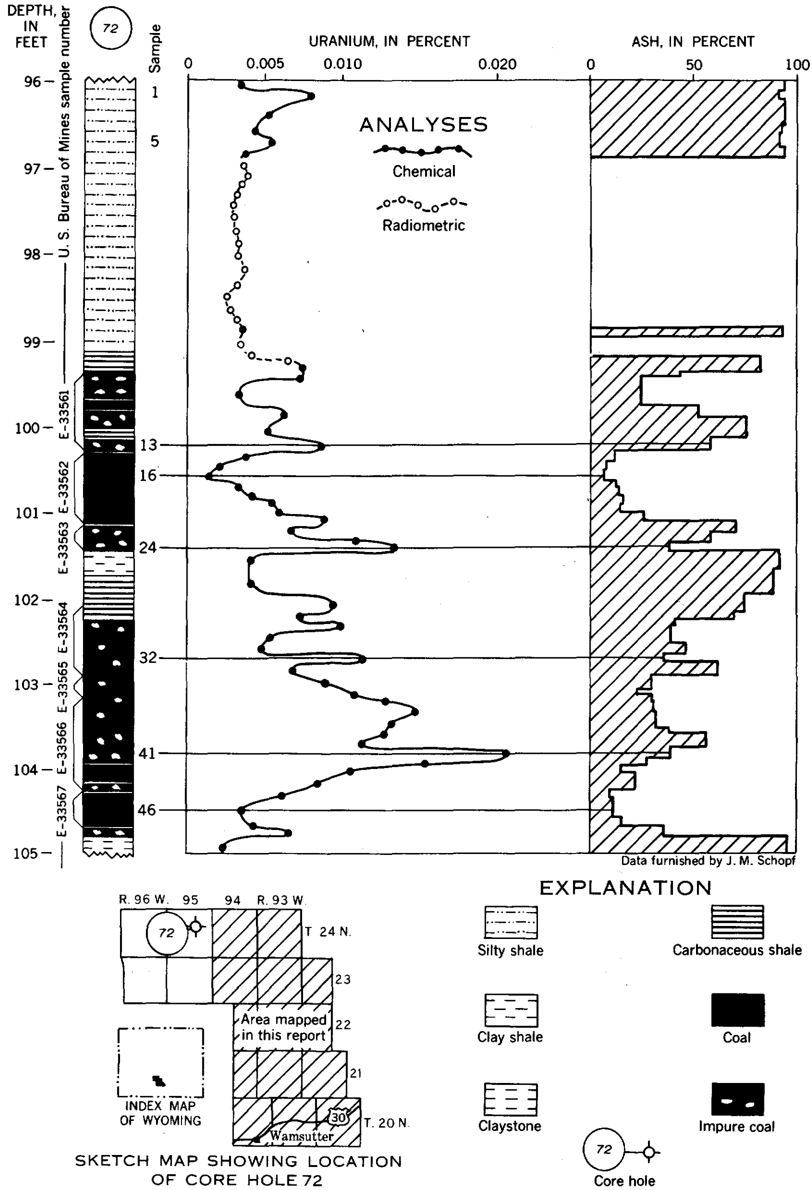

FIGURE 24.—Chart showing uranium and ash content of Luman coal bed No. 1 in 8-inch-diameter core hole.

layers amounts to about 0.3 millidarcy; the permeability of the pure-coal layers is less than 0.1 millidarcy. The uranium content of the pure-coal layers (0.001 percent) may represent an approximation of the original or syngenetically emplaced uranium. The impure coal layers of higher uranium content (0.020 percent) reflect the addition of uranium owing to their more favorable location with respect to permeable layers and to the easier permeation of the impure coal by the uranium.

The irregular distribution of the uranium may partly be due to the differing capacity of the coal layers to take up uranium. J. M. Schopf (written communication) has suggested that the attrital coal rich in translucent waxy material contains more uranium than the coal composed of other types of organic debris. However, the fact that coal layers close to a permeable bed have a higher uranium content than apparently similar coal layers farther from the permeable bed suggests that the position is a more important factor than the chemical composition of the coal.

ASSOCIATED TRACE ELEMENTS

Anomalously high concentrations of several trace elements occur in coal, organic shale, and clayey sandstone where the uranium content is also high. At Creston Ridge, in the southeast corner of the area, higher concentrations of lanthanum, molybdenum, neodymium, lead, scandium, and yttrium occur in the coal beds unconformably overlain by the conglomerate than in the beds stratigraphically lower. The semiquantitative spectrographic analyses (tables 5, 6) show that there is 10 to 100 times the concentration of these constituents in the upper coal bed as there is in the bed 40 feet below the unconformity (fig. 25).

At Eagles Nest, 2 miles west of the northwest corner of the area, the Wasatch formation contains massive buff coarse-grained fluviatile sandstone interbedded with brown to black lacustrine papery organic shale. At the contact with the shale the sandstone is stained orange and the organic shale is stained purple. Chemical and semiquantitative spectrographic analyses show a positive correlation between the uranium and iron, molybdenum, fluroine, gallium, lead, scandium, and vanadium. These elements are concentrated in two thin layers of organic shale interbedded with sandstone and at the top of the main shale bed adjacent to the sandstone (fig. 26). Similar patterns of concentration of trace elements are present in aureoles around channel

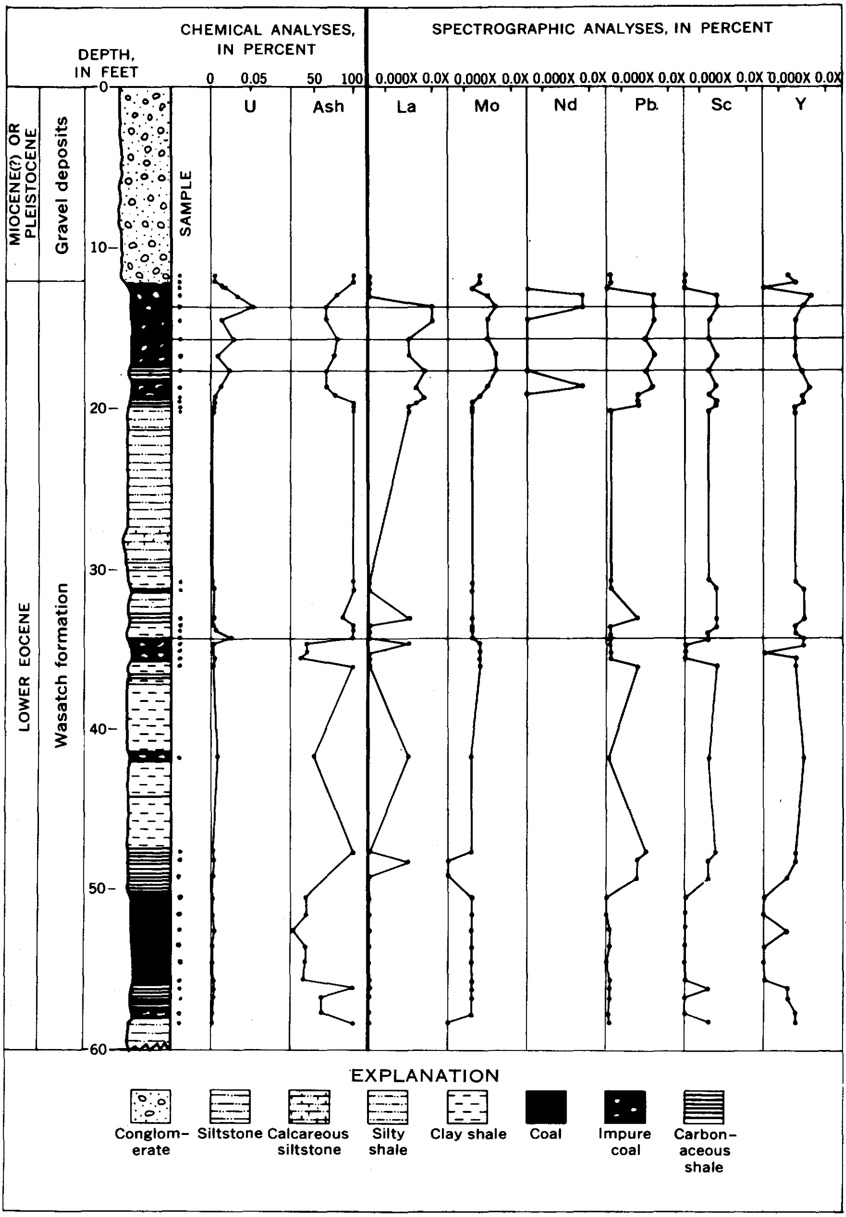

FIGURE 25.—Diagram showing distribution of uranium and selected trace elements in the Creston coal zone at Creston Ridge.

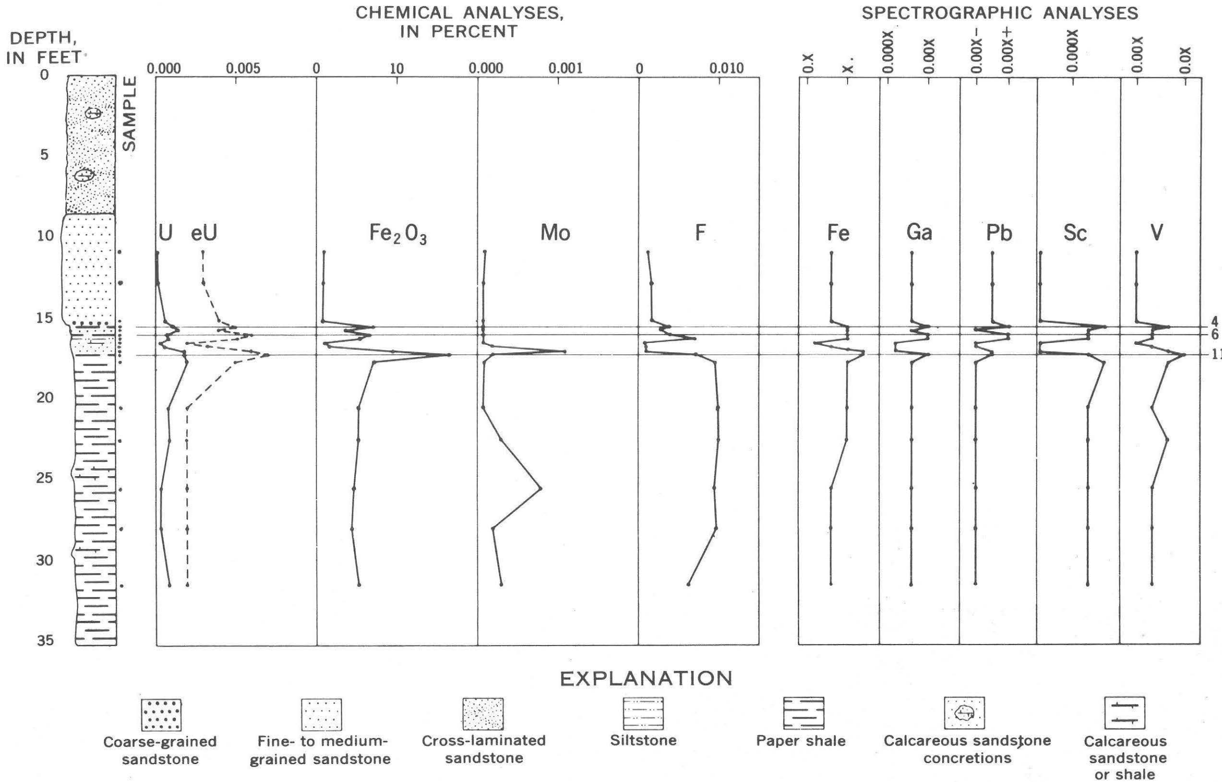

FIGURE 26.—Diagram showing distribution of selected elements in interbedded sandstone and paper shale in the Battle Spring formation exposed at Eagles Nest along Lost Creek.

FIGURE 27.—View of Painted Bluff showing location of analyzed samples. The well-sorted sandstone of the irregular channels is a good transmitter of uraniferous ground water. See figure 28 for analyses.

sandstones in the Battle Spring formation at Painted Bluff, 6 miles north of Eagles Nest (figs. 27, 28), and in an area extending about 20 miles to the northeast of the area. The parallel distribution patterns of uranium and these trace constituents indicate that they may have been similarly emplaced.

Semiquantitative spectrographic analyses of samples from core holes 11, 12, 13, 16, 17, 24, 43, 71, and 72 were made by the U.S. Geological Survey laboratory in Washington. Analysts were Mona L. Frank and Joseph Haffty. Sample numbers correspond to measured increments of core described in table 4.

Analyses of samples from surface sections RW 1138 and 1161 were made by the U.S. Geological Survey laboratory in Denver, Colo. Analysts were N. M. Conklin, P. J. Dunton, and R. G. Havens.

Spectrographic analyses were made of the ash of coal and carbonaceous shale, except as noted. Several analyses were run on both the ashed and unashed samples from core hole 13 and surface section RW 1161.

Results of spectrographic analyses are reported in terms of percent content: X. percent equals 1 to 9 percent; 0.X equals 0.1 to 0.9 percent. To conserve space the percentage groups are designated by letters: A equals XX. percent, B equals X. percent, and so forth. These designations are shown at the top of tables 4–6. Results for part of the samples are bracketed into three groups. For example, for the range 1 to 10 percent, X+ represents the higher portion from about 5 to 10 percent; X. the middle portion, about 2 to 5 percent; and X−, the lower portion, 1 to about 2 percent. This type of semiquantitative results is consistent with those obtained by quantitative methods, either chemical or spectrographic, in at least 60 percent of the cases investigated.

The limits of detectability given are based on the semiquantitative method described by Myers and Barnett (1953). The concentrations are reported as elements, not as oxides or compounds.

Approximate visual detection limits for the elements determined by using the semiquantitative method for samples RW 1138 and 1161

[Two results for an element indicate that a second exposure is required for the higher detection limits given, using a 20-mg sample charge]

Element	*Percent*	*Element*	*Percent*	*Element*	*Percent*	*Element*	*Percent*
Ag	0.00005	Ga	0.001	Nb	0.001	Sn	0.001
Al	.001	Gd	.005	Nd	.01	Sr	.0001
As	.05	Ge	.0005	Ni	.0005	Ta	.05
Au	.003	Hf	.05	Os	.005	Te	.08
B	.005	Hg	1.0–0.1	P	.1	Th	.05
Ba	.0001	In	.001	Pb	.001	Ti	.0005
Be	.0001	Ir	.005	Pd	.0005	Tl	.01
Bi	.001	K	.5	Pt	.003	U	.05
Ca	.001		.001	Rb	--------	V	.001
Cd	.005	La	.005		.01	W	.01
Ce	.05	Li	.01	Re	.005	Y	.001
Co	.0005		.0001	Rh	.005	Yb	.0001
Cr	.0001	Mg	.001	Ru	.005	Zn	.02
Cu	.00005	Mo	.001	Sb	.01	Zr	.001
Dy	.05	Mn	.0005	Sc	.001		
Er	.005	Na	.05	Si	.001		
Fe	.001		.0005	Sm	.01		

Detection limits for the remainder of the samples are the same as those given above, except for the following differences (two results for an element indicate that a second exposure is required for the higher detection limits given, using a 20-mg sample charge):

Element	*Percent*	*Element*	*Percent*
Ag	0.0001	Cu	0.0001
As	.1	Gd	.05
Au	.005	Hf	.1
Cr	.0005	K	1.0
			.001

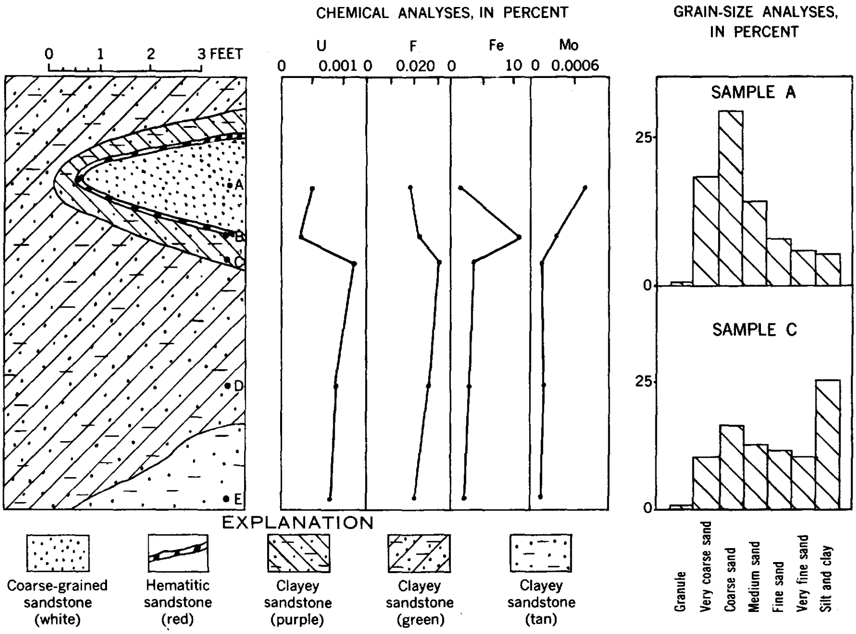

FIGURE 28.—Diagram showing distribution of selected elements and grain-size analyses of samples from a channel sandstone and the enclosing strata in the Battle Spring formation exposed at Painted Bluff along Lost Creek.

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TABLE 4.—*Chemical and semiquantitative spectrographic analyses of samples from core holes*

Sample: Sample number is repeated if duplicate spectrographic analyses of the sample were made. Semiquantitative spectrographic analyses: A, X0 percent; B, X.0 percent; C, 0.X percent; D, 0.0X percent; E, 0.00X percent; F, 0.000X percent; a, >10 percent; b, 5–10 percent; c, 1–5 percent; d, 0.5–1 percent; e, 0.1–0.5 percent; f, 0.05–0.1 percent; g, 0.01–0.05 percent; h, 0.005–0.01 percent; i, 0.001–0.005 percent; j, 0.0005–0.001 percent; k, 0.0001–0.0005 percent

Interval sampled (depth in feet)	Rock type	Sample	Chemical analyses (percent)			Semiquantitative spectrographic analyses																																					
			Uranium in sample	Ash	Uranium in ash	Al	Si	Fe	K	Ca	Mg	Na	Ti	Ba	Sr	Mn	B	Ni	Co	Cr	Ce	Pb	Cu	Mo	V	Sc	La	Nd	Zr	Ga	Y	Sn	Yb	Be	Ag	Ge	Dy	Zn	P	Tb	Nb	As	Pr
CORE HOLE 11																																											
Battle No. 3 coal bed																																											
30.29– 31.06	Siltstone	101557	0.001	------	------	A	A	B	B	B	C	B	C	C	D	D	D	D	D	D	--	E	D	E	E	E	E	--	E	E	E	--	F	F	F	--	--	--	--	--	--	--	--
31.06– 31.37	do	101558	.002	------	------	A	A	B	B	C	C	B	C	C	D	D	D	D	D	D	D	E	E	--	E	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
31.37– 31.58	Shale	101559	.002	------	------	A	A	B	B	C	C	B	C	C	D	D	D	D	D	D	D	E	E	--	E	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
31.58– 32.00	do	101560	.003	------	------	B	B	C	--	B	C	C	D	E	E	E	D	E	--	E	--	E	E	--	E	--	--	--	E	--	E	--	F	--	--	--	--	--	--	--	--	--	--
32.00– 32.42	Coal	101561	.002	7.6	0.029	A	A	A	--	B	B	C	C	D	D	D	C	D	D	D	--	D	D	D	D	D	E	D	D	E	D	--	E	E	--	--	--	D	--	--	--	--	--
32.42– 32.92	do	101562	.003	10.7	.032	A	A	B	B	B	C	C	C	D	D	D	C	D	D	D	D	D	D	E	D	E	D	D	E	E	D	--	E	F	F	--	--	E	--	--	--	--	--
32.92– 33.42	do	101563	.004	16.0	.022	B	A	B	C	B	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	E	D	D	E	--	D	--	E	F	F	--	--	E	--	--	--	--	--
33.42– 33.85	do	101564	.004	28.6	.015	A	A	B	B	B	B	C	C	D	D	D	D	D	D	D	C	D	D	D	D	E	D	D	E	E	D	--	E	F	--	--	--	E	--	--	--	--	--
33.85– 34.17	do	101565	.009	27.6	.032	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	E	D	D	E	E	D	E	E	F	F	--	--	--	--	--	--	--	--
34.17– 34.58	do	101566	.010	25.0	.038	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	E	D	D	E	E	D	--	E	F	F	--	--	D	--	--	--	--	--
34.58– 34.81	do	101567	.003	13.0	.026	B	B	A	--	B	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	E	D	D	E	E	D	--	E	F	F	--	--	E	--	--	--	--	--
36.00– 36.37	do	101568	.002	12.4	.014	B	B	A	--	B	C	C	D	D	D	D	D	D	D	D	D	E	D	D	D	E	D	D	E	E	E	--	E	F	--	--	--	--	--	--	--	--	--
36.37– 36.79	do	101569	.003	21.2	.013	B	A	B	C	B	C	C	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	D	E	E	D	--	E	F	--	--	--	--	--	--	--	--	--
36.79– 37.17	do	101570	.006	25.0	.024	B	A	B	B	B	C	B	C	D	D	D	D	D	D	D	D	D	D	D	D	E	D	D	E	E	D	--	E	F	F	E	--	E	--	--	--	--	--
37.17– 37.70	Clay	101571	.006	82.8	.007	A	A	B	B	B	C	C	C	C	D	D	D	D	D	D	D	D	D	--	D	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
37.70– 38.29	Sandstone	101572	.003	------	------	A	A	B	B	B	C	B	C	C	D	D	D	D	D	D	D	D	D	E	E	E	D	D	E	E	E	E	F	F	--	--	--	--	--	--	--	--	--
38.29– 38.70	do	101573	.002	------	------	A	A	B	B	B	C	B	C	C	D	D	D	D	D	D	--	E	D	D	E	E	D	--	E	E	E	E	F	F	--	--	--	--	--	--	--	--	--
Monument No. 2 coal bed																																											
101.50–101.67	Shale	101574	0.004	------	------	A	A	B	B	B	C	B	C	C	D	D	D	D	D	D	D	E	E	--	D	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
101.67–102.33	Clay	101575	.003	------	------	A	A	B	B	C	B	B	C	D	D	D	E	D	D	D	D	E	E	--	E	E	E	D	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
102.33–102.75	Shale, carbonaceous	101576	.005	62.8	0.008	A	A	B	B	C	B	C	C	D	D	D	D	D	D	D	D	D	D	E	D	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
102.75–103.43	Shale	101577	.004	------	------	A	A	B	C	C	C	C	C	D	E	D	D	E	--	E	--	E	E	--	E	E	--	--	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
103.43–103.85	Coal	101578	.001	22.2	.005	A	A	B	C	B	B	C	C	C	D	D	C	D	D	D	D	D	D	E	E	E	D	D	E	E	D	--	F	F	--	--	--	--	--	--	--	--	--
103.85–104.10	do	101579	.003	22.4	.013	A	A	B	C	B	B	C	C	C	D	C	C	D	D	D	D	D	D	E	D	E	D	D	E	D	D	--	F	F	--	E	--	--	--	--	--	--	--
104.10–104.58	Shale	101580	.003	------	------	A	A	B	C	C	C	C	C	D	D	E	D	D	E	D	D	E	D	E	E	E	D	D	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
104.58–105.00	do	101581	.003	------	------	A	A	B	--	B	B	B	C	D	D	D	C	D	--	D	--	D	D	D	D	--	--	--	--	D	D	--	F	--	--	--	--	--	--	--	--	--	--
105.00–105.45	Coal	101582	.003	27.0	.012	A	A	A	C	B	C	C	C	D	D	D	D	D	D	D	D	D	D	E	D	E	D	D	E	E	D	E	F	F	--	--	--	--	--	--	--	--	--
105.45–105.75	do	101583	.002	16.3	.012	B	A	A	--	B	C	C	C	D	D	D	C	D	D	D	D	D	D	D	D	E	D	D	E	E	D	E	F	F	--	--	--	--	--	--	--	--	--
105.75–106.00	do	101584	----------	22.2	.001	B	C	B	--	A	C	C	D	D	D	C	D	E	D	E	--	--	D	E	E	--	E	--	--	E	D	E	--	--	--	--	--	--	--	A	--	--	--
106.00–106.50	do	101585	.002	11.1	.021	A	A	B	--	A	B	C	D	D	D	D	C	D	D	D	D	D	D	D	D	E	D	D	E	E	D	E	E	F	--	--	--	--	--	--	--	--	--
106.50–106.95	do	101586	.004	17.9	.020	A	A	B	C	B	C	C	C	D	D	D	C	D	D	D	D	D	D	D	D	E	D	D	E	D	D	--	F	F	--	E	--	--	--	--	--	--	--

TABLE 4.—*Chemical and semiquantitative spectrographic analyses of samples from core holes*—Continued

Interval sampled (depth in feet)	Rock type	Sample	Chemical analyses (percent)			Semiquantitative spectrographic analyses																																					
			Uranium in sample	Ash	Uranium in ash	Al	Si	Fe	K	Ca	Mg	Na	Ti	Ba	Sr	Mn	B	Ni	Co	Cr	Ce	Pb	Cu	Mo	V	Sc	La	Nd	Zr	Ga	Y	Sn	Yb	Be	Ag	Ge	Dy	Zn	P	Tb	Nb	As	Pr
CORE HOLE 11—continued																																											
Monument No. 2 coal bed—Continued																																											
106.95–107.31	Shale	101587	0.006			A	A	B	C	C	C	B	C	D	E	E	D	D	D	E	D	D	D	E	E	E	D	D	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
107.31–107.75	do	101588	.003			A	A	B	B	C	B	B	C	D	D	D	D	D	D	D	D	D	D	--	E	E	D	D	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
107.75–108.20	do	101589	.003			A	A	B	B	C	B	B	C	D	D	D	D	D	D	D	D	D	D	--	E	E	D	D	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
108.20–108.54	do	101590	.005			A	A	B	C	C	C	C	C	D	E	E	D	E	E	E	D	E	D	E	E	E	D	D	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
108.54–109.20	do	101591	.007			B	B	B	--	C	C	C	D	D	E	E	D	D	E	E	--	E	D	E	E	F	--	--	--	E	E	--	F	--	--	--	--	--	--	--	--	--	--
109.50–110.08	do	101592	.007			A	A	B	C	C	C	C	C	D	D	E	D	D	D	D	D	D	D	E	D	E	D	D	E	E	D	--	F	--	--	--	--	--	--	--	--	--	--
110.08–110.42	do	101593	.006			A	A	B	B	C	C	C	C	D	D	D	D	D	D	D	--	D	D	E	E	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
110.42–110.70	do	101594	.006			A	A	B	B	C	C	C	C	D	D	D	D	D	E	D	D	D	D	E	E	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
110.70–111.12	Coal	101595	.009	32.0	0.028	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	E	D	D	E	E	D	--	E	E	--	--	--	D	--	--	--	--	--
111.12–111.60	Shale	101596	.004			A	A	B	B	B	C	B	C	D	D	D	D	D	D	D	--	D	D	E	E	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
111.60–111.95	do	101597	.003			A	A	B	B	C	B	B	C	D	D	D	D	D	D	D	--	D	D	E	E	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
111.95–112.60	do	101598	.002			A	A	B	B	B	B	B	C	C	D	D	E	D	D	D	--	D	D	E	E	E	D	--	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
Monument No. 1 coal bed																																											
122.29–122.77	Shale	101599	0.002			A	A	B	B	C	B	B	C	C	D	D	D	D	D	D	--	D	E	--	E	E	D	--	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
122.77–123.08	do	101600	.002			A	A	B	B	C	C	B	C	C	D	D	D	D	D	D	--	D	E	E	E	E	D	--	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
123.08–123.58	do	101601	.004			A	A	B	B	C	C	C	C	D	D	D	D	D	E	D	--	D	E	E	E	E	E	--	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
123.58–123.95	Coal	101602	.006	34.4	0.016	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	D	D	D	E	D	E	D	D	E	E	D	--	F	F	--	--	--	--	--	--	--	--	--
123.95–124.29	do	101603	.004	42.6	.009	A	A	B	B	B	C	C	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	D	E	E	D	--	F	F	--	--	--	--	--	--	--	--	--
124.29–124.75	do	101604	.003	31.7	.009	A	A	B	B	B	B	C	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
124.75–125.12	do	101605	.003	20.0	.015	A	A	B	B	B	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	E	D	D	E	E	D	--	F	F	--	--	--	--	--	--	--	--	--
125.12–125.54	do	101606	.004	36.0	.012	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	D	D	D	E	D	E	D	D	E	E	D	--	F	F	--	--	--	--	--	--	--	--	--
125.54–126.00	do	101607	.003	25.4	.012	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	D	D	D	E	E	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
126.00–126.50	do	101608	.005	37.0	.013	A	A	B	B	B	C	C	C	C	D	D	D	D	D	D	D	D	D	E	E	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
126.50–126.92	Shale	101609	.004			A	A	B	B	C	C	C	C	D	D	--	D	D	D	D	D	D	E	E	E	E	D	--	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
126.92–127.70	do	101610	.003			A	A	B	B	C	C	B	C	D	D	D	E	D	D	D	--	D	E	E	E	E	D	--	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
127.70–128.08	Coal	101611	.004	21.3	.021	A	A	B	B	B	C	B	C	D	D	D	D	D	D	D	D	D	D	D	D	E	D	D	D	E	E	--	F	F	F	E	--	D	--	--	--	--	--
128.08–128.46	do	101612	.003	11.4	.027	A	A	B	--	B	C	B	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	--	F	F	--	--	--	--	C	--	--	--	--
128.46–128.77	do	101613	.008	11.9	.068	A	A	B	--	B	C	B	C	C	D	D	D	D	D	D	C	D	D	D	D	E	D	D	D	E	D	E	E	F	F	E	E	--	--	D	--	E	--
128.77–129.17	Shale	101614	.005			A	A	B	B	C	C	C	C	E	D	D	D	D	D	D	D	D	D	--	E	E	D	E	D	--	E	D	F	F	--	--	--	--	--	--	--	--	--
129.17–129.67	Coal	101615	.006	40.1	.015	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	C	D	D	E	D	E	D	D	D	E	D	E	E	F	--	--	--	--	--	--	--	--	--
129.67–130.25	do	101616	.002	16.4	.011	A	A	B	--	B	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	E	D	D	D	E	E	--	F	F	--	--	--	D	--	--	--	--	--
130.25–130.54	do	101617	.002	62.3	.004	A	A	B	B	B	B	C	C	C	D	D	D	D	D	D	D	D	D	--	D	E	D	D	D	E	E	--	E	F	--	--	--	D	--	--	--	--	--
130.54–131.00	do	101618	.004	35.8	.010	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	D	D	D	E	D	E	D	D	D	E	E	E	F	F	F	--	--	D	--	--	--	--	--
131.18–131.70	do	101619	.002	24.3	.010	A	A	B	C	B	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	E	D	D	D	E	E	--	F	F	--	--	--	--	--	--	--	--	--
131.70–131.95	do	101620	.004	30.1	.013	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	D	D	D	E	D	E	D	D	D	E	D	--	E	F	F	--	--	--	--	--	--	--	--

131.95–132.33	do	101621	.002	13.4	.013	B	A	B	--	B	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	E	D	E	D	E	E	E	F	F	F	--	--	D	--	--	--	--	--
132.33–132.70	do	101622	.001	11.6	.008	B	B	A	--	B	C	B	D	D	D	D	D	D	D	D	E	D	D	D	D	E	E	E	D	E	E	--	F	F	--	--	--	D	--	--	--	--	--
132.70–133.02	do	101623	.003	9.27	.028	B	B	A	--	B	C	B	D	C	D	D	D	D	D	D	D	D	D	D	D	E	D	D	D	E	D	--	E	F	--	E	--	--	--	--	E	--	--
133.02–133.29	Shale	101624	.018	----	----	A	A	C	C	C	C	C	C	D	E	E	D	D	--	D	D	D	D	--	D	E	D	E	D	E	E	--	F	F	--	--	--	--	--	--	--	--	--
133.29–133.62	Coal	101625	.009	28.2	.032	A	A	B	B	B	C	C	C	C	D	D	D	D	D	D	D	D	E	E	D	E	D	D	D	E	D	--	E	F	F	--	--	D	--	--	--	--	--
133.62–133.87	do	101626	.002	23.8	.008	A	A	B	B	B	C	C	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	D	D	E	D	--	E	F	--	E	--	--	--	--	--	--	--
133.87–134.37	Shale	101627	----	----	----	A	A	C	B	C	C	C	C	D	D	E	D	D	--	D	E	D	E	--	E	E	--	--	D	E	E	--	F	F	--	--	--	--	--	--	--	--	--

Sourdough No. 2 coal bed

179.89–180.33	Clay	101628	0.001	----	----	A	A	B	B	B	C	C	C	C	D	E	D	D	D	D	E	D	E	--	D	E	--	--	D	E	E	--	F	F	--	--	--	--	--	--	--	--	--
180.33–180.62	Coal	101629	.001	13.8	0.009	B	A	B	B	B	C	B	C	C	D	D	D	D	D	D	D	--	D	E	D	E	E	--	E	E	E	E	F	E	--	--	--	--	--	--	--	--	--
180.62–180.95	do	101630	.002	13.1	.015	A	A	B	B	B	C	B	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	D	E	E	D	E	F	F	--	--	--	--	--	--	--	--	--
180.95–181.37	do	101631	.002	10.3	.015	B	A	B	B	B	C	B	C	C	D	D	C	D	D	D	D	D	D	E	D	E	D	D	E	E	E	E	F	F	--	--	--	--	--	--	--	--	--
181.37–181.75	do	101632	.001	7.52	.017	A	A	B	C	B	B	B	D	C	D	D	C	E	E	E	D	D	D	D	D	E	D	D	E	E	D	E	F	E	--	--	--	--	--	--	--	--	--
181.75–182.17	do	101633	.002	7.97	.030	A	A	B	C	B	C	B	D	C	D	D	C	E	E	D	D	D	D	D	D	E	E	D	E	E	E	E	F	E	--	--	--	--	--	--	--	--	--
182.17–182.83	Shale	101634	.003	----	----	A	A	B	B	C	B	C	C	D	E	E	D	E	E	E	D	D	E	--	E	E	D	D	E	E	E	E	F	F	--	--	--	--	--	--	--	--	--
182.83–183.20	Coal	101635	.005	27.9	.018	A	A	B	B	B	C	C	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	D	E	E	D	E	F	F	--	--	--	--	--	--	--	--	--
183.20–183.44	do	101636	.003	42.1	.006	A	A	B	B	B	C	C	C	C	E	D	D	D	D	D	D	D	D	E	E	E	D	D	E	E	E	E	F	F	--	--	--	--	--	--	--	--	--
183.44–183.98	do	101637	.005	14.7	.034	A	A	B	C	B	C	B	C	C	D	D	D	D	D	D	D	D	D	D	D	E	D	D	E	E	E	E	F	E	--	--	--	--	--	--	--	--	--
183.98–184.33	Shale	101638	.004	----	----	A	A	B	B	C	C	C	C	D	E	E	D	E	--	E	D	D	E	--	E	E	D	D	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
184.33–184.62	do	101639	.004	----	----	B	B	B	--	C	C	C	D	E	E	E	D	E	--	E	--	E	E	E	E	F	--	--	--	E	E	--	F	--	--	--	--	--	--	--	--	--	--
184.62–184.92	Coal	101640	.002	12.0	.081	A	A	B	--	B	C	B	C	C	D	D	C	D	D	D	D	D	D	D	D	E	D	D	E	E	E	E	F	F	--	--	--	--	--	--	--	--	--
184.92–185.14	Coal, impure	101641	.005	67.7	.007	A	A	B	B	C	C	C	C	C	E	E	D	D	D	E	D	D	D	E	D	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
186.00–186.62	Shale	101642	.006	----	----	A	A	B	B	C	C	C	C	D	E	E	D	E	E	E	--	D	E	E	E	E	D	--	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
186.62–187.04	Coal	101643	.006	17.2	.032	A	A	B	C	B	C	B	C	D	D	D	C	D	D	D	D	D	D	E	D	E	D	D	E	E	D	E	F	F	--	--	--	--	--	--	--	--	--
187.04–187.33	do	101644	.002	12.9	.012	B	B	A	B	B	C	B	C	C	D	D	C	D	D	D	E	E	D	D	D	--	E	--	E	E	D	--	F	F	--	--	--	--	--	--	--	--	--
187.33–187.70	do	101645	.001	18.5	.006	B	B	A	B	B	C	C	C	D	D	D	C	E	E	D	--	--	D	D	E	F	E	--	E	E	E	--	F	F	--	--	--	--	--	--	D	--	--
187.70–188.06	do	101646	.005	16.2	.030	A	A	B	C	B	C	B	C	C	D	D	C	D	D	D	D	D	D	E	D	E	D	D	E	E	D	--	F	F	--	--	--	--	--	--	--	--	--
188.06–188.54	do	101647	.001	10.0	.014	B	B	A	--	B	C	B	D	C	D	D	D	D	D	D	D	D	E	D	E	E	D	--	E	E	D	E	E	F	--	--	--	--	--	--	--	--	--
188.54–188.98	do	101648	.002	12.2	.016	A	A	B	C	B	C	C	D	D	D	D	D	D	D	D	D	E	D	D	E	E	D	--	E	E	E	--	E	F	--	--	--	--	--	--	--	--	--
188.98–189.33	do	101649	.002	9.99	.020	A	A	B	C	B	C	B	D	C	D	D	D	D	D	D	D	D	D	D	D	E	D	D	E	E	D	E	E	F	--	--	--	--	--	--	--	--	--
189.33–189.64	do	101650	.003	15.4	.017	A	A	B	C	B	C	C	C	D	D	D	D	D	D	D	C	D	D	D	D	E	D	D	E	E	D	--	E	F	--	--	E	E	--	--	--	--	--
189.64–190.17	Shale	101651	.008	----	----	B	B	C	--	C	C	D	D	D	E	E	D	E	--	D	D	E	E	E	E	E	E	--	--	E	E	--	F	F	--	--	--	--	--	--	--	--	--
190.17–190.50	Coal	101652	.003	11.4	.026	B	A	B	C	B	C	B	D	D	D	D	D	D	D	D	D	D	D	D	E	D	D	E	E	D	--	E	F	--	--	E	E	--	--	--	--	--	--
190.50–190.75	do	101653	.002	7.92	.028	A	A	B	C	B	C	B	C	D	D	D	D	D	D	D	C	D	D	D	D	E	D	C	E	E	D	E	E	E	--	--	D	--	--	--	--	--	D
190.75–191.02	do	101654	.002	7.32	.029	A	A	B	C	B	C	B	D	D	D	D	D	D	D	D	D	D	D	D	E	D	D	E	E	D	--	E	F	--	--	E	--	--	--	--	--	--	--
191.02–191.48	do	101655	.007	19.4	.038	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	C	D	D	D	D	E	D	D	E	E	D	E	E	F	--	--	D	D	--	--	--	--	D
191.48–191.69	Shale	101656	.010	----	----	A	A	C	C	C	C	C	D	E	E	E	D	D	E	D	D	D	E	E	E	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
191.69–191.98	Coal	101657	.012	14.0	.084	A	A	B	B	B	C	B	C	D	D	D	D	D	D	D	C	D	D	D	D	E	D	D	E	E	D	E	E	F	F	D	D	D	--	--	--	--	D
191.98–192.37	Shale	101658	.011	----	----	A	A	B	C	C	C	C	C	D	E	E	D	D	D	D	D	D	D	E	E	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
192.37–192.79	do	101659	.009	----	----	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	D	D	D	E	D	E	D	--	E	E	E	--	F	F	--	--	--	E	--	--	--	--	--
192.79–193.10	do	101660	.009	----	----	A	A	B	B	B	C	C	C	D	D	E	D	D	D	D	D	D	D	E	D	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
193.10–193.50	Sandstone	101661	.001	----	----	A	A	C	B	C	C	B	C	C	D	E	D	D	D	D	E	D	D	D	E	E	E	--	E	E	E	E	F	F	--	--	--	--	--	--	--	--	--

TABLE 4.—*Chemical and semiquantitative spectrographic analyses of samples from core holes*—Continued

Interval sampled (depth in feet)	Rock type	Sample	Chemical analyses (percent): Uranium in sample	Ash	Uranium in ash	Semiquantitative spectrographic analyses: Al	Si	Fe	K	Ca	Mg	Na	Ti	Ba	Sr	Mn	B	Ni	Co	Cr	Ce	Pb	Cu	Mo	V	Sc	La	Nd	Zr	Ga	Y	Sn	Yb	Be	Ag	Ge	Dy	Zn	P	Tb	Nb	As	Pr
CORE HOLE 12																																											
Sourdough No. 2 coal bed																																											
100.40–101.98	Shale, carbonaceous	113535	0.009	79.5	0.011	A	A	B	--	B	C	C	C	C	D	D	D	D	D	D	--	D	--	E	E	E	D	D	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
101.98–103.25	Coal	113536	.004	16.8	.021	B	A	A	--	B	C	C	C	D	D	D	C	D	C	D	--	D	D	D	D	E	D	D	E	E	D	E	E	E	--	--	--	--	--	--	--	--	--
103.25–104.15	Coal, impure	113537	.006	26.5	.022	A	A	A	--	B	C	C	C	D	D	D	D	D	C	D	--	D	D	D	D	E	D	D	E	E	D	E	E	F	--	--	--	--	--	--	--	--	--
104.60–105.92	Shale, carbonaceous	113538	.009	58.3	.016	A	A	B	--	B	B	C	C	D	D	D	D	D	--	D	--	D	D	E	E	E	D	D	E	E	E	--	E	F	--	--	--	--	--	--	--	--	--
CORE HOLE 13																																											
Monument No. 2 coal bed																																											
35.00–35.60	Clay	113539	0.002			A	A	B	--	C	C	B	C	--	D	E	D	E	E	D	--	E	E	--	E	E	E	E	--	E	E	--	F	F	--	--	--	--	--	--	--	--	--
35.60–36.04	Shale, carbonaceous	113540	.005			A	A	B	--	C	C	C	D	D	E	E	D	D	E	E	--	E	D	--	E	F	E	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
36.04–37.83	Clay	113541	.001			A	A	B	--	C	B	B	C	C	D	E	D	D	D	D	--	E	E	--	E	E	E	--	--	E	E	--	F	F	--	--	--	--	--	--	--	--	--
37.83–38.17	Coal, impure	113542	.004	41.8	0.009	A	A	B	--	C	B	B	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	--	E	E	D	--	E	E	--	E	--	--	--	--	--	--	--
38.17–39.83	Shale	113543	.002			A	A	B	--	C	B	B	C	C	D	D	D	D	E	D	--	E	E	E	E	E	E	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
41.00–44.02	Shale, carbonaceous	113544	.004			A	A	B	--	C	C	B	C	D	--	D	D	D	E	D	D	--	D	E	E	E	E	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
45.00–47.11	do	113545	.004			A	A	B	--	C	C	C	C	D	--	D	D	D	E	D	D	--	D	--	E	E	E	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
47.11–48.50	Clay, carbonaceous	113546	.007	76.3	.009	A	A	B	--	C	B	C	C	C	--	D	D	D	E	D	D	D	D	E	D	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
48.50–49.39	Coal	113547	.002	45.3	.005	A	A	B	--	B	B	C	C	C	--	D	D	D	D	D	D	D	D	D	D	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
49.39–49.98	Coal	113548	.006	71.0	.008	A	A	B	--	C	C	C	C	D	--	D	D	D	E	D	D	D	D	E	D	E	D	--	E	E	D	--	E	F	--	--	--	--	--	--	--	--	--
49.98–50.85	do	113549	.003	20.3	.016	A	A	B	--	B	C	C	C	D	--	D	D	D	D	D	D	D	D	D	D	E	D	--	E	E	D	--	E	F	--	--	--	--	--	--	--	--	--
50.85–51.32	Shale	113550	.005			A	A	B	--	C	C	C	C	D	--	D	D	D	E	D	--	--	D	--	E	F	--	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
51.32–52.29	do	113551	.002			A	A	B	--	C	C	B	C	D	D	D	D	D	E	D	--	E	E	--	E	E		--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
52.29–52.75	Shale carbonaceous	113552	.007			A	B	B	--	C	C	C	C	D	D	D	D	D	--	E	--	E	--	E	D	E	--	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
52.75–53.13	Shale	113553	.004			A	A	B	--	C	C	C	C	D	D	D	D	D	--	D	--	E	D	--	E	E		--	--	E	E	--	F	F	--	--	--	--	--	--	--	--	--
53.13–53.75	Coal	113554	.004	16.7	.024	A	A	A	--	B	C	C	C	C	D	D	D	D	D	D	D	D	D	D	C	F	D	--	D	F	D	E	E	E	--	--	--	--	--	--	--	--	--
54.90–55.43	Shale carbonaceous	113555	.011			A	A	B	--	C	C	C	C	D	E	E	D	D	--	E	--	E	D	E	D	E	--	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
55.43–56.86	do	113556				A	A	B	--	C	C	C	C	C	D	D	D	D	E	D	D	D	D	E	D	E	D	--	--	E	E	--	F	F	--	--	--	--	--	--	--	--	--
56.86–57.64	Coal	113557				A	A	A	--	B	C	C	C	--	D	C	C	D	C	D	D	D	D	D	D	E	D	--	E	E	D	E	E	E	--	--	--	--	--	--	--	--	--
57.64–58.76	do	113558				B	B	C	--	C	C	D	E	E	E	--	D	E	--	E	--	--	E	E	--	--	--	--	--	--	E	--	F	--	--	--	--	--	--	--	--	--	--
58.76–60.63	do	113559				C	B	C	--	C	D	D	E	E	E	D	D	E	--	E	--	--	E	E											--	--	--	--	--	--	--	--	--
60.63–61.40	do	113560				C	B	C	--	C	D	D	E	E	E	D	D	E	--	E	--	--	E	E	E	--	--	--	--	--	E	--	F	--	--	--	--	--	--	--	--	--	--
61.40–61.89	do	113561	.004	20.7	.017	A	A	B	--	B	C	C	C	C	D	D	D	D	D	D	C	D	D	E	D	E	D	--	E	E	D	--	E	F	--	--	--	--	--	--	--	--	--
61.89–62.71	Coal, impure	113562	.004	35.7	.010	A	A	B	--	B	C	C	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
62.71–63.61	Coal	113563	.003	21.6	.012	A	A	B	--	B	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	E	D	--	E	E	D	--	E	F	--	--	--	--	--	--	--	--	--
64.90–66.92	Shale	113564	.004			A	A	B	--	C	C	C	C	D	D	D	D	D	E	D	--	D	D	--	E	E	E	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--

Monument No. 1 coal bed

66.92-67.27	Shale	113565	0.003	--	--	A	A	B	--	B	C	C	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	--	E	E	D	--	E	F	--	--	--	--	--	--	--	--	--
67.27-67.96	Shale carbonaceous	113566	.008	67.2	0.012	A	A	B	--	B	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	E	D	--	E	E	D	--	E	E	--	--	--	--	--	--	--	--	--
67.96-68.34	do	113567	.004	35.7	.012	A	A	B	--	B	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	E	D	--	E	E	D	--	F	F	--	--	--	--	--	--	--	--	--
68.34-59.50	do	113568	.005	64.3	.008	A	A	B	--	B	C	C	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
69.60-71.02	do	113569	.002	--	--	A	A	B	--	C	C	C	C	D	E	D	D	D	D	D	--	D	E	--	E	E	--	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
71.02-71.83	do	113570	.004	--	--	B	B	C	--	C	C	C	E	E	E	--	D	E	--	E	--	E	--	E	E	--	--	--	--	E	E	--	F	F	--	--	--	--	--	--	--	--	--
71.02-71.83	do	113570	.004	28.0	.014	A	A	B	--	B	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	E	D	--	--	E	D	--	E	E	--	--	--	--	--	--	--	--	--
71.83-73.33	do	113571	.004	--	--	A	A	B	--	C	C	C	C	D	E	E	D	D	--	E	--	E	D	--	E	E	--	--	E	E	E	--	F	--	--	--	--	--	--	--	--	--	--
73.33-74.08	do	[1] 113572	.005	--	--	A	A	B	--	C	C	C	C	D	E	E	D	D	--	E	--	E	D	E	E	F	--	--	E	E	E	--	E	--	--	--	--	--	--	--	--	--	--
73.33-74.08	do	113572	.005	66.5	.008	A	A	B	--	C	B	C	B	D	D	D	D	D	D	D	--	D	D	E	D	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
74.20-75.44	Coal, impure	[1] 113573	.004	--	--	A	A	B	--	C	C	C	C	D	E	E	D	D	--	D	--	E	D	--	E	F	--	--	--	E	E	--	F	--	--	--	--	--	--	--	--	--	--
74.20-75.44	do	113573	.004	60.0	.007	A	A	B	--	B	B	C	B	C	D	D	D	D	D	D	D	D	D	E	D	E	D	--	E	E	D	--	E	F	--	--	--	--	--	--	--	--	--
75.44-76.00	Shale carbonaceous	113574	.008	56.4	.015	A	A	B	--	B	B	C	B	C	D	D	D	D	D	D	D	D	D	E	D	E	D	--	E	E	D	--	E	F	F	--	--	--	--	--	--	--	--
76.90-77.76	do	113575	.005	--	--	A	A	B	--	C	C	C	C	D	E	D	D	D	--	D	--	E	D	F	E	E	E	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
77.76-78.27	Coal, impure	113576	.012	63.7	.019	A	A	B	--	C	C	C	C	D	E	D	D	D	--	E	--	D	D	E	E	E	E	--	--	E	E	--	F	--	--	--	--	--	--	--	--	--	--
78.27-78.90	do	113577	.004	12.4	.034	A	A	B	--	B	B	C	C	D	C	C	C	D	D	D	D	D	D	D	D	E	D	--	E	D	D	E	E	E	F	D	E	D	--	--	--	--	--
78.90-79.41	Shale, carbonaceous	113578	.010	--	--	A	A	B	--	C	C	C	C	D	D	E	D	D	--	D	--	D	D	E	E	E	E	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
79.41-80.11	do	113579	.006	--	--	A	A	B	--	C	C	C	C	D	D	E	D	D	E	D	--	D	D	E	E	E	E	--	E	--	E	E	F	F	--	--	--	--	--	--	--	--	--

CORE HOLE 16

Monument No. 1 coal bed

25.42-25.70	Shale, carbonaceous	114153	0.004	--	--	A	A	B	B	C	C	C	C	D	E	D	D	D	--	D	--	D	D	--	E	E	--	--	E	E	--	--	F	F	--	--	--	--	--	--	--	--	--
26.70-27.30	Shale	114154	.004	--	--	A	A	B	B	C	C	C	C	D	E	D	D	D	E	D	--	D	D	E	E	F	E	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
27.30-27.81	Shale, carbonaceous	114155	.007	63.2	0.011	A	A	B	B	C	C	C	C	C	D	D	D	D	E	D	D	D	D	E	E	E	D	--	E	E	E	--	F	F	F	--	--	--	--	--	--	--	--
27.81-28.36	Shale	114156	.004	52.6	.007	A	A	B	B	C	C	C	C	C	D	D	D	D	D	D	D	D	D	E	E	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
28.36-28.63	Coal, impure	114157	.004	35.2	.011	A	A	B	B	B	C	C	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	--	E	E	E	--	F	F	F	--	--	--	--	--	--	--	--
28.63-29.29	Coal	114158	.003	16.9	.019	A	A	A	B	B	C	C	C	C	D	D	C	D	D	D	D	D	D	D	D	E	D	--	E	E	D	--	E	F	F	--	--	--	--	--	--	--	--
29.29-29.68	Coal, impure	114159	.007	46.5	.015	A	A	B	B	B	C	C	C	C	--	D	D	D	D	D	D	D	D	E	D	E	D	--	E	E	D	--	E	F	F	--	--	--	--	--	C	--	--	--
29.68-30.04	Coal	114160	.004	35.4	.012	A	A	B	B	B	C	C	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	--	E	E	D	--	E	F	--	--	--	--	--	--	--	--	--
30.04-30.98	do	114161	--	--	--	A	A	B	B	B	C	C	C	C	C	D	D	D	D	D	C	D	D	E	D	E	D	--	E	E	D	--	E	F	F	--	--	--	--	--	--	--	--
30.98-31.42	Coal, impure	114162	.006	40.9	.015	A	A	B	B	C	C	C	C	C	D	D	D	D	E	D	D	D	D	E	E	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--

Sourdough No. 2 coal bed

68.29-68.81	Clay, carbonaceous	114163	0.006	70.1	0.009	A	A	B	B	B	C	C	C	C	D	D	D	D	E	D	D	D	D	E	E	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
69.33-70.61	Coal, impure	114164	.005	60.0	.009	A	A	B	B	B	C	C	C	C	D	D	D	D	D	D	D	D	D	E	D	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
70.61-71.38	do	114165	.004	44.0	.008	A	A	B	B	B	C	C	C	D	D	D	D	D	D	D	--	D	D	E	D	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
71.38-72.87	do	114166	.006	65.4	.009	A	A	B	B	C	C	C	C	D	D	D	D	D	D	D	--	D	D	E	E	E	D	--	E	E	E	--	F	F	--	--	--	--	--	--	--	--	--
76.00-76.32	do	114167	.008	27.2	.028	A	A	B	B	B	C	C	C	C	D	D	D	D	D	D	C	D	D	D	D	E	D	--	F	E	D	--	E	F	F	--	--	--	--	--	--	--	--
76.32-76.77	do	114168	.005	11.2	.048	A	A	B	B	B	C	B	C	D	D	D	C	D	D	D	D	D	D	D	D	E	D	--	E	E	D	E	E	F	F	--	--	--	--	--	--	--	--

TABLE 4.—*Chemical and semiquantitative spectrographic analyses of samples from core holes*—Continued

Interval sampled (depth in feet)	Rock type	Sample	Chemical analyses (percent)			Semiquantitative spectrographic analyses																																					
			Uranium in sample	Ash	Uranium in ash	Al	Si	Fe	K	Ca	Mg	Na	Ti	Ba	Sr	Mn	B	Ni	Co	Cr	Ce	Pb	Cu	Mo	V	Sc	La	Nd	Zr	Ga	Y	Sn	Yb	Be	Ag	Ge	Dy	Zn	P	Tb	Nb	As	Pr
CORE HOLE 17																																											
Battle No. 3 coal bed																																											
156.21–156.90	Clay, carbonaceous	114387	0.008	42.0	0.018	a	a	b	d	c	d	e	d	f	g	h	g	g	g	g	g	g	g	i	h	i	g	--	h	i	i	--	k	k	--	--	--	--	--	--	--	--	--
161.80–162.02	Coal	114388	.013	25.6	.052	a	a	b	c	c	d	d	e	e	f	g	g	g	g	g	f	g	f	h	g	i	g	--	h	h	g	--	i	j	--	--	--	--	--	--	--	--	--
162.70–163.08	Shale, carbonaceous	114390	.013	40.6	.031	a	a	b	c	c	d	e	e	f	f	h	g	g	g	g	f	g	g	g	g	i	g	--	h	i	g	--	i	k	--	--	--	--	--	--	--	--	--
163.08–163.83	Coal	114391	.009	26.6	.032	a	a	a	d	c	d	e	d	f	f	g	g	g	g	g	f	g	g	g	g	i	g	--	h	i	g	--	i	j	--	--	--	--	--	--	--	--	--
164.00–164.58	Clay	114392	.004	73.6	.006	a	a	b	c	c	c	d	d	f	g	h	g	g	g	g	g	g	g	i	i	i	g	--	h	i	i	--	k	k	--	--	--	--	--	--	--	--	--
168.40–169.12	Coal	114393	.005	17.2	.031	a	a	a	d	c	e	e	d	f	f	g	g	g	g	g	e	g	g	g	g	i	g	--	h	i	g	--	i	i	--	--	--	--	--	--	--	--	--
Monument No. 2 coal bed																																											
250.04–250.77	Clay, carbonaceous	114395	0.007	84.6	0.008	a	a	c	c	c	d	d	d	f	g	h	h	h	g	g	--	g	g	i	i	i	g	--	h	i	i	--	k	k	--	--	--	--	--	--	--	--	--
252.67–252.90	Coal	114396	.009	43.8	.020	a	a	a	c	c	d	e	d	f	g	h	g	g	g	g	g	g	g	g	g	i	g	--	h	e	g	--	i	k	--	--	--	--	--	--	--	--	--
259.94–260.48	Shale, carbonaceous	114397	.006	54.8	.011	a	a	b	c	c	d	e	d	f	g	h	g	g	g	g	g	g	g	i	g	i	g	--	h	i	g	--	j	k	--	--	--	--	--	--	--	--	--
261.85–262.58	do	114398	.008	47.0	.016	a	a	b	c	c	d	e	d	f	g	h	g	g	g	h	g	g	g	h	g	i	g	--	h	i	g	--	i	k	--	--	--	--	--	--	--	--	--
262.58–263.35	Coal, impure	114399	.009	51.4	.017	a	a	b	c	c	d	e	d	f	g	h	g	h	g	h	--	g	g	i	i	i	g	--	h	i	g	--	i	k	--	--	--	--	--	--	--	--	--
263.35–263.63	Coal	114400	.014	30.2	.047	a	a	b	c	c	d	e	d	f	f	h	g	g	g	g	g	g	g	g	g	i	g	--	h	h	g	--	i	i	--	--	--	--	--	--	--	--	--
264.34–264.99	Shale, carbonaceous	114401	.006	52.3	.011	a	a	c	c	c	d	e	d	f	g	h	g	g	g	g	--	g	g	i	g	i	g	--	h	i	i	--	j	k	--	--	--	--	--	--	--	--	--
Monument No. 1 coal bed																																											
266.81–267.02	Clay, carbonaceous	114402	0.007	77.5	0.009	a	a	b	c	c	d	e	d	f	g	h	g	g	g	g	g	g	g	i	h	i	g	--	h	i	i	--	k	k	--	--	--	--	--	--	--	--	--
267.02–268.25	Coal, impure	114403	.005	48.0	.010	a	a	b	c	c	d	e	d	f	g	h	g	g	g	g	--	g	g	h	g	i	g	--	h	i	i	--	j	k	--	--	--	--	--	--	--	--	--
268.25–268.71	Coal	114404	.005	22.0	.021	a	a	a	d	c	e	e	e	g	g	g	g	g	g	g	g	g	g	g	g	i	g	--	h	i	h	--	j	k	--	--	--	--	--	--	--	--	--
269.06–269.76	Clay, carbonaceous	114405	.005	49.3	.011	a	a	b	c	c	d	e	d	f	g	h	g	g	g	g	--	g	g	i	g	i	g	--	h	i	i	--	j	k	--	--	--	--	--	--	--	--	--
269.76–270.03	Coal	114406	.005	14.5	.034	a	a	b	d	c	e	d	d	f	f	g	g	g	g	g	g	g	g	h	g	i	g	--	h	i	g	--	i	k	--	--	--	--	--	--	--	--	--
270.03–270.30	Coal, impure	114407	.004	31.8	.014	a	a	b	c	c	d	e	d	f	f	h	g	g	g	g	--	g	g	i	g	i	g	--	h	i	g	--	j	k	--	--	--	--	--	--	--	--	--
276.79–277.13	do	114408	.007	32.1	.021	a	a	b	c	c	d	e	e	f	f	h	g	g	g	g	g	g	g	i	h	i	g	--	h	i	g	--	i	k	--	--	--	--	--	--	--	--	--
277.13–277.43	Coal	114409	.009	12.7	.073	a	a	a	--	c	e	d	d	f	f	g	g	g	f	g	e	g	g	g	g	i	g	--	h	g	g	--	i	i	--	i	--	--	--	--	--	--	--
277.71–277.90	do	114411	.019	15.0	.130	a	a	a	--	c	e	e	e	f	f	h	f	g	g	f	--	f	e	h	g	i	g	--	i	i	g	--	j	k	--	--	--	--	--	--	--	--	--
278.40–278.75	do	114412	.005	19.5	.028	a	a	b	e	c	e	e	e	f	f	h	f	g	g	g	--	g	f	i	h	i	g	--	i	i	g	--	i	k	--	--	--	--	--	--	--	--	--
280.61–281.02	do	114413	.013	23.3	.055	a	a	c	e	c	e	e	e	f	f	h	g	g	g	g	e	f	e	h	g	i	g	--	i	i	g	--	i	j	--	--	--	--	--	--	--	--	--
281.86–282.20	do	114414	.007	21.8	.032	a	a	c	c	b	d	d	e	f	f	g	g	g	g	g	g	g	f	i	g	i	g	--	i	h	g	--	i	i	--	g	--	--	--	--	--	--	--

CORE HOLE 24

Monument No. 2 coal bed

148.16–148.82	Coal	114658	0.007	67.1	0.011	a	a	c	c	c	c	c	e	f	g	i	g	g	g	g	--	g	g	i	i	i	g	--	i	i	i	--	k	k	--	--	--	--	--	--	--	--	--
150.15–150.28	do	114660	.007	86.7	.008	a	a	c	c	c	c	c	e	f	g	h	h	g	g	g	--	g	g	i	i	i	g	--	i	i	i	--	k	k	--	--	--	--	--	--	--	--	--
154.63–155.31	Coal, impure	114661	.010	35.5	.028	a	a	b	d	c	d	e	e	f	f	i	g	g	f	f	g	g	f	i	g	i	g	--	i	i	g	--	i	j	--	--	--	--	--	--	--	--	--
156.40–157.25	Coal	114662	.005	13.5	.033	a	a	b	d	b	d	d	e	e	f	g	e	g	g	g	g	g	g	h	g	i	g	--	i	h	g	--	i	j	--	i	--	--	--	--	--	--	--
159.42–160.00	do	114663	.007	17.2	.041	a	a	b	c	c	e	d	e	f	f	h	f	g	g	g	g	g	g	g	g	i	g	--	i	h	g	--	i	k	--	--	--	--	--	--	--	--	--
161.35–161.59	Coal, impure	114667	.012	20.0	.060	a	a	a	d	c	e	d	e	f	f	i	f	g	e	g	g	g	g	g	f	i	g	--	i	h	g	--	i	k	--	--	--	--	--	--	--	--	--
162.16–162.44	do	114669	.010	28.5	.034	a	a	a	c	c	e	d	e	g	g	i	f	g	g	g	g	g	g	i	g	i	g	--	i	h	g	--	i	k	--	i	--	--	--	--	--	--	--

Monument No. 3 coal bed

167.14–167.31	Coal	114670	0.012	44.1	0.027	a	a	c	c	c	c	d	e	f	f	h	g	g	g	g	g	g	g	i	g	i	g	--	i	i	g	--	i	k	--	--	--	--	--	--	--	--	--
168.44–168.70	Coal, impure	114672	.010	34.2	.028	a	a	b	d	c	d	e	e	f	f	i	g	g	g	g	g	g	g	g	g	i	g	--	i	h	g	--	i	j	--	--	--	--	--	--	--	--	--
169.61–170.23	Coal	114674	.009	23.9	.036	a	a	a	d	c	e	d	e	g	f	h	f	g	e	g	g	g	g	g	g	i	g	--	i	h	g	--	i	j	--	--	--	--	--	--	--	--	--
170.29–171.09	do	114675	.005	29.3	.017	a	a	b	d	c	e	e	e	f	f	i	g	g	g	g	--	g	g	h	h	i	g	-	i	i	g	--	j	k	--	--	--	--	--	--	--	--	--
171.09–171.51	do	114676	.009	31.5	.028	a	a	b	d	c	e	e	e	g	f	i	g	g	g	g	g	g	g	h	h	i	g	--	i	i	g	--	i	j	--	--	--	--	--	--	--	--	--
171.51–171.72	do	114677	.005	17.1	.026	b	b	a	--	c	e	d	e	g	f	i	f	g	g	g	--	g	g	g	g	i	h	--	i	h	h	i	i	j	--	--	--	--	--	--	--	--	--
171.72–172.34	Coal, impure	114678	.028	57.5	.049	a	a	c	d	c	e	e	e	g	f	i	g	g	g	g	g	f	g	h	g	i	g	--	i	i	g	--	i	k	--	--	--	--	--	--	--	--	--
172.34–172.82	Clay, carbonaceous	114679	.007	81.4	.009	a	a	c	c	c	e	d	e	f	g	i	g	i	h	h	--	g	g	j	i	i	g	--	i	i	i	--	k	k	--	--	--	--	--	--	--	--	--
173.47–173.98	do	114681	.018	86.9	.020	a	a	c	c	c	d	e	e	f	g	i	g	h	--	h	g	g	g	i	i	i	g	--	i	i	h	--	j	k	--	--	--	--	--	--	--	--	--

CORE HOLE 43

Monument No. 2 coal bed

128.27–128.60	Coal	116537	----------	--------	----------	a	a	a	--	c	d	e	e	e	g	f	f	g	f	f	g	g	g	g	g	i	g	--	g	h	h	--	j	k	k	--	--	--	--	--	--	--	--

Sourdough No. 2 coal bed

203.90–204.38	Coal	116538	0.002	33.0	0.007	a	a	b	--	c	d	d	f	g	g	f	f	f	g	g	g	g	g	h	g	i	g	--	h	h	h	--	j	k	k	--	--	--	--	--	--	--	--
212.35–212.74	do	116539	.006	16.4	.034	a	a	b	--	c	d	c	f	g	g	f	f	f	f	g	g	g	g	g	g	i	g	--	h	h	g	i	i	i	k	i	--	--	--	--	--	--	--
215.80–216.30	Coal, impure	116540	.010	21.3	.046	c	b	a	--	c	d	d	f	g	g	f	f	--	f	f	-	g	g	g	g	i	i	--	g	h	g	--	i	i	k	g	--	--	--	--	--	--	--

CORE HOLE 71

Hadsell No. 2 coal bed

46.00–47.51	Shale, carbonaceous	123773	0.002	64.3	0.004	a	a	c	c	d	d	e	d	e	g	h	g	f	g	g	g	f	g	h	g	i	g	-	g	h	h	--	j	k	--	i	--	--	--	--	--	--	--
47.51–48.58	Shale	123774	.003	78.9	.004	a	a	c	d	d	d	e	d	e	g	g	g	g	g	g	g	g	g	i	g	i	g	--	h	h	h	--	j	k	k	--	--	--	--	--	--	--	--
48.58–49.35	Coal, impure	123775	.002	27.1	.009	a	a	b	c	c	c	e	e	e	g	g	f	g	g	g	g	f	g	h	g	i	g	--	i	h	g	--	i	i	k	i	--	--	--	--	--	--	--
49-35–50.38	Shale, carbonaceous	123776	.003	64.7	.004	a	a	c	c	d	c	e	d	e	g	g	g	g	g	g	g	f	g	h	g	i	g	--	g	h	h	--	j	k	k	--	--	--	--	--	--	--	--
50-38–52.00	do	123777	.004	57.6	.006	a	a	c	c	d	c	d	d	e	g	g	g	g	g	g	g	f	g	h	g	i	g	--	h	h	h	--	j	k	k	--	--	--	--	--	--	--	--
56.71–58.00	do	123778	.002	79.1	.003	a	a	c	c	d	c	d	d	e	g	e	g	g	g	g	g	f	g	i	g	i	g	--	h	h	h	--	j	k	k	--	--	--	--	--	--	--	--

TABLE 4.—*Chemical and semiquantitative spectrographic analyses of samples from core holes*—Continued

Interval sampled (depth in feet)	Rock type	Sample	Chemical analyses (percent): Uranium in sample	Ash	Uranium in ash	Semiquantitative spectrographic analyses: Al	Si	Fe	K	Ca	Mg	Na	Ti	Ba	Sr	Mn	B	Ni	Co	Cr	Ce	Pb	Cu	Mo	V	Sc	La	Nd	Zr	Ga	Y	Sn	Yb	Be	Ag	Ge	Dy	Zn	P	Tb	Nb	As	Pr
Hadsell No. 1 coal bed																																											
68.00–68.52	Shale, carbonaceous	123779	0.002	78.9	0.002	a	a	c	c	d	c	c	d	e	g	f	g	g	g	g	g	f	g	i	g	i	g	--	h	h	h	--	j	k	k	--	--	--	--	--	--	--	--
68.52–69.21	Coal	123780	.002	35.8	.006	a	a	b	d	c	c	e	d	e	f	h	f	g	g	g	--	f	g	h	g	i	g	--	g	h	g	--	i	i	--	i	--	--	--	--	--	--	--
111.90–112.81	Coal, impure	123781	.005	72.1	.007	a	a	c	d	c	d	e	d	d	e	h	g	g	h	g	g	f	g	h	g	i	g	--	h	h	g	--	i	k	k	--	--	--	--	--	--	--	--
Creston No. 3 coal bed																																											
112.81–113.16	Coal	123782	0.002	20.6	0.009	a	a	a	d	c	d	e	e	f	f	g	e	f	f	f	g	f	f	g	g	i	g	--	g	h	g	--	i	j	k	--	--	--	--	--	--	--	--
113.16–114.17	Coal, impure	123783	.004	44.9	.008	a	a	b	c	c	c	d	d	e	f	g	g	g	g	g	g	f	f	h	g	i	g	--	g	h	h	--	j	k	k	--	--	--	--	--	--	--	--
114.17–115.18	Shale	123784	.003	86.2	.004	a	a	c	c	e	d	d	d	e	g	h	g	g	g	g	g	f	g	i	h	i	g	-	i	h	i	--	k	k	k	--	--	--	--	--	--	--	--
115.18–116.00	do	123785	.003	71.3	.004	a	a	c	c	c	c	d	d	e	g	g	g	g	g	g	g	f	g	h	g	i	g	--	f	h	i	--	k	k	k	--	--	--	--	--	--	--	--
116.00–117.00	Shale, carbonaceous	123786	.002	60.2	.003	a	a	c	c	d	c	d	d	e	g	g	g	g	g	g	--	g	g	h	g	i	g	--	h	h	h	--	j	k	k	--	--	--	--	--	--	--	--
117.00–117.86	do	123787	.002	70.5	.003	a	a	c	c	d	c	e	d	e	g	h	g	g	g	g	g	f	g	i	g	i	g	--	h	h	h	--	j	k	k	--	--	--	--	--	--	--	--
128.15–129.00	Shale	123788	.003	89.7	.003	a	a	c	c	d	c	d	d	e	g	h	g	g	g	g	--	f	g	i	g	i	g	--	h	h	i	--	k	k	--	--	--	--	--	--	--	--	--
129.00–129.46	Shale, carbonaceous	123789	.005	49.6	.011	a	a	c	c	d	c	d	d	e	f	h	g	g	g	g	g	f	f	h	g	i	g	--	h	h	g	--	i	k	k	--	--	--	--	--	--	--	--
129.46–130.18	do	123790	.003	78.1	.004	a	a	c	c	d	c	d	d	e	g	g	g	h	g	g	i	f	g	i	g	--	g	--	h	h	h	--	j	k	--	--	--	--	--	--	--	--	--
Creston No. 2 coal bed																																											
150.00–151.46	Shale	123791	0.002	86.4	0.003	a	a	c	c	d	c	d	d	e	g	h	g	h	h	g	--	f	g	i	g	i	g	--	h	h	h	--	j	k	--	--	--	--	--	--	--	--	--
151.46–152.31	Shale, carbonaceous	123792	.002	50.6	.004	a	a	c	c	d	c	e	e	e	g	g	g	g	g	g	--	g	g	i	h	i	g	--	i	h	i	--	k	k	--	--	--	--	--	--	--	--	--
153.86–154.97	Coal, impure	123973	.003	40.4	.006	a	a	c	d	c	d	e	e	e	f	g	g	g	g	g	--	g	g	h	g	i	g	--	g	h	i	--	k	k	--	--	--	--	--	--	--	--	--
160.44–161.20	Shale, carbonaceous	123794	.004	69.9	.006	a	a	d	c	d	d	e	d	e	g	g	g	h	h	g	--	f	g	i	g	i	g	--	h	h	i	--	k	k	--	--	--	--	--	--	--	--	--
161.20–162.46	do	123795	.002	50.7	.004	a	a	d	d	d	d	e	e	e	g	g	g	g	g	g	--	f	g	i	g	i	g	--	g	h	i	--	k	k	l	--	--	--	--	--	--	--	--
162.46–163.13	Coal	123796	.002	17.8	.012	a	a	b	e	c	d	d	e	e	f	f	e	f	f	g	g	g	g	g	g	i	g	--	g	h	h	--	j	j	--	--	--	--	--	--	--	--	--
163.13–164.00	Coal, impure	123797	.003	59.8	.004	a	a	c	c	d	c	e	d	e	g	g	g	g	h	g	g	f	g	i	g	i	g	--	i	h	i	--	k	k	--	--	--	--	--	--	--	--	--
164.00–165.39	Shale, carbonaceous	123798	.003	79.0	.004	a	a	c	c	d	c	e	d	e	g	h	g	g	h	g	g	f	g	i	g	i	g	--	f	h	i	--	k	k	l	--	--	--	--	--	--	--	--
165.39–166.00	do	123799	.003	74.8	.004	a	a	c	c	d	c	e	d	e	g	g	g	h	h	g	g	f	g	i	h	i	g	--	i	h	h	--	j	k	j	--	--	--	--	--	--	--	--
166.00–167.25	do	123800	.004	69.3	.005	a	a	c	c	d	c	e	d	e	g	f	g	g	g	g	g	g	g	i	g	i	g	--	h	h	i	--	j	k	k	--	--	--	--	--	--	--	--
167.25–168.00	Coal, impure	123801	.004	39.3	.010	a	a	b	c	c	d	d	e	e	g	g	g	g	g	g	g	f	g	g	g	i	g	--	f	h	h	--	j	k	j	--	--	--	--	--	--	--	--
168.00–169.04	Shale	123802	.002	90.8	.002	a	a	c	c	e	c	d	d	e	g	h	g	h	h	g	g	g	g	i	h	i	g	--	h	h	i	--	k	k	k	--	--	--	--	--	--	--	--
169.04–170.00	Shale, carbonaceous	123803	.004	79.1	.005	a	a	c	c	d	c	e	d	e	g	g	g	g	g	g	g	g	g	i	g	i	g	--	h	h	h	--	j	k	j	--	--	--	--	--	--	--	--
170.00–170.42	do	123804	.003	80.7	.004	a	a	c	c	d	c	e	d	e	g	h	g	h	h	g	g	f	g	i	g	i	g	--	h	h	h	--	j	k	k	--	--	--	--	--	--	--	--
170.42–171.54	Coal	123805	.003	29.9	.009	a	a	b	d	d	d	d	e	e	g	g	e	g	g	g	g	f	g	h	g	i	g	--	h	h	h	--	j	k	k	--	--	--	--	--	--	--	--
171.54–172.33	Shale, carbonaceous	123806	.004	66.2	.005	a	a	c	c	d	c	e	e	e	g	g	g	h	h	g	--	g	g	i	g	i	g	--	h	h	h	--	j	k	j	--	--	--	--	--	--	--	--
172.33–172.90	Coal, impure	123807	.002	66.9	.003	a	a	c	c	d	c	e	d	e	g	h	g	h	h	g	--	g	g	i	g	i	g	--	h	h	i	--	k	k	k	--	--	--	--	--	--	--	--
172.90–174.00	do	123808	.002	69.9	.003	a	a	c	c	d	c	e	d	e	g	h	g	h	h	g	--	g	g	i	g	i	g	--	h	h	i	--	k	k	k	--	--	--	--	--	--	--	--

CORE HOLE 72

Luman No. 1 coal bed

95.97–96.08	Shale	123721	0.0032	92.2	0.0037	a	a	b	--	d	c	c	d	e	h	g	h	h	g	g	g	g	h	--	i	i	g	--	h	i	--	--	j	k	--	--	--	--	--	--	--	--	--
96.08–96.18	do	123722	.0078	89.9	.0086	a	a	b	--	d	c	c	d	e	h	g	h	h	g	g	g	f	g	i	h	i	g	h	i	i	h	--	j	k	--	--	--	--	--	--	--	--	--
96.18–96.49	do	123723	.0051	92.2	.0055	a	a	b	--	d	c	c	d	e	h	g	h	g	g	g	g	g	g	i	h	i	g	h	i	i	i	--	k	k	--	--	--	--	--	--	--	--	--
96.49–96.58	do	123724	.0042	91.5	.0046	a	a	b	--	c	c	c	d	e	h	g	h	g	g	g	h	g	g	--	h	--	g	--	i	i	i	--	k	k	--	--	--	--	--	--	--	--	--
96.58–96.75	do	123725	.0053	90.1	.0059	a	a	b	--	d	c	d	d	e	h	g	h	h	g	g	g	f	g	--	h	i	g	h	i	i	i	--	j	k	--	--	--	--	--	--	--	--	--
96.75–96.87	do	123726	.0040	92.9	.0043	a	a	b	--	d	c	c	d	e	h	g	h	g	g	g	g	g	g	i	h	i	g	h	i	i	i	--	k	k	--	--	--	--	--	--	--	--	--
98.83–98.95	do	123727	.0032	91.9	.0035	a	a	b	--	d	c	c	d	e	h	g	h	g	g	g	g	g	g	i	h	i	g	h	i	i	i	--	k	k	--	--	--	--	--	--	--	--	--
99.18–99.31	do	123728	.0073	81.5	.0089	a	a	b	--	d	c	d	d	e	n	g	g	g	g	g	g	f	g	i	g	i	g	h	i	i	g	--	j	j	--	--	--	--	--	--	--	--	--
99.31–99.41	Shale, carbonaceous	123729	.0072	42.7	.0168	a	a	b	--	c	d	e	e	f	g	g	g	f	f	f	e	f	f	i	g	i	f	g	i	h	g	--	i	i	--	i	h	--	--	--	--	--	--
99.41–99.77	Coal, impure	123730	.0034	24.1	.0141	a	a	b	--	b	d	d	e	f	f	g	f	f	f	f	e	f	g	h	g	i	f	f	i	h	g	--	i	i	--	h	--	--	--	--	--	--	--
99.77–99.88	do	123731	.0056	52.4	.0107	a	a	b	--	c	c	e	d	e	g	g	g	g	g	g	g	f	f	i	g	i	g	h	i	i	h	--	j	k	--	--	--	--	--	--	--	--	--
99.88–100.13	Shale	123732	.0048	75.2	.0064	a	a	b	--	d	c	d	d	e	h	g	g	g	g	g	h	f	g	i	g	i	g	--	i	i	h	--	k	k	--	--	--	--	--	--	--	--	--
100.13–100.28	Shale, carbonaceous	123733	.0084	56.7	.0146	a	a	b	--	c	d	e	d	f	h	g	g	g	g	g	f	f	f	i	g	i	g	g	i	i	h	i	i	j	--	--	--	--	--	--	--	--	--
100.28–100.40	Coal	123734	.0036	11.7	.0282	a	a	b	--	b	d	c	e	f	f	g	e	f	f	g	f	f	g	g	g	i	f	g	i	h	e	h	h	j	--	i	h	--	--	--	--	--	--
100.40–100.50	do	123735	.0014	7.72	.0181	b	b	b	--	a	d	c	e	e	f	f	e	f	f	g	e	f	g	g	g	i	f	f	i	h	e	--	h	j	--	--	h	--	--	--	--	--	--
100.50–100.63	do	123436	.0011	7.22	.0152	b	b	b	--	a	d	c	e	e	e	f	e	f	f	f	e	f	g	g	g	i	e	f	i	h	e	--	h	i	--	--	h	--	--	--	--	--	--
100.63–100.72	do	123737	.0034	12.6	.0269	a	a	b	--	b	d	d	e	f	g	f	f	g	g	g	f	f	f	g	g	i	g	g	i	h	g	h	i	j	--	--	h	--	--	--	--	--	--
100.72–100.82	do	123738	.0034	12.9	.0263	a	a	b	--	b	d	d	e	f	g	f	e	g	g	g	e	f	f	g	g	i	f	f	i	h	f	i	i	j	--	--	h	--	--	--	--	--	--
100.82–100.92	do	123739	.0049	15.8	.0310	a	a	b	--	b	d	d	e	f	g	f	f	g	g	f	e	f	f	h	g	h	f	f	h	h	e	i	h	j	--	--	h	--	--	--	--	--	--
100.92–101.02	do	123740	.0056	14.2	.0394	a	a	b	--	b	d	d	d	f	g	f	f	f	g	g	e	f	f	g	g	i	--	g	h	h	e	i	h	j	--	--	h	--	--	--	--	--	--
101.02–101.12	do	123741	.0084	25.4	.0330	a	a	b	--	b	c	d	c	e	e	f	f	f	f	f	e	e	e	g	f	h	f	f	h	g	f	f	h	j	--	--	--	--	--	--	--	--	--
101.12–101.23	Shale, carbonaceous	123742	.0067	69.2	.0096	a	a	b	--	c	d	e	d	f	g	h	g	g	g	g	f	f	g	i	h	i	g	g	i	h	h	--	j	k	--	--	--	--	--	--	--	--	--
101.23–101.34	do	123743	.0104	57.1	.0182	a	a	b	--	c	d	e	d	f	g	h	g	g	g	g	f	f	g	i	g	i	g	h	i	h	h	--	j	k	--	--	--	--	--	--	--	--	--
101.34–101.44	do	123744	.013	36.9	.034	a	a	b	--	c	d	e	d	e	f	g	g	g	g	g	e	f	f	h	g	h	f	f	h	h	f	i	i	j	--	--	h	--	--	--	--	--	--
101.44–101.65	Shale	123745	.004	89.9	.004	a	a	b	--	c	c	d	d	e	g	g	g	g	g	g	g	f	g	i	h	i	g	h	i	h	i	i	j	k	--	--	--	--	--	--	--	--	--
101.65–101.95	Shale, carbonaceous	123746	.004	87.7	.005	a	a	b	--	d	c	d	d	e	g	g	g	g	g	g	g	f	g	i	h	i	g	h	i	h	j	--	j	k	--	--	--	--	--	--	--	--	--
101.95–102.16	do	123747	.0092	73.9	.0124	a	a	b	--	d	d	e	c	f	h	g	g	g	g	g	f	f	g	i	g	i	g	h	h	h	h	i	--	--	--	--	--	--	--	--	--	--	--
102.16–102.26	do	123748	.0071	69.2	.0102	a	a	b	--	d	d	e	d	f	h	h	g	h	g	g	g	f	f	i	g	i	g	h	i	h	h	i	j	k	--	--	--	--	--	--	--	--	--
102.26–102.34	do	123749	.0094	40.9	.0229	a	a	b	--	d	d	e	d	f	g	g	g	g	g	g	e	f	e	h	g	i	f	g	h	h	g	i	i	k	k	--	--	--	--	--	--	--	--
102.34–102.54	do	123750	.0050	38.5	.0128	a	a	b	--	d	d	e	e	f	g	h	g	g	g	g	g	f	g	i	g	j	g	h	i	h	g	i	i	k	--	--	--	--	--	--	--	--	--
102.54–102.65	do	123751	.0042	45.6	.0092	a	a	b	--	b	d	e	e	f	g	h	g	g	g	g	f	f	g	i	h	i	g	h	i	h	g	--	j	k	--	--	--	--	--	--	--	--	--
102.65–102.74	do	123752	.0107	34.5	.0310	a	a	b	--	b	d	e	e	f	g	h	g	g	g	--	f	f	f	h	g	i	f	g	i	h	g	i	i	j	--	--	--	--	--	--	--	--	--
102.74–102.92	do	123753	.0065	61.1	.0106	a	a	b	--	c	d	e	e	f	g	h	g	h	g	g	g	f	g	i	h	i	g	h	i	h	h	i	j	k	--	--	--	--	--	--	--	--	--
102.92–103.08	Coal	123754	.0085	29.6	.0287	a	a	b	--	b	d	e	e	f	g	g	f	g	g	g	e	f	f	i	g	i	f	f	i	h	f	i	h	j	--	--	h	--	--	--	--	--	--
103.08–103.15	do	123755	.0106	21.5	.0493	a	a	b	--	b	d	e	e	f	g	g	f	g	g	g	f	f	f	h	g	i	g	g	i	h	f	i	h	j	--	--	h	--	--	--	--	--	--
103.15–103.26	do	123756	.0124	29.7	.0417	a	a	b	--	b	d	e	e	f	g	g	g	f	g	g	f	f	f	h	g	i	f	g	i	h	f	i	i	j	--	--	h	--	--	--	--	--	--
103.26–103.35	do	123757	.0155	30.2	.0456	a	a	b	--	c	d	d	e	f	g	g	g	h	g	g	f	f	f	i	h	i	g	h	i	h	g	i	i	j	--	--	h	--	--	--	--	--	--
103.35–103.54	do	123758	.0127	31.4	.0404	a	a	b	--	b	d	e	e	f	g	g	g	g	g	g	e	f	f	i	g	i	f	f	h	h	f	i	i	j	--	--	h	--	--	--	--	--	--
103.54–103.60	do	123759	.0126	37.8	.0333	a	a	b	--	c	d	e	e	g	f	g	g	g	g	g	g	f	g	h	h	i	g	h	i	h	g	i	i	j	--	--	--	--	--	--	--	--	--
103.60–103.77	Coal, impure	123760	.0110	55.9	.0196	a	a	b	--	d	d	e	e	g	g	g	g	g	h	h	g	f	g	h	h	i	g	g	i	h	g	i	i	j	j	--	--	--	--	--	--	--	--
103.77–103.88	do	123761	.0202	38.5	.0525	a	a	b	--	c	d	d	d	f	f	g	g	g	g	g	e	f	f	h	g	i	f	f	h	h	e	i	i	j	--	--	h	--	--	--	--	--	--
103.88 103.98	do	123762	.0156	27.6	.0565	a	a	b	--	c	d	d	d	f	f	g	f	g	f	g	e	f	g	g	g	i	f	f	h	h	e	i	i	j	k	--	h	--	--	--	--	--	--
103.98 104.07	Coal	123763	.0101	14.9	.0677	a	a	b	--	c	d	d	e	f	f	g	f	g	f	g	e	f	g	g	g	i	f	f	h	h	e	i	h	j	k	--	h	--	--	--	--	--	--
104.07 104.27	do	123764	.0083	22.0	.0377	a	a	b	--	c	d	e	e	f	f	g	f	g	g	g	f	f	g	g	g	i	f	f	h	h	f	i	i	j	k	--	h	--	--	--	--	--	--
104.27 104.36	do	123765	.0059	10.6	.0566	a	a	c	--	b	d	c	e	f	f	f	e	g	g	g	f	f	g	g	h	i	g	g	h	h	f	i	h	j	k	--	h	--	--	--	--	--	--
104.36 104.58	do	123766	.0032	11.0	.0290	a	b	a	--	b	e	c	e	f	f	f	e	g	f	g	g	g	g	g	g	i	g	h	h	h	g	i	i	j	--	--	--	--	--	--	--	--	--
104.58 104.70	do	123767	.0041	14.7	.0278	a	a	b	--	b	d	c	d	f	f	--	f	--	f	--	--	f	--	--	--	i	--	h	h	--	e	i	i	j	--	h	h	--	--	--	--	--	--
104.70 104.82	Shale, carbonaceous	123768	.0061	34.9	.0174	a	a	b	--	c	d	e	d	g	f	g	g	g	g	g	g	f	g	h	h	i	g	h	h	h	f	--	i	j	--	g	--	--	--	--	--	--	--
104.82 105.00	Clay	123769	.0023	93.8	.0025	a	a	c	--	d	d	c	e	e	g	g	h	g	g	g	--	g	g	h	i	i	g	--	h	h	i	--	k	k	--	--	--	--	--	--	--	--	--

TABLE 5.—*Chemical and semiquantitative spectrographic analyses of unashed samples from surface sections*

[Semiquantitative spectrographic analyses: a, XX.; a−, XX.−; b+, X.+; b, X.; b−, X.−; c+, X+; c, 0.X; c−, 0.X−; d+, 0.0X+; d, 0.0X; d−, 0.0X−; e+, 0.00X+; e, 0.00X; e−, 0.00X−; f+, 0.000X+; f, 0.000X; f−, 0.000X−; 0, looked for but not detected; tr, near threshold]

Sample	Rock type	Thickness sampled (feet)	Uranium in sample (percent)	Semiquantitative spectrographic analyses																												
				Al	Si	Fe	K	Ca	Mg	Na	Ti	Ba	Sr	Mn	B	Ni	Co	Cr	Ce	Pb	Cu	Mo	V	Sc	La	Nd	Zr	Ga	Y	Yb	Ge	P
Locality 209 (R W 1161) Creston No. 3 coal bed																																
211546	Gravel	0.5	[1]0.002	a	a	b−	c+	c+	c	b−	c−	d+	d	d−	0	e−	f+	e−	0	tr	e−	e−	e	0	0	0	d−	tr	f+	f−	0	0
211547	do	.2	[1].002	a	a	b−	b−	c+	c−	b−	c	c−	d	d	0	e−	f+	e−	0	tr	e−	e	e	0	0	0	d−	tr	e−	f−	0	0
211548	Coal	.2	.014	c	c	c+	0	c−	d−	0	d−	d−	f+	0	0	e−	f+	f+	0	0	e−	f+	e−	0	0	0	0	0	0	tr	0	0
211549	do	.5	.033	b+	b	b	0	b−	c	c	d+	d+	d	d	0	e	e−	e	d+	e+	e+	e	e	e−	d	d−	e+	f+	e+	f+	0	c
211550	do	1.0	.051	b	b	b	0	b−	c	c	c−	d+	d	d	0	e	e−	e	d	e+	e+	e+	e+	e−	d	d−	e+	f+	e	f+	0	c
211551	do	1.0	.012	b+	b+	b−	c+	c+	c+	c	c	d+	d−	e+	e	e−	f	e	0	e+	e+	e	e+	f+	e	0	e+	e−	e−	f−	0	0
211552	do	1.0	.029	b	b−	b	0	c+	c−	c	c−	d+	d−	f+	0	e−	f	e	0	e	e+	e	e	f+	e	0	e	f+	e−	f−	0	0
211553	do	1.0	.009	b+	b+	b+	c+	c+	c	c	c	c−	d+	e−	e	e−	0	e+	d	e+	d−	e+	e+	e−	d−	0	e+	e−	e−	f	0	c
211554	do	1.0	.022	b	b	b	c+	c+	c	c−	c−	d+	d−	e−	0	e	0	e	d	e	e+	e+	e+	f+	e+	0	e+	f+	e	f	0	0
211555	do	1.0	.011	b+	b+	b+	c+	b−	c	c	c	d+	d	e	tr	e	f	e+	d+	e+	d−	e	e+	e−	d−	d−	e+	e−	e+	f+	0	0
211556	do	.5	.005	b+	b	b+	b−	c+	c	c	c−	d+	d	e	tr	e	0	e	0	e−	e+	e−	e+	f+	e+	0	e+	f+	e	f	0	0
211557	Clay shale	.2	.004	a	b+	a	b−	c+	c+	c	c−	d+	d+	e	e	e	f	e+	d	e−	e+	f+	e+	e−	e+	0	e+	e	e	f	e−	0
211558	Siltstone	.2	.002	a	a	a	b−	c	c+	c+	c	d+	d	e+	e	e−	f	e+	0	e−	e	f+	e+	e−	e	0	d−	e−	e−	f	0	0
211559	do	.5	.001	a	a	a	b−	c	c+	c+	c−	d+	d−	e+	e	e−	f+	e+	0	tr	e	f+	e+	f+	e	0	d−	f+	e−	f	0	0
211560	Clay shale	.3	[1].002	a	b+	a	b−	b	c+	c+	c−	d	d−	d	e	e−	f+	e	0	tr	e	f+	e+	f+	0	0	e+	e−	e−	f−	0	0
211561	Coal	.4	.002	a	b+	a	b−	d−	c+	c	c−	d	e	d−	e	e	e−	e	0	tr	e+	f+	e+	e−	0	0	e+	e−	e	f	0	0
211562	Shale, carbonaceous	.7	.002	a	a	a	b	e+	c+	c+	c−	d+	d	e+	e+	e−	f	e+	0	e−	e+	f+	e+	e−	e	0	e+	e−	e	f	0	0
211563	Shale	.5	.002	a	b+	a	b−	d−	c+	c+	c−	d	d−	d−	e	e−	f+	e	0	tr	e	f+	e+	e−	0	0	e+	f+	e−	f	0	0
211564	Clay shale	.3	.006	a	b+	a	b−	e+	c+	c+	c−	d	d−	e+	e	e−	f	e	0	tr	e	f+	e+	f+	0	0	e+	e−	e−	f−	0	0
211565	Coal	.2	.024	b−	b	b−	0	d−	c+	c−	d+	d−	d−	d−	0	e	e−	e	0	tr	e	f+	e	f+	0	0	e	tr	e	f−	0	0
211566	do	.5	.002	b−	b−	b−	0	d−	c+	c	d+	c−	d+	d−	0	e−	e−	e	0	tr	e	e−	e+	0	e	0	e	tr	e	f−	0	0
211567	do	.5	[1].002	b−	c+	b−	0	d−	c+	c	d+	d−	d−	d−	0	e−	f+	e−	0	tr	e	e−	e	0	0	0	e−	tr	0	tr	0	0
211568	do	.4	.003	c+	c+	c+	0	d	c+	c	d	d−	d−	d	0	e−	f+	e−	0	tr	e	e−	e	0	0	0	e−	tr	e−	f−	0	0
211569	Clay shale	.2	.002	a	b+	a	b−	d	b−	c	c	d+	d−	d	tr	e−	f+	e	0	e−	e+	e−	e+	e−	0	0	e+	f+	e−	f−	0	0
211570	Coal	.6	.007	b	b−	b	c+	e−	c−	c−	d+	d−	e+	e−	0	e	e−	e−	0	tr	e	f+	e+	f+	e	0	e	tr	e	f	e−	0
211571	Shale, carbonaceous	.5	.001	a	a	b−	b	c−	c+	c	c−	d	d−	e	e	f+	0	e+	0	e	e+	f+	e+	e−	0	0	e+	e−	e−	f−	0	0
211572	Coal	.5	.001	a	b+	b−	b−	c	c+	c	c−	d	e	e+	e	f+	0	e+	0	e−	e	0	e+	f+	e	0	e+	e−	e−	f−	0	0
211573	Shale, carbonaceous	1.5	.001	a	b	b−	b−	b−	c+	c	c−	d	e+	e	e	f+	0	e	0	e−	e	0	e	f+	0	0	e	f+	f+	f−	0	0
211574	Coal	1.0	[1].002	c+	c	b−	0	c	d−	d+	d	d−	e−	f	0	e	f	e−	0	0	e	f+	e−	0	0	0	0	tr	0	tr	0	0
211575	do	1.0	[1].002	c+	c	c+	0	c	d−	0	d	e+	e−	f	0	e−	0	e−	0	0	e	f+	e−	0	0	0	0	0	0	tr	0	0

211576	-----do-----	1.0	0.003	c+	b	c+	0	c	d	0	d+	tr	e−	f	tr	e−	0	e−	0	tr	e	f+	e−	0	0	0	e	0	f+	tr	0	----	0	----	0
211577	-----do-----	1.0	[1].002	c	b−	c+	0	c−	d−	0	d	tr	e−	f	tr	e−	0	e−	0	tr	e	f+	e	0	0	0	e−	0	0	tr	0	----	0	----	0
211578	-----do-----	1.0	[1].002	c	c+	c+	0	c−	d−	0	d−	0	f+	0	0	e−	0	f+	0	0	e−	f+	e−	0	0	0	0	0	0	tr	0	----	0	----	0
[2]211579	-----do-----	1.0	.002	c	b−	b−	0	c−	d−	d+	d	0	e−	0	0	f+	0	e−	0	tr	e	f+	e−	0	0	0	e−	tr	0	tr	0	----	0	----	0
211580	Clay-------	.4	.002	b+	a	b−	b−	c−	c	c−	c−	e	e+	e−	e	f+	0	e	0	tr	e	f+	e+	f+	0	0	e+	tr	f+	f−	0	----	0	----	0
[2]211581	-----do-----	.9	.002	b−	b+	b−	b−	c−	c−	d+	d+	tr	e	e−	tr	e−	f	e	0	tr	e	f+	e	0	0	0	e	tr	f+	f−	0	----	0	----	0
211582	-----do-----	1.0	[1].002	c+	b	b−	0	d+	c−	d+	d	0	f+	e−	0	e	f+	e−	0	tr	e−	f+	e	0	0	0	e	tr	e−	f−	tr	----	0	----	0
211583	-----do-----	.2	.001	a	a	b−	b	d+	c+	c−	c−	tr	e+	e+	tr	e−	f+	e+	0	tr	e	0	e+	f+	0	0	e+	f+	e−	f−	tr	----	0	----	0

Eagles Nest Section (R W 1138)

100880	Sandstone-	0.5	0.0001	b+	a	b−	b	c+	c−	b−	d+	d+	d−	e+	0	e−	0	e	0	e	e−	0	e	0	0	0	e+	e−	tr	0	f−	f	--	0	--
100881	-----do-----	.5	.0002	b+	a	b−	b	c−	c−	b−	d+	d+	d−	e+	0	e−	0	e	tr	e	f+	0	e	0	e+	0	e+	e−	e−	f−	0	tr	--	0	--
100882	-----do-----	.5	.0006	b+	a	b−	b	c−	c−	b−	d+	d+	d−	e+	0	e−	0	e	0	e	f+	0	e	0	e	0	e+	e−	f+	0	0	0	--	0	--
100883	Shale------	.1	.0012	b+	a	b	b	c	b−	b−	c−	d+	d−	d−	0	e−	f+	e	tr	e+	e	0	d−	e−	e+	0	e+	e	e−	f−	tr	0	--	0	--
100884	Sandstone-	.3	.0014	b+	a	b	b	c	b−	b−	c−	d+	d−	d−	0	e−	f+	e	tr	e−	e−	0	e+	f+	e+	0	d−	e−	e−	f−	0	0	--	0	--
100885	Shale------	.2	.0007	b+	a	b	b	c	b−	b−	c	d+	d−	d−	0	e−	f+	e	tr	e+	e	0	e+	f+	d−	tr	e	e	e−	f−	tr	0	--	0	--
100886	Siltstone---	.3	.0008	b+	a	b	b	c+	b−	b−	c	d	d−	d−	0	e−	e−	e	tr	e+	e	0	e+	f+	0	tr	e+	e	e−	f−	tr	0	--	0	--
100887	Sandstone-	.5	.0003	b	a	b+	b	c	c	b−	d	d	d−	d	0	f+	0	e	0	e−	f+	0	e	0	0	0	e	f+	e+	f+	0	0	--	0	--
100888	-----do-----	.5	.0006	b+	a	b−	b	c	c	b−	d+	d+	d−	e+	0	f+	0	e	0	e−	e−	tr	e+	0	0	0	e	f+	0	0	0	0	--	0	--
100889	-----do-----	.1	.0018	b+	a	b+	b	c	c−	b−	d+	d+	d−	e+	0	f+	f+	e	0	e	e	e	d−	0	0	0	e+	f+	tr	f−	0	0	--	tr	--
100890	Shale------	.1	.0018	b+	b+	b+	b	c	c+	e+	c−	d	d−	e	tr	f+	0	e	0	e	e	tr	d	f+	0	0	e	e	tr	f−	0	0	--	0	--
100891	Shale, paper	.5	.0020	b+	a	b	b	e+	b−	c	c−	d−	d−	e+	e−	e−	f+	e	0	e	e	0	d−	e−	0	0	e+	e−	tr	f−	tr	0	--	0	--
100892	-----do-----	1.0	.0008	b+	b+	b	b−	b−	b−	c	c−	d−	d−	d	e−	e	f+	e	0	e−	e	0	e+	f+	0	0	e	e−	e−	f−	tr	0	--	0	--
100893	-----do-----	1.0	.0009	b+	b+	b	b−	c+	b−	c	c−	d−	d−	d−	e−	e	f+	e	0	e−	e	tr	d−	f+	0	0	e+	e−	e−	f−	tr	0	--	0	--
100894	-----do-----	1.0	.0003	b+	b+	b−	b−	b−	b−	c	c−	d−	d−	d−	e−	e−	f+	e	0	e−	e	tr	e+	f+	0	0	e	e−	tr	f−	0	0	--	0	--
100895	-----do-----	1.0	.0003	b+	a	b−	b−	c+	b−	c	c−	d−	d−	d−	e−	e−	f+	e	0	e−	e	0	e+	f+	0	0	e	e−	tr	f−	0	0	--	0	--
100896	-----do-----	1.0	.0009	b	b+	b−	b−	b−	b−	c	c−	d−	d−	d	e−	e−	f+	e	0	e−	e	tr	e+	f+	0	0	e	e−	e−	f−	0	0	--	0	--

[1] Equivalent uranium.

TABLE 6.—*Duplicate chemical and semiquantitative spectrographic analyses of ashed samples from surface sections*

Semiquantitative spectrographic analyses: a, XX.; a−, XX.−; b+, X.+; b, +.; b−, X.−; c+, X+; c, 0.X; c−, 0.X−; d+, 0.0X+; d, 0.0X; d−, 0.0X−; e+, 0.00X+, e, 0.00X; e−, 0.00−; f+, 0.000X+; f, 0.000X; f−, 0.000X−; 0, looked for but not detected; tr, near threshold. Samples were previously analyzed in unashed condition (see table 5)]

Sample	Chemical analyses (percent)			Semiquantitative spectrographic analyses																													
	Uranium in sample	Ash	Uranium in ash	Al	Si	Fe	K	Ca	Mg	Na	Ti	Ba	Sr	Mn	B	Ni	Co	Cr	Ce	Pb	Cu	Mo	V	Sc	La	Nd	Zr	Ga	Y	Yb	Be	Nb	P
Locality 209 (R W 1161) Creston No. 3 coal bed																																	
211548	0.014	79.4	0.017	a	a	b	b−	b−	c	d+	c−	c	d	e	d	d−	e	e+	d	e+	d−	e+	d−	e−	d	d	e	e	e+	f+	f−	0	0
211549	.033	66.5	.045	b+	a	b	c+	b−	c+	c	d+	c−	c−	d	e+	e	f+	e	d+	d−	d−	e+	e+	e−	d	d	e	e−	e+	f+	f−	0	c−
211551	.012	79.5	.015	a	a	b	b−	b−	c+	c	c−	d+	d	d−	d	e−	f+	e+	d−	e+	d−	e+	d−	e−	e+	0	e	e	e−	f−	f−	0	0
211553	.009	77.2	.012	a	a	b	b−	c+	c+	c	c	c−	c−	e−	d	e	f	e+	d	d−	d−	e+	d−	e−	d	d	e+	e	e	f	f−	e−	c−
211554	.022	66.2	.031	a	a	b	b−	b−	c+	c	c−	d+	d+	e−	d	e	f	e+	d	d−	d−	d−	d−	e−	d−	d	e	e	e	f	f−	0	0
211556	.005	77.6	.006	a	a	b	b−	b−	c+	c	c−	d+	d−	e	d	e+	f	e+	d	e	d−	e+	d−	e−	d	d	e+	e−	e	f	f	0	0
211561	.002	86.8	.003	a	a	b	c+	b−	b−	c	c−	d+	d+	d	d	e+	e−	e+	d−	e−	e+	e−	d−	e−	e	0	e+	e−	e	f	f	e−	0
211568	.003	32.3	.008	a	b+	b	b−	b	b	c+	c−	d+	d	c−	d	e+	e	e+	d	e+	d−	e+	e+	e−	d−	d−	e	e	e+	f+	f+	0	0
211569	.007	48.9	.014	a	a	b	b−	b−	b−	c	c	d+	d	d	d	e	f+	e+	d−	e	e+	e	d−	e−	e	0	e+	e−	e	f−	f−	0	0
211576	.003	24.2	.011	a	a	b	b−	b−	c	c−	c	d+	d	e	d+	e+	f+	e+	d	e+	d−	e+	d−	e−	d	d	e+	e	e	f	f−	e−	0
211579	.002	36.8	.006	b+	a	b+	b−	c	c	c−	c−	d+	d−	e−	d	e	f	e	d−	e	e+	e	e+	e−	d−	d−	e	e−	e−	f−	f−	0	0
211581	.004	60.1	.004	a	a	b	b−	c−	c	c−	c	d	d	e	d	e	f+	e+	d−	e	e+	e	d−	e−	e+	0	e+	e−	e	f−	f−	e−	0

LEACHING AND EXTRACTION OF URANIUM

Tolmachev (1943), Moore (1954), Szalay (1954), and Breger, Deul, and Rubinstein (1955) have shown that uranium is readily removed from aqueous solution by coal and is held irreversibly as a disseminated constituent associated with the organic matter. Breger, Deul, Meyrowitz, and Rubinstein (1955) have reported on the geochemistry and mineralogy of a Red Desert coal, and Breger, Meyrowitz, and Warr (1953) reported on the recovery of uranium from the same coal.

Experiments were carried out by Wayne Mountjoy at the author's suggestion to determine whether uranium could be leached from schroeckingerite-bearing rock, whether coal would extract uranium from aqueous solution at the concentration and pH expectable in Red Desert natural waters, and whether uranium could penetrate coal blocks.

Several drill holes in the northwestern part of the area struck strong artesian flow of water containing as much as 47 ppb (parts per billion) uranium (table 7). Surface waters in Lost Creek contain from 27 to 180 ppb uranium near the schroeckingerite deposit 7 miles north of the area. Schroeckingerite, $NaCa_3(UO)_2(CO_3)_3(SO_4)F \cdot 10H_2O$, is a secondary uranium mineral that occurs in calichelike masses within 8 feet of the surface along the Cyclone Rim fault zone. It probably forms by the evaporation of ground water escaping from a small artesian basin and rising to the surface along the fault zone.

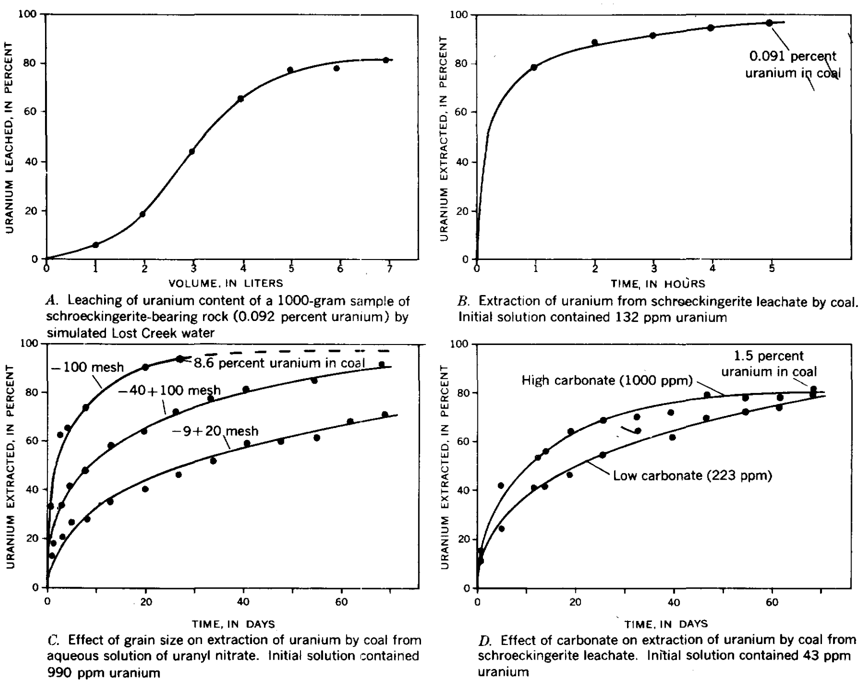
Water with mineral content and pH similar to that from Lost Creek was mixed with schroeckingerite-bearing rock and the filtrate passed over Red Desert coal. The water leached 84 percent of the uranium from the schoreckingerite-bearing rock (fig. 29*A*), and the coal removed 95 percent of the uranium from the filtrate (fig. 29*B*). In a second experiment the coal also effectively removed uranium from water containing 47 ppb uranium. A third experiment showed that the rate of removal of uranium from a uranyl nitrate solution containing 990 ppm (parts per million) uranium is faster for finely powdered coal than for the coarser grain sizes (fig. 29*C*). Also, coal removed uranium faster from a solution containing 1,000 ppm carbonate than from a solution containing 223 ppm (parts per million) carbonate (fig. 29*D*).

The experiment using the uranyl nitrate solution containing 990 ppm uranium was continued to test the maximum removal of uranium from solution by coal. At the end of 27 days, the powdered coal (minus 100 mesh) had removed 95 percent of the uranium from the solution and contained 8.6 percent uranium. An X-ray determination did not reveal the presence of any uranium mineral in the coal. The sample was reimmersed in a uranyl nitrate solution containing 550 ppm uranium. At the end of 120 days, the coal had removed 35 per-

TABLE 7.—*Analyses of water samples, Red Desert area, Sweetwater County, Wyo.*

[Results are given in parts per million, except as noted. Analysts: R. F. Dufour, J. W. Meadows, Wayne Montjoy, W. W. Niles, U.S. Geological Survey]

Sample		Source	Location			Formation	U (ppb)	CO_3	HCO_3	Cl	SO_4	F	NO_3	Ca	Na	K	pH
Laboratory No.	Field No.		Sec.	T.	R.												
202711	RW-1145	Lost Creek	19	26 N.	94 W.		27	0.8	91	6.9	105	0.6	28	18	33	2	8.18
202709	RW-1143	do	31	26 N.	94 W.		180	3.3	78	2.2	59	.4	4.7	19	20	2	8.12
202708	RW-1142	SK well	16	24 N.	94 W.		2	0	56	.2	24	.2	.8	8	14	1	7.15
52558	RW-10	Reservoir	34	27 N.	94 W.	Fort Union	30										
71369	RW-1018W	Circle Bar Lake	7	23 N.	93 W.	Battle Spring	23										
D98270	RW-1136	Battle Spring	25	24 N.	94 W.	Battle Spring or Wasatch	1					.3					
52559	RW-27	Artesian well	34	20 N.	94 W.	do	40										
D98272	RWC 17W-2	do	32	24 N.	94 W.	do	47					.5					
D78133	DY	Pump well	17	29 N.	91 W.	Browns Park	39										
D78334	DZ	do	15	29 N.	91 W.	do	50										



A. Leaching of uranium content of a 1000-gram sample of schroeckingerite-bearing rock (0.092 percent uranium) by simulated Lost Creek water

B. Extraction of uranium from schroeckingerite leachate by coal. Initial solution contained 132 ppm uranium

C. Effect of grain size on extraction of uranium by coal from aqueous solution of uranyl nitrate. Initial solution contained 990 ppm uranium

D. Effect of carbonate on extraction of uranium by coal from schroeckingerite leachate. Initial solution contained 43 ppm uranium

FIGURE 29.—Graphs showing leaching of schroeckingerite and extraction of uranium by coal from aqueous solution. Wayne Mountjoy, analyst.

cent of the uranium from solution and contained about 13 percent uranium. X-ray determination again failed to show the presence of any uranium mineral. However, at high magnification (× 800), a polished section showed that the fragments of coal were surrounded by minute black particles of pitchblende(?), according to J. W. Adams; this sample was also examined by E. J. Dwornik, using X-ray techniques, who found that there was a slight intensification of two of the d-spacings that is characteristic of mixed patterns of uraninite and pyrite. The removal of large amounts of uranium from solution without attaining chemical equilibrium suggests that the uranium may have been precipitated by reduction from the 6- to the 4-valent state rather than forming an organometallic coumpound.

Reduction of 6-valent uranium to the 4-valent state would require that the carbonaceous material have a negative Eh (oxidation-reduction or redox potential; see ZoBell, 1946; Krumbein and Garrels, 1952.) The Eh and pH of about 40 samples of coal, organic shale, siltstone, and sandstone from the Red Desert were determined to test the effectiveness of the carbonaceous material as a reducing agent. In addition, the pH and Eh of water draining from drill holes in subbituminous coal at the working face in two mines north of Denver, Colo., were determined using portable meters. The samples were taken at approximately the 200-foot level in the mines (see following table). Tests of the samples show that as normal subsurface conditions are approached, the more nearly neutral (pH 7) the solutions become. However, the unexpectedly positive (oxidizing) Eh values may be due to the introduction of atmospheric oxygen. The presence of pyrite in many of the coal cores indicates that reducing conditions must have existed in the coal underground (Krumbein and Garrels, 1952).

Acidity (pH) and redox potential (Eh) values for coal samples

	Coal from outcrop [1]		Coal from core [1]	Coal from underground mine [2]	
	Sourdough bed	Creston bed	Luman bed	Sterling mine	Washington mine
pH	3.2	3.5	6.0	7.3	7.7
Eh [3] (volts)	+0.332	+0.326	+0.411	+0.444	+0.448

[1] Determinations made on slurry of powdered coal and distilled water, using glass electrode pH meter.
[2] Determinations made on water from drill holes in coal in working faces of mines, using analytical measurements pocket pH meter.
[3] Corrected to pH 7.

Another experiment was designed to test the infiltration of coal by uranium solutions. Two blocks of coal from core-hole samples were suspended in uranyl solution for about 5 months, sawed in half, and the cut face sampled in a T-pattern (fig. 30). Analyses showed that the uranium entered the coal blocks most easily along the bedding planes, but it also crossed the bedding.

Results of the experiments indicate: (a) coal can extract uranium from the ground water passing through it at the present time, and the uranium will enter into solid coal; (b) water from Lost Creek will leach uranium from schroeckingerite and deposit it on coal, raising the uranium content to ore grade; (c) concentration of uranium in ground water in excess of 50 ppb is apparently necessary to cause enrichment of the coal to ore grade; (d) coal not only removes uranium from solution but probably affects the solutions in its vicinity. This may be an effective mechanism for the deposition of "primary type" uranium minerals near carbonaceous material.

ORIGIN

PREVIOUSLY KNOWN OCCURRENCES OF RARE ELEMENTS IN COAL

Uranium and other trace elements have long been known to occur in carbonaceous rocks. Uranium in coal was known to occur as early as 1874, when it was identified in the coal at the Old Leyden mine near Golden, Colo. (Berthoud, 1875). In 1930, V. M. Goldschmidt

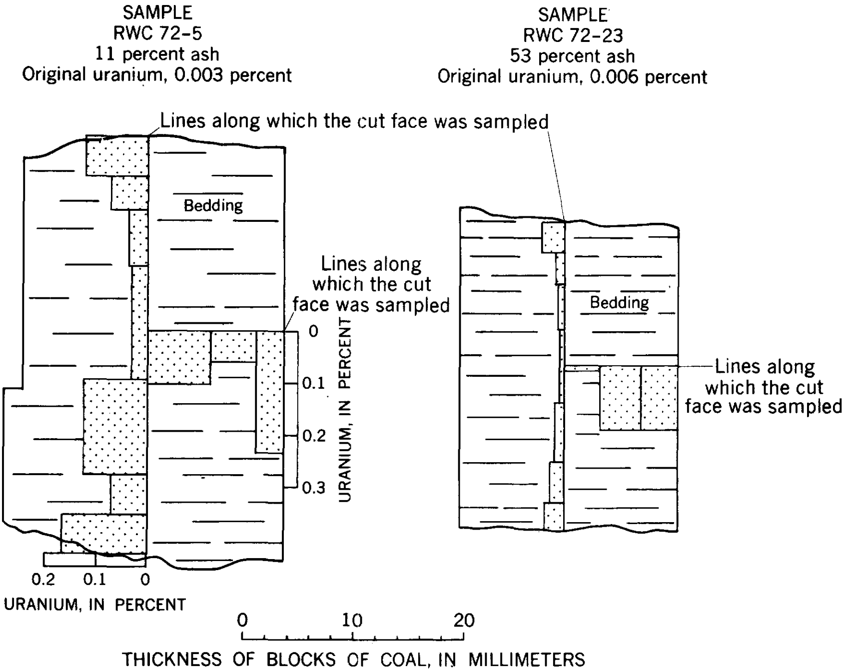


FIGURE 30.—Diagram showing penetration of uranium from aqueous solution into blocks of coal. The blocks were suspended for 171 days in a solution containing 16 ppm uranium. The stippled parts of each block graphically indicate the percentage of uranium found along the lines sampled. Wayne Mountjoy, analyst.

(1944) discovered that unusually high concentrations of germanium occurred in coal ash. He found that several other rare elements were present in coal ash with enrichment factors as much as 20,000 times their concentration in average rocks of the earth's surface (Goldschmidt, 1950, p. 243). These enriched elements were represented on most divisions of the periodic table and the assemblage was quite different from those resulting from the known geochemical processes of concentration. In addition, he found that the rare elements were not associated with the adventitious ash—the visible mineral impurities in the coal, but rather with the inherent ash—the residuum of the organic material itself. He proposed three possible processes of concentration:

1. Concentration during the life of the plant; for example, boron and rare earth oxides are concentrated in leaves of the hickory tree.
2. Concentration during the decay of the organic matter in forest litter and forest humus, exemplified by germanium, nickel, and silver.

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3. Concentration after the plant has been buried under sediments, by reaction of the coal or associated minerals with circulating aqueous solutions containing rare elements, either by reducing to insoluble compounds or by adsorption, for example, the frequent concentration of arsenic in the pyrite of coal.

Certain coal deposits in the U.S.S.R. investigated by Silbermintz (1935) contain unusually high concentrations of rare elements in coal ash; V_2O_5, 5.56 percent; Cr_2O_3, 1.42 percent; and NiO, 0.84 percent. He attributed these concentrations to infiltration (secondary deposition) of the coal by the rare elements derived from the breakdown of the vanadiferous segregations of titanomagnetite in the rocks of the Ural Mountains flanking the coal basin. Vinogradov and Bergman (1935) also stated that unusually high concentrations of trace metals may occur in coal in "cases of the infiltration of coal by solutions containing vanadium; but under these circumstances the coal usually contains other heavy metals also, e. g., uranium, chromium, copper and so forth."

Several geologists continued the investigation of rare elements in British coal started by Goldschmidt. Reynolds (1948) showed that lenses of vitrain overlying coal beds contain notable quantities of vanadium, chromium, titanium, and nickel. He also found that values of copper and lead are higher at the top of some seams and stated that these metals were probably precipitated from circulating water during coal formation. Horton and Aubrey (1950) spectroscopically analyzed three vitrains from the Barnsley seam for 18 minor elements. They found that titanium, vanadium, nickel, and germanium are some of the most abundant elements associated with the pure coal substance. Aubrey (1952) examined samples of 200 British coal beds and found that the germanium content averaged about 7 ppm, which is equal to the germanium content of average sedimentary rocks. He attributes the high germanium content reported by Goldschmidt to the marked concentration effect of ashing the coals.

Germanium in American coal has been investigated by Headlee (1953), who found that the germanium was concentrated in the top and bottom 3 inches of the coal seam and that other notably high concentrations within the bed occurred adjacent to partings. He concluded that the germanium was associated with the organic fraction of the coal and that it was extracted by the coal from aqueous solution or from gases containing volatile germanium compounds. Headlee's findings explain the lack of agreement on the germanium content of the British coal. Goldschmidt's sample probably came from the top of a bed, whereas Aubrey's samples comprised the full-bed thickness and mixed the material of high concentration with that of low concentration. Stadnichenko and others (1953) confirmed that the germanium content in American coals is higher at the top and bottom of seams. They report that the highest concentrations of germanium, amounting to as much as 7.5 percent in the coal ash, were found in isolated coalified logs in Cretaceous sediments. In these deposits the germanium is most highly concentrated in bright woody coal (vitrain) and less concentrated in fusain (mineral charcoal). The general conclusion of these workers is that many trace metals in coal are associated with the organic fraction and were epigenetically emplaced.

SUGGESTED HYPOTHESES FOR EMPLACEMENT OF URANIUM IN COAL

Uranium received little attention in the course of the early investigations of trace elements. The analytical work was based largely on the spectrographic method, which is not effective in analyzing for uranium. In addition, coal is commonly considered to be among the least radioactive rocks. In logging drill holes in the coal measures of Britain, it is possible to pick out workable coal seams because of their very low radioactivity (Davidson and Ponsford, 1954).

BIOGENETIC HYPOTHESIS

The studies of Helen Cannon (1953) have shown that a simple botanical mechanism (enrichment in uranium during growth of the plants) is insufficient to account for the large concentration of uranium in some coal seams. Even vegetation rooted in uranium ore rarely contains more than 0.011 percent uranium in the ash, whereas coalified logs may contain as much as two thousand times this amount.

SYNGENETIC AND DIAGENETIC HYPOTHESES

During the course of an investigation of the Lost Creek schroeckingerite deposit in Sweetwater County, Wyo., A. L. Slaughter and J. M. Nelson (written communication, 1946) discovered the uranium-bearing coal in the Red Desert. In 1948 and 1949, D. G. Wyant and E. P. Beroni (written communication, 1950) discovered uranium-bearing lignite in North Dakota, South Dakota, and Montana. E. P. Beroni and H. L. Bauer (written communication, 1952) continued this work in 1949, and Wyant, Sharp, and Sheridan (1956) visited the Red Desert area the same year. Two hypotheses were advanced as a result of this work: the first (syngenetic hypothesis) states that uranium was deposited from surface waters at the same time as the carbonaceous debris from which the lignite formed; the second (diagenetic hypothesis) states that uranium was deposited with other detrital minerals in sediments overlying or marginal to the lignite, was leached and carried downward or laterally, and was fixed by the carbon of the lignite before coalification occurred.

That uranium can be syngenetically emplaced in vegetable material has been demonstrated in the field and in the laboratory. In North Park, Colo., springs issuing from a small peat deposit contain about 56 ppb uranium, which is probably derived from uranium-bearing veins in the surrounding granite. In the vicinity of the springs, the peat contains as much as 0.39 percent uranium and 0.84 percent in the ash (Roger Malan, oral communication). Szalay (1954) suspecting that the uranium in Hungarian brown coal had been emplaced before coalification occurred, demonstrated in the laboratory that peat would extract as much as 10 percent uranium from aqueous solution. He proposed that the uranium in the carbonaceous rocks was originally derived by the decomposition of granite and was carried in solution to the surrounding swamps where it was concentrated by the humic acid in the peat.

Waters and Granger (1953) considered but rejected the possibility of a "built-in" source for the Colorado Plateau deposits. By this hypothesis the uranium would have been derived from the devitrification of volcanic debris in the main part of the Chinle formation and in the Brushy Basin shale member of the Morrison formation, which directly overlie the ore-bearing Shinarump and Saltwash sandstone members of these formations, respectively.

EPIGENETIC HYPOTHESIS

As the result of work in the Dakotas, Denson, Bachman, and Zeller (1959) proposed another hypotheses. This states that the uranium is epigenetic in origin, having been extracted by the lignite from uraniferous ground water percolating downward from overlying tuffaceous source rocks. They proposed that the uranium was a finely disseminated primary constituent of volcanic ash and that it was released and made available to the ground water through weathering and devitrification of the ash.

Koeberlin (1938) earlier proposed that volcanic ash may be a source of metals. He stated that the gold found in the volcanic ash near Hartsel, Colo., is not oxidizable and cannot migrate from its original host rock in contrast to the sulfides which could be leached from the ash and migrate to favorable sites of deposition. The copper in the red bed type of deposit and the lead and zinc in deposits where evidence for hydrothermal conduits is lacking may have been derived from this source.

EPIGENETIC ORIGIN OF THE URANIUM IN RED DESERT COAL

The following observations suggest to the writer that the uranium in the coal of the Red Desert was epigenetically emplaced:

1. The highest concentration of uranium and other trace elements occurs in the upper part of the stratigraphically highest carbonaceous bed directly below the unconformity on which the Miocene(?) rocks were deposited.
2. The uranium content of coal is greater adjacent to coarse-grained permeable sandstone beds, which generally underlie the coal. Where the coal is underlain and overlain by permeable sandstone, the uranium content of the coal is high at the bottom and top of the bed.
3. The uranium content of the coal is higher to the northeast, corresponding to an increase in the proportion of coarse-grained permeable sandstone interbedded with the coal.
4. Within a sequence of coal and carbonaceous shale, the lowest uranium content is found in the central part of the highly impermeable pure coal splits. Conversely, the highest uranium content is found in the impure coal adjacent to the relatively permeable layers with high ash content.
5. Organic shale (low-grade oil shale) and clayey sandstone adjacent to permeable coarse-grained sandstone have an anomalously high uranium and trace metal content.
6. Experimental work shows that the Red Desert coal is highly effective in extracting uranium from solution.
7. Artesian water from aquifers interbedded with coal carries as much as 47 ppb uranium at the present time. Experimental work shows that the Red Desert coal will extract uranium from this solution.

The relationship of the uranium content of coal to the permeability of the surrounding rocks and the fact that the coal can extract uranium, as proved by recent tests, indicate that the uranium probably was emplaced after coalification occurred.

POSSIBLE SOURCES OF URANIUM

Observations on possible sources of the uranium distributed to the coal by ground water are:

1. Hydrothermal.—A group of highly alkalic volcanic rocks of middle Eocene age (Van Houten, 1954) crop out in the Rattlesnake Hills, 40 miles north of the area. A few miles from these vents there are many sandstone-type uranium deposits similar to those surrounding the laccoliths of Tertiary age in the Colorado Plateau (Waters and Granger, 1953, p. 23). Hydrothermal solutions accompanying the emplacement of the volcanic rocks may have risen along fault zones to form sandstone-type deposits or may have spread laterally through the ground-water system to form the low-grade deposits in the coal (fig. 31*A*). The

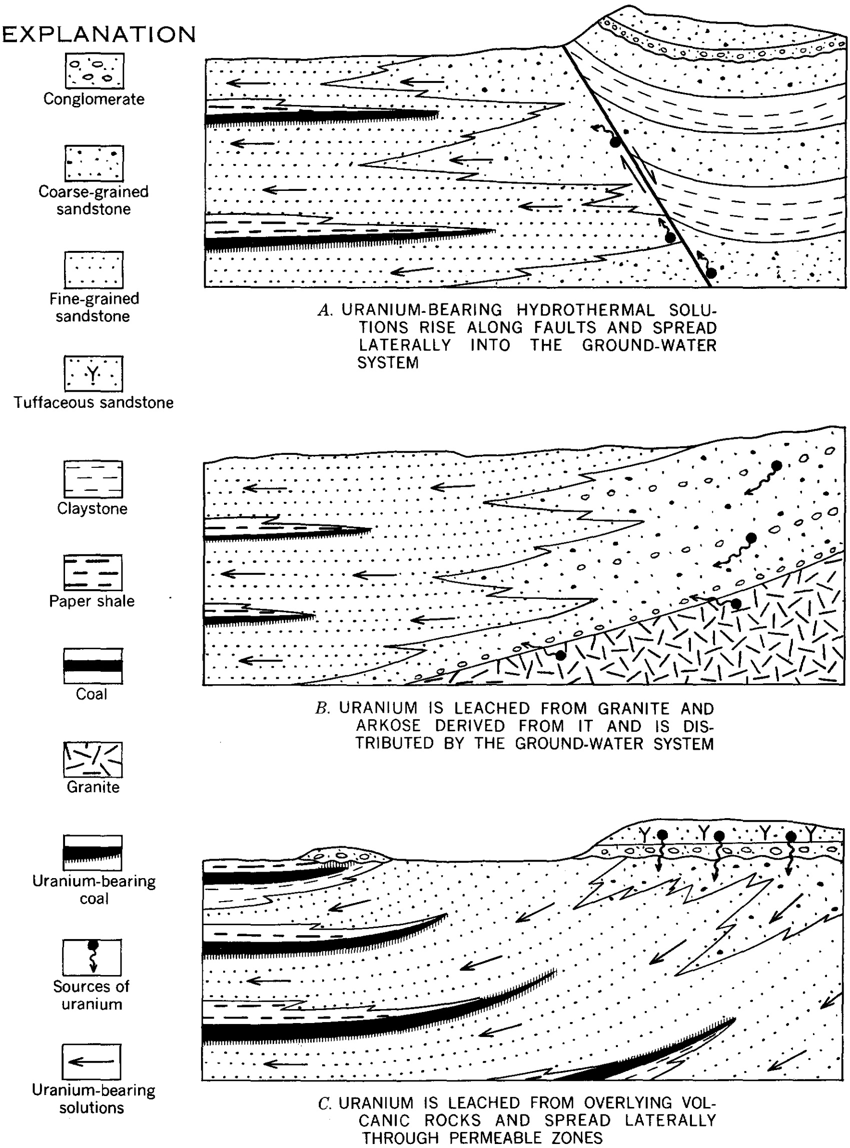

FIGURE 31.—Diagram showing three possible sources of uranium in coal-bearing rocks.

presence of a uranium mineral (torbernite) in the gouge along a thrust-fault zone in the Crooks Gap area (Stephens, 1954, p. 122), the schroeckingerite deposit along the Cyclone Rim fault zone, and the iron stains and uranium near small faults at Painted Bluff and Eagles Nest, all point to the possibility of a hydrothermal source of uranium.

2. Granite leach.—Analyses of six samples of granite from the Granite Mountains of Precambrian age and boulders derived from it show that it contains from 0.002 to 0.003 percent uranium. The arkose in the Battle Spring and Wasatch formations of early Eocene age, derived from the granite of the Granite Mountains, contains from 0.0005 to 0.001 percent uranium. Piggot (1929), Hurley (1950), Brown and others (1953), and Jahns (1953) have shown that the major part of the uranium in a granite is contained in the intergranular films surrounding the grains. Crushing and mildly leaching the granite resulted in the removal of about nine-tenths of the radioactivity, probably because of the easily leachable films (Hurley, 1950). The remaining one-tenth was probably contained in the uranium-bearing heavy minerals. By analogy, the major part of the uranium would be released from the granitic material by the time it was reduced to individual grains of sand size. Thus enormous tonnages of uranium could be released by the weathering of granite and granitic boulder conglomerate and be spread laterally through the ground-water system (fig. 31*B*).
3. Volcanic ash leach.—Tuffaceous rocks of the Browns Park formation of Miocene(?) age crop out near the Cyclone Rim fault zone and near Crooks Gap to the north of the area, at Rawlins to the east, and at Baggs to the south. Within the area, gravel capping on high benches that may be remnants of the basal conglomerate of the Browns Park formation shows that the volcanic rocks which blanketed the area may have closely overlain the present land surface. The concentration of uranium in the uppermost carbonaceous rocks overlain by these gravels indicates deposition by downward-migrating solutions. Where the volcanic rocks overlapped the sandstone of the Battle Spring formation, the uranium-bearing solutions could have entered the aquifers and moved downward and laterally for miles under hydrostatic head and deposited uranium on coal (fig. 31*C*). Possible volcanic source rocks of middle and late Eocene age, Oligocene age, and Pliocene age also occur in adjacent areas. However, since the ground water from the Miocene rocks shows the highest uranium content, these (table 7) rocks may be the source of the uranium.

Whatever the original source of the uranium, the uranium-bearing coal of the Red Desert is in a sector of low-grade occurrences marginal to an area of high-grade deposits. The presence of uranium at Crooks Gap north of the area confirms the evidence from the distribution pattern in the coal and indicates that the area that lies north and east of the coal area and contains coarse-grained arkose with thin carbonaceous zones is favorable for the occurrence of high-grade deposits.

The Crooks Gap deposit is localized adjacent to thin carbonaceous zones in coarse-grained arkose, whereas the Lost Creek schroeckingerite is a calichelike deposit along the Cyclone Rim fault zone. The uranium in these three occurrences possibly had the same source; the uranium in the Crooks Gap deposits and in the Red Desert coal may have been concentrated by the chemical effect of carbonaceous matter, whereas the uranium at the Lost Creek deposit was probably concentrated by structural control of ground-water flow and by evaporation of the uraniferous ground water due to the arid climate.

OTHER INDEXES TO THE SOURCE OF URANIUM

There is a large suite of trace elements present in the uranium-bearing coal at Creston Ridge, according to semiquantitative spectrographic analyses. Volcanic rocks of several ages and the granite of the Granite Mountains of Precambrian age from which the trace elements in the coal may have been derived by leaching were analyzed spectrographically for comparison of their trace-metal content with that of the coal. The trace-metal content of all the rocks is remarkably similar, and no index constituent was observed that is uniquely present in any one possible source rock and the coal (fig. 32). Sodium is present in the coal and the granite, but it is also a notable constituent in the Rattlesnake volcanic rocks. Comparison of the relative abundance of trace metals in a source rock with that in the coal is complicated by the possible differential leaching of material from the source rock and by differential extraction of uranium by the coal. Either of these factors might alter the relative proportions of the trace elements observed. It is possible that more detailed quantitative spectrographic analyses would make possible correlations that are obscured by the more generalized results obtained by using the semiquantitative spectrographic method.

SUGGESTIONS FOR PROSPECTING

Evidence from the field and laboratory shows that the geologic features favoring the localization of uranium are:

1. Lenses or thin layers of carbonaceous material in direct contact with source rocks or in highly permeable rocks, which will allow easy access to uranium-bearing solutions.
2. Impure carbonaceous layers in a sequence that contain more uranium than do pure layers, as they are more easily permeated by uranium-bearing solutions.

Areas favorable for prospecting in the Great Divide Basin are, therefore:

1. Topographically high areas, which may be capped by volcanic source rocks, such as the rim of Bison Basin, the area lying west

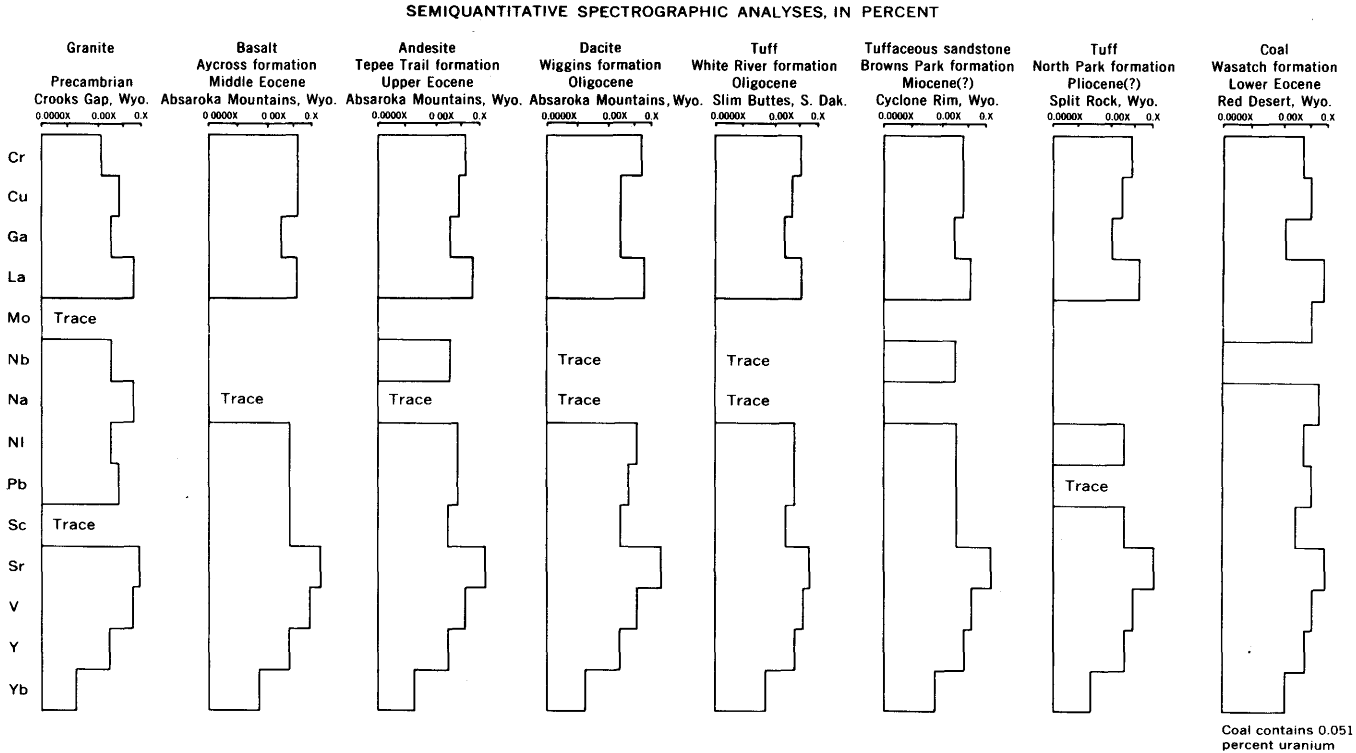

FIGURE 32.—Diagram showing comparison between the trace-metal content of uranium-bearing coal and that of possible source rocks.

of Crooks Mountain, and the extensive terraces extending northeast from Creston Ridge.

2. Areas underlain by the Battle Spring formation in which thin carbonaceous shale is interbedded with arkose. The large area in the northeast corner of the Great Divide Basin lying between the eastern Red Desert area and the north end of the Rawlins uplift is favorable.
3. Areas where carbonaceous beds in older rocks are overlapped by the highly permeable sandstone of the Battle Spring formation. At the east end of Crooks Mountain, coal-bearing rocks of the Paleocene and Cretaceous units are unconformably overlain by the Eocene arkose and boulder conglomerate.

EXPLORATION

The primary objective of the core-drilling program was to determine the amount of uranium-bearing coal in the eastern part of the Red Desert. A secondary objective was to determine controls for uranium mineralization in the coal as a guide in the search for higher grade uranium deposits in the Red Desert area.

Sixty core holes were drilled in a northwestward-trending zone, about 25 miles in length, along the axis of maximum coal deposition. An 8-inch core hole was drilled in the northern part of the Red Desert area to obtain a large fresh sample of the Luman No. 2 coal bed for coal-utilization studies. The total footage drilled was 12,783.

The average drill-hole depth was 211 feet; the deepest, 385.0 feet; and the shallowest, 77.7 feet. Core recovery in coal beds averaged 92 percent. The core was logged in detail immediately on removal from the core barrel. Coal core from 21 holes was shipped to the U.S. Geological Survey coal geology laboratory in Columbus, Ohio.

The coal core from 16 holes was split in the field. One split was placed in watertight cans and submitted to the U.S. Bureau of Mines for standard fuel analysis. The other split was sent to the Washington laboratory of the U.S. Geological Survey for uranium analysis. Coal core from the remaining 23 NX (2.156 inches in diameter) holes was sampled for uranium analysis only. The 11-foot section of 8-inch core was blocked in the inner core barrel, and the whole assembly boxed and shipped to the Geological Survey coal geology laboratory at Columbus, Ohio. Selected intervals of noncoal-bearing core were retained for lithologic study.

Artesian water was found in several holes (fig. 33) but was sealed off without difficulty, except in core hole 17. Here the artesian water broke out around the casing and formed a hole 12 feet in diameter in the unconsolidated lake sediments (fig. 34). Charges of dynamite were used to seal the hole above the aquifer and cut off the flow of water.

Radioactivity logs were made of several core holes, but caving from the unconsolidated sandstone rapidly filled most holes. Radioactivity road logs were made using a carborne scintillation counter. A comparison between a radioactivity road log, the radioactivity log of a

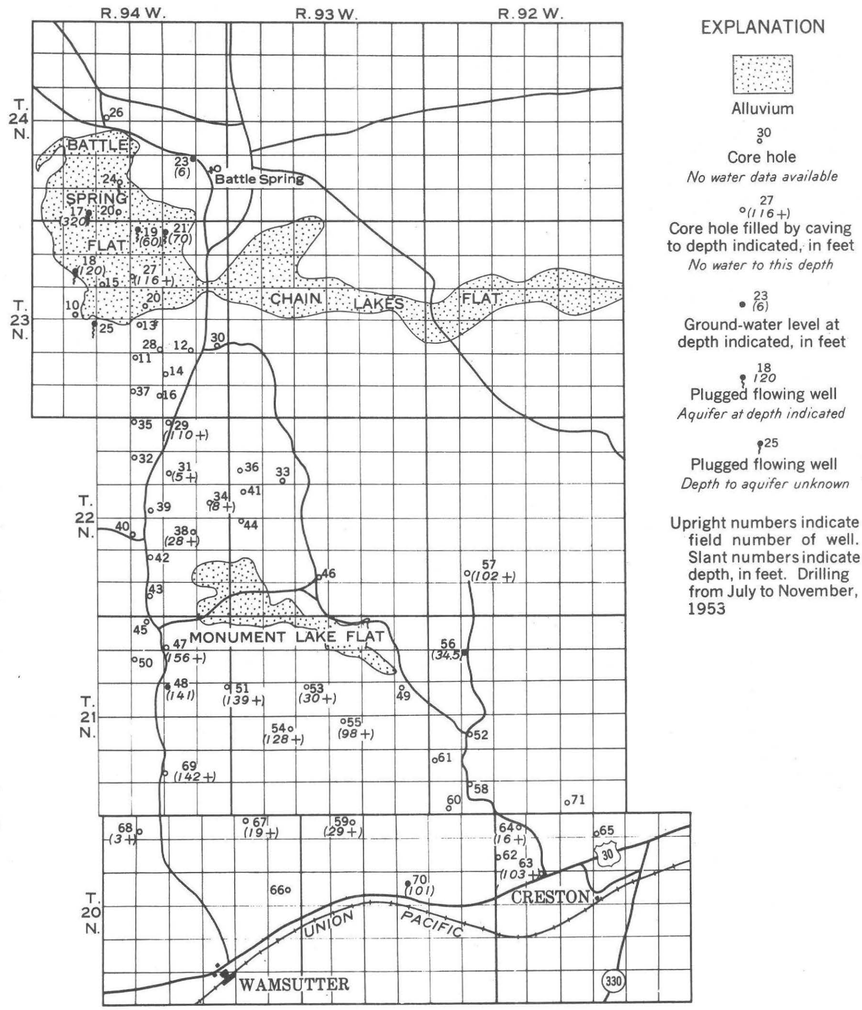

FIGURE 33.—Sketch map showing hydrologic data from core holes.

core hole, and the lithologic core log of the same beds with the uranium content of the coal beds is shown in figure 35. The carborne counter is very effective in picking up the radioactivity of thin coal beds containing 0.010 percent or more uranium. However, on Creston

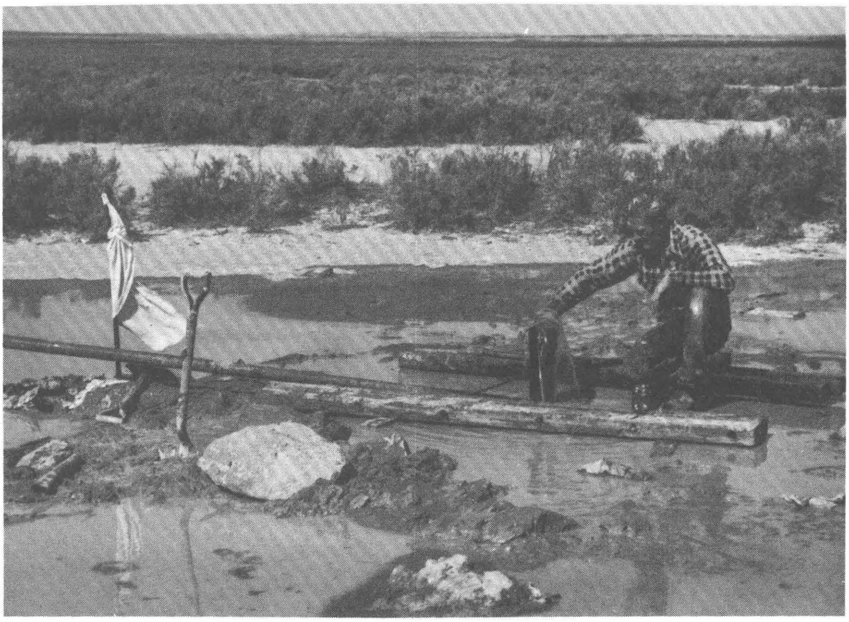

FIGURE 34.—Artesian water from core hole 17 in Battle Spring flat flowed at 20 gpm and contained 47 ppb uranium before the hole was sealed off.

Ridge 5 feet of gravel, overlying carbonaceous rocks containing as much as 0.050 percent uranium, effectively shielded the rocks and prevented their detection by the carborne counter.

RESERVES

Reserves of underground and potentially strippable coal, uranium in coal, uranium in coal ash, and uranium in carbonaceous shale are summarized in the following table. Reserves by bed in each township in the eastern Red Desert area are shown by maps and tables in figures 34 to 70. Procedures followed in the breakdown into coal-reserve categories are, in general, those outlined by Averitt, Berryhill, and Taylor (1953, p. 6–12).

Tonnage of coal reserves in the eastern Red Desert area, Great Divide

Range in thickness (feet)	Measured and indicated coal [1] (thousands of short tons)	Potentially strippable coal included in measured and indicated reserves [2] (thousands of short tons)
2.5–5	289, 478	64, 226
5.0–10	578, 519	197, 003
>10	1, 236, 043	194, 038
Total	2, 104, 040	452, 823

Approximate content of uranium in coal reserves and carbonaceous shale

Uranium content		Measured and indicated coal [1] (thousands of short tons)	Pontentially strippable coal [2]	
Tons	Percent		Coal (thousands of short tons)	Uranium content (short tons)
Coal				
23, 746	>0. 003	691, 399	100, 485	3, 542
1, 534	>. 005	28, 371	6, 004	334
212	>. 010	2, 121	----------	----------
Coal ash				
9, 378	>0. 015	242, 596	37, 866	1, 558
2, 735	>. 020	75, 712	4, 930	278
212	>. 030	2, 121	595	54
Carbonaceous shale				
		Carbonaceous shale (thousands of short tons)	Potentially strippable carbonaceous shale [2]	
			Carbonaceous shale (thousands of short tons)	Uranium content (short tons)
4, 912	>0. 003	70, 593	32, 503	2, 855
4, 179	>. 005	50, 675	29, 404	2, 731
377	>. 010	3, 143	3, 143	377

[1] Includes coal beds which are more than 2.5 feet in thickness, contain less than 33 percent ash and less than 50 percent parting, and are within 2 miles of an outcrop or drill hole.
[2] Stripping limit defined by overburden-to-coal ratio of 10 to 1; 60 ft maximum overburden.

COAL

Measured reserves of coal are presumably accurate within 20 percent; such reserves lie within half a mile of the outcrop or drill holes that cut the coal seams. Indicated reserves are based on projection of coal beds for a reasonable distance from an outcrop or core hole and, in general, lie within a strip 1½ miles wide surrounding the measured coal. Inferred reserves are based on broad knowledge of the geology of the beds and extend beyond the 2-mile limit enclosing the measured and indicated reserves. Coal weight used in this estimate is 1770 short tons per acre foot. The thicknesses given in figures 36–72 are averages, which were weighted according to the approximate area of bed represented by each observation point (outcrop, core hole, or auger hole). Beds and parts of beds made up of thin layers of coal and partings were omitted if the partings made up more than one-half the total thickness or if the ash content exceeded 33 percent. Thickness categories used are as follows: 2.5 to 5.0 feet, 5.0 to 10.0 feet, and more than 10 feet.

Measured and indicated coal reserves are grouped together in figures 36 to 72. Original reserves of measured and indicated subbituminous coal lying within 1,000 feet of the surface amount to 2,104 million short tons. An additional 100 million tons of coal is present in the inferred category. Measured reserves make up about 20 percent of

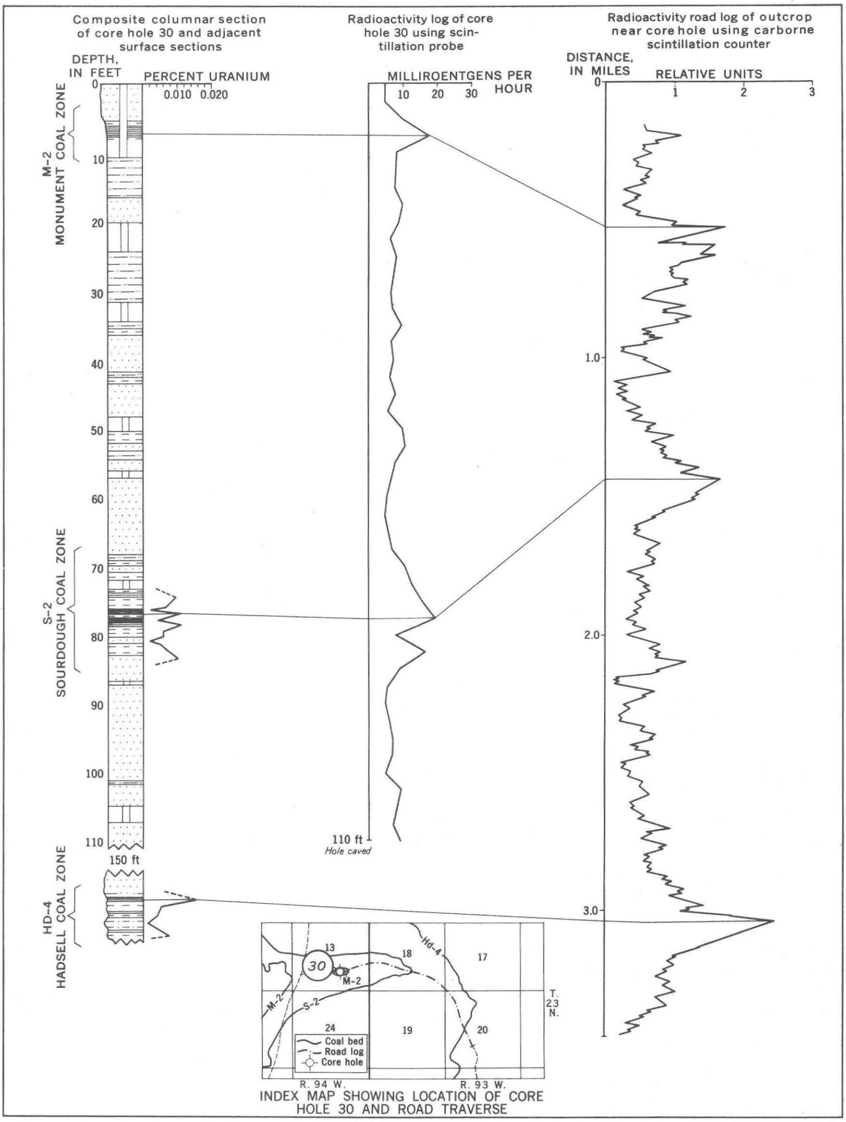

FIGURE 35.—Chart showing comparison of radiometric anomalies detected by a carborne scintillation counter with those recorded by a scintillation probe in a core hole penetrating the same uranium-bearing beds.

the measured and indicated reserves or about 421 million short tons. The inferred reserves are not shown on the maps and tables, and are limited to reserves beyond the 2-mile limit in the Hadsell No. 4 bed, Creston No. 2 and No. 3 beds, and Latham No. 3 and No. 4 beds in Tps. 21 and 22 N., Rs. 92, 93, and 94 W.

The percentage of ash and the percentage of uranium in ash (figs.

36-72) were determined by the U.S. Geological Survey in Washington, D.C. The percentage of uranium in coal was calculated from the percentage of ash and the percentage of uranium in ash.

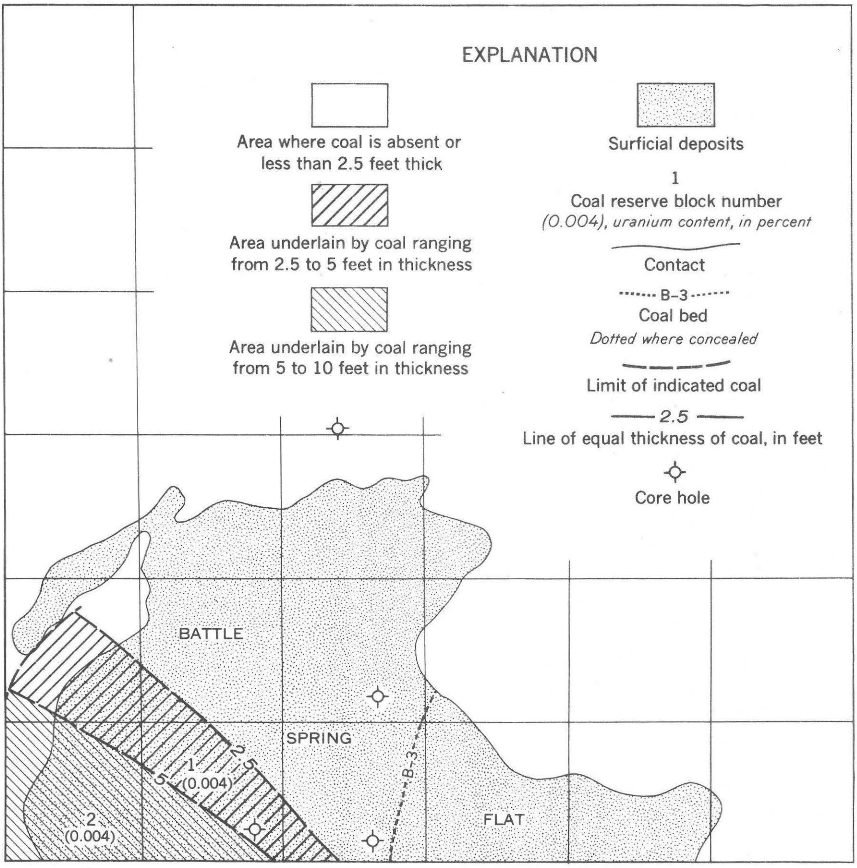

FIGURE 36.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Battle No. 3 bed in T. 24 N., R. 94 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal: Percent	Uranium in coal: Short tons	Uranium in ash: Percent	Uranium in ash: Short tons
Measured and indicated coal								
1	797	3.8	5,361	25	0.004	214	0.016	214
2	806	6.7	9,558	25	.004	382	.016	382
Total			14,919			596		596

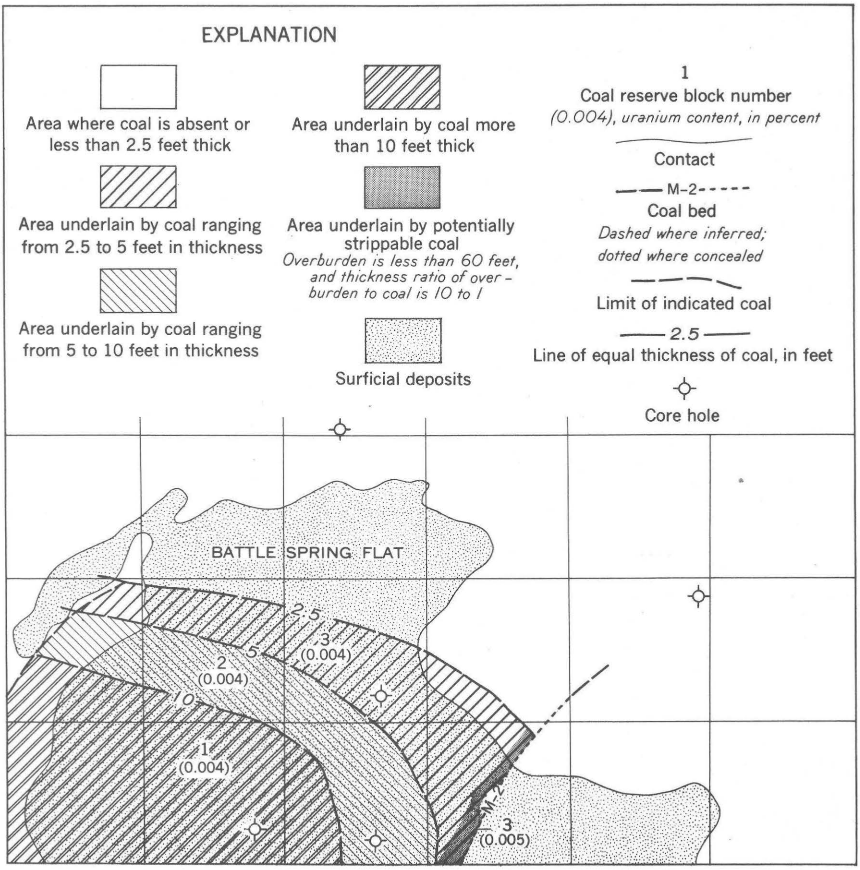

FIGURE 37.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Monument No. 2 bed in T. 24 N., R. 94 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	1,690	13.2	39,485	23	0.004	1,579	0.017	1,579
2	995	7.5	13,209	24	.004	528	.016	528
3	1,091	3.8	7,338	18	.004	294	.022	294
Total			60,032			2,401		2,401
Potentially strippable coal (included in above blocks)								
3	77	3.8	518	24	0.005	26	0.021	26

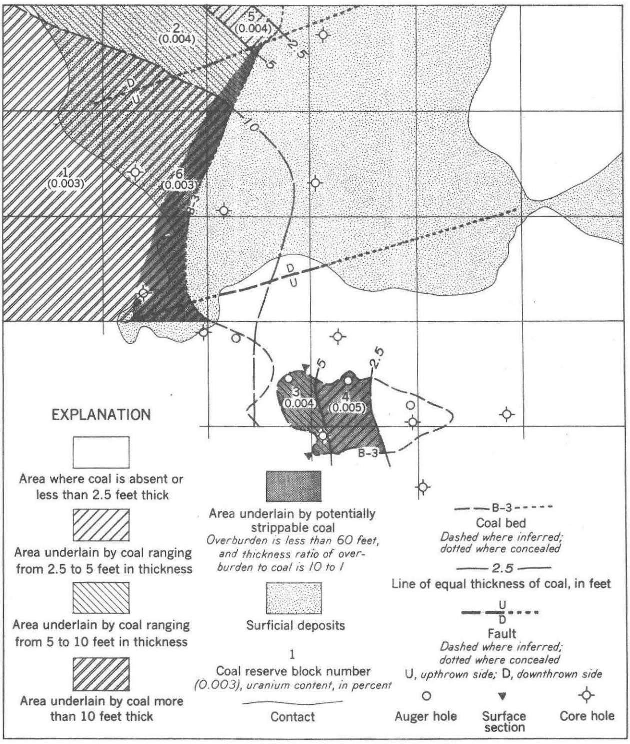

FIGURE 38.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Battle No. 3 bed in T. 23 N., R. 94 W.

Block	Coal reserves			Approximate uranium content				
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	3,178	13.0	73,126	21	0.003	2,194	0.014	----------
2	673	7.8	9,291	19	.004	372	.021	372
3	141	5.5	1,373	15	.004	55	.026	55
4	225	3.8	1,513	20	.005	76	.025	76
5	106	3.8	713	19	.004	29	.021	29
Total	----------	----------	86,016	----------	----------	2,726	----------	532
Potentially strippable coal (included in above blocks)								
1	450	13.0	10,355	27	0.003	311	0.011	----------
2	44	7.5	58	32	.004	2	.013	----------
3	141	5.5	1,373	15	.004	5	.026	5
4	225	3.8	1,513	21	.005	8	.024	8
Total	----------	----------	13,299	----------	----------	326	----------	13

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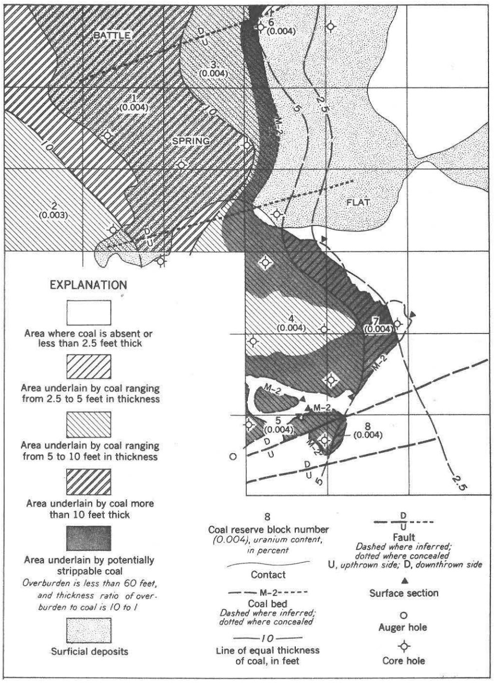

FIGURE 39.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Monument No. 2 bed in T. 23 N., R. 94 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	3,852	12.0	81,816	28	0.004	3,273	0.014	
2	1,005	8.5	15,120	15	.003	454	.023	454
3	1,014	8.2	14,717	19	.004	589	.021	589
4	1,551	6.8	18,668	24	.004	747	.017	747
5	288	7.8	3,976	30	.004	159	.013	
6	20	4.6	163	24	.004	7	.017	7
7	426	3.8	2,865	30	.004	115	.013	
8	20	4.5	159	33	.004	6	.012	
Total			137,484			5,350		1,797
Potentially strippable coal (included in above blocks)								
3	306	6.9	3,737	24	0.004	149	0.017	149
4	995	6.8	11,976	24	.004	479	.017	479
5	288	7.8	3,976	30	.004	159	.013	
6	20	4.6	163	24	.004	7	.017	7
7	426	3.8	2,865	30	.004	115	.013	
8	20	4.5	159	33	.004	6	.012	
Total			22,822			913		636

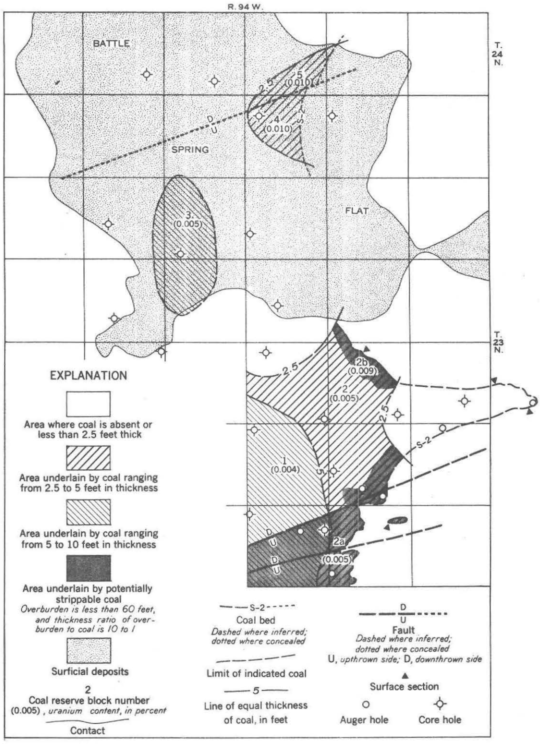

FIGURE 40.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Sourdough No. 2 bed in Tps. 23 and 24 N., R. 94 W.

Block	Coal reserves: Area (acres)	Coal reserves: Average thickness (feet)	Coal reserves: Coal (thousands of short tons)	Approximate uranium content: Ash (percent)	Uranium in coal: Percent	Uranium in coal: Short tons	Uranium in ash: Percent	Uranium in ash: Short tons
Measured and indicated coal								
1	1,249	6.7	14,812	25	0.004	592	0.016	592
2	1,626	3.8	10,936	21	.005	547	.025	547
3	673	9.9	11,793	21	.005	590	.025	59
4	271	2.8	1,343	30	.010	134	.032	134
5	157	2.8	778	30	.010	78	.032	78
Total			39,662			1,941		1,941
Potentially strippable coal (included in above blocks)								
1	423	6.6	4,941	27	0.004	198	0.016	198
2a	359	4.3	2,732	18	.005	137	.028	137
2b	84	4.0	595	20	.009	54	.044	54
Total			8,268			389		389

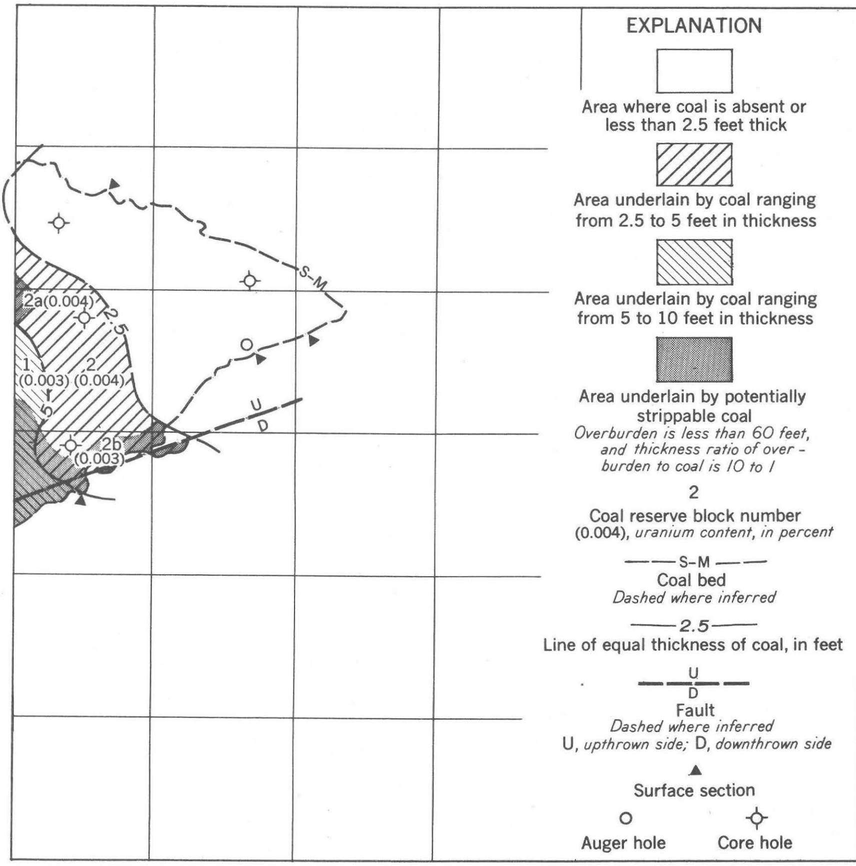

FIGURE 41.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Sourdough-Monument coal bed in T. 22 N., R. 93 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	190	5.5	1,850	25	0.003	55	0.012	----------
2	635	3.8	4,271	25	.004	171	.016	171
Total	----------	----------	6,121	----------	----------	226	----------	171
Potentially strippable coal (included in above blocks)								
1	122	5.5	1,188	25	0.003	36	0.012	----------
2a	16	4.0	113	25	.004	5	.016	5
2b	97	3.2	549	25	.003	16	.012	----------
Total	----------	----------	1,850	----------	----------	57	----------	5

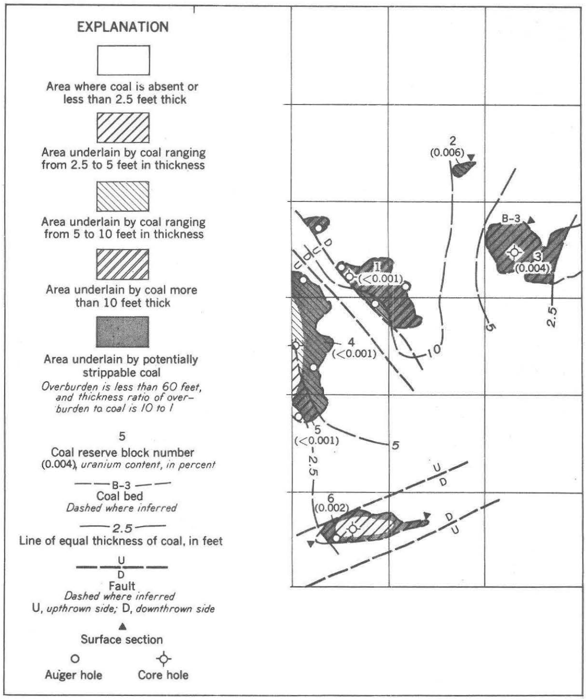

FIGURE 42.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Battle No. 3 bed in T. 22 N., R. 94 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	194	13.7	4,704	18	0.001		0.003	
2	13	9.8	225	27	.006	14	.021	14
3	212	3.5	1,313	27	.004	53	.013	
4	323	6.5	3,716	18	.001		.001	
5	147	3.8	989	18	.001		.001	
6	146	2.8	724	25	.002		.008	
Total			11,671			67		14
Potentially strippable coal (included in above blocks)								
1	194	13.7	4,704	18	0.001		0.003	
2	13	9.8	225	27	.006	14	.021	14
3	212	3.5	1,313	27	.004	53	.015	
4	265	6.5	3,049	18	.001		.001	
5	90	3.8	605	18	.001		.001	
6	88	2.8	436	25	.002		.008	
Total			10,332			67		14

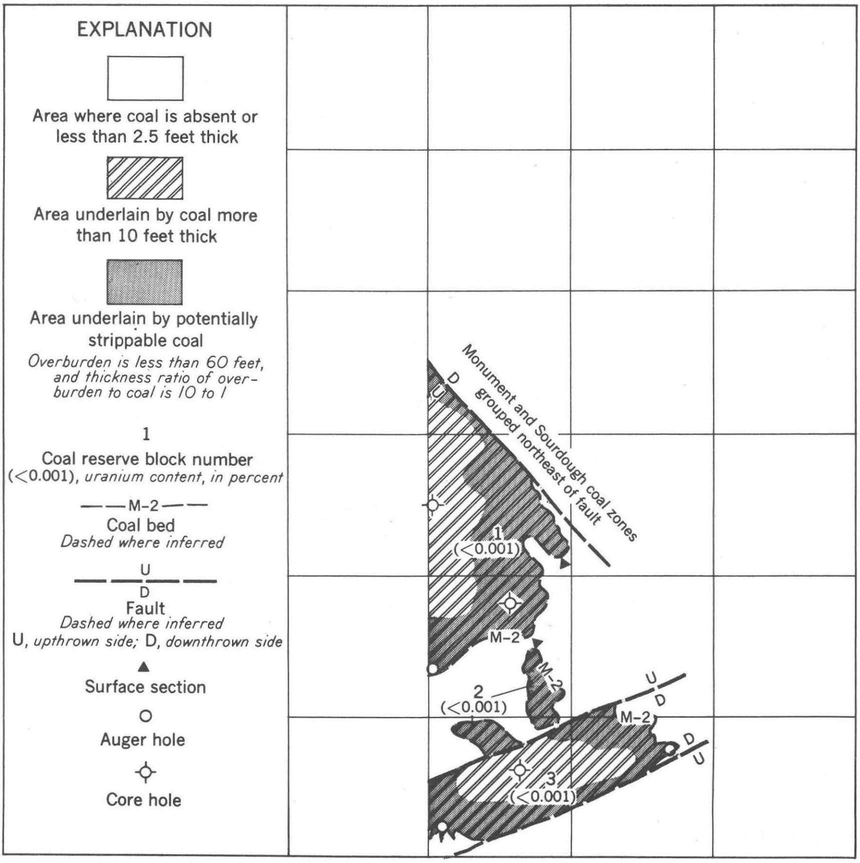

FIGURE 43.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Monument No. 2 bed in T. 22 N., R. 94 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	797	10.9	15,377	17	0.001		0.001	
2	91	10.0	1,611	10	.001		.007	
3	539	11.2	10,685	12	.001		.001	
Total			27,673					
Potentially strippable coal (included in above blocks)								
1	511	10.9	9,859	17	0.001		0.001	
2	91	10.0	1,611	10	.001		.007	
3	293	11.2	5,808	12	.001		.001	
Total			17,278					

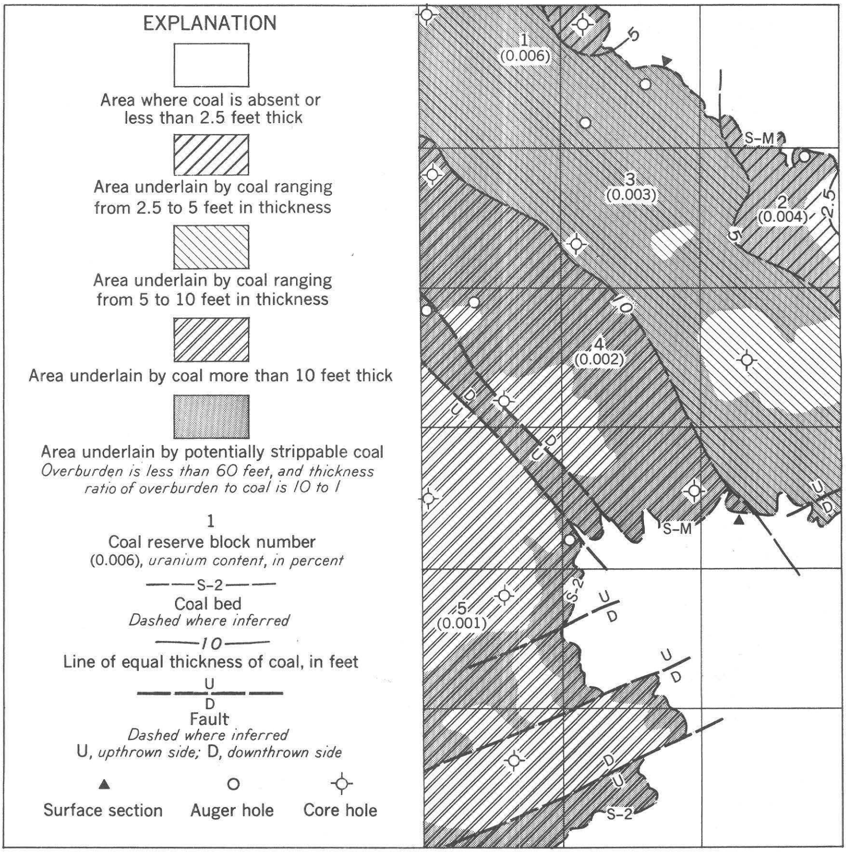

FIGURE 44.—Map and table (below) showing extent, thickness, size of coal reserves, uranium-content, and potentially strippable areas of coal in the Sourdough No. 2 bed and the Sourdough-Monument bed in T. 22 N., R. 94 W.

Block	Coal reserves: Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Approximate uranium content: Uranium in coal: Percent	Uranium in coal: Short tons	Uranium in ash: Percent	Uranium in ash: Short tons
Measured and indicated coal								
1	77	4.2	572	27	0.006	34	0.024	34
2	407	3.8	2,737	26	.004	109	.016	109
3	3,218	7.5	42,719	22	.003	1,282	.014	----------
4	2,057	10.7	38,958	21	.002	----------	.010	----------
5	2,360	10.1	42,190	18	.001	----------	.006	----------
Total	----------	----------	127,176	----------	----------	1,425	----------	143
Potentially strippable coal (included in above blocks)								
1	77	4.2	572	27	0.006	34	0.024	34
2	345	3.9	2,382	26	.004	95	.016	95
3	2,825	7.5	37,502	22	.003	1,125	.014	----------
4	1,794	10.7	33,977	21	.002	----------	.010	----------
5	813	10.0	14,390	18	.001	----------	.006	----------
Total	----------	----------	88,823	----------	----------	1,254	----------	129

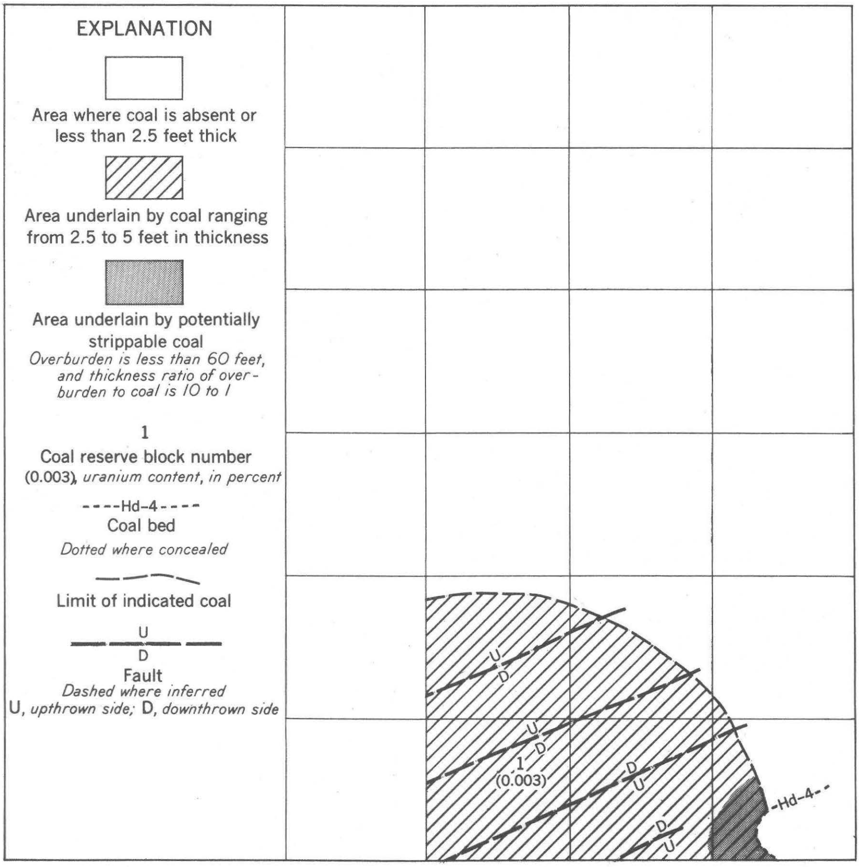

FIGURE 45.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Hadsell No. 4 bed in T. 22 N., R. 94 W.

Coal reserves					Approximate uranium content			
					Uranium in coal		Uranium in ash	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	2,369	4.5	18,869	27	0.003	566	0.011	---------
Potentially strippable coal (included in above blocks)								
1	106	4.5	844	27	0.003	25	0.011	---------

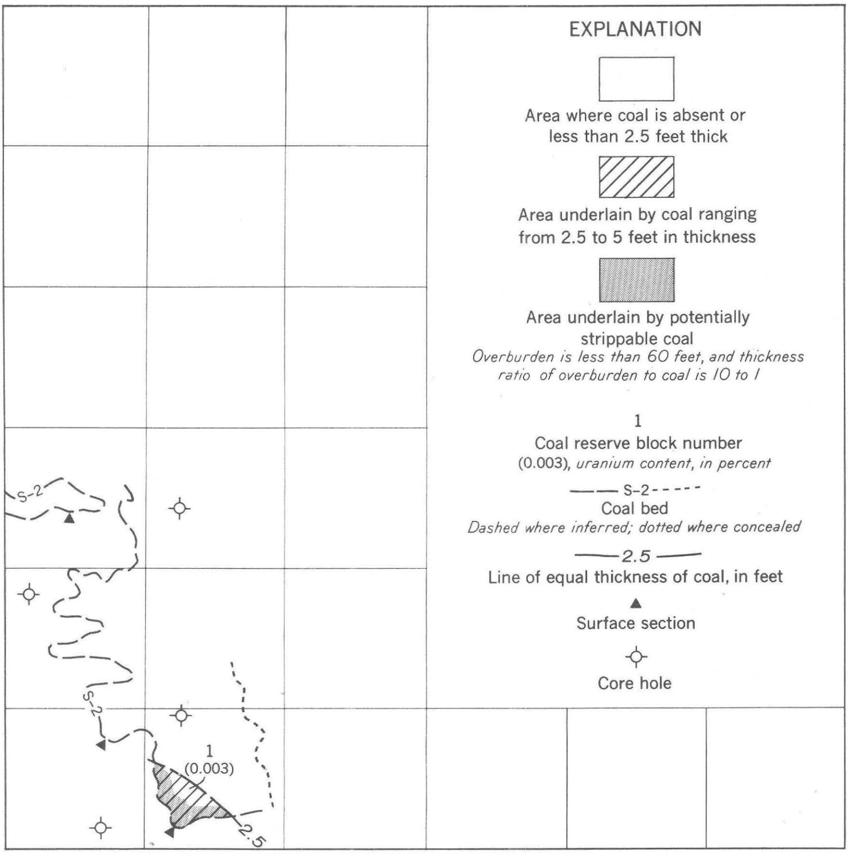

FIGURE 46.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Sourdough No. 2 bed in T. 21 N., R. 92 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	80	3.5	496	18	0.003	15	0.015	15
Potentially strippable coal (included in above blocks)								
1	53	3.5	328	18	0.003	10	0.015	10

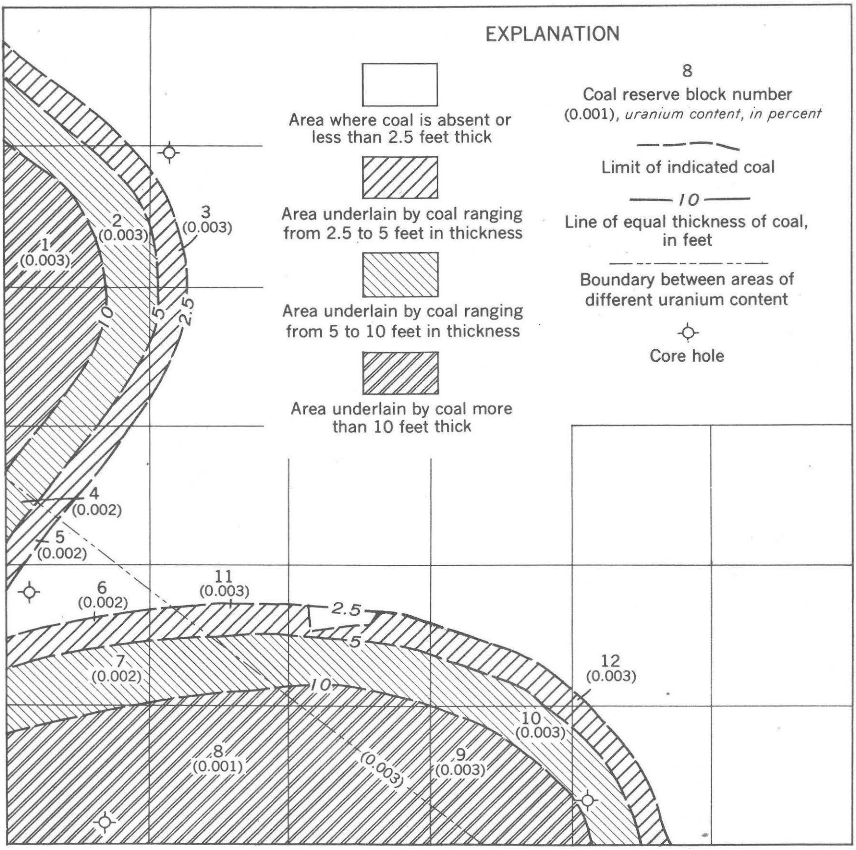

FIGURE 47.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Creston No. 2 bed in T. 21 N., R. 92 W.

Block	Coal reserves: Area (acres)	Coal reserves: Average thickness (feet)	Coal reserves: Coal (thousands of short tons)	Ash (percent)	Approximate uranium content: Uranium in coal: Percent	Uranium in coal: Short tons	Uranium in ash: Percent	Uranium in ash: Short tons
Measured and indicated coal								
1	724	15.0	19,222	26	0.003	577	0.012	----------
2	750	7.5	9,956	26	.003	299	.012	----------
3	494	3.8	3,323	26	.003	100	.012	----------
4	34	7.5	451	23	.002	----------	.009	----------
5	60	3.8	404	23	.002	----------	.009	----------
6	173	3.8	1,164	21	.002	----------	.010	----------
7	461	7.5	6,120	21	.002	----------	.010	----------
8	1,687	17.3	51,658	21	.001	----------	.004	----------
9	795	16.7	23,499	27	.003	705	.011	----------
10	685	7.5	9,093	28	.003	273	.011	----------
11	112	3.8	753	23	.003	23	.013	----------
12	380	3.8	2,556	29	.003	77	.010	----------
Total	----------	----------	128,199	----------	----------	2,054	----------	----------

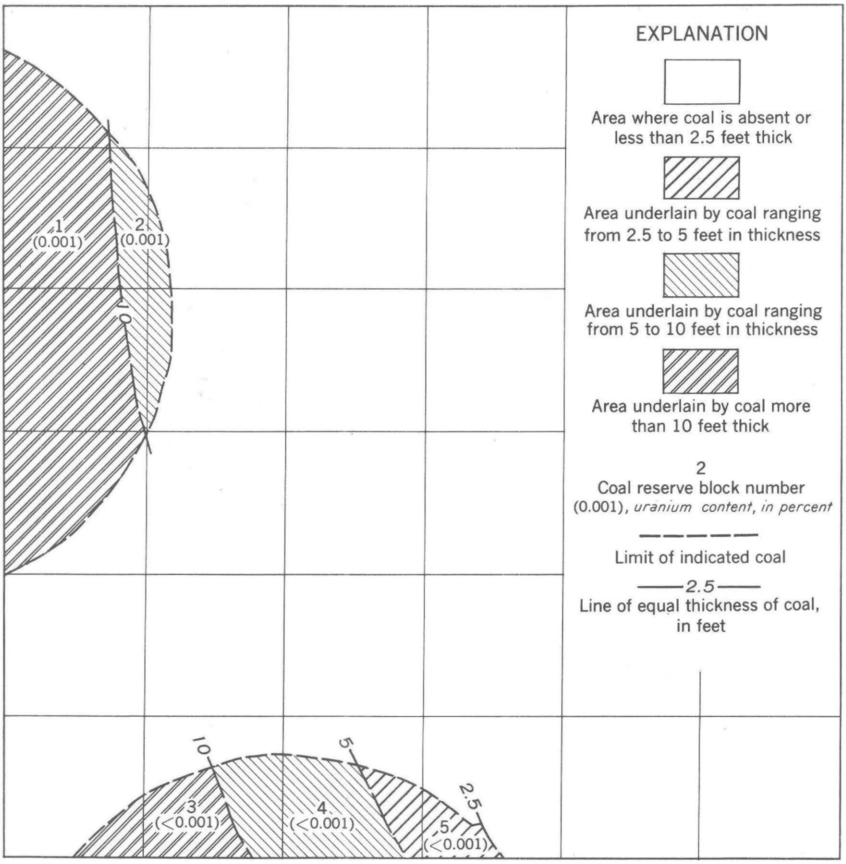

FIGURE 48.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Latham Nos. 3 and 4 beds in T. 21 N., R. 92 W.

Block	Coal reserves			Ash (percent)	Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	1,706	15.0	45,294	23	0.001		0.005	
2	323	9.3	5,317	26	.001		.005	
3	299	11.8	6,245	27	.001		.001	
4	489	7.5	6,491	30	.001		.001	
5	218	4.0	1,543	33	.001		.003	
Total			64,890					

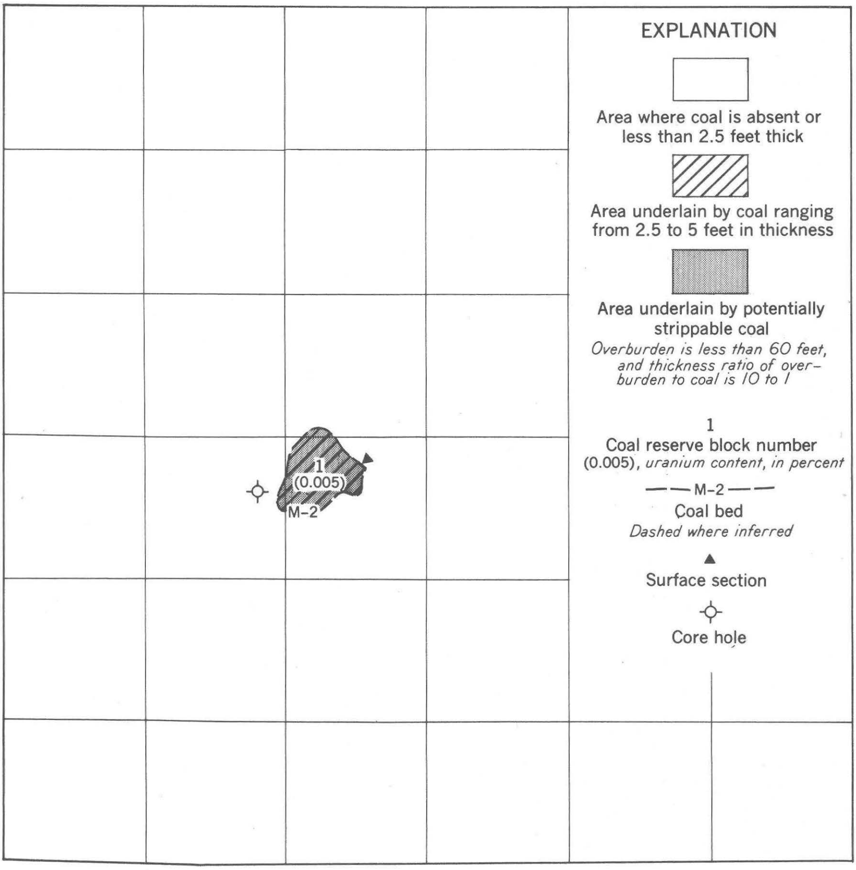

FIGURE 49.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Monument No. 2 bed in T. 21 N., R. 93 W.

Coal reserves				Ash (percent)	Approximate uranium content			
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	152	4.5	1,211	33	0.005	61	0.015	61
Potentially strippable coal (included in above blocks)								
1	152	4.5	1,211	33	0.005	61	0.015	61

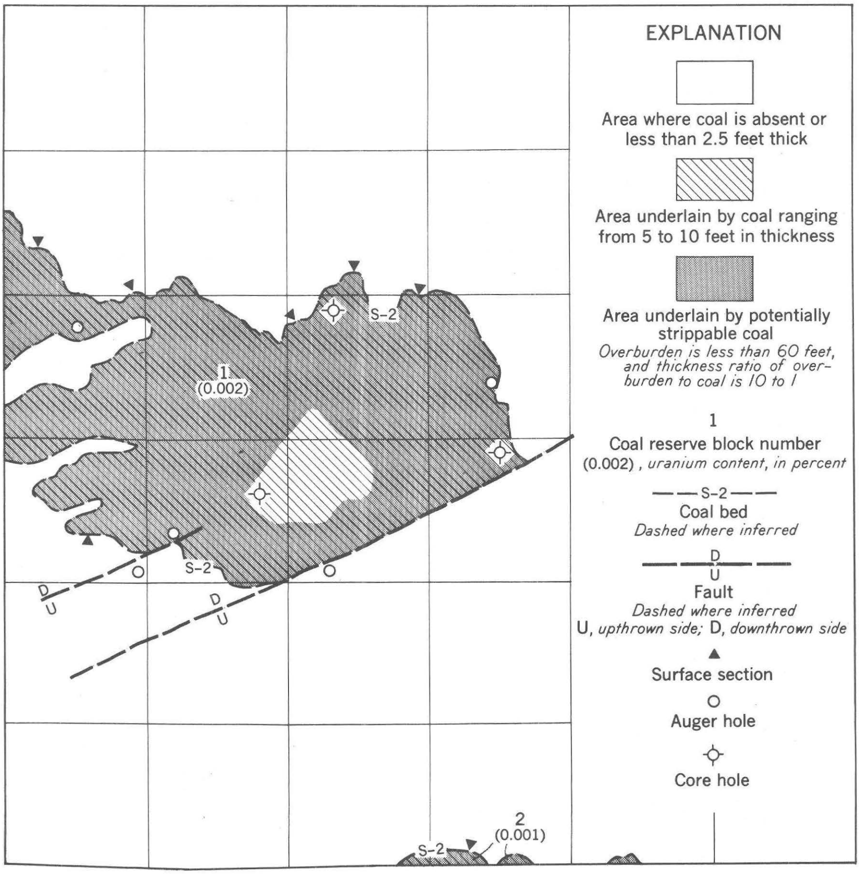

FIGURE 50.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Sourdough No. 2 bed in T. 21 N., R. 93 W.

Block	Coal reserves			Ash (percent)	Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	3,492	8.3	51,301	23	0.002	----------	0.010	----------
2	46	7.5	611	26	.001	----------	.004	----------
Total	----------	----------	51,912	----------	----------	----------	----------	----------
Potentially strippable coal (included in above blocks)								
1	3,180	8.3	46,717	23	0.002	----------	0.010	----------
2	46	7.5	611	26	.001	----------	.004	----------
Total	----------	----------	47,328	----------	----------	----------	----------	----------

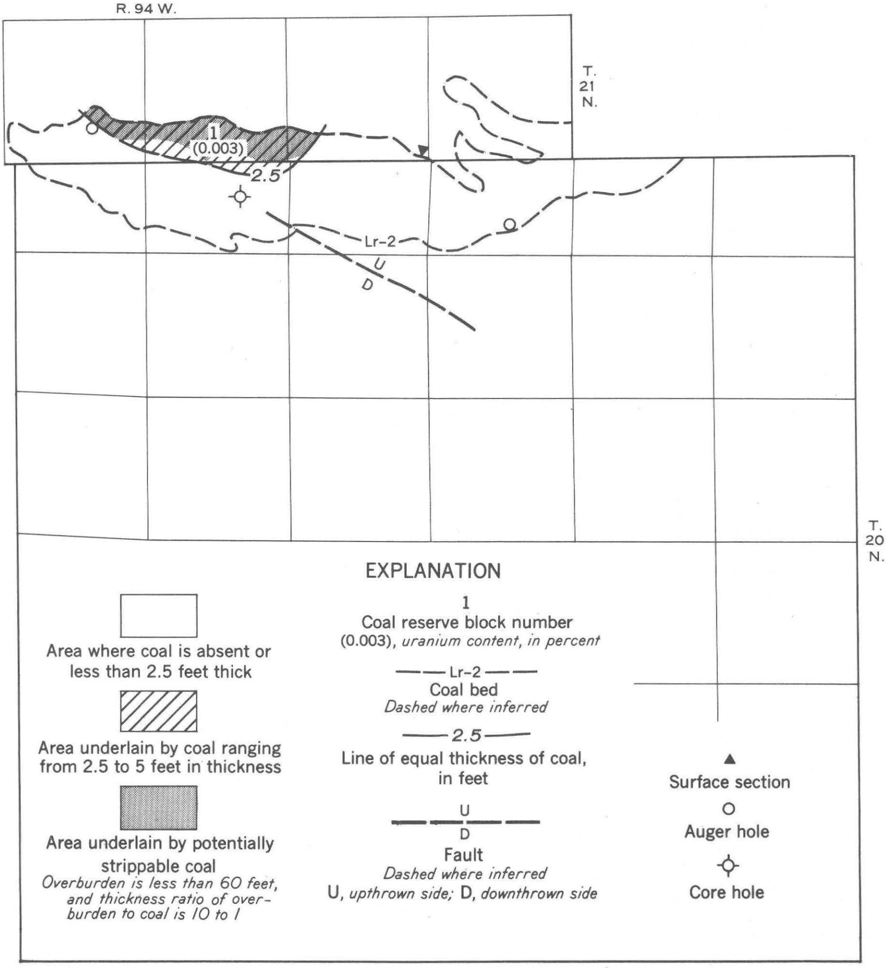

FIGURE 51.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Larsen No. 2 bed in Tps. 20 and 21 N., R. 90 W.

Coal reserves				Ash (percent)	Approximate uranium content			
					Uranium in coal		Uranium in ash	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	257	2.9	1,319	21	0.003	40	0.012	
Potentially strippable coal (included in above blocks)								
1	178	2.9	914	21	0.003	27	0.012	

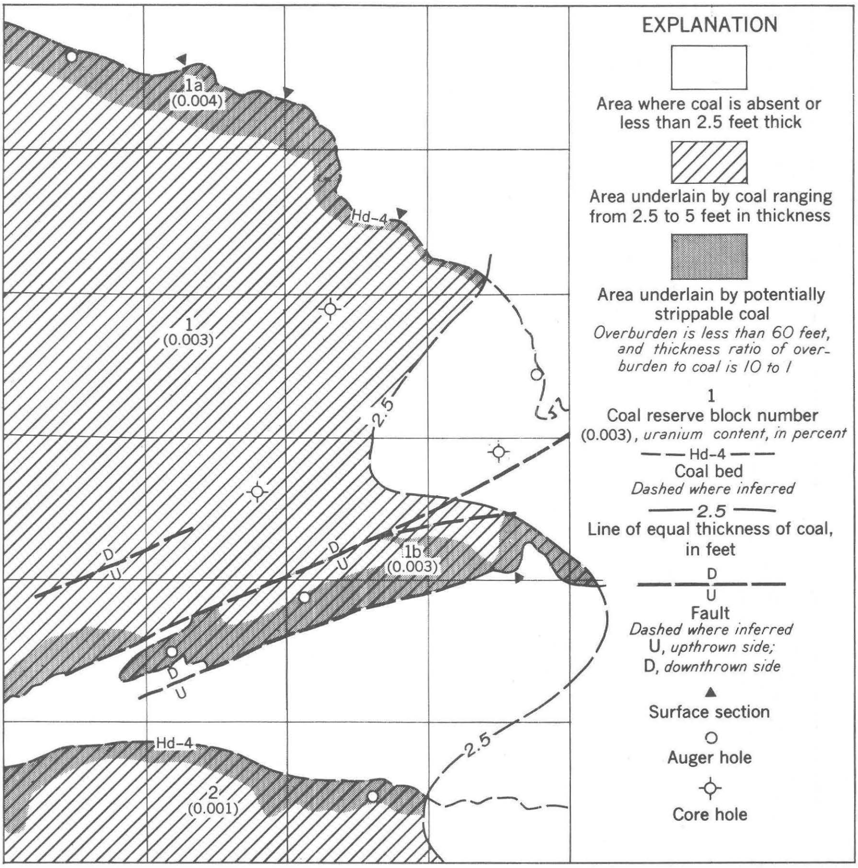

FIGURE 52.—Map and table (below) showing extent, thickness, size of uranium content, and potentially strippable areas of coal in the Hadsell Nos. 3 and 4 beds in T. 21 N., R. 93 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	9,187	3.5	56,913	23	0.003	1,707	0.015	1,707
2	1,369	2.9	7,027	20	.001	----------	.005	----------
Total	----------	----------	63,940	----------	----------	1,707	----------	1,707
Potentially strippable coal (included in above blocks)								
1a	584	3.3	3,411	26	0.004	136	0.015	136
1b	644	4.1	4,674	22	.003	140	.015	140
2	391	2.9	2,007	20	.001	----------	.005	----------
Total	----------	----------	10,092	----------	----------	276	----------	276

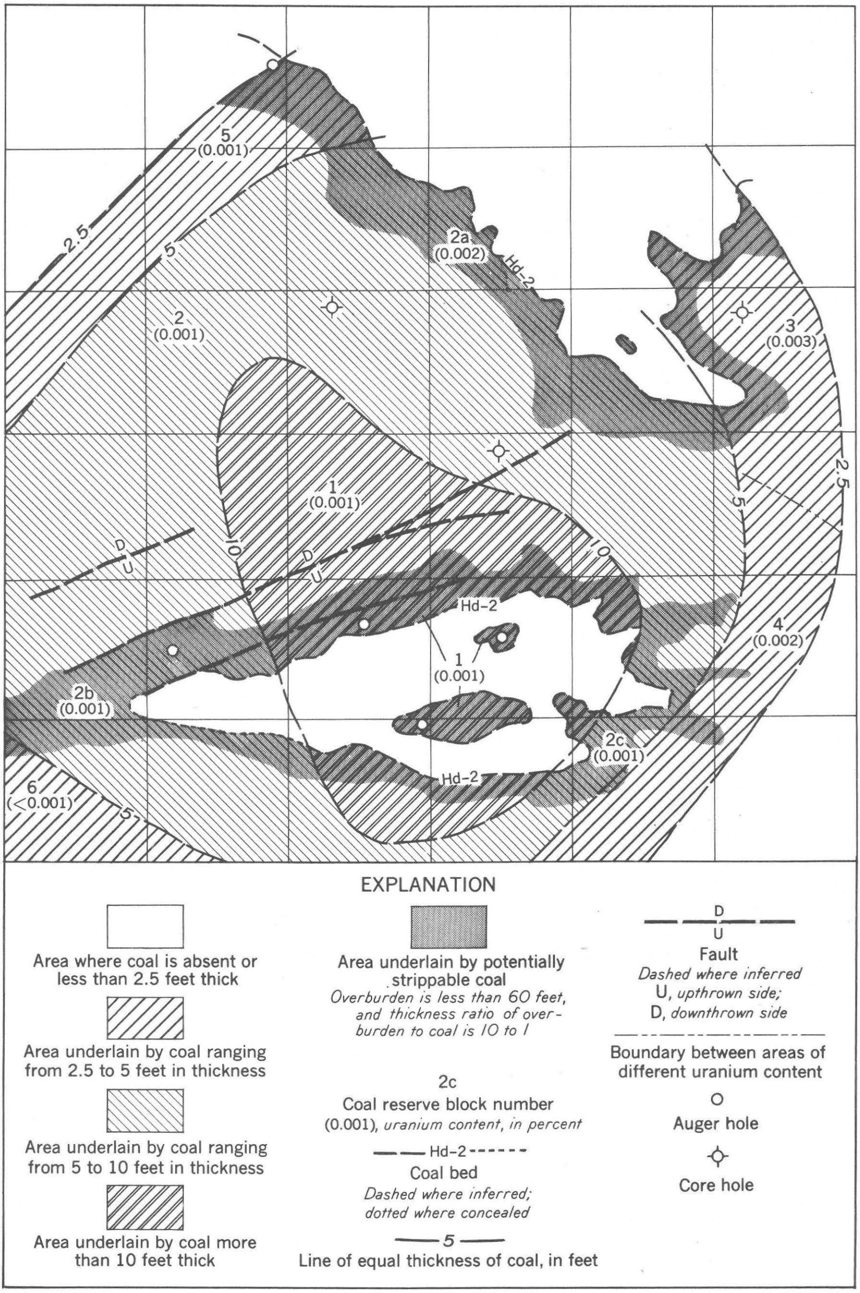

FIGURE 53.—Map and table (p. B–121) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of caol in the Hadsell Nos. 1 and 2 beds in T. 21 N., R. 93 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	2,806	12.3	61,089	28	0.001		0.004	
2	8,996	7.5	119,422	24	.001		.005	
3	1,032	3.8	6,941	27	.003	208	.011	
4	1,070	3.8	7,197	24	.002		.008	
5	1,101	3.8	7,405	20	.001		.005	
6	431	4.4	3,357	20	.001		.005	
Total			205,411			208		
Potentially strippable coal (included in above blocks)								
1	961	12.3	20,922	32	0.001		0.004	
2a	774	6.9	9,453	20	.002		.010	
2b	618	7.5	8,204	24	.001		.005	
2c	361	7.5	4,792	24	.001		.005	
3	323	3.8	2,172	27	.004	87	.014	
4	53	4.3	403	24	.001		.005	
5	217	3.8	1,460	20	.002		.010	
6	12	5.0	106	24	.001		.005	
Total			47,512			87		

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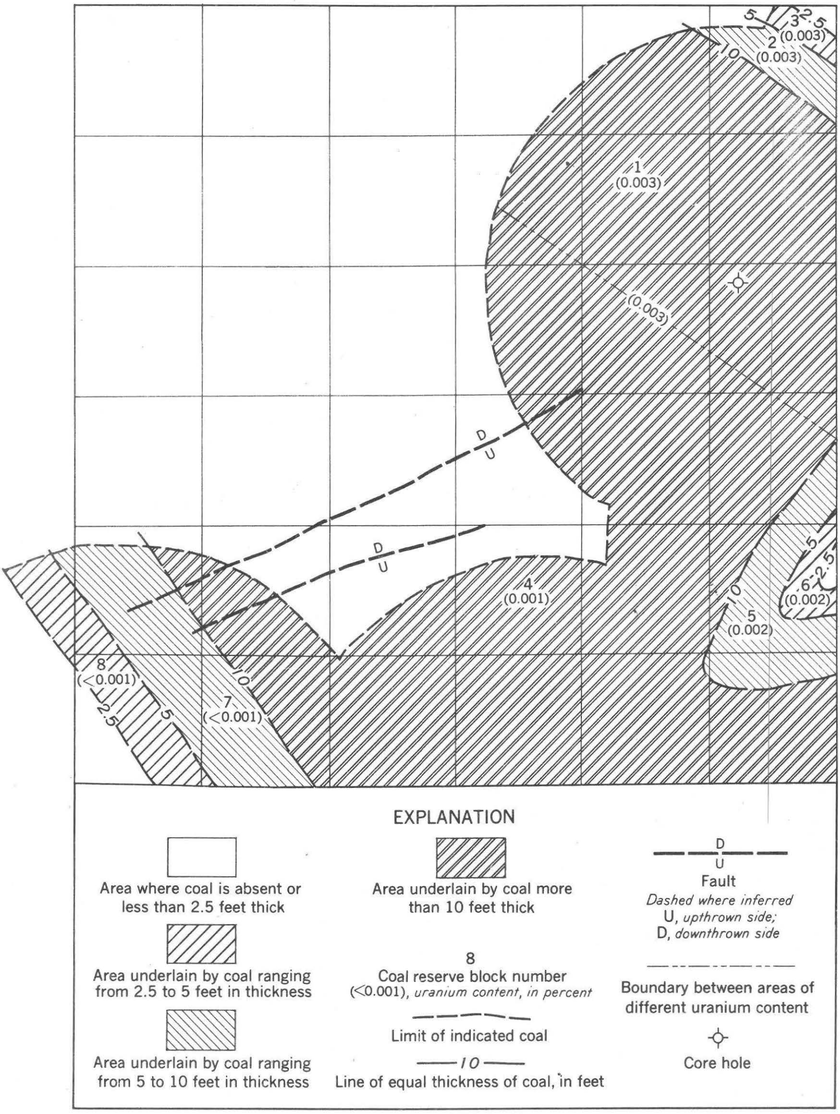

FIGURE 54.—Map and table (p. B-123) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Creston Nos. 2 and 3 beds in T. 21 N., R. 93 W.

Measured and indicated coal reserves					Approximate uranium content			
					Uranium in coal		Uranium in ash	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Percent	Short tons	Percent	Short tons
1	3,119	20.1	110,965	26	0.003	3,329	0.010	
2	716	7.5	9,505	26	.003	285	.010	
3	77	3.8	518	26	.003	16	.010	
4	234	16.5	6,834	20	.001		.005	
5	617	7.5	8,191	20	.002		.010	
6	139	3.8	935	20	.002		.010	
7	948	7.5	12,585	16	.001		.005	
8	524	3.8	3,524	18	.001		.005	
Total			153,057			3,630		

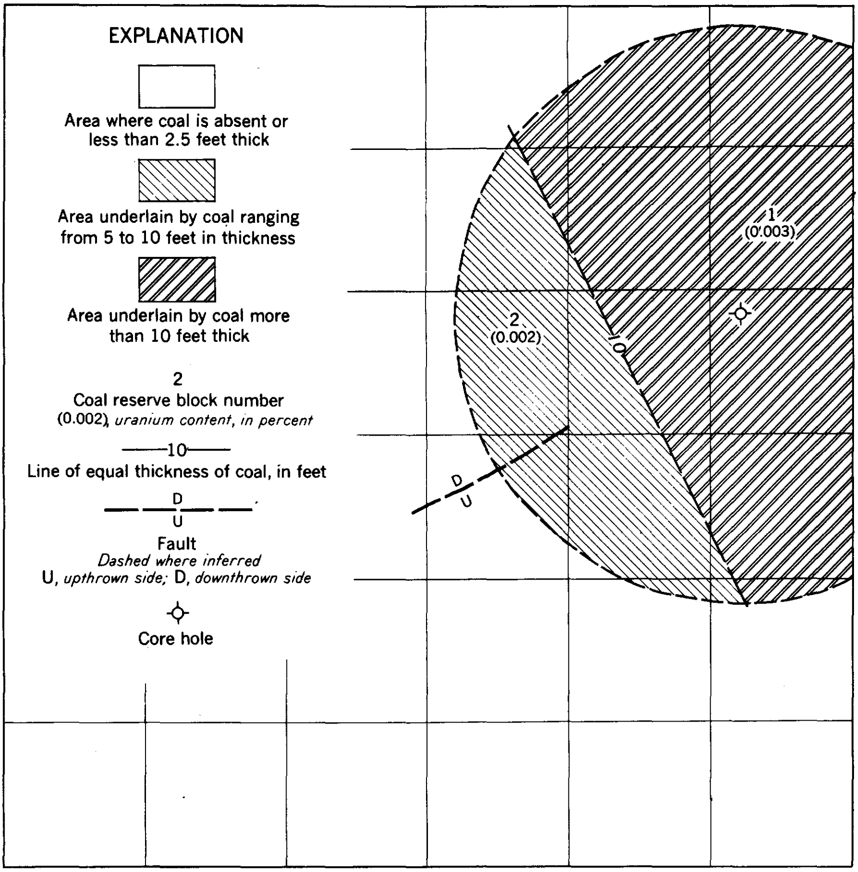

FIGURE 55.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Latham No. 4 bed in T. 21 N., R. 93 W.

Measured and indicated coal reserves				Ash (percent)	Approximate uranium content			
					Uranium in coal		Uranium in ash	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
1	4,083	14.7	106,236	23	0.001		0.005	
2	1,891	9.4	31,462	23	.001		.005	
Total			137,698					

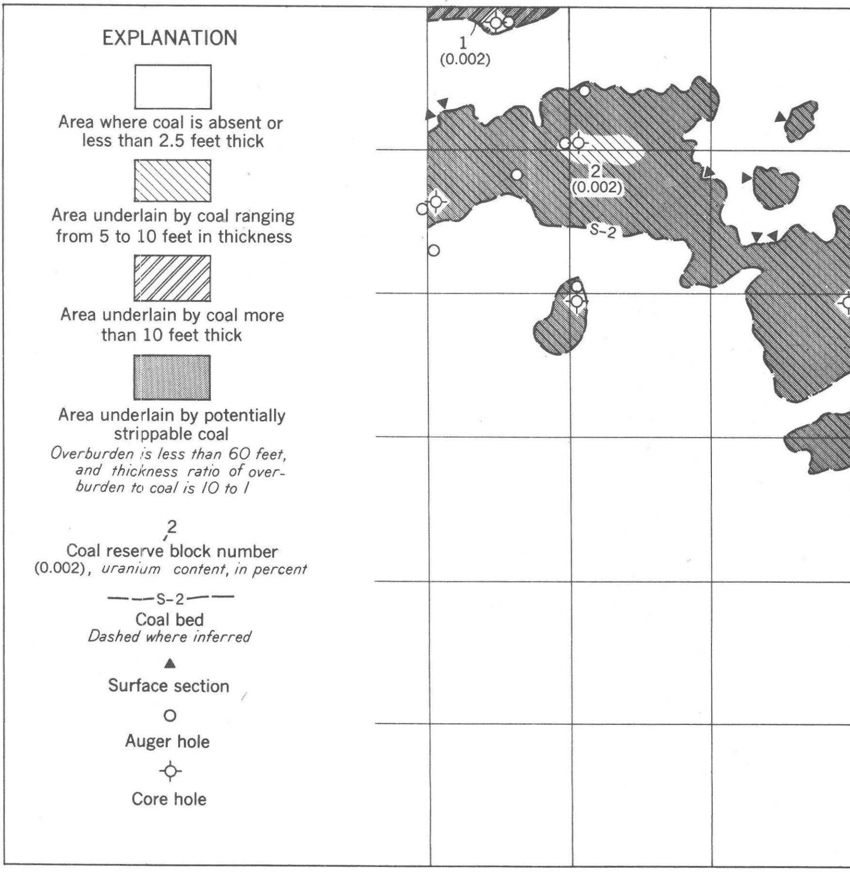

FIGURE 56.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Sourdough No. 2 bed in T. 21 N., R. 94 W.

Block	Coal reserves: Area (acres)	Coal reserves: Average thickness (feet)	Coal reserves: Coal (thousands of short tons)	Ash (percent)	Approximate uranium content: Uranium in coal: Percent	Approximate uranium content: Uranium in coal: Short tons	Approximate uranium content: Uranium in ash: Percent	Approximate uranium content: Uranium in ash: Short tons
Measured and indicated coal								
1	66	12.3	1,437	18	0.002		0.009	
2	1,858	7.3	24,007	19	.001		.007	
Total			25,444					
Potentially strippable coal (included in above blocks)								
1	66	12.3	1,437	18	0.002		0.009	
2	1,779	7.3	22,986	19	.001		.007	
Total			24,423					

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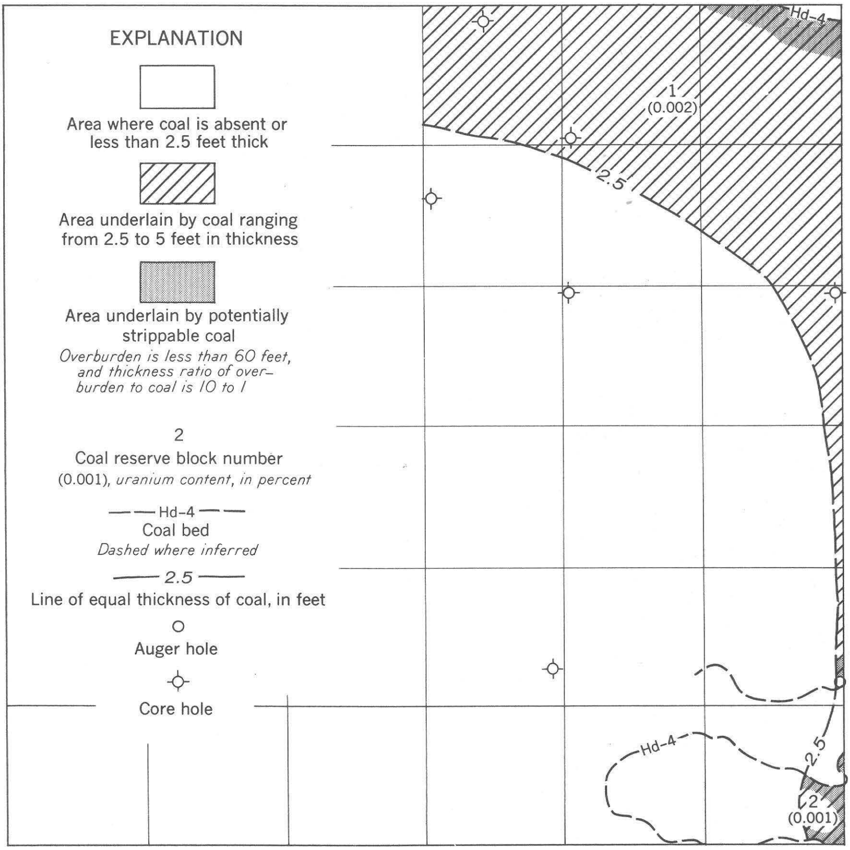

FIGURE 57.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Hadsell No. 4 bed in T. 21 N., R. 94 W.

Block	Coal reserves: Area (acres)	Coal reserves: Average thickness (feet)	Coal reserves: Coal (thousands of short tons)	Ash (percent)	Approximate uranium content: Uranium in coal: Percent	Uranium in coal: Short tons	Uranium in ash: Percent	Uranium in ash: Short tons
Measured and indicated coal								
1	2,906	3.3	16,974	27	0.003	509	0.011	
2	332	2.8	1,645	30	.001		.004	
Total			18,619			509		
Potentially strippable coal (included in above blocks)								
1	124	3.3	724	27	0.003	22	0.011	
2	58	2.8	287	30	.001		.004	
Total			1,011			22		

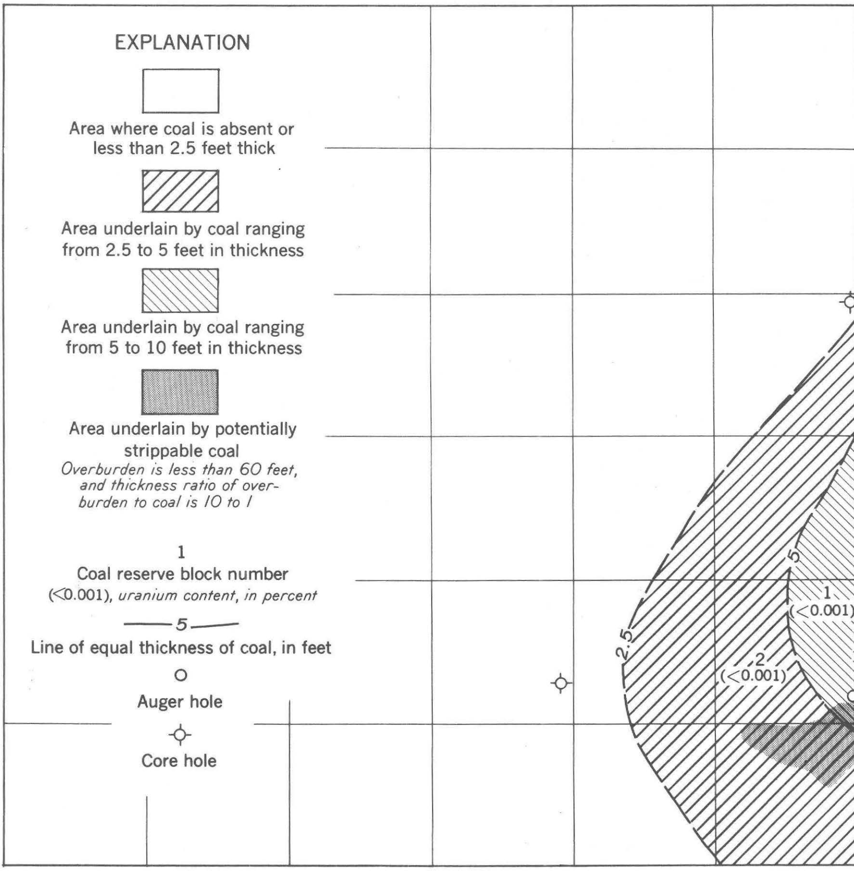

FIGURE 58.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Hadsell Nos. 1 and 2 beds in T. 21 N., R. 94 W.

Block	Coal reserves: Area (acres)	Coal reserves: Average thickness (feet)	Coal reserves: Coal (thousands of short tons)	Ash (percent)	Approximate uranium content: Uranium in coal: Percent	Uranium in coal: Short tons	Uranium in ash: Percent	Uranium in ash: Short tons
Measured and indicated coal								
1	435	5.3	4,081	23	0.001	----------	0.005	----------
2	2,308	3.8	15,524	23	.001	----------	.005	----------
Total	----------	----------	19,605	----------	----------	----------	----------	----------
Potentially strippable coal (included in above blocks)								
1	14	5.0	124	23	0.001	----------	0.005	----------
2	163	4.3	1,241	23	.001	----------	.005	----------
Total	----------	----------	1,365	----------	----------	----------	----------	----------

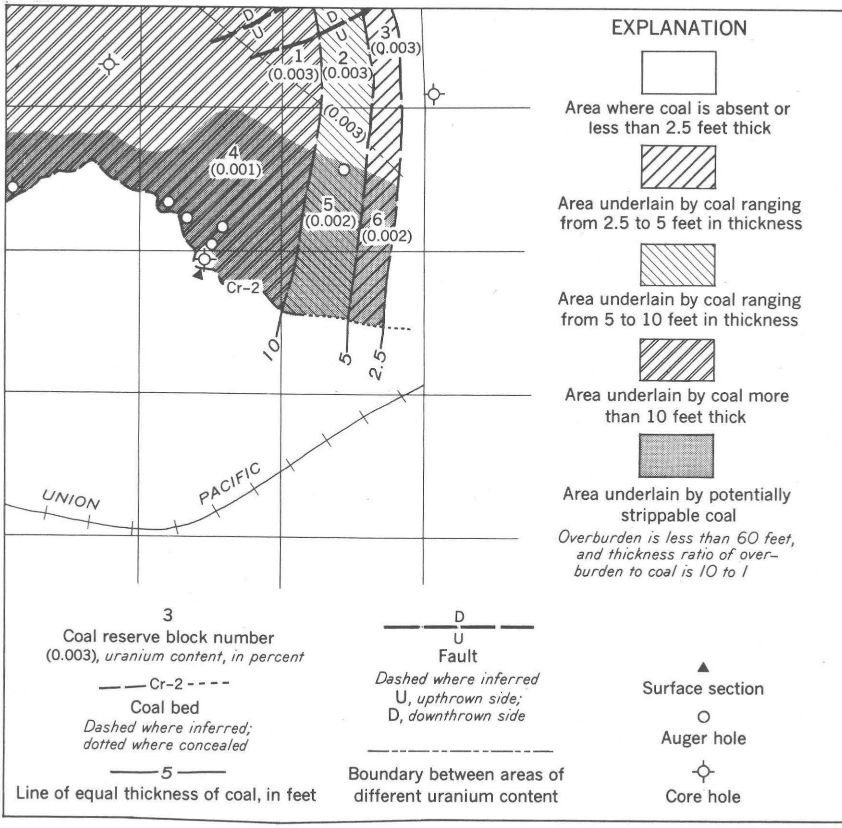

FIGURE 59.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Creston Nos. 2 and 3 beds in T. 20 N., R. 92 W.

Block	Coal reserves: Area (acres)	Coal reserves: Average thickness (feet)	Coal reserves: Coal (thousands of short tons)	Coal reserves: Ash (percent)	Approximate uranium content: Uranium in coal: Percent	Approximate uranium content: Uranium in coal: Short tons	Approximate uranium content: Uranium in ash: Percent	Approximate uranium content: Uranium in ash: Short tons
Measured and indicated coal								
1	157	15.0	4,168	29	0.003	125	0.012	
2	179	7.5	2,367	29	.003	71	.012	
3	140	3.8	942	29	.003	28	.012	
4	1,910	25.0	84,518	20	.001		.005	
5	353	7.5	4,686	28	.002		.007	
6	167	3.8	1,123	33	.002		.007	
Total			97,813			224		
Potentially strippable coal (included in above blocks)								
4	830	25.0	36,728	20	0.001		0.005	
5	281	7.5	3,730	28	.002		.007	
6	157	3.8	1,056	33	.002		.007	
Total			41,514					

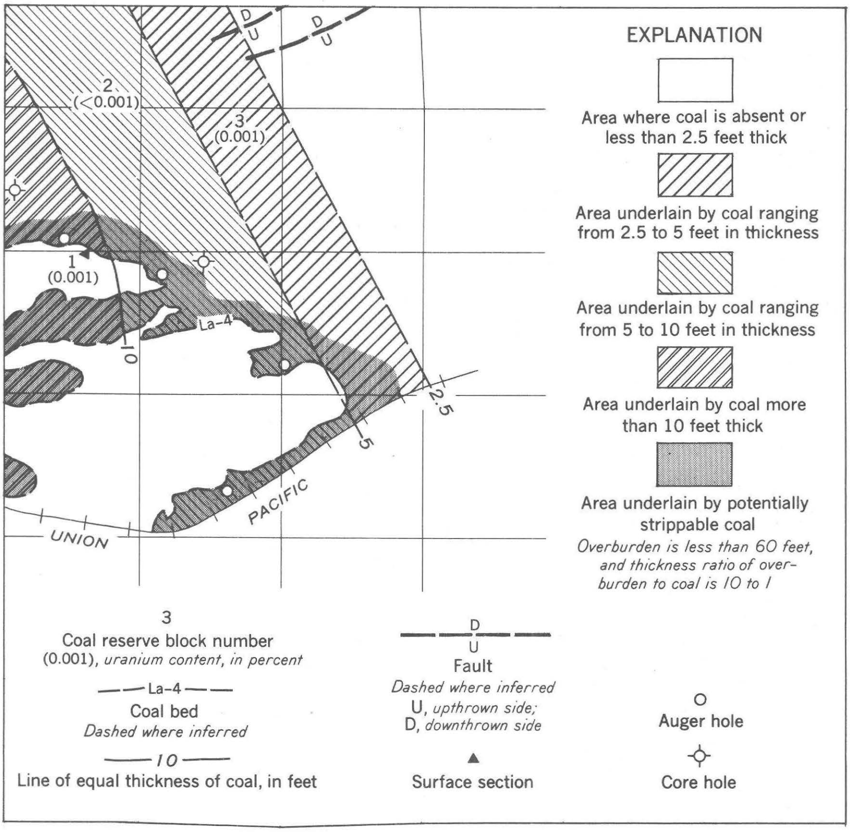

FIGURE 60.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Latham Nos. 3 and 4 beds in T. 20 N., R. 92 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	590	10.9	11,383	27	0.001	----------	0.005	----------
2	1,702	7.5	22,594	33	.001	----------	.001	----------
3	1,208	3.8	8,125	28	.001	----------	.005	----------
Total	----------	----------	42,102	----------	----------	----------	----------	----------
Potentially strippable coal (included in above blocks)								
1	354	10.9	6,830	27	0.001	----------	0.005	----------
2	459	7.5	6,093	33	.001	----------	.001	----------
3	126	3.8	847	28	.001	----------	.005	----------
Total	----------	----------	13,770	----------	----------	----------	----------	----------

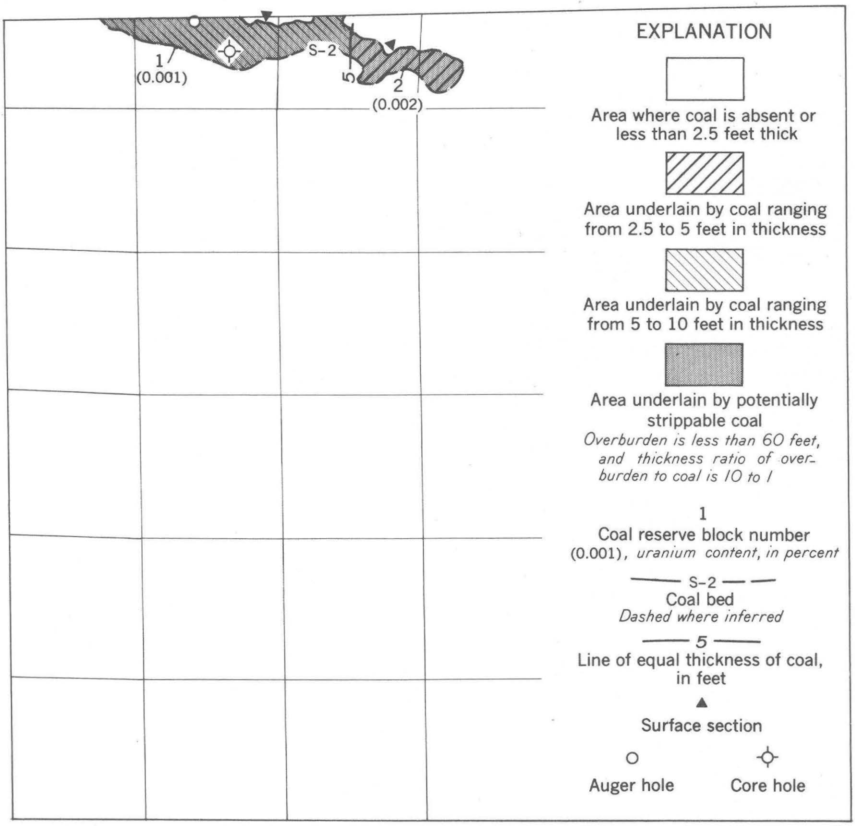

FIGURE 61.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Sourdough No. 2 bed in T. 20 N., R. 93 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	223	5.7	2,250	17	0.001	----------	0.009	----------
2	136	4.5	1,083	14	.002	----------	.013	----------
Total	----------	----------	3,333	----------	----------	----------	----------	----------
Potentially strippable coal (included in above blocks)								
1	223	5.7	2,250	17	0.001	----------	0.009	----------
2	136	4.5	1,083	14	.002	----------	.013	----------
Total	----------	----------	3,333	----------	----------	----------	----------	----------

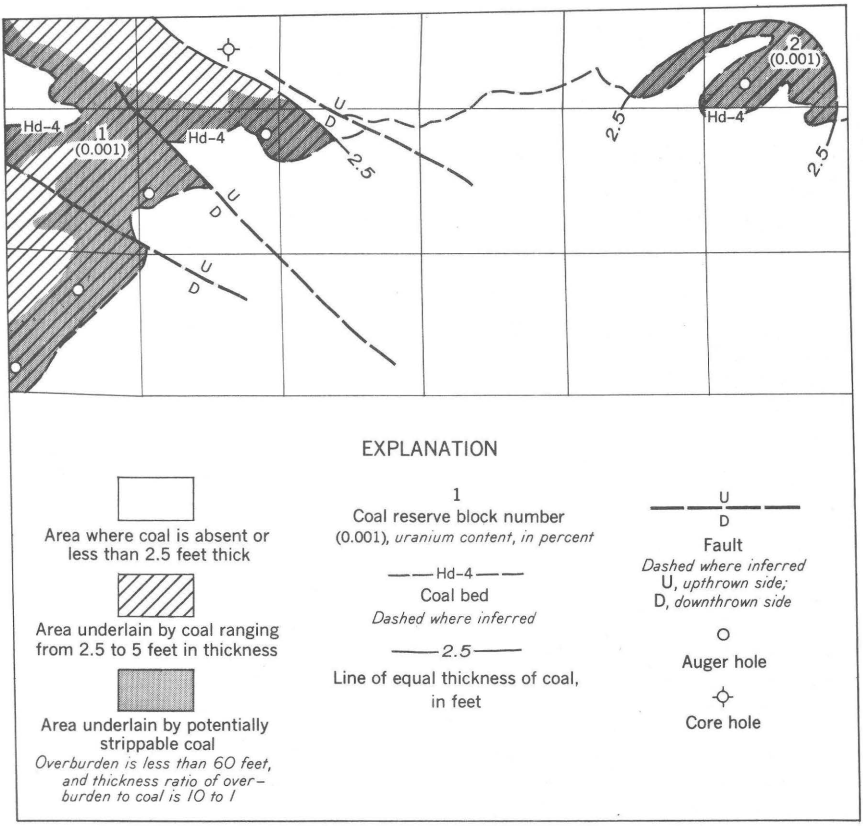

FIGURE 62.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Hadsell Nos. 3 and 4 beds in T. 20 N., R. 93 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	1,472	2.9	7,556	27	0.001		0.005	
2	322	3.0	1,710	27	.001		.005	
Total			9,266					
Potentially strippable coal (included in above blocks)								
1	867	2.9	4,450	27	0.001		0.005	
2	322	3.0	1,710	27	.001		.005	
Total			6,160					

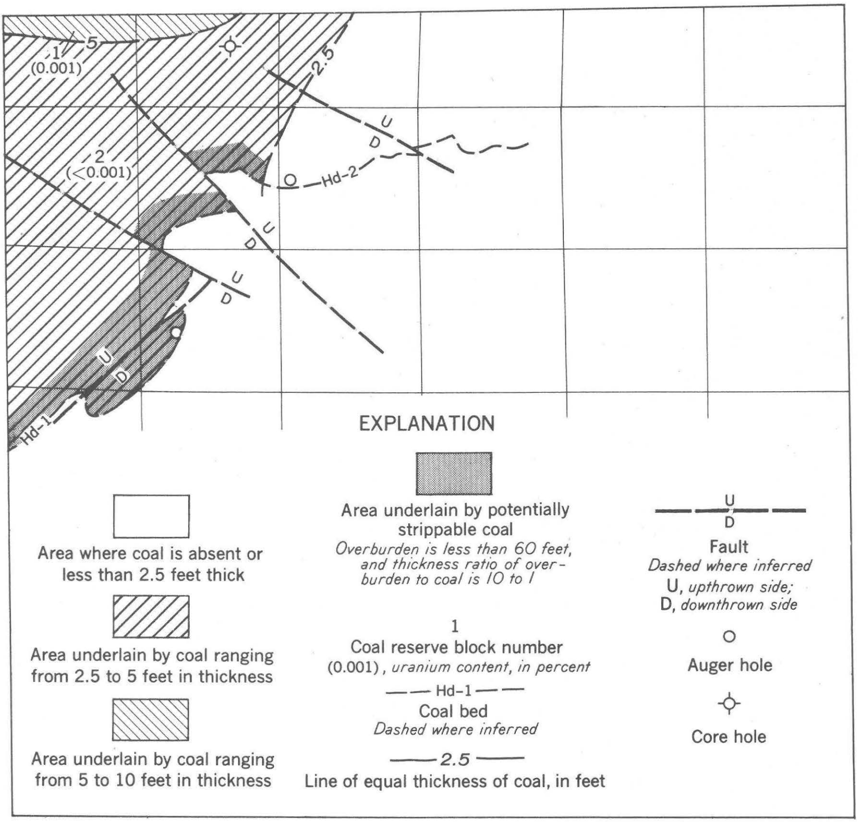

FIGURE 63.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Hadsell Nos. 1 and 2 beds in T. 20 N., R. 93 W.

Block	Coal reserves: Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Approximate uranium content: Uranium in coal, Percent	Uranium in coal, Short tons	Uranium in ash, Percent	Uranium in ash, Short tons
Measured and indicated coal								
1	163	5.0	1,443	27	0.001	----------	0.005	----------
2	2,659	3.2	15,061	27	.001	----------	.004	----------
Total	----------	----------	16,504	----------	----------	----------	----------	----------
Potentially strippable coal (included in above blocks)								
2	575	2.8	2,850	27	0.001	----------	0.004	----------

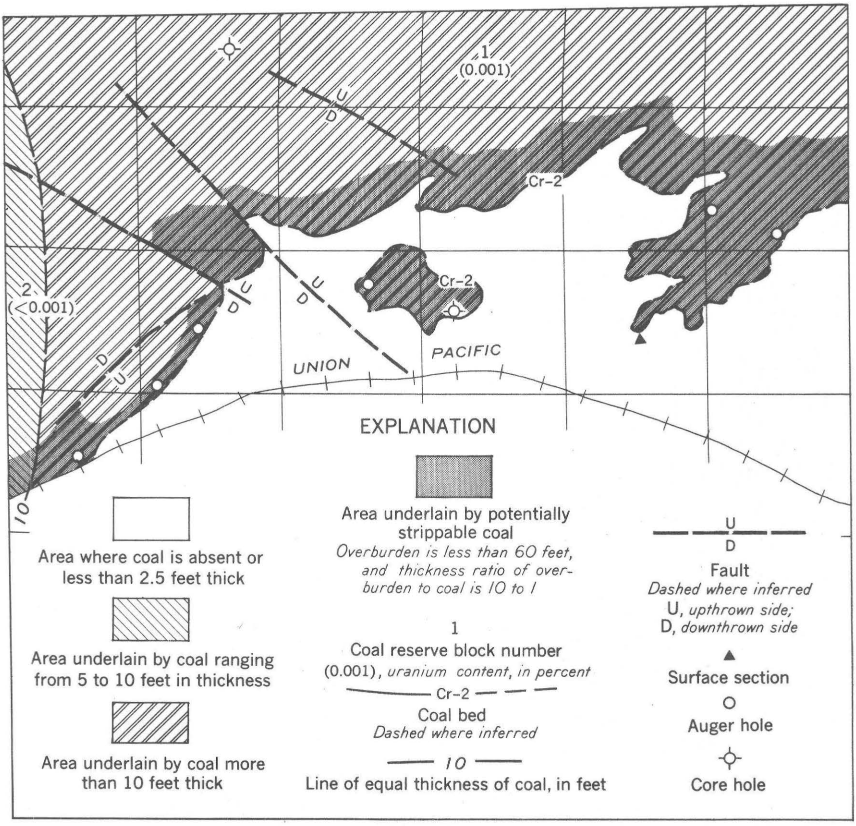

FIGURE 64.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Creston Nos. 2 and 3 beds in T. 20 N., R. 93 W.

Block	Coal reserves: Area (acres)	Coal reserves: Average thickness (feet)	Coal reserves: Coal (thousands of short tons)	Ash (percent)	Uranium in coal: Percent	Uranium in coal: Short tons	Uranium in ash: Percent	Uranium in ash: Short tons
Measured and indicated coal								
1	5,907	17.4	181,924	18	0.001	----------	0.005	----------
2	399	7.5	5,297	16	.001	----------	.005	----------
Total	----------	----------	187,221	----------	----------	----------	----------	----------
Potentially strippable coal (included in above blocks)								
1	1,932	17.4	59,502	18	0.001	----------	0.005	----------
2	26	7.5	345	16	.001	----------	.005	----------
Total	----------	----------	59,847	----------	----------	----------	----------	----------

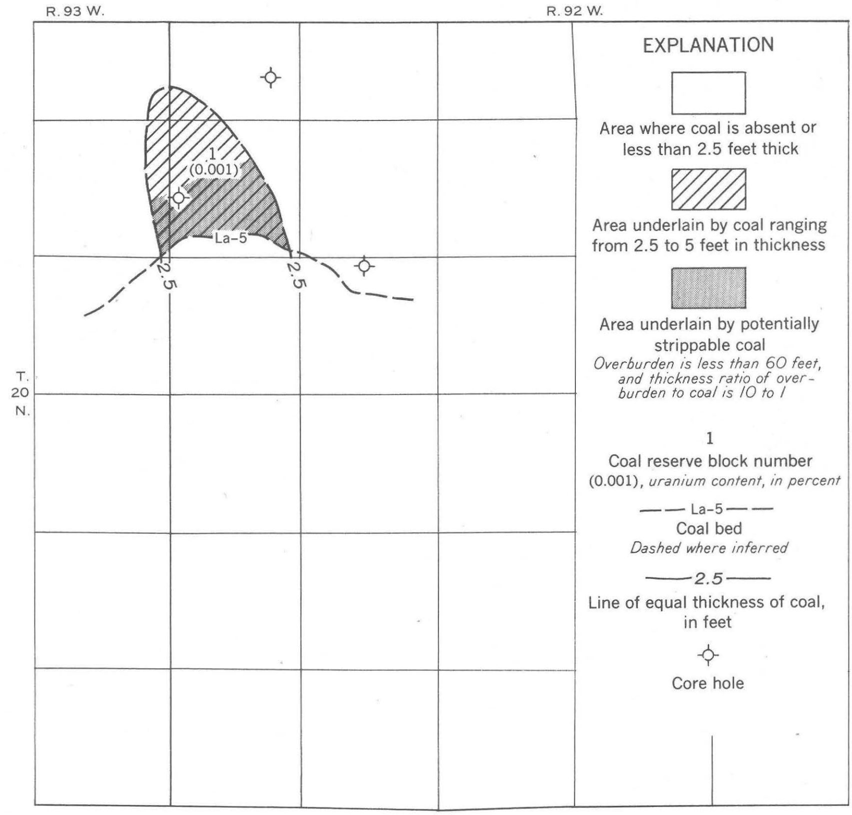

FIGURE 65.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Latham No. 5 bed in T. 20 N., Rs. 92 and 93 W.

Coal reserves				Ash (percent)	Approximate uranium content			
					Uranium in coal		Uranium in ash	
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)		Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	544	3.4	3,274	21	0.001		0.003	
Potentially strippable coal (included in above blocks)								
1	257	3.4	1,547	21	0.001		0.003	

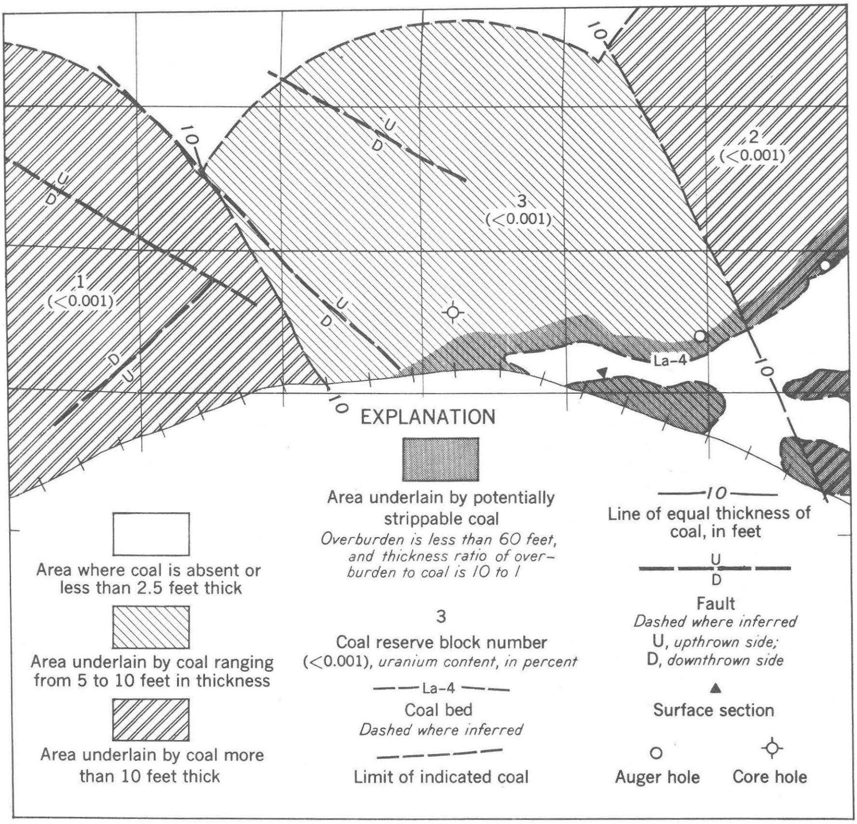

FIGURE 66.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Latham Nos. 3 and 4 beds in T. 20 N., R. 93 W.

Block	Coal reserves: Area (acres)	Coal reserves: Average thickness (feet)	Coal reserves: Coal (thousands of short tons)	Ash (percent)	Approximate uranium content: Uranium in coal: Percent	Uranium in coal: Short tons	Uranium in ash: Percent	Uranium in ash: Short tons
Measured and indicated coal								
1	2,646	12.7	59,479	24	0.001	----------	0.004	----------
2	1,755	10.9	33,859	27	.001	----------	.005	----------
3	4,495	9.2	73,197	21	.001	----------	.001	----------
Total	----------	----------	166,535	----------	----------	----------	----------	----------
Potentially strippable coal (included in above blocks)								
2	203	10.9	3,916	27	0.001	----------	0.005	----------
3	454	9.2	7,393	21	.001	----------	.001	----------
Total	----------	----------	11,309	----------	----------	----------	----------	----------

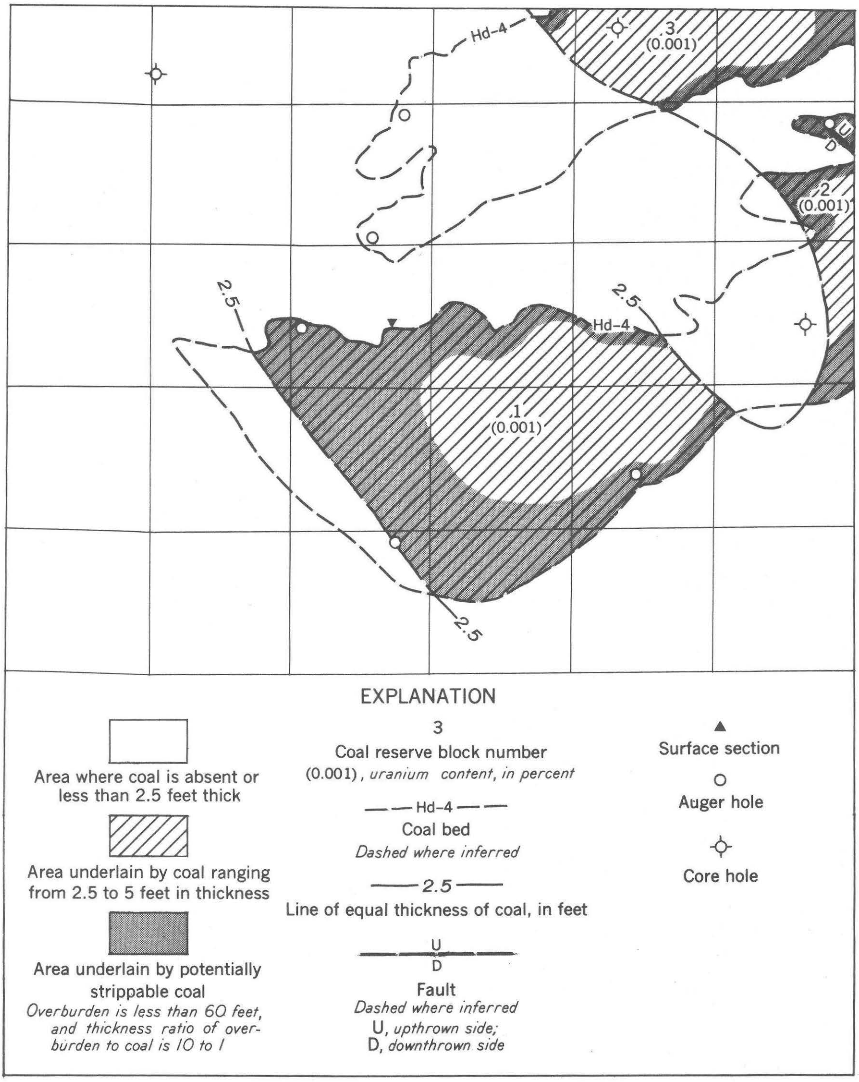

FIGURE 67.—Map and table (p. B–137) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Hadsell Nos. 3 and 4 beds in T. 20 N., R. 94 W.

Block	Coal reserves: Area (acres)	Coal reserves: Average thickness (feet)	Coal reserves: Coal (thousands of short tons)	Coal reserves: Ash (percent)	Approximate uranium content: Uranium in coal: Percent	Approximate uranium content: Uranium in coal: Short tons	Approximate uranium content: Uranium in ash: Percent	Approximate uranium content: Uranium in ash: Short tons
Measured and indicated coal								
1	2,684	3.2	15,202	29	0.001	----------	0.005	----------
2	334	2.5	1,478	29	.001	----------	.005	----------
3	669	2.9	3,434	29	.001	----------	.005	----------
Total	----------	----------	20,114	----------	----------	----------	----------	----------
Potentially strippable coal (included in above blocks)								
1	1,540	3.2	8,723	29	0.001	----------	0.005	----------
2	189	2.5	836	29	.001	----------	.005	----------
3	154	2.9	790	29	.001	----------	.005	----------
Total	----------	----------	10,349	----------	----------	----------	----------	----------

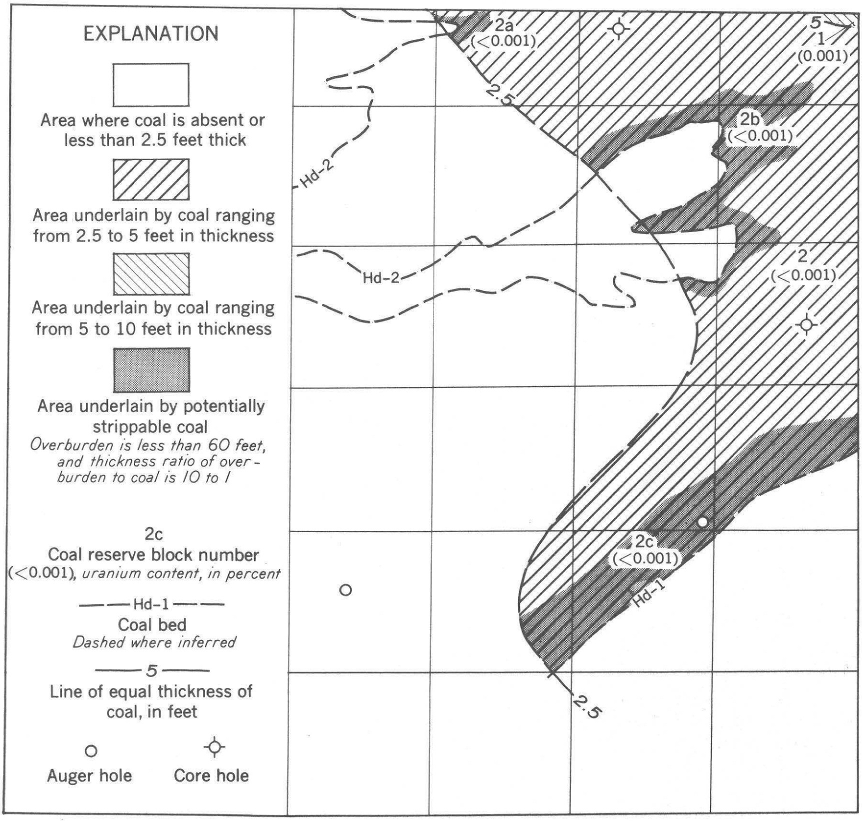

FIGURE 68.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Hadsell Nos. 1 and 2 beds in T. 20 N., R. 94 W.

Block	Coal reserves				Approximate uranium content			
	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated coal								
1	20	5.0	177	27	0.001		0.005	
2	4,081	3.1	22,392	27	.001		.004	
Total			22,569					
Potentially strippable coal (included in above blocks)								
2a	27	2.5	119	27	0.001		0.004	
2b	410	3.1	2,250	27	.001		.004	
2c	625	3.1	3,429	27	.001		.004	
Total			5,798					

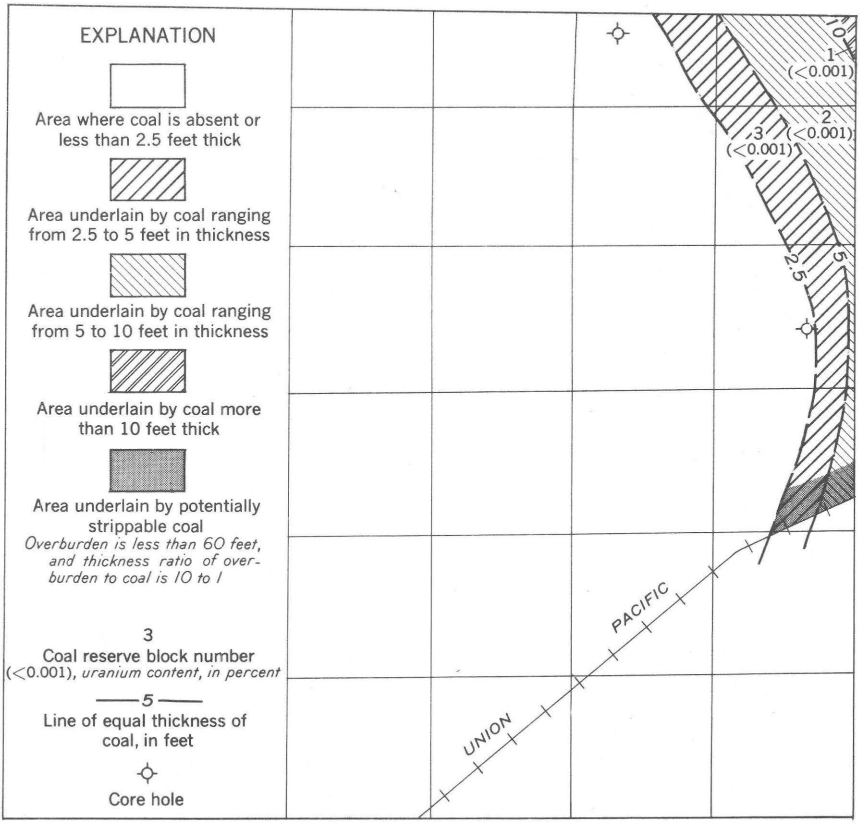

FIGURE 69.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas of coal in the Creston Nos. 2 and 3 beds in T. 20 N., R. 94 W.

Block	Coal reserves: Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Approximate uranium content: Uranium in coal: Percent	Uranium in coal: Short tons	Uranium in ash: Percent	Uranium in ash: Short tons
Measured and indicated coal								
1	20	10.0	354	15	0.001		0.005	
2	586	6.3	6,534	16	.001		.005	
3	759	3.8	5,105	18	.001		.005	
Total			11,993					
Potentially strippable coal (included in above blocks)								
2	43	6.0	457	16	0.001		0.005	
3	32	3.8	215	18	.001		.005	
Total			672					

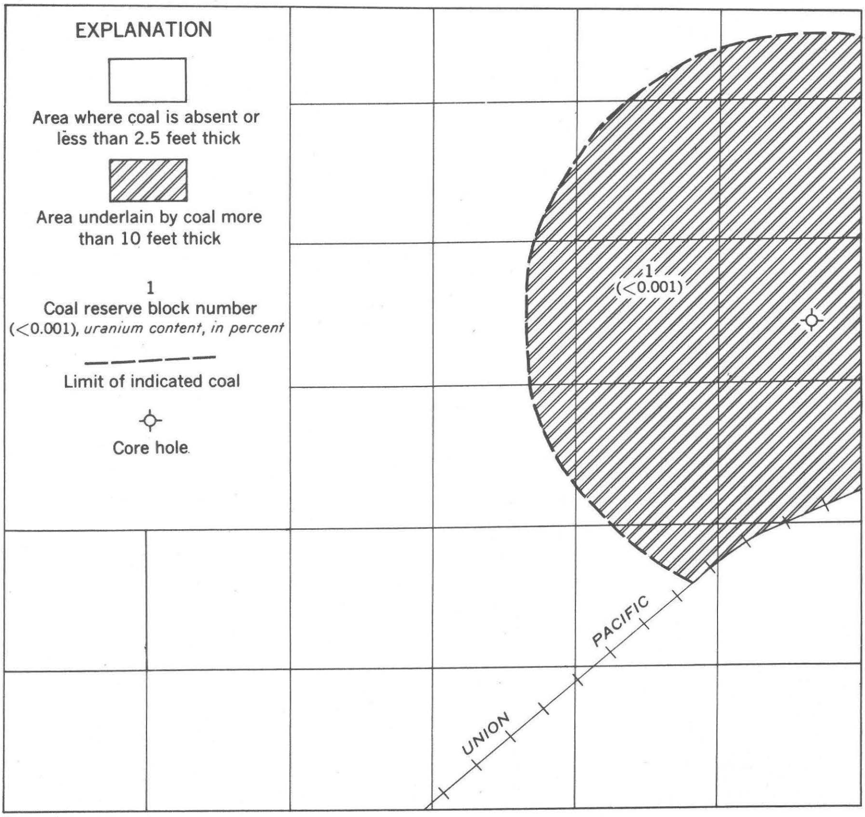

FIGURE 70.—Map and table (below) showing extent, thickness, size of coal reserves, uranium content, and potentially strippable areas in the Latham Nos. 3 and 4 beds in T. 20 N., R. 94 W.

Measured and indicated coal reserves					Approximate uranium content			
Block	Area (acres)	Average thickness (feet)	Coal (thousands of short tons)	Ash (percent)	Uranium in coal		Uranium in ash	
					Percent	Short tons	Percent	Short tons
1	4, 501	15. 3	121, 892	24	0. 001	----------	0. 003	----------

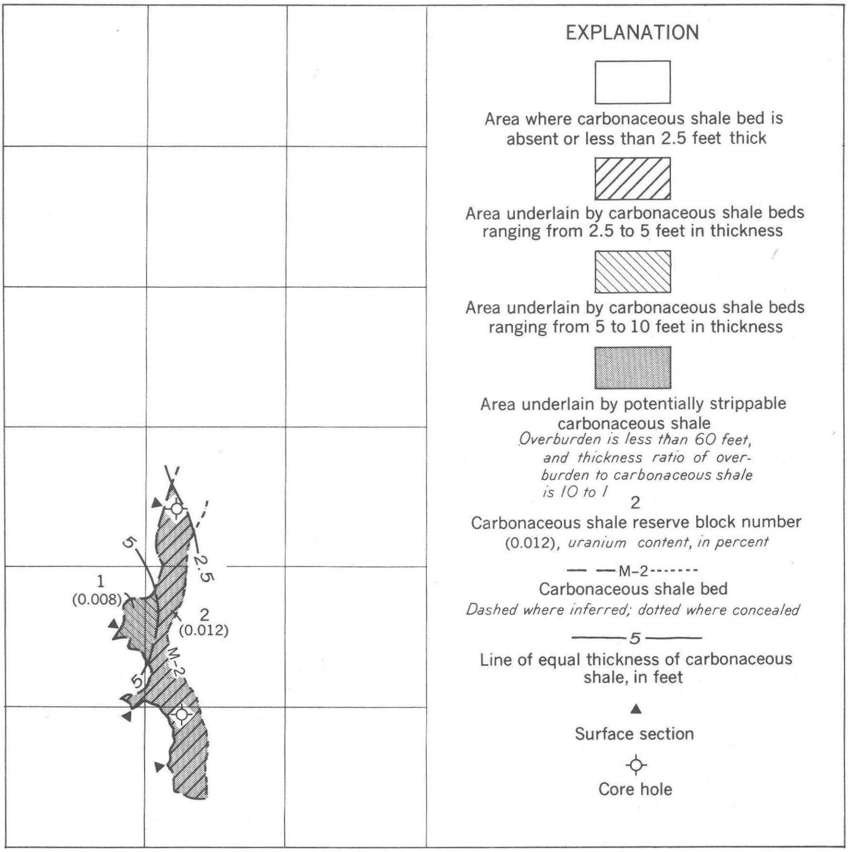

FIGURE 71.—Map and table (below) showing extent, thickness, tonnage of carbonaceous shale, uranium content, and potentially strippable areas of carbonaceous shale in the Monument No. 2 bed in T. 21 N., R. 92 W.

Tonnage of carbonaceous shale				Ash (percent)	Approximate uranium content			
Block	Area (acres)	Average thickness (feet)	Carbonaceous shale (thousands of short tons)		Uranium in carbonaceous shale		Uranium in ash	
					Percent	Short tons	Percent	Short tons
Measured and indicated shale								
1	56	6.3	953	72	0.008	76	0.011	----------
2	291	4.0	3,143	72	.012	377	.017	377
Total	----------	----------	4,096	----------	----------	453	----------	377
Potentially strippable shale (included in above blocks)								
1	56	6.3	953	72	0.008	76	0.011	----------
2	291	4.0	3,143	72	.012	377	.017	377
Total	----------	----------	4,096	----------	----------	453	----------	377

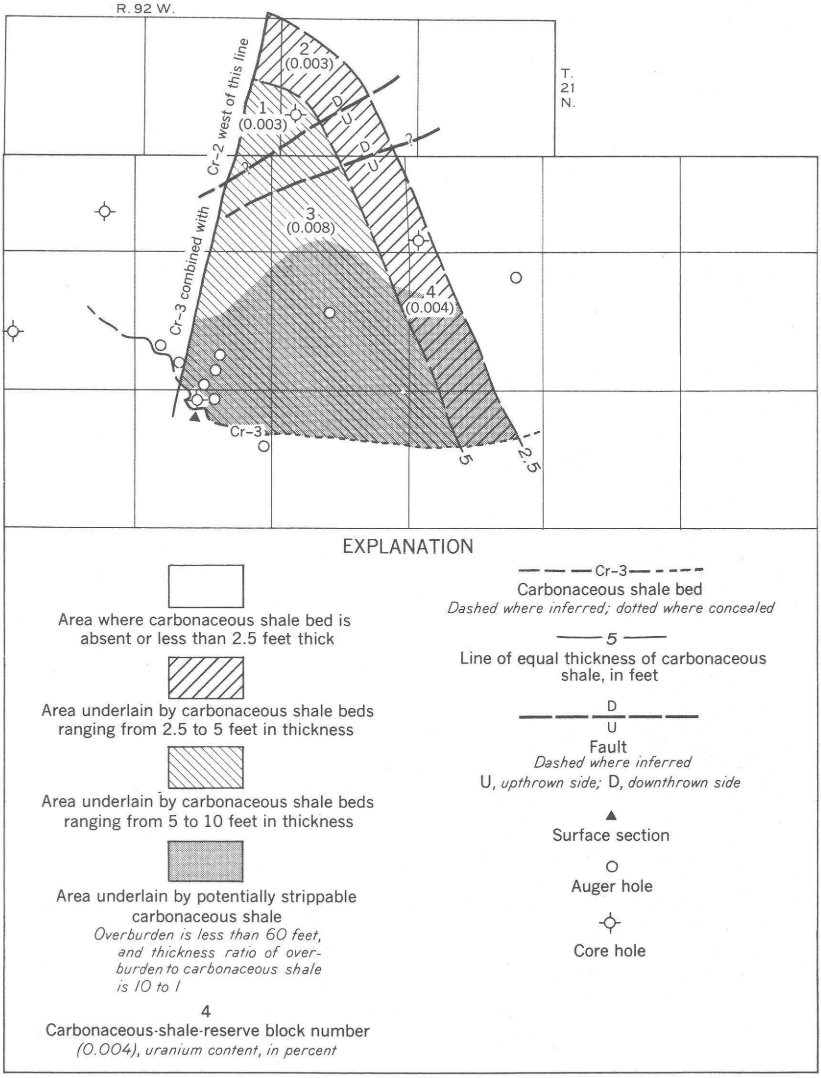

FIGURE 72.—Map and table (p. B–143) showing extent, thickness, tonnage of carbonaceous shale, uranium content, and potentially strippable areas of carbonaceous shale in the Creston No. 3 bed in Tps. 20 and 21 N., R. 92 W.

Block	Tonnage of carbonaceous shale: Area (acres)	Average thickness (feet)	Carbonaceous shale (thousands of short tons)	Ash (percent)	Approximate uranium content: Uranium in carbonaceous shale: Percent	Short tons	Uranium in ash: Percent	Short tons
Measured and indicated shale								
1	182	6.5	3,194	59	0.003	96	0.005	
2	314	3.8	3,222	55	.003	97	.006	
3	2,537	6.8	46,579	66	.008	3,726	.012	
4	1,316	3.8	13,502	55	.004	540	.008	
Total			66,497			4,459		
Potentially strippable shale (included in above blocks)								
3	1,284	7.3	25,308	70	0.009	2,278	0.013	
4	302	3.8	3,099	55	.004	124	.008	
Total			28,407			2,402		

More than 453 million short tons (23 percent) of the measured and indicated reserves are considered to be potentially strippable coal. The same thickness and ash-content cutoffs were used to define the potentially strippable coal as were used to define the underground mining reserves. An overburden-to-coal ratio of 10 to 1, with a maximum of 60 feet of overburden, was used to delimit the area underlain by potentially strippable coal.

URANIUM CONTENT OF COAL

Total reserves of measured and indicated coal containing 0.003 percent or more uranium amount to 691 million short tons. A weighted average uranium content was determined from the analyses of samples from each observation point and from these values an average uranium content was computed for each coal-reserve block. Uranium-grade cutoffs are 0.003 percent or more, 0.005 percent or more, and 0.010 percent or more. In a few places, where part of a coal-reserve block contained more than 0.003 percent uranium and part of the block less, the block was divided so that the higher grade part would fall within the minimum-grade cutoff.

In many places the uranium content of the impure coal layers is greater than that of the pure coal layers. Inclusion of these impure layers increased the ash content of the coal reserve block as well as the uranium content. The U.S. Bureau of Mines fuel analyses in table 2 give ash contents that are significantly lower than the ash contents of coal reserve blocks with boundaries drawn to include the maximum uranium content. Even though thin layers of coal, in places contain as much as 0.047 percent uranium, the average content of a whole bed over a reserve block does not exceed 0.010 percent uranium.

URANIUM CONTENT OF COAL ASH

Uranium in coal ash was computed for each coal-reserve block. Thin splits of coal contain as much as 0.140 percent uranium in the ash, but no reserve block contained an average of more than 0.030 percent uranium in the ash and most coal reserve blocks contain less than 0.015 percent uranium in the ash. About 243 million short tons of measured and indicated coal reserves contain 0.015 percent or more uranium in the coal ash or about 9,000 short tons of uranium. The tonnage and uranium content of coal containing 0.020 percent or more uranium, and 0.030 percent or more uranium in the ash, and potentially strippable coal are summarized in the table on page B–101.

URANIUM CONTENT OF CARBONACEOUS SHALE

Thin splits of impure coal and carbonaceous shale are the units with the highest uranium content investigated. At Creston Ridge a split of carbonaceous shale, 1 foot thick, contains 0.051 percent uranium in the shale and 0.080 percent in the ash, and at Bison Basin a bed, 0.6 foot thick, contains 0.056 percent uranium. Tonnages computed for two blocks, which seemed to be of sufficient thickness and extent to be of interest, totaled almost 71 million tons of shale containing 5,000 short tons of uranium. The average uranium content of the carbonaceous shale does not exceed 0.012 percent. The weight of carbonaceous shale (2,700 tons of shale per acre foot) was determined from apparent specific gravities of carbonaceous shale in the core of the Luman coal zone. The tonnage estimates of the Creston Ridge area are based on a minimum of information, owing to the difficulty of coring the weathered carbonaceous rocks underlying the 5 to 20 feet of gravel capping Creston Ridge. It is possible that, in places, the impure coal and carbonaceous shale underlying Creston Ridge are of much higher grade than that now known.

MINING

There has been no mining in the area. Loss during mining was not considered and reserve estimates are based on coal in the ground. Present practices allow recovery of approximately 50 percent by underground mining and 80 percent by strip mining. Surficial deposits are as much as 58 feet thick in Battle Spring flat where much of the coal, as a consequence, lies below the strippable limit. Mine water might be a problem at Battle Spring flat where a strong flow of artesian water was found in several core holes (fig. 33). In the one coal prospect pit in the area (sec. 27, T. 21 N., R. 93 W.), the unconsolidated siltstone overlying the coal slumped so badly that the pit was abandoned (C. Hadsell, oral communication). Similar rocks overlie the coal beds in much of the area. The coal beds commonly have a floor of sandstone.

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