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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
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Dr. Phillip L. Merritt, Assistant Director
Division of Raw Materials
U. S. Atomic Energy Commission
16th and Constitution Avenue, N. W.
Washington 25, D. C.

Dear Phil:

Transmitted herewith are three copies of TEI-456, "Results of core drilling for uranium-bearing lignite, Mendenhall area, Harding County, South Dakota," by James R. Gill, June 1954.

We are asking Mr. Hosted to approve our plan to publish this report as a Survey bulletin.

Sincerely yours,

Dwight M. Common

for W. H. Bradley
Chief Geologist

Geology and Mineralogy

This document consists of 91 pages, plus 5 figures.
Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

RESULTS OF CORE DRILLING FOR URANIUM-BEARING LIGNITE MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA*

By

James R. Gill

June 1954

Trace Elements Investigations Report 456

This preliminary report is distributed without editorial and technical review for conformity with official standards and nomenclature. It is not for public inspection or quotation.

*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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GEOLOGY AND MINERALOGY

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RESULTS OF CORE DRILLING FOR URANIUM-BEARING LIGNITE, MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA

By James R. Gill

ABSTRACT

Core drilling for data on uranium-bearing lignite in the Mendenhall area, Harding County, S. Dak., was conducted by the U. S. Bureau of Mines during the period October 1952 to July 1953. Forty-two core holes totaling 9,683 feet drilled in an area of about six square miles indicate a reserve of about 127,000,000 tons of lignite of which about 49,000,000 tons contain an average of 0.005 percent uranium or more. The Mendenhall area is near the center of the Slim Buttes, which are about 30 miles long from north to south. The uranium-bearing lignite averages 5.4 feet in thickness and occurs in the Ludlow member of the Fort Union formation of Paleocene age.

Fuel analyses of about 130 samples indicate that the lignite contains about 15 percent ash, 36.7 percent moisture, 24 percent fixed carbon, 23.9 percent volatile matter, and 1.5 percent sulfur and has heating values of about 5,800 btu (as received). Uranium analyses of about 700 samples of lignite core indicate that about 2,790 tons of uranium are present in the Mendenhall area. Inferred uranium reserves of 2,335 and 1,050 tons are indicated by grade cutoffs of 0.005 and 0.01 percent uranium in the lignites, and 2,065 and 1,355 tons are indicated by grade cutoffs of 0.03 and 0.05 percent uranium in the lignite ash. The above

grade cutoffs have been incorporated on maps showing areal distribution and thickness of mineralized beds.

In the Slim Buttes both north and south of the Mendenhall area approximately 60 square miles are underlain by uranium-bearing lignite having an average thickness of five feet and an average uranium content of 0.007 percent or more. Thus, the Slim Buttes, exclusive of the Mendenhall area, has a potential reserve of 340,000,000 tons of mineralized lignite containing 24,000 tons of uranium.

In the cores, only the stratigraphically highest lignite beneath the unconformity at the base of the Chadron formation (Oligocene) contains appreciable quantities of uranium. The data suggest that the uranium in the lignite is of secondary origin having been leached and transported by ground water from the mildly radioactive tuffaceous rocks that unconformably overlie the lignite-bearing strata.

INTRODUCTION

Core drilling for uranium-bearing lignite in the Mendenhall area, Harding County, S. Dak., by the U. S. Bureau of Mines, began October 1, 1952, and ended July 6, 1953. Glen Walker, Mine Examination and Exploration Engineer, was in charge of the drilling. Forty-two holes totaling about 9,683 feet were drilled. Mineralized lignite was recovered in cores from 31 holes.

Location and accessibility

The Mendenhall area includes 9 square miles in the central part of

the Slim Buttes (fig. 1) about 18 airline miles southeast of Buffalo in southeastern Harding County, S. Dak. The west part of the area may be reached from Buffalo by traveling 12 miles east on State Highway 8, 7 miles south on a county road, and 4 miles east on an unimproved road. The central part of the Mendenhall area, occupying the flat table land at the top of the Slim Buttes, can best be reached from J. B. Pass by a Forest Service road that extends north along the crest of the divide for 4 miles. The nearest rail-shipping points are Bowman, N. Dak., 70 miles to the north, and Newell, S. Dak., 70 miles to the south.

Previous work

The geology and lignite deposits of the Slim Buttes area have been described by Winchester and others (1916), the structural geology in relation to oil and gas by Toepelman (1923), and the general geology by Baker (1952). In 1949, uraniferous lignite was discovered by Beroni and Bauer (1952) in the vicinity of Reva Gap, located about 4 miles north of the Mendenhall area. The following year, Denson and others (1950) extended the area of known occurrence in the Slim Buttes and in the Dakotas. As a result of this work, an exploratory drilling program was started in the Slim Buttes area in 1951 (Zeller, 1952) and continued in 1952 (Zeller, 1953).

Concurrently with exploratory drilling a petrographic examination of the mineralized lignite was undertaken by Schopf (Schopf, 1952; Schopf and Gray, 1954) and Koppe (Bates and others, 1952). The

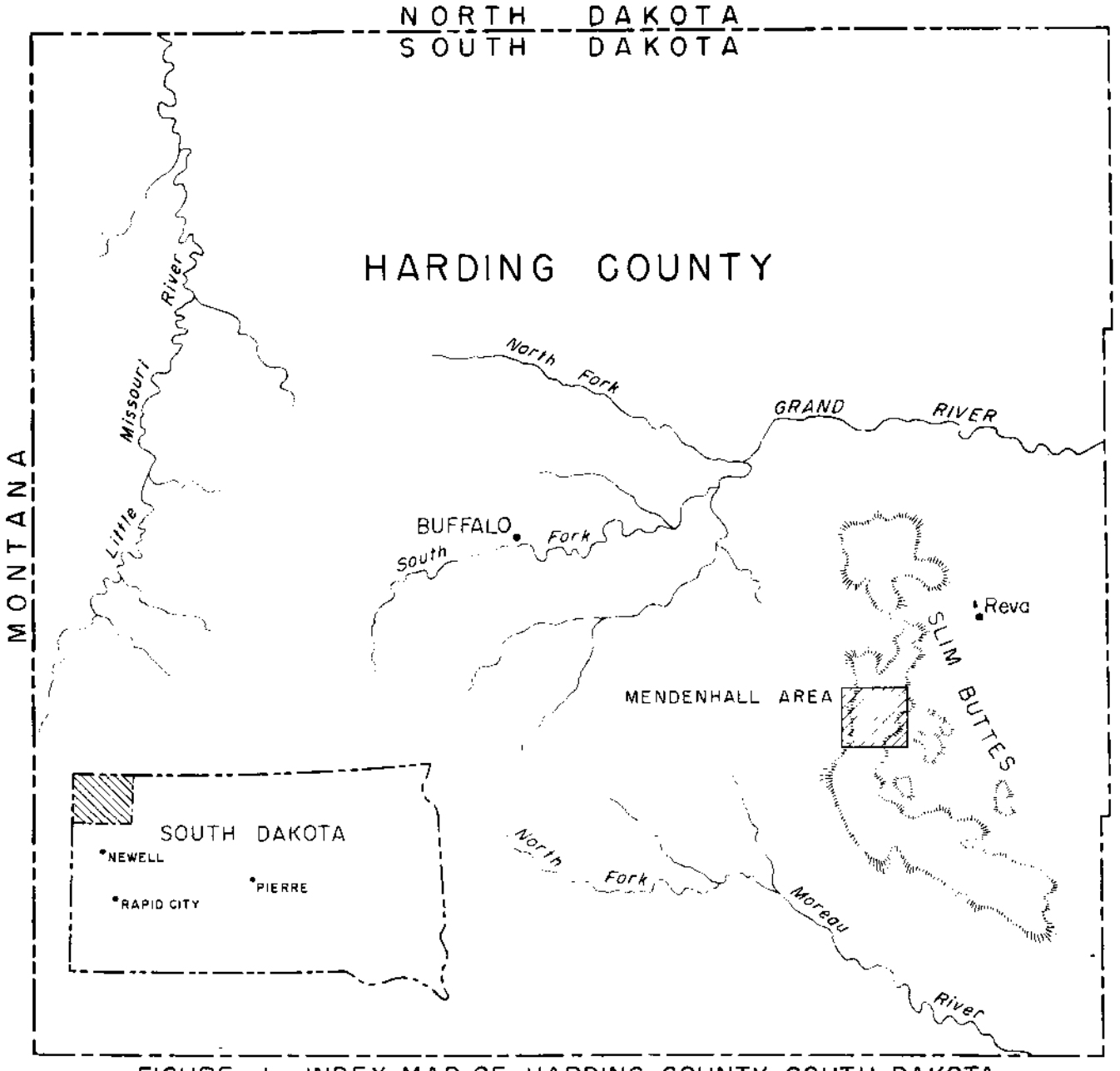


FIGURE 1.—INDEX MAP OF HARDING COUNTY, SOUTH DAKOTA, SHOWING LOCATION OF MENDENHALL AREA

geochemistry of the lignites was investigated by Breger and Duel (1952). The investigation of the mineralized lignite was undertaken on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

Acknowledgments

George W. Moore logged cores and cuttings from the drilling in February 1953 and returned to the area in June to assist in the completion of the geologic studies related to the drilling. Roy C. Kepferle, Murray Levish, and Robert E. Melin joined the project in July and assisted the writer until its termination in August 1953.

During the course of the field work James M. Schopf, John Huddle, William W. Vaughn, William Spackman, Edward F. Koppe, and Robert C. Ellman visited the project and contributed helpful discussions on the physical character and origin of the uranium in the lignite.

James M. Schopf and associates, of the Geological Survey Coal Geology Laboratory at Columbus, Ohio, processed several of the lignite cores and provided detailed descriptions and radioactivity logs of the core (Appendix A). Chemical analyses, radioactivity measurements, and semi-quantitative spectrographic determinations (Appendix B) were made by the Washington and Denver laboratories of the Geological Survey. Proximate and ultimate analyses of lignite cores (Appendix C) were made by the U. S. Bureau of Mines, Central Experiment Station, Pittsburgh, Pa.

The writer expresses his appreciation to the local ranchers,

particularly Vernon, William, and Esther Wammen, for the many courtesies extended.

DRILLING OPERATIONS

1951-1952 drilling

In the summer of 1951 the B. H. Mott Drilling Company of Huntington, W. Va., under contract with the U. S. Geological Survey, drilled 7 holes totaling 1,464 feet in the Mendenhall area and 1 hole in the Bar H area (Zeller, 1952). Eight additional holes were drilled in the spring of 1952 under the same contract in the Bar H area in the northern part of the Slim Buttes (Zeller, 1953). Core data for the 7 holes drilled in the Mendenhall area have been incorporated in this report.

1952-1953 drilling

The information obtained in previous investigations and exploratory drilling indicated that the lignites in the Slim Buttes area were potential sources of uranium and fuels resources. In order to investigate this possibility further more detailed exploration of the uraniferous lignite in the Mendenhall area (fig. 2) by drilling was begun October 1, 1952 by the U. S. Bureau of Mines in cooperation with the U. S. Geological Survey, on behalf of the Division of Raw Materials, of the U. S. Atomic Energy Commission.

Under the terms of the cooperative agreement between the Bureau of Mines, the Atomic Energy Commission, and the Geological Survey, the

R.7 E.

R.8 E.

T. 18 N.

T. 17 N.

Olesrud Mine

Mendenhall Strip Mine

Wammen Mine

Pink Buttes Spr.

Halfpint Spr.

Carroll Spr.

Leatherbury Spr.

Camp Spr.

Willo Spr.

Colonel Spr.

Jones Spr.

Wammen Spr.

Gray Spr.

Wammen House Spr.

3200

3300

EXPLANATION

Recent and Pleistocene		Qls	Landslide material
Miocene		Ta	Arikaree fm.
Oligocene	White River group	Tbr	Brule fm.
		Tc	Chadron fm.
Paleocene		Tfl	Ludlow member of Ft. Union fm.

QUATERNARY

TERTIARY

Geologic contact
(Dashed where approximately located)

Radioactive lignite
(Dashed where approximately located)

Nonradioactive lignite
(Dashed where approximately located)

Clinker

Section corner recovered

Custer National Forest boundary

Core drill hole U.S.G.S. 1951

Core drill hole AEC 1952-53

Strike and dip of beds

—3300—
Contours on Olesrud bed (upper bench); contour interval 25'; datum mean sea level

Geologic mapping in 1953 by J. R. Gill. Base map compiled from aerial photographs.

0 5000
Scale in feet

GPO 832774

FIGURE 2.--GEOLOGIC MAP OF THE MENDENHALL AREA, SLIM BUTTES, HARDING COUNTY, SOUTH DAKOTA, SHOWING LOCATIONS OF CORE DRILL HOLES

Bureau of Mines was to drill the holes, recover, pack, ship, and split the core at its laboratories. The location and elevations of holes were also to be determined. A report on the strippable and underground mining reserves of uraniferous lignite is to be prepared.

The Geological Survey was to advise the Bureau of Mines on location of holes with respect to lignite beds or drilling conditions, the need for redrilling holes, and to advise of areas in which geologic evidence indicated core drilling would be unwarranted. Also, the Geological Survey was to determine when the drill hole had reached its objective and to stop drilling if it became apparent that the geologic objective could not be obtained. The Geological Survey logged the holes, wrapped the lignite core, and indicated intervals to be analyzed for uranium, and made radioactivity logs of the holes. The Geological Survey retained the non-lignite-bearing core from holes SD-9A for heavy-mineral and thin-section studies. The lignite and enclosing strata from holes SD-12, -16, and -23 were shipped to the Bureau of Mines testing laboratories at College Park, Md., for roof and pillar studies. The lignite from holesSD-8, -10, and -19 was submitted for petrographic study to the Survey's Coal Geology Laboratory in Columbus, Ohio.

In this report the description of the geology of the drilled area includes an interpretation of the geological significance of the distribution of the uranium in the receptor beds, the structure and correlation of the lignites and associated strata, the vertical and areal extent of active aquifers, and estimates of reserves of lignite, uranium-bearing

lignite, and uranium.

Drilling was begun by the Bureau of Mines on October 14, 1952 with one drill rig; a second drill rig was placed in operation on December 22. Drilling operations continued throughout the winter, each drill operating from one to three 8-hour shifts per day. Forty-two holes totaling 9,682.9 feet were drilled. Table 1 shows the footage of core and solid bit drilling done by the Bureau of Mines as well as a summary of the Survey's drilling in the Mendenhall area during 1951-52. Drilling operations were completed July 6, 1953.

In drilling the uranium-bearing lignites, coring was started 20 feet or more above the stratigraphically highest lignite and continued 60 feet below its base. The lignite core was securely wrapped in waxed paper and the sample intervals for uranium determination evaluated. The sample intervals were approximately a foot in length. All lignite beds, regardless of stratigraphic position, were sampled and analyzed.

The lignite core was split at the Bureau of Mines Laboratory at Grand Forks, N. Dak. Half the core was forwarded to the Geological Survey's Trace Elements laboratories in Washington for uranium determination; the other half was sent by the Bureau for proximate and ultimate fuel analysis. Only those lignite samples containing 0.003 percent equivalent uranium or more were chemically analyzed for uranium.

Table 1.--Location, depth, and type of drilling for holes drilled in the Mendenhall area, Harding County, S. Dak., in 1951 by the U. S. Geological Survey, and in 1952-53 by the U. S. Bureau of Mines.

Hole	Location (Sec., T., R.)	Elevation (surface)	Total depth	Solid bit drilling	Core drilling
GS-1	SE SW 1-17N-7E	3,301	50.0	15.0	35.0
GS-2	SW NE 1-17N-7E	3,307	75.0	35.0	40.0
GS-3	SW SE 36-18N-7E	3,327	141.0	20.0	121.0
GS-4	NW SE 36-18N-7E	3,301	93.0	22.0	71.0
GS-16	SE NW 31-18N-8E	3,575	348.0	216.0	132.0
GS-17	SW SW 6-17N-8E	3,633	375.0	290.0	85.0
GS-18	SE NE 1-17N-7E	3,613	382.0	300.0	82.0
SD-1	NE NW 12-17N-7E	3,324	106.2	3.0	103.2
SD-2	SW SE 1-17N-7E	3,412	194.3	96.2	98.1
SD-3	SE SW 1-17N-7E	3,281	100.0	15.0	85.0
SD-3A	SE SW 1-17N-7E	3,312	82.0	23.0	59.0
SD-4	NW SE 1-17N-7E	3,308	135.0	41.0	94.0
SD-5	SW NE 1-17N-7E	3,304	114.1	21.0	93.1
SD-6	NW NE 1-17N-7E	3,314	93.0	13.0	80.0
SD-7	SE SW 36-18N-7E	3,310	25.0	15.0	10.0
SD-7A	SE SW 36-18N-7E	3,310	143.0	13.0	130.0
SD-7B	SE SW 36-18N-7E	3,310	99.0	13.0	86.0
SD-8	SE NW 36-18N-7E	3,327	163.0	13.0	150.0
SD-9	NW SW 7-17N-8E	3,595	270.0	270.0	-
SD-9A	NW SW 7-17N-8E	3,595	342.0	5.7	336.3
SD-10	NE SE 12-17N-7E	3,635	391.5	260.0	131.5
SD-11	NE NE 12-17N-7E	3,523	290.0	173.0	117.0
SD-12	SW NW 7-17N-8E	3,495	321.0	130.0	191.0
SD-13	SW NE 7-17N-8E	3,461	220.5	120.0	100.5
SD-14	SW SE 6-17N-8E	3,370	143.0	83.0	60.0
SD-15	NW SW 6-17N-8E	3,616	413.0	291.0	122.0
SD-16	NW NE 6-17N-8E	3,604	397.0	270.0	127.0
SD-17	SE NE 6-17N-8E	3,536	382.0	200.0	182.0
SD-17A	SE NE 6-17N-8E	3,536	100.0	100.0	-
SD-18	SW NE 5-17N-8E	3,359	183.0	100.0	83.0
SD-18A	SW NE 5-17N-8E	3,319	150.0	65.0	85.0
SD-19	SW SW 31-18N-8E	3,606	420.0	310.0	110.0
SD-20	SW SE 31-18N-8E	3,610	378.2	292.0	86.2
SD-21	SE SE 31-18N-8E	3,619	417.0	292.0	125.0
SD-22	SE NE 31-18N-8E	3,595	400.0	290.0	110.0
SD-23	NE NW 31-18N-8E	3,568	372.0	232.0	140.0
SD-24	NW NW 31-18N-8E	3,593	379.9	10.0	369.9
SD-25	NE SE 36-18N-7E	3,602	405.0	292.0	113.0
SD-26	NE SE 7-17N-8E	3,357	170.0	81.0	89.0

Table 1.--Location, depth, and type of drilling for holes drilled in the Mendenhall area, Harding County, S. Dak., in 1951 by the U. S. Geological Survey, and in 1952-53 by the U. S. Bureau of Mines.--Continued

Hole	Location (Sec., T., R.)	Elevation (surface)	Total depth	Solid bit drilling	Core drilling
SD-27	NE SW 8-17N-8E	3,293	103.0	22.0	81.0
SD-28	SE NE 7-17N-8E	3,436	228.7	143.0	85.7
SD-29	SW NW 8-17N-8E	3,328	114.0	43.0	71.0
SD-30	SW SE 6-17N-8E	3,318	143.0	10.0	133.0
SD-31	SE SE 6-17N-8E	3,286	99.0	10.0	89.0
SD-32	NE SE 6-17N-8E	3,307	149.0	35.0	114.0
SD-33	SE NW 5-17N-8E	3,297	100.0	30.0	70.0
SD-35	NE SW 6-17N-8E	3,590	400.5	300.0	100.5
SD-36	SW NE 32-18N-8E	3,254	114.0	13.0	101.0
SD-38	SE SW 32-18N-8E	3,317	135.0	13.0	122.0
SD-39	NW SE 7-17N-8E	3,516	296.5	182.0	114.5

STRATIGRAPHY

Lignite-bearing strata in the Mendenhall area are of Paleocene age and are unconformably overlain by bentonitic clays and tuffaceous sandstones of Oligocene and Miocene age. The Paleocene conformably overlie Cretaceous strata. The rocks are all of continental origin, but conditions of sedimentation ranged from those favoring the deposition of lignite to those favoring the deposition of volcanic ash. The sequence of sedimentation has been broken by at least two periods of uplift and erosion; one is indicated by the unconformity at the base of rocks of Oligocene age and the other by the unconformity at the base of rocks of Miocene age.

Tertiary rocks

Fort Union formation

Ludlow member -- The Ludlow member of the Fort Union formation of Paleocene age conformably overlies the Hell Creek formation of Cretaceous age. The Ludlow member is the lowermost member of the Fort Union formation and is the sole representative of rocks of Paleocene age in the Mendenhall area as it is unconformably overlain by rocks of the Chadron formation of Oligocene age. Elsewhere in the northern part of Harding County the Ludlow grades into the marine Cannonball formation and is conformably overlain by the Tongue River member of the Fort Union formation.

Rocks of the Ludlow member consist of poorly indurated yellowish-brown fine-grained sandstone and siltstone, gray clay shale, and beds of lignite, some of which contain uranium. In the Mendenhall area the Ludlow is estimated to be about 200 feet thick. At the type locality near the Ludlow Post Office (sec. 28, T. 22 N., R. 6 E.) its thickness is about 350 feet.

The rocks of the Ludlow member are covered at most places by vegetation and landslide debris from the overlying White River and Arikaree formations. The lignite beds are traceable for only short distances along the face of the buttes, but core-hole data indicate that the lignites are the most persistent beds in the Ludlow. They vary considerably in thickness throughout the area and may diverge or come together in short distances indicating that closely spaced surface sections or core holes are necessary to avoid miscorrelation (fig. 3). The sandstones, siltstones, and shales are lenticular and are not reliable for correlation (fig. 4-8).

Most of the sandstone and siltstone is poorly consolidated, and attempts to core this material were not always successful because the drilling water had a tendency to wash away the core. The lignite was cored with recovery except in shallow holes where it had been subjected to weathering near the surface. The designation of rock types lost in coring was hampered as the water return was generally poor and cuttings could not be recovered. In shallow holes, the rock types lost in coring could generally be ascertained from nearby surface exposures or adjacent core holes. Consistent loss of water in uncased holes made the

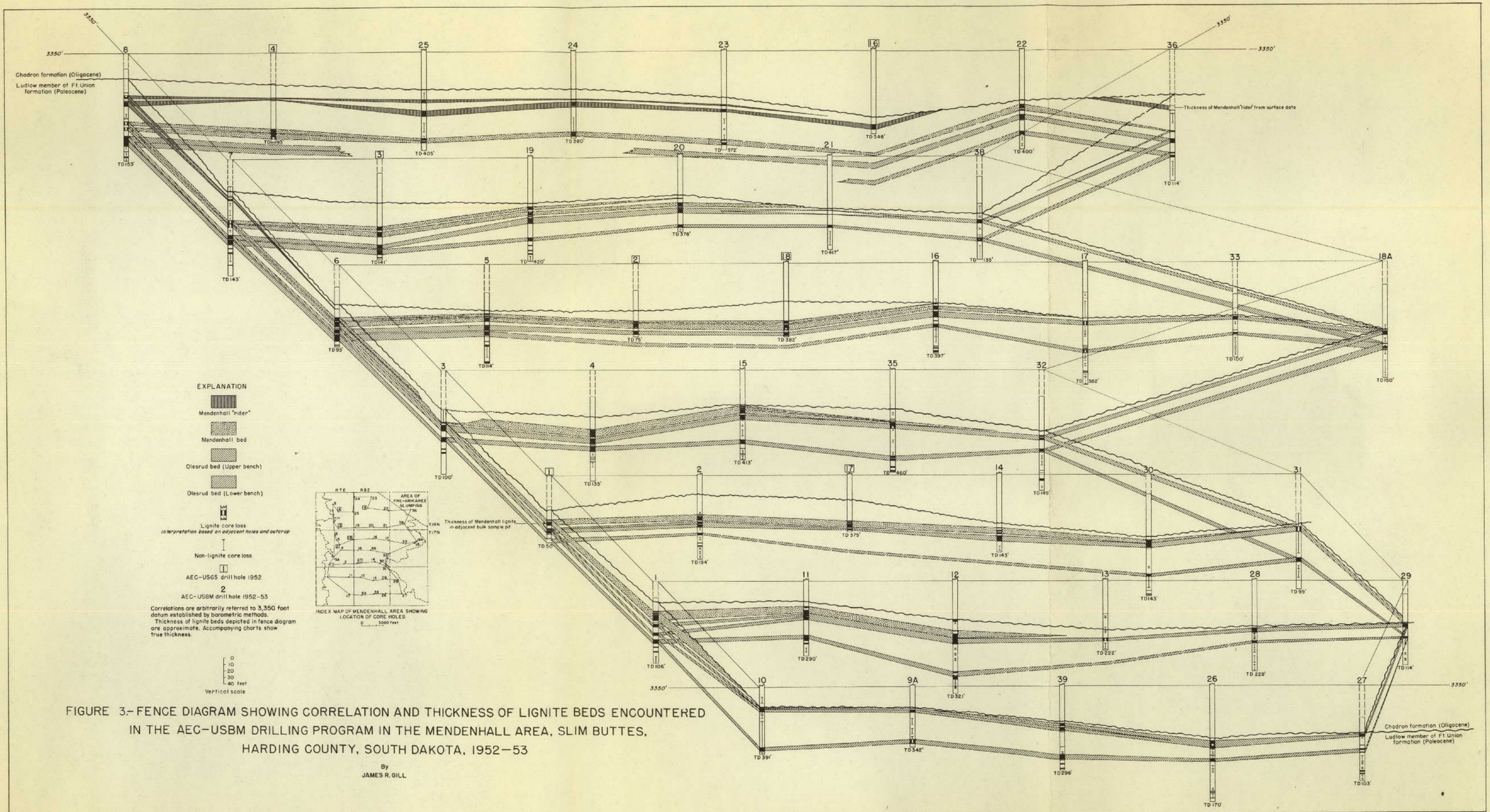


FIGURE 3.- FENCE DIAGRAM SHOWING CORRELATION AND THICKNESS OF LIGNITE BEDS ENCOUNTERED IN THE AEC-USBM DRILLING PROGRAM IN THE MENDENHALL AREA, SLIM BUTTES, HARDING COUNTY, SOUTH DAKOTA, 1952-53

By
JAMES R. GILL

determination of aquifers in the Ludlow impossible.

The Ludlow member of the Fort Union formation is unconformably overlain by the Chadron formation of Oligocene age. The contact between the two formations is difficult to identify because of yellow staining of the uppermost beds of the Ludlow and reworking of similar-colored materials into the lower few feet of the Chadron.

White River group

The White River group of Oligocene age is composed of the Chadron and Brule formations. The Chadron formation unconformably overlies the Ludlow member of the Fort Union formation and is present throughout the area. The Brule formation is preserved only in downdropped blocks (fig. 2) that represent the landslides that took place prior to the deposition of the overlying Arikaree formation.

Chadron formation--The Chadron formation of Oligocene age unconformably overlies the Ludlow member of the Fort Union formation. In normal succession the Chadron is conformably overlain by the Brule formation. However, at most places in the Mendenhall area, the Chadron is unconformably overlain by the Arikaree formation. The basal part of the Chadron formation consists of bright yellow to dark yellowish-orange sandstone and siltstone reworked from the underlying rocks. The remainder of the formation is composed of white fine-grained to coarse-grained pebbly sandstone and light olive-gray bentonite. Lenticular beds of

tuffaceous sandstone and opalized clay are present locally.

The thickness of the Chadron formation ranges from 60 feet in the northeastern part of the area to over 150 feet in the southwest. Impervious beds of bentonite near or at the top of the formation form the base of a perched water table. Springs issue at this horizon along the margins of the buttes. In the southern part of the Slim Buttes carnotite-bearing sandstones have been found at this horizon (Gill and Moore, 1954). The sandstones and bentonites of the Chadron contain about 0.001 percent uranium, compared to the average for sandstones of 0.00012 (Rankama an and Sahama, 1950). The water from springs that issue from this formation contains from 10 to 200 parts per billion uranium.

Brule formation--The Brule formation of Oligocene age is exposed in narrow northwest-trending pre-Arikaree landslide blocks in the northeast part of the Mendenhall. The formation is composed of thin-bedded to massive pink to tan sandy tuffaceous claystone and sandstone and is similar in lithology and age to the Brule in the Big Badlands of Pennington County, S. Dak. The thickness of the Brule formation ranges from 20 to over 140 feet, with an unknown thickness having been eroded.

Valleys more than 300 feet deep were cut into the Brule, Chadron and Ludlow rocks of this area prior to the deposition of the Arikaree formation. Subsequent to valley cutting, large scale landsliding took place with massive blocks of Brule and Chadron rocks sliding into the valleys. These landslide blocks average about 300 yards in width and

at many places have a linear extent of several miles. The trend of the blocks is consistently northwest with dips toward the plane of movement ranging from 5 to 30°. The Chadron rocks involved in slumping are generally highly contorted while the more indurated Brule rocks show little evidence of movement other than having steep uniform dips.

Tuffaceous claystone and sandstone of the Brule formation contain on the average about 0.001 percent uranium, and vertebrate fossils from these rocks commonly contain more than 0.01 percent uranium. At many places the fossils are coated with a yellow nonfluorescent uranium mineral.

Arikaree formation

The Arikaree formation of Miocene age is composed dominantly of yellowish-gray very fine-grained tuffaceous sandstone. In the Mendenhall area it has a thickness of about 200 feet. The basal 50 feet contains much material reworked from the underlying Brule and Chadron formations and is thin-bedded in contrast with the more massive upper part. Locally one or more beds of conglomerate occur at or near the base of the formation. These beds of conglomerate are usually made up of claystone pebbles and cobbles averaging 2 inches in diameter, most of which appear to have been derived from the Brule formation.

Tuffaceous sandstone forms the caprock of the Arikaree formation and the steep upper cliffs at Slim Buttes. No fossils have been found in the Arikaree formation in the Slim Buttes region. A beaver of upper Miocene age has been described by Wood (1945) from similar rocks in

southeastern Montana which probably correlate with those in the Slim Buttes.

Rocks of the Arikaree formation like those of the Chadron and Brule formations contain an average of about 0.001 percent uranium. It is thought that this uranium was introduced with the volcanic material, which composes the greater part of the formation.

Quaternary deposits

Deposits of probable Pleistocene age consist of fans extending from the bases of the cliffs, terraces along many of the stream valleys, and landslide material. Many of these deposits are similar in appearance to the White River rocks, as much of the material of which they are composed was derived from these rocks. The terrace deposits have flat upper surfaces, and recent erosion has cut into these surfaces at many places, leaving the deposits as isolated "tables". These deposits were not mapped. Landslides are extensive around the periphery of the Slim Buttes. The landslide blocks and masses are made up largely of Arikaree and White River formations but at a few places may contain rocks of the Ludlow member of the Fort Union formation.

STRUCTURE

The broad regional structure of the Ludlow member of the Fort Union formation is that of a gentle homocline that dips about 1° to the northeast into the Williston Basin. Structure contours on the top of the

upper bench of the Olesrud lignite in the Mendenhall area show the presence of minor structures that are alined normal to the regional dip (fig. 2). These minor structures are small anticlines and synclines, the axes of which strike northeast. The Arikaree formation is essentially horizontal as are the Chadron and Brule formations except where they are landslide blocks.

LIGNITE DEPOSITS

The Mendenhall area is underlain by four important lignite seams in the Ludlow member of the Fort Union formation. From top to bottom these are the Mendenhall "rider" bed, the Mendenhall bed, and the upper and lower benches of the Olesrud bed. The lignite beds dip gently to the north and are truncated by rocks of the overlying Chadron formation. Thus, the areal extent of the stratigraphically highest bed, the Mendenhall "rider", is confined in the northern one-third of the area, the Mendenhall bed underlies the northern half of the area, and the upper and lower benches of the Olesrud bed underlie all of the area (fig. 9). Each bed is radioactive, however, only where the stratigraphically highest bed is not present. Two beds stratigraphically below the lower bench of the Olesrud are here designated the "Y" and "Z" beds (fig. 4-8). They are present throughout much of the area, and at few places are as much as 2.5 feet thick. In hole SD-6 (fig. 4) where the lignite beds are close together, 30 feet of coal occurs in a stratigraphic interval of 34 feet.

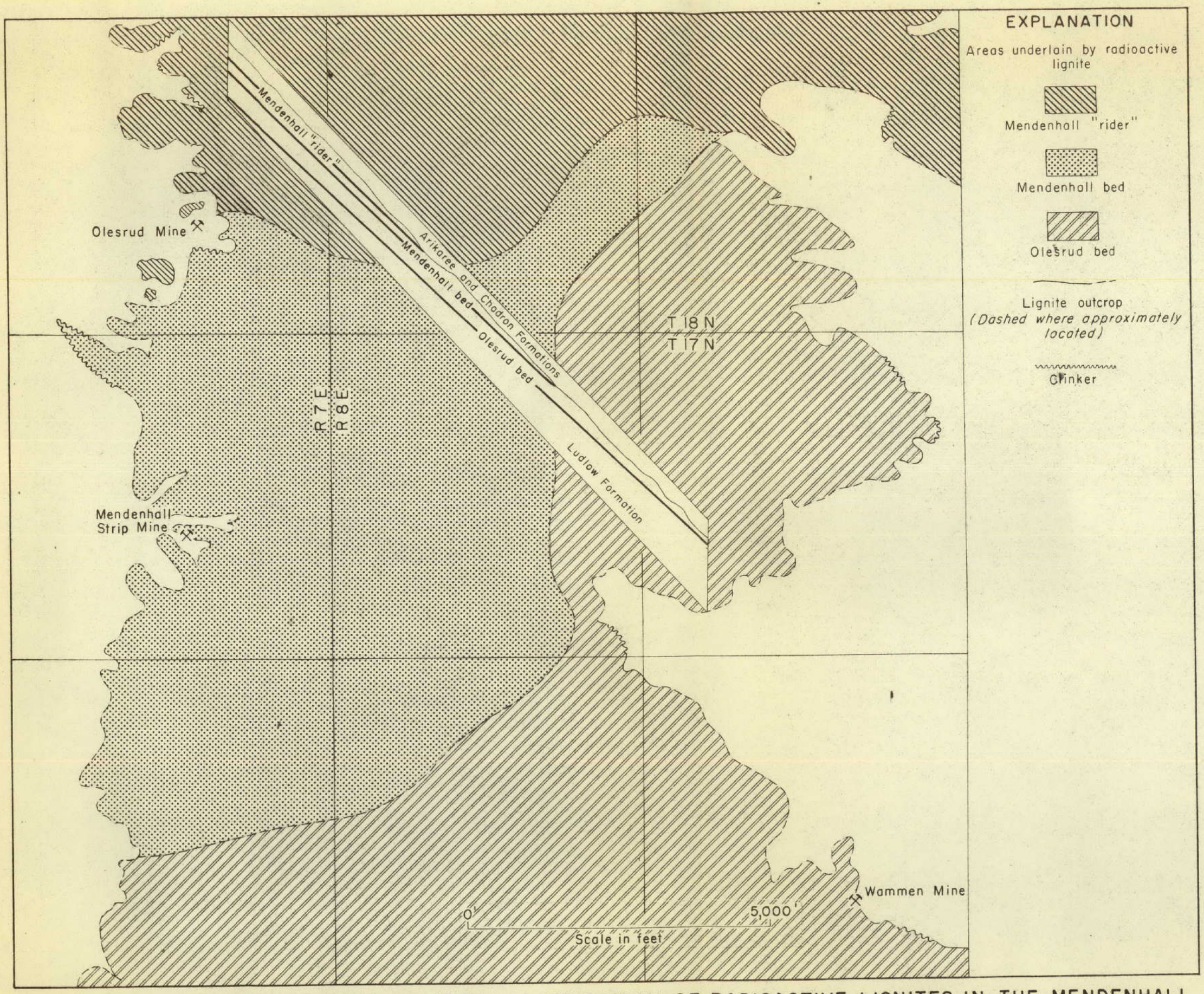


FIGURE 9.—SKETCH MAP SHOWING AREAL DISTRIBUTION OF RADIOACTIVE LIGNITES IN THE MENDENHALL AREA, SLIM BUTTES, HARDING COUNTY, SOUTH DAKOTA, 1953

In connection with petrographic work on the lignites, the staff of the Coal Geology Laboratory made a preliminary investigation of the plant microfossil assemblages. Their work indicated the presence of a distinctive group of plant spores and pollen in the lower bench of the Olesrud which helped confirm the correlations made in the field.

Quality

The lignite in the Mendenhall area is dark brown to black and has a dull luster on a fresh surface. On exposure to air the lignite loses moisture and slacks in a short time. Weathering also results in a change in luster from dull to vitreous. A detailed study of the various lignite constituents and their relationship to uranium is being undertaken by the Survey's Coal Geology Laboratory (Schopf, 1952; Schopf and Gray, 1954), and by the School of Mineral Industries, Pennsylvania State University (Bates and others, 1952).

U. S. Bureau of Mines analyses show that the lignite samples of the four beds in the Mendenhall area range in moisture content from 14 to 18 percent, 35 to 38 percent ash, 20 to 27 percent fixed carbon, and 1.4 to 1.9 percent sulfur with heating values ranging from 4,480 to 5,930 Btu. These figures are based on "as received" condition (table 2).

A total of 134 samples of lignite from six beds was submitted to the U. S. Bureau of Mines for proximate fuel analyses (Appendix B). Ultimate fuel analyses were made for 111 of the 134 samples (Appendix B). Proximate and ultimate analyses for each bed have been averaged and

Table 2. --Average fuel analyses for lignite beds cored in the Mendenhall area.

Bed	Proximate analyses (as received) Moisture	Volatile matter	Fixed carbon	Ash	Btu	No. of samples
Mendenhall "rider"	36.6	24.8	24.3	14.3	5,590	5 1/
Mendenhall bed	37.7	23.3	26.7	12.3	5,870	33
Olesrud bed (upper bench)	34.9	23.5	25.7	15.9	5,930	38
Olesrud bed (lower bench)	36.6	23.8	25.6	14.0	5,630	29
"Y" bed	33.6	23.5	26.0	17.3	5,830	11
"Z" bed	35.7	23.7	27.0	13.6	5,990	11

1/ Samples E-32880, E-24658, E-24659, D-68859 and D-68860 were excluded from the average because the lignite in these samples was highly weathered.

Table 2.--Average fuel analyses for lignite beds cored in the Mendenhall area--Continued.

Bed	Ultimate analyses (as received)							
	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Ash	Ash softening temperature	No. of samples
Mendenhall "rider"	5.8	30.9	0.4	43.1	1.7	18.1	2,180	7
Mendenhall bed	6.1	35.4	0.4	42.3	1.9	13.9	1,990	22
Olesrud bed (upper bench)	5.9	34.8	0.4	41.6	1.1	16.2	2,060	34
Olesrud bed (lower bench)	6.3	33.4	0.4	43.2	1.6	15.1	2,150	28
"Y" bed	5.9	34.4	0.4	39.8	1.4	18.1	2,140	10
"Z" bed	6.1	35.9	0.5	41.7	1.5	14.3	2,080	10

are summarized in table 2. Five samples of lignite from the Mendenhall "rider" bed, E-32880, E-24658, E-24659, D-68859, and D-68860, were excluded from these averages because the lignite in the cores obviously was weathered. Analyses of this material show ash contents that are higher than unweathered lignite and Btu contents that are lower.

Concurrently with drilling operations in the Mendenhall area, the Bureau of Mines collected five 5-ton bulk samples of lignite for ashing and burning experiments (U. S. Bureau of Mines, 1954). Location and graphic logs of Bureau of Mines sample pits are shown on figures 10 and 11. Table 3 shows the comparison between analyses of weathered lignite from sample pits with unweathered lignite from the same bed in nearby core holes.

Lignite reserves

In estimating reserves of lignite in the Mendenhall area the author has used the coal-reserve estimation procedures of the U. S. Geological Survey (Averitt and Berryhill, 1950). These are summarized below:

1. Thickness categories.--Lignite reserves are calculated and reported by beds in the following thickness categories:

more than 10
5 to 10 feet
2.5 to 5 feet

Partings more than 0.05 foot thick are omitted in determining the thickness of individual beds. Beds and parts of beds made up of alternating layers of lignite and shale are omitted if the shale partings

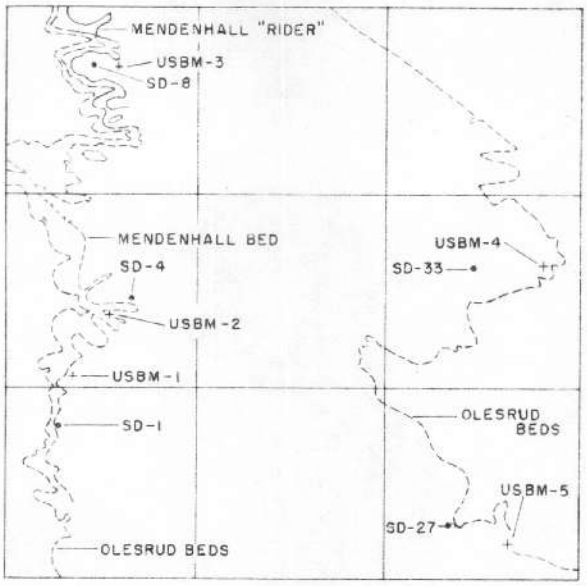


FIGURE 10.-INDEX MAP SHOWING LOCATION OF USBM BULK SAMPLE PITS AND SELECTED CORE HOLES

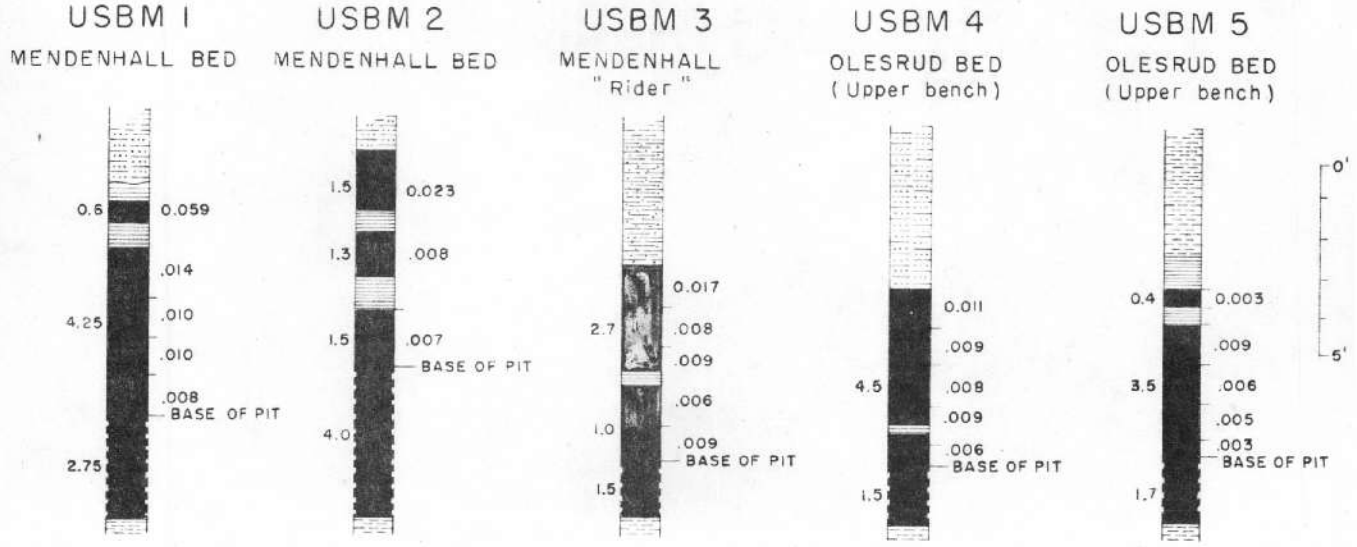


FIGURE 11.-GRAPHIC LOGS SHOWING URANIUM CONTENT AND THICKNESS OF LIGNITE IN USBM BULK SAMPLE PITS

	As Received	USBM-1	SD-1	USBM-2	SD-4	USBM-3	SD-8	USBM-4	SD-33	USBM-5	SD-27
PROXIMATE	Moisture	44.3	36.3	45.1	24.9	43.9	39.0	49.0	34.6	45.8	35.8
	Vol. Matter	24.3	23.6	25.5	26.0	24.2	25.5	19.0	24.0	20.8	23.7
	Fixed C.	12.5	30.0	14.5	35.4	18.3	29.5	16.0	25.4	15.6	25.5
	Ash	18.9	10.1	14.9	13.7	13.6	6.0	16.0	16.0	17.8	15.0
ULTIMATE	Hydrogen	6.1	6.2	6.2	5.5	6.2	6.9	6.7	6.0	6.3	6.2
	Carbon	22.0	36.7	23.8	43.8	26.4	39.2	23.2	33.9	23.0	34.0
	Nitrogen	0.4	0.4	0.4	0.6	0.5	0.5	0.5	0.5	0.5	0.4
	Oxygen	50.7	44.4	52.6	34.6	51.7	46.4	53.3	42.5	51.6	43.6
	Sulphur	1.9	2.2	2.1	1.8	1.6	1.0	0.3	1.1	0.8	0.8
	Ash	18.9	10.1	14.9	13.7	13.0	6.0	16.0	16.0	17.8	15.0
	Btu.	3110	6120	3370	7450	3920	6510	3480	5430	3420	5590

Table 3.- Comparison of analytic values of weathered lignite from USBM bulk sample pits with unweathered lignite from the same bed in nearby core holes.

make up more than one-half of the total thickness.

2. Areal extent.--Limits of the areas underlain by lignite beds included in reserve estimates are determined by core-hole and surface-section control, and the beds are not extended beyond half a mile from the last point of control.

3. Weight of lignite.--Reserve estimates are based on 1750 tons of lignite per acre foot.

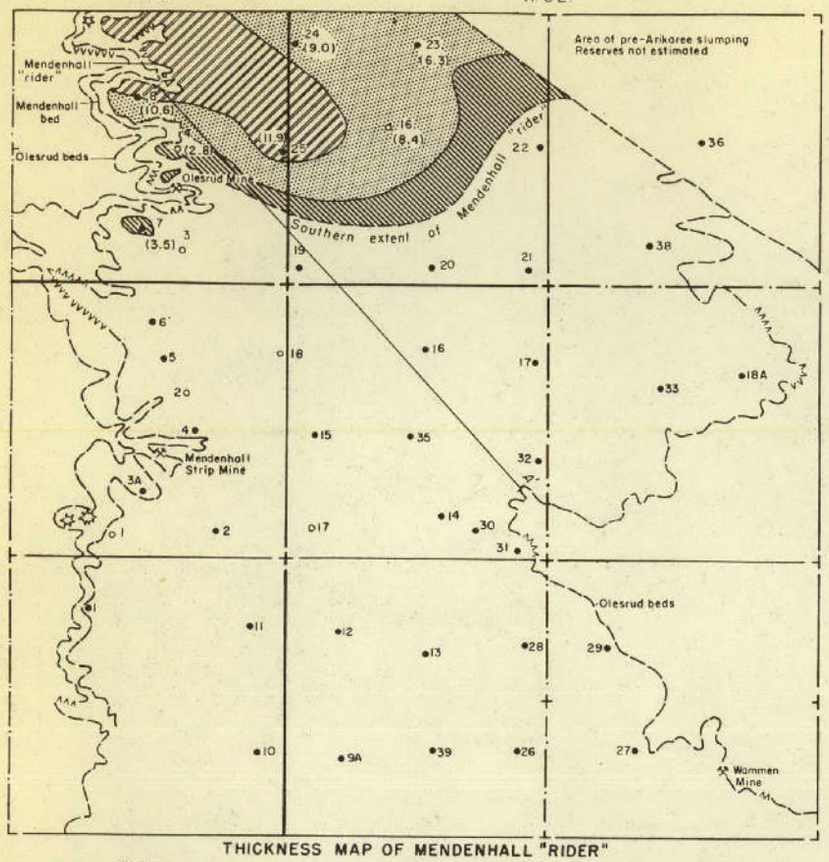
4. Reserve categories.--The lignite reserves listed in this report are classed as measured reserves because the continuity of lignite beds and the close spacing of core holes indicate that the computed tonnage is probably accurate to within 20 percent. Maps showing thickness and distribution of the four minable lignite beds in the Mendenhall area are shown on figure 12. A summary of lignite reserves for each of the four beds is given below.

Bed	Average thickness (Feet)	Area (Acres)	Lignite (Short tons)
Mendenhall "rider"	5.3	540	7,883,000
Mendenhall bed	8.5	2,135	31,973,000
Olesrud bed (upper bench)	6.8	3,885	46,944,000
Olesrud bed (lower bench)	5.7	4,025	40,494,000
Total measured reserve			127,294,000

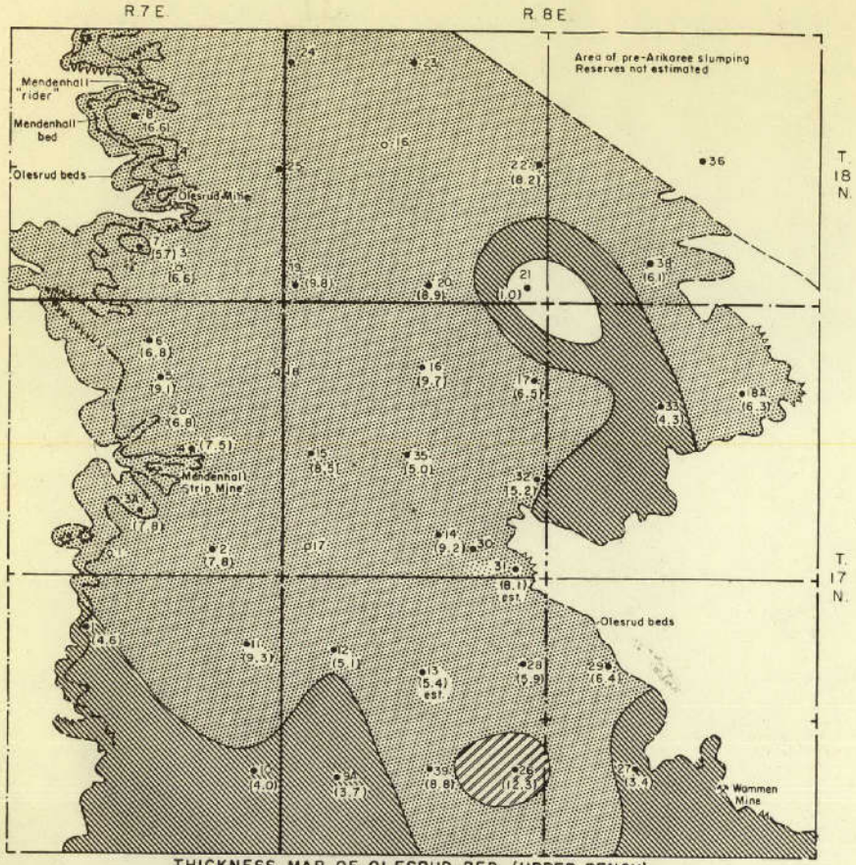
LIGNITE RESERVES
(Measured)

Bed	Av. Thick. (Feet)	Area (Acres)	Lignite 1/ (Short tons)
Mendenhall "rider"	3.3	140	808,000
	8.1	275	3,898,000
	11.0	165	3,177,000
		Subtotal 7,883,000	
Mendenhall	3.8	220	1,463,000
	7.3	1,210	15,458,000
	12.2	705	15,052,000
		Subtotal 31,973,000	
Olesrud (Upper bench)	4.0	730	5,110,000
	7.4	3,110	40,858,000
	12.4	45	976,000
		Subtotal 46,944,000	
Olesrud (Lower bench)	3.8	1,320	8,778,000
	6.7	2,705	31,716,000
		Subtotal 40,494,000	
		Grand total	127,294,000

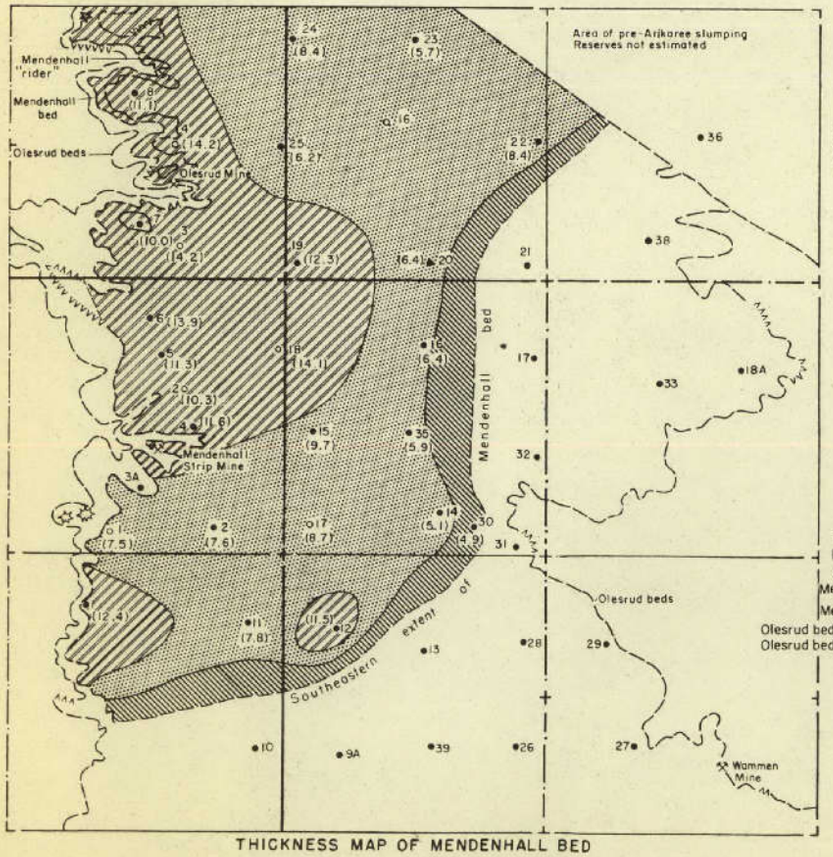
1/ Calculations based on 1750 short tons per acre foot - net result rounded to nearest 1,000 tons.



THICKNESS MAP OF MENDENHALL "RIDER"



THICKNESS MAP OF OLESRUD BED (UPPER BENCH)



THICKNESS MAP OF MENDENHALL BED

EXPLANATION

Thickness of lignite

- Absent or less than 2.5'
- 2.5–5'
- 5'–10'
- 10' or more

Lignite outcrop
(dashed where approximately located)

Clinker

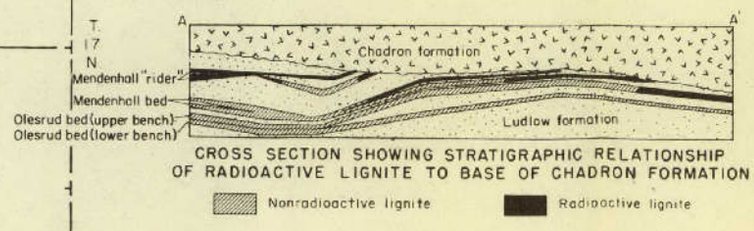
o2 (4.1) Core hole U.S.G.S. 1951

•2 (3.2) Core hole A.E.C. 1952–53

Number in parenthesis indicates thickness of lignite in core hole.

Custer National Forest boundry

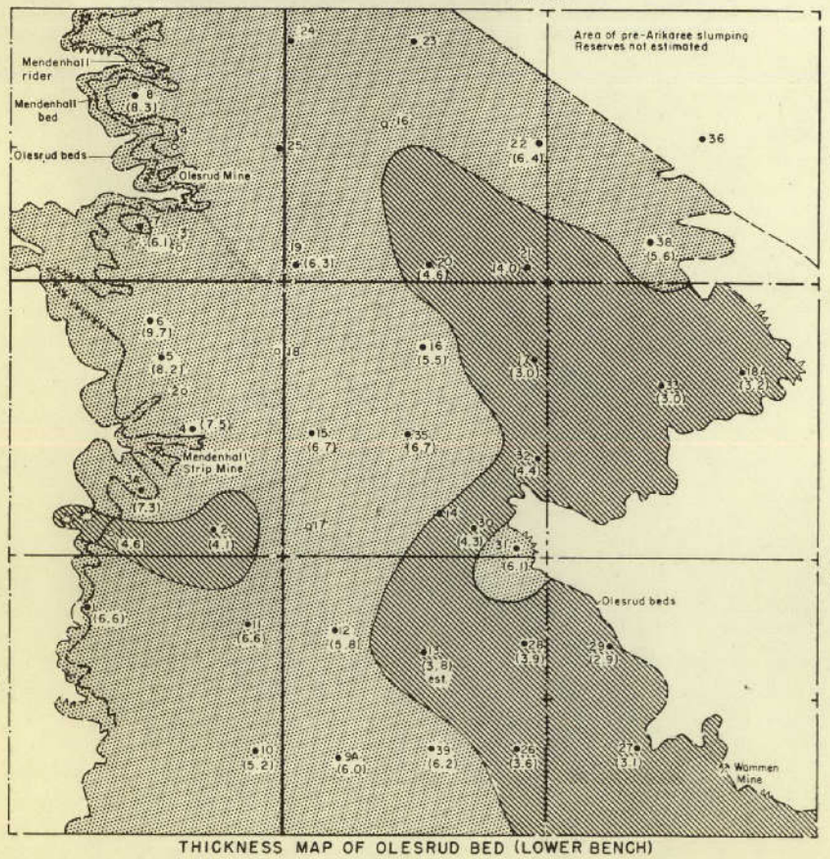
0 — 5,000 Feet



CROSS SECTION SHOWING STRATIGRAPHIC RELATIONSHIP OF RADIOACTIVE LIGNITE TO BASE OF CHADRON FORMATION

Nonradioactive lignite — Radioactive lignite

Vertical exaggeration 13:1



THICKNESS MAP OF OLESRUD BED (LOWER BENCH)

FIGURE 12– MAPS SHOWING THICKNESS AND DISTRIBUTION OF LIGNITE BEDS IN MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA

Uranium reserves

The Mendenhall area is underlain by three beds of uranium-bearing lignite, from top to bottom, the Mendenhall "rider", the Mendenhall, and the upper bench of the Olesrud. With few exceptions the stratigraphically highest lignite below the base of the Chadron formation is the only lignite that contains much uranium. (See cross section, fig. 12.) In the northern part of the area the Mendenhall "rider" is the stratigraphically highest lignite; in the central part of the area the Mendenhall bed is the highest lignite; and in the southern part the upper bench of the Olesrud is the stratigraphically highest lignite. Although the upper bench of the Olesrud underlies all of the area, it is radioactive only where the Mendenhall "rider" and Mendenhall bed have been removed by erosion prior to the deposition of the overlying Chadron formation. Similarly the Mendenhall bed is radioactive only where the Mendenhall "rider" has been removed by erosion. Correlation of the lignite beds in the drill holes and their relationship to the unconformity at the base of the Chadron are shown in the accompanying charts (figs. 4-8) and fence diagram (fig. 3).

Essentially the same procedures used in the calculation of lignite reserves (p. 28) were used in calculating reserves of uranium in lignite; the following uranium categories were established.

1. Total reserves of uranium-bearing lignite irrespective of grade.
2. Reserves having a uranium content of 0.005 percent or more.

3. Reserves having a uranium content of 0.01 percent or more.
4. Reserves having a uranium content of 0.03 percent or more in the lignite ash.
5. Reserves having a uranium content of 0.05 percent or more in the lignite ash.

Reserves in the above categories are shown in table 4 and on maps (fig. 13) showing thickness, grade, and areal distribution of the uranium-bearing beds. The uranium reserves are classed as inferred because of the lack of confirming data on the variation in uranium content between core holes.

An overburden map of the Mendenhall area (fig. 14) shows that an area of 680 acres is overlain by 60 feet or less of overburden.

The total uranium reserve for the Mendenhall area is 2,790 tons of which 820 tons occurs in beds averaging 3.9 feet in thickness, 1,435 tons in beds averaging 6.8 feet in thickness, 80 tons in beds averaging 10.8 feet in thickness, and 355 tons in beds less than 2.5 feet thick.

Sixty square miles in the Slim Buttes are conservatively estimated to be underlain by uranium-bearing lignite having an average thickness of 5 feet and a uranium content of 0.007 percent. Therefore, the Slim Buttes exclusive of the Mendenhall area has a potential reserve of about 300,000,000 tons of uranium-bearing lignite containing 26,000 tons of uranium.

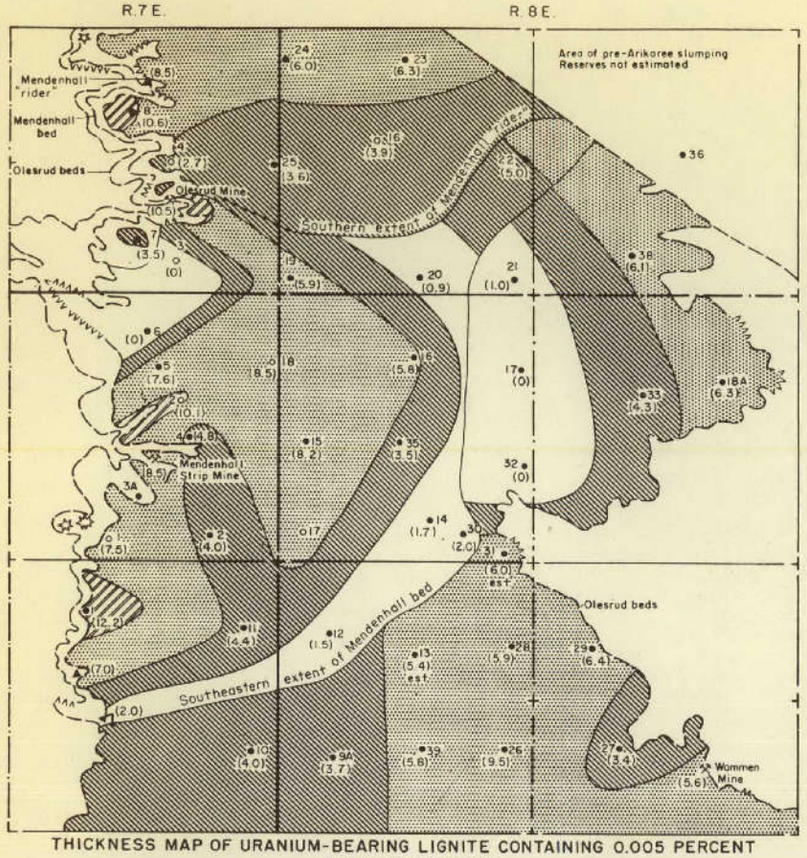
Table 4.--Summary of inferred reserves of uranium in lignite in the Mendenhall area, Harding County, South Dakota.

	Av. thick. (feet)	Area (acres)	Percent U (in lignite)	Percent ash	Lignite (short tons)	Uranium (short tons)
Total reserves of uranium in lignite (no grade cutoff)						
Mendenhall "rider"	7.5	585	0.010	22.6	27,580,000	760
Mendenhall bed	9.2	1,555	.003	14.1	24,150,000	965
Olesrud bed (Upper bench)	5.8	1,750	.006	18.0	17,800,000	1,065
Total		3,890			49,530,000	2,790
Minimum grade of 0.005 percent uranium in lignite						
Mendenhall "rider"	4.9	585	0.012		5,046,000	525
Mendenhall bed	6.1	1,150	.007		12,202,000	870
Olesrud bed (Upper bench)	5.2	1,405	.007		12,823,000	940
Total		3,140			30,071,000	2,335
Minimum grade of 0.010 percent uranium in lignite						
Mendenhall "rider"	5.6	115	0.018		1,141,000	165
Mendenhall bed	4.5	530	.010		4,211,000	425
Olesrud bed (Upper bench)	3.3	795	.010		4,591,000	460
Total		1,440			9,943,000	1,050
Minimum grade of 0.03 percent uranium in lignite ash						
Mendenhall "rider"	6.1	340	0.042 (in ash)	25.1	3,621,000	325
Mendenhall bed	6.1	1,110	.041	16.6	11,634,000	805
Olesrud bed (Upper bench)	5.0	1,330	.046	18.0	11,588,000	935
Total		2,780			26,843,000	2,065

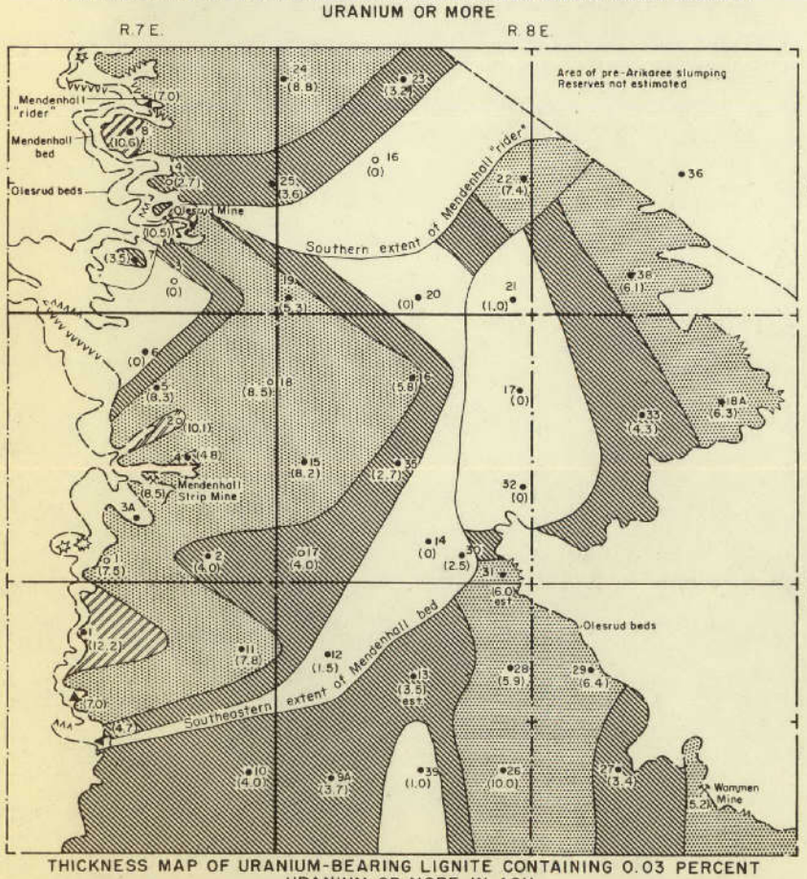
Table 4.--Summary of inferred reserves of uranium in lignite in the Mendenhall area, Harding County, South Dakota--Continued.

Minimum grade of 0.05 percent uranium in lignite ash

	Av. thick. (feet)	Area (acres)	Percent U (in lignite)	Percent ash	Lignite (short tons)	Uranium (short tons)
Mendenhall "rider"	4.0	190	0.065	25.5	1,335,000	195
Mendenhall bed	5.0	775	.052	15.3	6,804,000	555
Olesrud bed (Upper bench)	4.3	890	.058	15.9	6,660,000	605
		1,855			14,799,000	1,355



THICKNESS MAP OF URANIUM-BEARING LIGNITE CONTAINING 0.005 PERCENT URANIUM OR MORE



THICKNESS MAP OF URANIUM-BEARING LIGNITE CONTAINING 0.03 PERCENT URANIUM OR MORE IN ASH

URANIUM RESERVES
(Inferred)

Bed	Av. Thick. (Feet)	Area (Acres)	Percent uranium (In lignite)	Percent ash	Lignite (Short tons)1/	Uranium (Short tons)2/
Minimum grade of 0.005 percent uranium in lignite						
Mendenhall "rider"	3.4	340	0.015		2,023,000	305
	6.9	235	.007		2,837,000	200
	10.6	10	.012		186,000	20
	Subtotal	585			5,046,000	525
Mendenhall bed	4.2	465	.005		3,418,000	170
	7.1	645	.008		8,014,000	640
	11.0	40	.008		770,000	60
	Subtotal	1,150			12,202,000	870
Olesrud bed (Upper bench)	3.9	635	.008		4,334,000	345
	6.3	770	.007		8,489,000	595
	Subtotal	1,405			12,823,000	940
	Grand total	3,140			30,071,000	2,335
Minimum grade of 0.01 percent uranium in lignite						
Mendenhall "rider"	3.1	60	.025		325,000	80
	8.0	45	.010		630,000	65
	10.6	10	.012		186,000	20
	Subtotal	115			1,141,000	165
Mendenhall bed	3.5	390	.010		2,389,000	240
	7.2	130	.010		1,638,000	165
	10.5	10	.010		184,000	20
	Subtotal	530			4,211,000	425
Olesrud bed (Upper bench)	3.3	795	.010		4,591,000	460
	Subtotal	795			4,591,000	460
	Grand total	1,440			9,943,000	1,050
Minimum grade of 0.03 percent uranium in lignite ash						
			(in ash)			
Mendenhall "rider"	3.3	140	.054	29.0	809,000	125
	7.9	190	.030	23.0	2,627,000	180
	10.6	10	.128	9.4	185,000	20
	Subtotal	340			3,621,000	325
Mendenhall bed	4.0	370	.036	16.7	2,590,000	155
	6.7	690	.043	16.6	8,090,000	580
	10.9	50	.047	15.9	954,000	70
	Subtotal	1,110			11,634,000	805
Olesrud bed (Upper bench)	3.8	770	.049	18.6	5,120,000	465
	6.6	560	.042	17.3	6,468,000	470
	Subtotal	1,330			11,588,000	935
	Grand total	2,780			26,843,000	2,065
Minimum grade of 0.05 percent uranium in lignite ash						
Mendenhall "rider"	3.3	165	.063	26.9	953,000	160
	7.5	15	.050	15.0	197,000	15
	10.6	10	.128	9.4	185,000	20
	Subtotal	190			1,335,000	195
Mendenhall bed	4.0	565	.050	14.9	3,955,000	295
	7.6	200	.057	16.3	2,660,000	245
	10.8	10	.050	17.0	189,000	15
	Subtotal	775			6,804,000	555
Olesrud bed (Upper bench)	3.6	675	.059	16.2	4,252,000	405
	6.4	215	.055	15.0	2,408,000	200
	Subtotal	890			6,660,000	605
	Grand total	1,855			14,799,000	1,355

1/ Calculations based on 1750 tons per acre foot - net result rounded to nearest 1,000 tons
2/ Figures rounded to nearest 5 tons

EXPLANATION

THICKNESS OF LIGNITE

- Absent or less than 2.5'
- 2.5'-5'
- 5'-10'
- 10' or more

Lignite outcrop
Dashed where approximately located.

Clinker

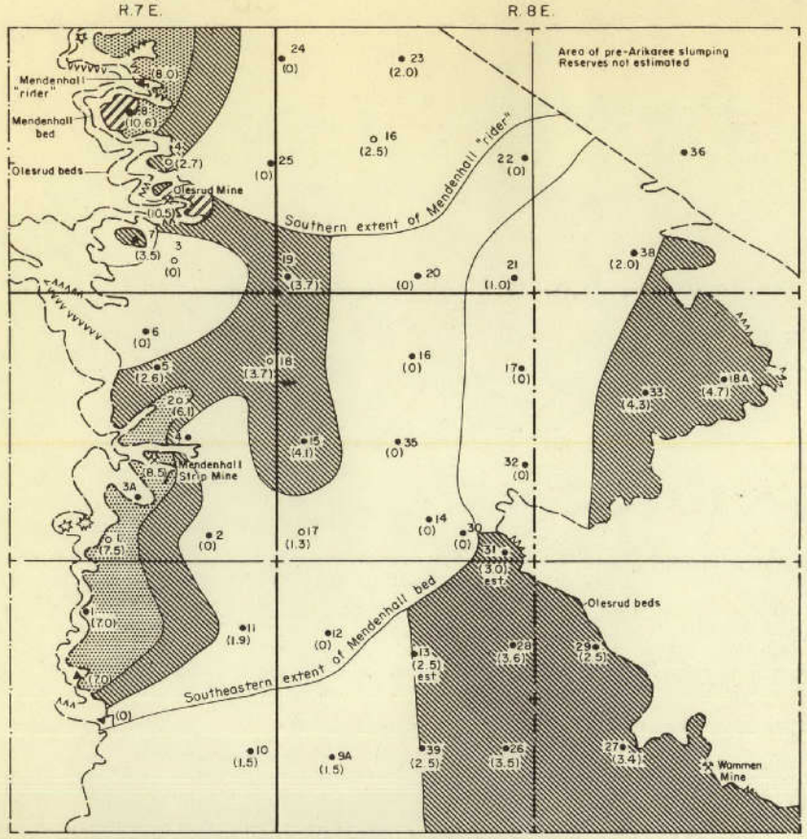
• 2
(3.2)
Core hole A.E.C. 1952-53

o 2
(4.1)
Core hole U.S.G.S. 1951

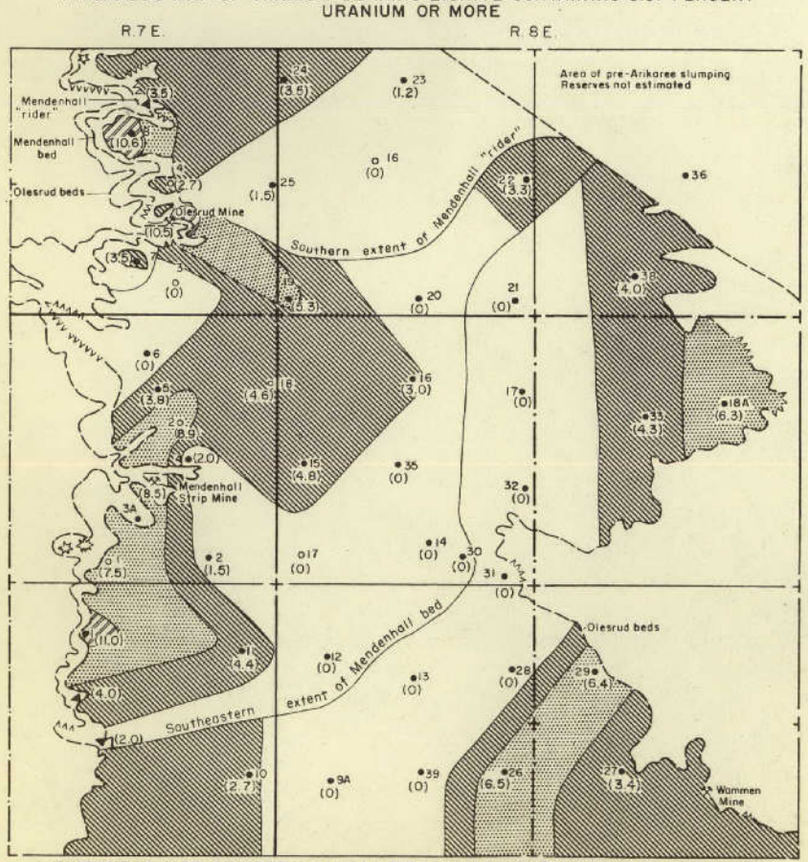
▲(7.0)
Surface section
Number in parenthesis indicates thickness of mineralized lignite in core hole

Custer National Forest boundary

0 5,000 Feet



THICKNESS MAP OF URANIUM-BEARING LIGNITE CONTAINING 0.01 PERCENT URANIUM OR MORE



THICKNESS MAP OF URANIUM-BEARING LIGNITE CONTAINING 0.05 PERCENT URANIUM OR MORE IN ASH

FIGURE 13.- MAPS SHOWING THICKNESS, GRADE, AND DISTRIBUTION OF URANIUM-BEARING LIGNITE IN MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA

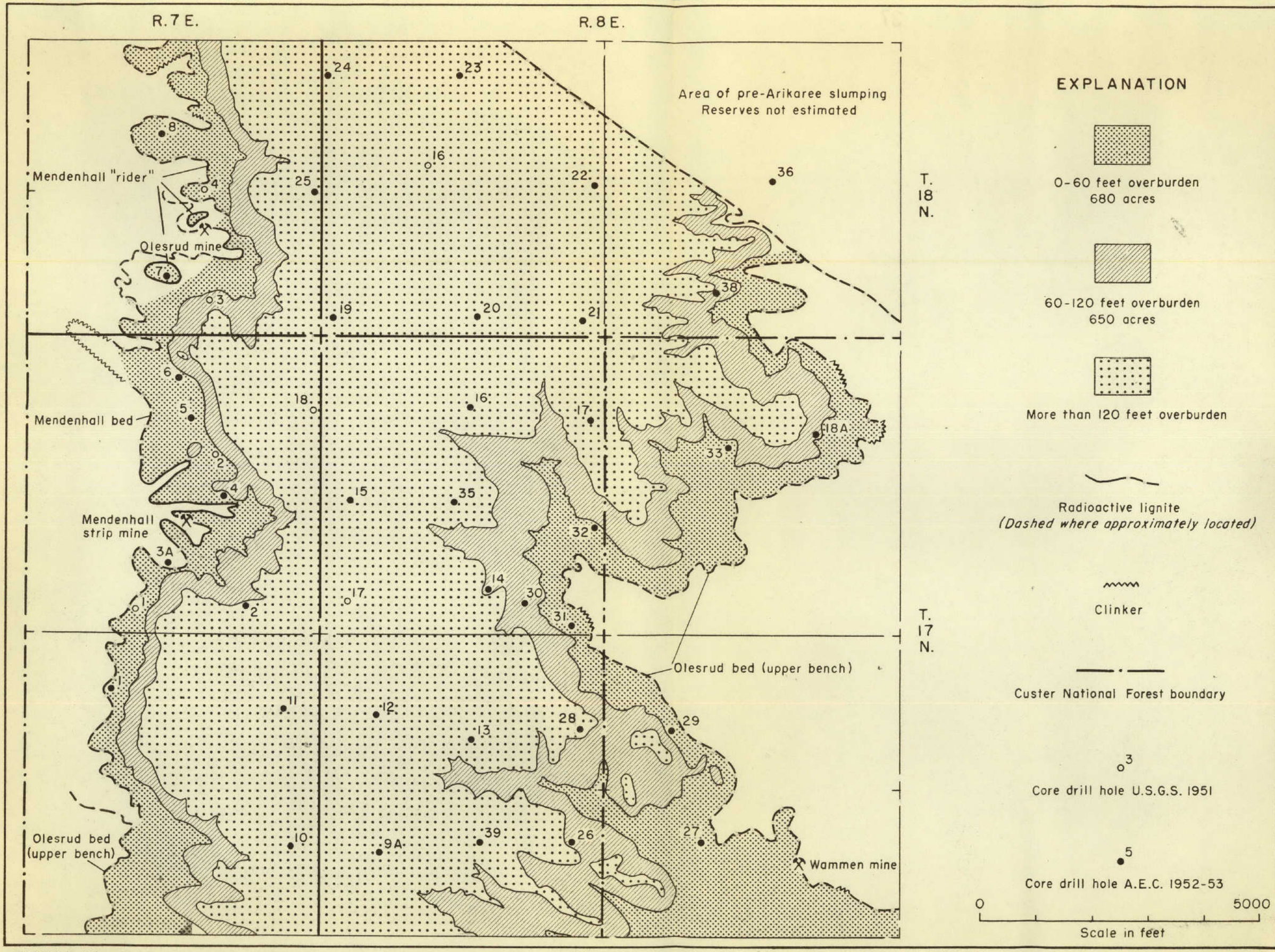


FIGURE 14.—MAP SHOWING POTENTIALLY STRIPPABLE AREAS OF RADIOACTIVE LIGNITE IN MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA

Geological significance of uranium in lignite

The origin of the uranium in the lignite should be considered briefly to explain the limits placed on the reserve areas in the individual beds and the limits of mining that should be established in any developments of the area as a source of uranium.

The uranium in the lignites in the Mendenhall area is believed to have been introduced into the lignites long after their formation. Enrichment may be going on today. Denson, Bachman, and Zeller (1950) first suggested that the uranium was leached by ground water from the Oligocene and Miocene tuffaceous rocks that unconformably overlie the lignite-bearing strata of the Ludlow member of the Fort Union formation. The ground water brought the uranium into contact with the lignite beds in which the uranium combined with carbon compounds to form a metalo-organic complex (Breger and Deul, 1952).

The Chadron and Arikaree formations contain on the average about 0.001 percent uranium, in comparison with the average uranium content of the earth's crust of 0.0004 percent (Mason, 1952) and in comparison with the average for sedimentary rocks of 0.00012 (Rankama and Sahama, 1950). These formations contain nearly 10 times the expectable amount of uranium, and these rocks seem to be logical source beds for the uranium. It is estimated that a cubic mile of the Chadron and Arikaree formations with a uranium content of 0.001 percent would contain about 130,000 tons of uranium. Springs issuing from the Chadron and Arikaree formations contain 10 to 200 parts per billion uranium compared to the average

uranium content of the ocean of 1.5 parts per billion (Rankama and Sahama, 1950).

The distribution of uranium in uranium-bearing lignite beds (figs. 4-8) appears to be related to the accessibility of the beds to uranium-bearing solutions coming from the overlying Oligocene and Miocene rocks rather than to such features as changes in physical character of the lignite. The observed distribution does not appear to correspond to any reasonable interpretation of the conditions under which the lignites were deposited (Schopf and Gray, 1954).

The geologic factors that appear to control the occurrence of uranium in the lignites in the Mendenhall area are the following (Denson, Bachman and Zeller, 1950):

1. Stratigraphic proximity of lignite to the base of the Chadron formation. The stratigraphically highest lignite beneath the base of the Chadron formation is generally the only radioactive lignite.
2. Permeability of rocks directly overlying the lignite. Where the stratigraphically highest lignite is overlain by impervious shale and clay, the uranium content is lower than where the same bed is overlain by sandstone.
3. Physical character of the lignite-absorptive properties and porosities of the organic constituents. Little information is yet available as to the absorptive properties of the lignitic constituents; but, in areas where the lignites have weathered and have greater

permeability, there appears to be an increase in the uranium content. The thickness map of uranium-bearing lignite containing 0.001 percent uranium or more (fig. 13) shows that the areas containing lignite with the highest uranium content are generally in the areas of the least overburden. This may indicate that these areas are being enriched by uranium-bearing ground water draining from the Chadron and Arikaree formations.

4. Position of past and present water tables. Little is known about past ground water conditions, but it is reasonable to expect that major fluctuations have taken place in past geologic time. Aside from the perched water table in the upper part of the Chadron and the lower part of the Arikaree formations the present water table is below the mineralized lignite.

Data obtained during this project indicate that the uranium in the lignite is secondary, having been introduced after coalification, and that the uranium has been and is being leached by ground water from the mildly radioactive tuffaceous rocks of the Chadron and Arikaree formations.

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APPENDIX A

LITHOLOGIC DESCRIPTIONS OF LIGNITE CORES FROM CORE HOLES SD-8, SD-10, AND SD-19, MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA,

By

James M. Schopf

Coal Geology Laboratory, Columbus, Ohio

General notes

Lithologic descriptions of lignite cores and the selection for analysis of Trace Elements (TE) and Bureau of Mines (BM) samples were made at the U. S. Geological Survey Coal Geology Laboratory, Columbus, Ohio, under the direction of James M. Schopf. Chemical determination of percent uranium (U) in the lignite was made at the U. S. Geological Survey Trace Elements Washington Laboratory and the proximate and ultimate analysis by the U. S. Bureau of Mines, Pittsburgh, Pa.

Sampling procedures at the Columbus Laboratory are as follows: TE samples represent an accurately sawed cut, including about 1/4 of the volume of the core. A similarly smooth-cut quadrant slice of about 5/8 inch on each of its radial sides was cut through the coal thickness to constitute the Bureau of Mines analytic samples of the lignite. The remainder of the core is reserved for preparation of thin sections and for more detailed study of radioactive-material distribution in lignite constituents.

Hole SD-8

DATES: Coal cored - 6/29/53 to 7/1/53
Shipment received at Columbus - 7/7/53 and 7/13/53
Described and sampled at Coal Geology Laboratory - 7/14/53 and 7/17/53
Samples sent Bureau of Mines and Trace Elements Laboratory - 7/21/53 and 7/25/53

LOCATION: SE NW sec. 36-18N-7E SURFACE ELEVATION: 3,327

36.05' (Top of box 1 and top of core sent to Columbus Laboratory)
Sandstone, medium-grained, yellow-tan; top 0.16' clay, silty, light ocher.
36.72'
Clay, silty, ocher and tan.
37.51'
Clay, gray; impure coal below 37.74'. Sample TE-1 (0.014U)
37.84'
Coal, abundantly medium-banded. Sample TE-2 (0.092U)
37.95'
0.60' loss in drilling; coal, described at drill site.
38.55'
4.45' loss in drilling; siltstone and sandstone, described at drill site.
43.00'
2.13' loss in drilling; lignite, described at drill site.
45.13' ----------
Coal, dominantly thick-banded. TE Sample 3 (0.011U)
45.63'
Coal, abundantly thick- and medium-banded. TE Sample 4 (0.012U)
45.97'
Coal, moderately thick-banded, with fusain lenses. TE Sample 5 (0.008U)
46.26'
Coal, a very thick wood band. TE Sample 6 (0.005U)
46.67'
Coal, sparsely thick-banded, with thin fusain lenses. TE Sample 7 (0.008U)
47.17'
Coal, abundantly thick-banded, with fusain lenses; pyritic. TE Sample 8 (0.006U)
47.50'
Coal, moderately thick-banded, with fusain lenses; pyritic. TE Sample 9 (0.004U)
47.80'
Coal, sparsely thick- and thin-banded; 0.10' wood band below 48.07'. TE Sample 10 (0.009U)
48.25' ----------

Bureau of Mines Laboratory Analysis No. E 19298 (Appendix B, p. 61)

48.25'
Clay, light gray.
49.21'
Clay, light gray.
49.99'
Clay, silty, light gray.
51.11'
Clay, silty, light gray.
51.90' ----------
Coal, moderately thick-banded; irregular fusain and woody lenses.
52.49'
Coal, abundantly very thick-banded; non-banded portion approximately 75% fusain.
52.86'
0.14' loss in coring accumulated below 43.00'
53.00' (Bottom ofbox 1 and top of box 2)
Clay, medium gray, carbonaceous; excluded from BM sample
53.38'
Coal, dominantly very thick-banded; 0.06' fusain parting below 57.71'.
53.77'
Coal, with sparse thick to thin irregular wood lenses; 0.02' fusain parting at base.
54.17'
Coal, sparsely medium-banded.
54.45'
Coal, abundantly thick-banded; 0.03' fusain parting at base.
54.74'
Coal, moderately thick- and thin-banded, with medium fusain lenses.
55.23'
Coal, dominantly medium-banded; 0.02' fusain parting below 55.44'.
55.50'
Coal, abundantly medium-banded, slightly pyritic; 0.10' wood band at top.
55.88'
Coal, impure; excluded from BM sample.
56.22'
Coal, sparsely medium-banded with a few thick and medium woody lenses.
56.72' ----------
Coal, impure.
57.16'
Coal, impure.
57.55'
Coal, impure.
57.93'
Coal, impure.

) Bureau of Mines Laboratory Analysis No. E 19299 (Appendix B, p. 61)

58.41'
Coal, impure.
58.72'
Coal, impure, badly broken in coring.
59.12'
Coal, impure, pulverized in coring.
59.48'
Coal, impure, badly broken in coring.
59.86'
Coal, impure, badly broken in coring.
60.30' (Pull at this depth)
Clay, light gray; 0.10' black clay at top.
61.29'
Clay, light gray, with a few carbonaceous streaks.
62.50' (Measured at drill site; bottom of box 2)
15.25' core not received at Columbus Laboratory.
77.75' (Measured at drill site; top of box 3)
Clay, light gray, slightly carbonaceous; more carbonaceous with occasional coaly streaks below 77.98'.
78.21'
Clay, gray, with medium and thick coal bands.
78.54'
Coal, 0.10' impure coal at top; 0.06' pyritic bands below 78.64', and 78.94'; 0.24' solid-wood band between pyrite zones.
79.00'
Coal, impure; clay, light gray and slightly carbonaceous below 79.18'.
79.40' (Measured at drill site)
26.50' core not sent to Columbus Laboratory.
105.90'
Clay, light gray, grading into clay, black.
106.48'
Coal, impure, pyritic.
106.83' ----------
Coal, abundantly thick- to medium-banded.
107.32'
Coal, abundantly thick- and thin-banded.
107.73'
Coal, impure, excluded from BM sample.
108.27'
Coal, dominantly thick-banded; 0.03' fusain parting at base.
108.56'
Coal, abundantly thin-banded; 0.07' wood band below 108.62'; 0.06' impure coal at top excluded from BM sample.
108.93'
Coal, abundantly thin-banded, pulverized in coring.

Bureau of Mines Laboratory Analysis No. E 19300 (Appendix B, p. 70)

109.21'
Coal, moderately thin- and thick-banded.
109.57'
Coal, abundantly thin- to thick-banded; pyritic, with thick fusain lens below 109.78'.
110.07'
Coal, abundantly thin- and medium-banded, with fusain partings.
110.53'
Coal, dominantly thick- and medium-banded, with thick fusain partings.
110.88'
Coal, abundantly thick- and medium-banded.
111.38'
Coal, abundantly thick- and medium-banded; 0.02' fusain parting below 111.54'
111.84'
Coal, moderately thick-banded; pyritic.
112.13'
Coal, sparsely thick-banded.
112.52'
Coal, sparsely thick-banded.
112.77' ----------
Clay, light gray, with plant fragments.
113.00' (Bottom of box 3 and top of box 4)
Clay, medium gray with plant fragments; 0.03' coaly at bottom.
113.28' ----------
Coal, dominantly thin-banded.
113.55'
Coal, dominantly thin-banded; 0.11' impure coal at top; excluded from BM sample.
113.89'
Coal, dominantly thin-banded, with a few small fusain lenses; 0.03' impure coal below 113.98'.
114.12'
Coal, impure. Excluded from BM sample.
114.52'
Coal, impure. -do-
114.90'
Coal, impure. -do-
115.30'
Coal, impure. -do-
115.75'
Coal, dominantly very thick-banded, badly broken in coring below 115.93'.
116.19'
Coal, crushed in coring.
116.58'
Coal, impure; 0.16' black clay below 116.83'. Excluded from BM sample.

Bureau of Mines Laboratory Analysis No. E 19301 (Appendix B, p. 76)

117.20'
Coal, abundantly medium- and thick-banded, probably high in ash.
117.51'
Coal, abundantly very thick-banded, with 0.05' fusain parting below 117.55'
117.84'
Coal, abundantly very thick-banded, with thin fusain lenses in upper 0.05'.
118.18'
Coal, dominantly very thick-banded; pyritic.
118.40'
Coal, attrital.
118.95'
Coal, dominantly thick-banded.
119.24'
Coal, abundantly thick-banded.
119.61'
Coal, moderately woody, irregular lenses; 0.08' irregular zone of impure coal, light gray clay and thick wood lenses below 119.72'.
119.98'
Coal, attrital, broken in coring, sparsely medium-banded below 120.23'.
120.34'
Coal, sparsely medium-banded; irregular fusain lenses at 120.45'.
120.76'
Coal, abundantly thick-banded. Sample CGL 83.
121.10' ----------
Impure coal and clay.
121.44'
Clay, dark gray, coaly.
121.83'
Clay, silty, light gray.
122.56'
0.44' loss in coring accumulated below 113.00.
123.00' (Bottom of box 4 and bottom of core received in Columbus Laboratory).

Hole SD-10

DATES: Coal cored - 2/21 to 2/28/53
Shipments received at Columbus - 3/6 and 3/18/53
Described and sampled at Coal Geology Laboratory - 3/12 and 13 and 3/18 and 19/53
Samples sent to BM and TE Laboratoryes 3/23 and 24/53

LOCATION: NESE sec. 12, T17 N, R7E SURFACE ELEVATION: 3,635

000.00
No core taken to depth of 260'. Solid bit drilling penetrated 230' of Arikaree and the upper part of the Chadron formation.
260'
21.7' of sandstone and clay core in the Chadron not sent to Columbus.
281.70' (Top of box 1 and top of core sent to Columbus Laboratory)
Shale, silty, light gray and sandstone, buff, fine-grained, soft.
282.25'
Clay, black, bedded with a few light buff sandy lenses. Sample TE-1. (0.0025U)
282.50'
Siltstone, light gray, bedded, moderately soft.
283.35' (Bottom of box 1)
27.85' of core not sent to Columbus. Field log shows clay, sandstone and siltstone of the Chadron formation.
311.20' (Top of box 2)
Clay, light buff, irregularly fragmented, with some light gray interstitial clay; light buff angular fragments larger in the lower part with clay matrix more abundant. Sample TE-2 (0.0001U)
311.93'
Shale and clay, silty, gray to slightly limonitic. Sample TE-3. (0.007U)
312.94'
Clay, light gray, with abundant limonitic bands in upper part, less limonitic below. Sample TE-4 (0.0048U)
313.42'
Clay medium gray to black, grading to coal below the top 2 inches; coal, impure, attrital. Sample TE-5 (0.002U)
314.04'
Clay, silty, brown in upper part, becoming somewhat more drab below; very thin coaly streaks and 1/8" limonitic band near the bottom. Sample TE-6 (0.0004U)
316.00'
Clay conglomerate; clay pebbles light tan to gray and characteristic of Chadron lithology; one lignitic fragment occurs near the middle and larger more angular clay pieces at the bottom. Regarded as lowest part of Chadron formation. Sample TE-7. (0.0003U)

316.27'
Clay, brown, with a scattering of thin woody streaks. Regarded as the topmost part of the Ludlow member of Fort Union formation. Sample TE-8. (0.0005U)

317.40 --
Coal, top inch and a half attrital, dominantly woody below. Sample TE-9. (0.003U)

317.78'
Pyritic layer, coherent but somewhat earthy in appearance. Excluded from BM and TE Samples.

317.82'
Coal, abundantly woody, Sample TE-10 (0.002U)

318.08'
Coal, moderately woody; two quarter-inch fusain lenticles near the middle. Sample TE-11. (0.002U)

318.66'
Coal, most attrital or very thin banded; one-inch woody band below 318.84'. Sample TE-12. (0.002U)

319.21'
Coal, sparsely woody. 1/4" fusain layer at base. Sample TE-13. (0.002U)

319.42'
One-fourth inch, thin pyritic laminae. Excluded from BM and TE Samples.

319.44'
Coal, sparsely woody. Sample TE-14. (0.004u)

319.71'
Coal, sparsely woody. Sample TE-15. (0.005U)

319.93'
Coal, nearly all attrital. Sample TE-16. (0.038U)

320.17'
Clay, coaly and black above 320.29', grading to dark gray clay, black with thin woody streaks below 320.37'. Excluded from BM Sample. Sample TE-17. (0.0010U)

320.61'
Coal, moderately woody. Sample TE-18. (0.005U)

320.79'
Shale, black, clayey, with 1/4" hard siltstone band below 320.89'. Excluded from BM Sample. Sample TE-19. (0.0007U)

321.10'
Coal, impure, grading below 321.28' to carbonaceous clay. Excluded from BM Sample. Sample TE-20. (0.003U)

321.36'
Coal, abundantly woody, thick bands, with 1/8" fusain parting below 321.49'. Sample TE-21. (0.005U)

321.58'
Coal, abundantly woody, thick bands. Sample TE-22. (0.002U)

321.91'
Coal, nearly solid wood. Sample TE-23 (0.003U)
322.19'
Clay, shaley, brown with coaly fragments. Excluded from BM Sample and omitted from TE Samples.
322.37'
Coal, attrital, except for thick woody band in middle. Sample TE-24. (0.014U)
322.56' ----------
Shale, brown, clayey. Sample TE-25. (0.0015U)
323.54'
Siltstone, gray, clayey with few thin coaly streaks in lower part. Sample TE-26. (0.0002U)
325.82' (Bottom of box 3)
Shale, siltstone and core losses; footage of 54.58' not sent to Columbus.
326.50' (Pull)
380.40' (Top of box 4)
Clay, silty, light buff, soft; 1/4" carbonaceous streak at the base. Sample TE-27 (0.0001U)
381.07' ----------
Coal, moderately woody. Sample TE-28. (0.006U)
381.29'
Coal, moderately woody, Sample TE-29. (0.004U)
381.50'
Coal, abundantly woody (one 2-inch band); 1/4' pyritic rosettes at base of layer. Sample TE-30. (0.009U)
381.78'
Coal, mostly attrital, 1-1/2" woody band at base. Sample TE-31. (0.016U)
382.07'
Coal, abundantly woody. Sample TE-32. (0.003U)
382.30'
Coal, moderately woody, 1/4" pyritic lenticle at the top; three-fourths inch carbonaceous clay parting at the bottom of this layer is excluded from BM Sample. Whole sample included as TE-33. (0.008U)
382.92'
Coal, abundantly woody. Sample TE-34. (0.001U)
383.24'
Coal, sparsely banded above, moderately woody below 383.50'. Sample TE-35. (0.004U)
383.83'
Coal, abundantly woody, in bands 1" to 2" thick. Sample TE-36. (0.002U)
384.30'
Coal, moderately woody above, moderately thin banded below 384.6'. Sample TE-37. (0.002U)

384.79'
Coal, moderately woody, thin and thick bands. Sample TE-38. (0.003U)
385.37'
Coal, moderately woody; 1/4" pyritic rosette above 385.69'. Sample TE-39. (0.008U)
386.00'
Coal, moderately woody. Sample TE-40. (a)
386.56' ----------
Shale, carbonaceous clayey, grading from 2" impure coal at top. Sample TE-41. (0.0001U)
387.10'
Coal, moderately woody. Sample TE-42. (0.003U)
387.27'
Coal, moderately woody. Sample TE-43. (0.015U)
387.48'
Shale, brown clayey, numerous 1/8 to 1/2" woody streaks. Sample TE-44. (0.004U)
388.01'
Shale, coaly streaks, much as above. Sample TE-45. (0.001U)
388.27'
Coal, moderately woody. Sample TE-46. (0.002U)
388.58'
Shale, brown, coaly and woody fragments. Sample TE-47 (a)
389.16'
Shale, black to gray and dark brown, with coaly streaks. Bottom half inch appears to contain buff clayey pellets somewhat resembling fragments of the White River clay. Sample TE-48. (0.0013U)
389.63'
1.92' loss in coring apparently accumulated down to the total depth of drilling.
391.55'.

Hole SD-19

DATES: Coal cored - 4/2 to 4/4/53
Shipments received at Columbus - 4/13/53
Described and sampled at Coal Geology Laboratory - 4/13 to 4/16/53
Samples sent to BM and TE Laboratories 4/21/53 and 4/23/53

LOCATION: SW SW sec. 31, 18N-8E SURFACE ELEVATION: 3,606

0'
No core taken to depth of 310'. Solid bit drilling penetrated Arikaree and upper part of Chadron formations.

310'
Sandstone and siltstone with 0.15' limonitic streak beneath 319.70'. Described at drill site and not sent to Columbus.

320'
Loss in drilling, 6.4'; clay, 2.6'; siltstone, 0.15' to base of Chadron formation at 329.15' and top of Ludlow formation. Limonite 0.2', siltstone, limonitic and pyritic in the top part, 3.65'. Described and interpreted at drill site; core not sent to Columbus.

332.00' (Top of box 1 and top of core sent to Columbus Laboratory)
Siltstone, gray with a few 1/8" pyritic lenticles in upper portion; below 332.94' very fine siltstone with coarser silty bands stained dark brown, possibly limonitic. Sample TE 1. (0.0055U)

333.41'
Siltstone, clayey, gray, dip about 8°. Sample TE 2. (0.0039U)

333.72'
Clay, carbonaceous, dark-brown and black; not coaly. Sample TE 3. (0.0285U)

333.83' (Top of first BM Sample ----------)
Coal, mostly attrital with 1/2" woody band below 333.91'; no apparent dip in coal. Sample TE 4. (0.026U)

334.08'
Coal, predominantly attrital. Sample TE 5. (0.016U)

334.42'
Coal, sparsely thin-banded. Sample TE 6. (0.014U)

334.75'
Coal, sparsely banded. Sample TE 7. (0.006U)

335.09'
Coal, dominantly attrital, two 1/2" woody lenses in lower part, thin pyritic facing on joint in upper part. Sample TE 8. (0.006U)

335.71'
Coal, moderately medium-banded. Sample TE 9. (0.006U)

336.35'
Coal, abundantly medium- and thin-banded. Sample TE 10. (0.010U)

Bureau of Mines Laboratory Analysis No. E 12615 (Appendix B, p. 65)

336.64'
Coal, one solid woody band. Sample TE 11. (0.015U)
336.82'
Coal, 1/2" woody band at top; includes several irregular pyritic rosettes 1/4" to 1/8" thick, and one 1/8" fusain lenticle. Sample TE 12 (0.006U)
336.94'
Coal, mostly woody; core slightly broken. Sample TE 13. (0.015U)
337.12'
Coal, moderately woody. Sample TE 14. (0.007U)
337.34'
Coal, dominantly woody; core slightly broken. Sample TE 15. (0.006U)
337.54'
Coal, moderately thin- and medium-banded. Sample TE 16. (0.006U)
338.10'
Coal, moderately thin-, medium-, and thick-banded, including 3/4" woody band at 338.2'. Sample TE 17. (0.004U)
338.67'
Coal, moderately medium-banded; core somewhat broken. Sample TE 18. (0.003U)
338.86'
Coal, moderately thin-banded; core somewhat broken. Sample TE 19. (0.005U)
339.12' (Bottom of first BM Sample)
Clay, shaly, brown and gray, with a scattering of thin coaly plant fragments in middle portion. Sample TE 20. (0.0008U)
340.92' (Top of second BM Sample)
Coal, perhaps slightly impure or broken by thin partings; core badly broken (pieces less than 1/2"). Sample TE 21. (0.004U)
341.37'
Loss in coring, 0.63', accumulated below 332.00'
342.00' (Core barrel pull; bottom of box 1 and top of box 2)
Coal, dominantly woody, one piece 1-1/4" thick, apparently dipping about 6°. Sample TE 22. (0.005U)
342.21'
Coal, sparsely thin- and medium-banded; core slightly broken. Sample TE 23. (0.003U)
342.51'
Coal, dominantly woody; one band 2-1/2" thick below 342.63'; 1/8" fusain below 342.56'; a few quarter-inch pyritic blebs in lower portion. Sample TE 24.
343.48'
Coal, dominantly woody with some very thick pieces. Sample TE 25.
344.08'
Coal, abundant woody bands, core slightly broken; white clayey specks appear in one woody band. Sample TE 26.

344.31'
Coal, nearly all attrital above, moderately woody in lower half, 1/16" of fusinized material in a woody band near the base. Sample TE 27.
344.81'
Coal, moderately thin-, medium-, and thick-banded, 1/4" fusain band below 345.01', and 3/16" fusain below 345.70'. Sample TE 28.
345.89'
Coal, sparsely thin- and medium-banded, woody band with white clayey specks in middle part. Sample TE 29.
346.89'
Coal, moderately medium- and thin-banded, core somewhat broken in the middle and possibly somewhat more impure, largely attrital in lower four inches. Sample TE 30.
347.92' (Bottom of second BM Sample)----------
Clay, light gray, with vein-like vertical black clay filling in upper portion; sparse to moderate frequency of woody streaks in lower 5-1/2" of this clay interval. Sample TE 31. (0.0002U)
349.05'
Coal more or less impure, with 0.11' of coaly clay at top, lower three inches woody. Sample TE 32.
349.63'
Shale, clayey, dark brown with sparse and very thin coaly streaks; lower 2 inches of interval dark brown to black. Sample TE 33. (0.0003U)
350.70' (Top of third BM Sample) ----------
Coal, dominantly attrital; core somewhat broken but thickness mostly represented in large fragments. Sample TE 34.
350.98'
Coal, sparsely thin- and medium-banded (thicker banded below.) Sample TE 35.
351.57'
Loss in drilling, 0.43', accumulated below 342'.
352.00' (Pull, depth, bottom of box 2, top of box 3)
Loss in drilling, 1.52', apparently at the top of this drill run.
353.52'
Coal, sparsely thin- and medium-banded; 1/2" pyritic rosette below 353.70'; core slightly broken in upper part. Sample TE 36.
354.52'
Coal, dominantly woody; tiny white clay lenses appear within the 1" woody band below 354.55'. Sample TE 37.
354.81'
Coal, sparsely thin-banded; 1/4" pyritic lens below 355.32'; core somewhat broken at top (large pieces). Sample TE 38.
355.36'
Coal, moderately thin- to medium- and thick-banded (1" woody bandy below 356.85' and 1-1/2" band below 357.1'): 1/4" fusain band below 356.34'; core slightly broken at top (large pieces). Sample TE 39.

Bureau of Mines Laboratory Analysis No. E 12617 (Appendix B, p. 71)

357.32'
Coal, abundantly thick-banded; 1/4" fusain below 357.84'; bedding of coal apparently is dipping about 11°. Sample TE 40.
357.93'
Coal, dominantly thin-, medium-, and thick-banded, with about 3/4" fusain in several thin- to medium layers below 358.63'; apparent dip about 6°. Sample TE 41.
359.15'
Coal, predominantly woody, including two bands exceeding 3" thickness; apparent dip varies from 5° to 9°. Sample TE 42.
360.45' (Bottom of third BM Sample)
Shale, clayey, carbonaceous; dark to black in upper four inches, grading to medium gray clayey shale below; two 3/4" pyritic rosettes occur between 361.70' and 361.80'; silty layer 1" thick below 361.06'. Sample TE 43. (0.0003U)
362.00' (Bottom of box 3)
Loss in drilling, 1.00', siltstone. Described at drill site.
363.00'
Siltstone. Described at drill site and not sent to Columbus.
372.00'
Loss in drilling, 0.75'. Siltstone described at drill site.
372.75'
Shale, lower 0.30' carbonaceous, described at drill site and not sent to Columbus.
382.00' (Top of box 4 sent to Columbus Laboratory)
Shale, black, carbonaceous and coaly; 0.08' coal stringer below 382.00'; becomes clayey at base. Sample TE 44.
383.08" (Top of fourth BM Sample)
Coal, sparsely banded to attrital, with very thick wood bands below 383.38' and 383.62', 0.02' fusain parting with sand blebs below 383.68', and thin fusain parting with large pyrite nodule below 383.35'; 0.03' clay parting below 383.46' excluded from Bureau of Mines sample. Sample TE 45.
383.81'
Coal, dominantly attrital with 0.25' wood band below 384.68'; 0.04' coaly clay parting below 384.50' excluded from BM Sample. Sample TE 46.
384.96'
Coal, impure with thin lens of sand blebs below 385.03'. Excluded from BM Sample. Sample TE 47.
385.15'
Coal, abundantly thick-banded with irregular medium to thick bands of wood in the more attrital portions; upper 0.20' contains clay blebs and fusain. Sample TE 48.
386.59'
Clay, black, carbonaceous, excluded from BM Sample. Sample TE 49.
386.69'
Coal, moderately thick- to thin-banded. Sample TE 50.

Bureau of Mines Laboratory Analyses No. E 13500. (Appendix B, p. 77)

387.83')
Coal, dominantly very thick-banded. Sample TE 51.)
388.93' (Bottom of fourth BM Sample)----------)
Siltstone, carbonaceous, medium gray. Upper 0.12' clay, black, carbonaceous. Sample TE 52. (0.0003U)
391.39'
Sandstone, fine-grained, light gray with carbonaceous streaks; omitted from TE samples.
391.74'
Loss in drilling 0.26', accumulated below 382.00'.
392.00' (Bottom of box 4 and top of box 5)
Loss in drilling 0.38'; siltstone (described at drill site).
392.38'
Siltstone, brownish-gray with carbonaceous streaks and occasional lenses of light tan sand; 0.27' medium gray, fine-grained sandstone below 392.38'; 0.03' woody coal bands below 393.23' and below 394.75'. Sample TE 53 (0.0002U)
394.78'
Coal, moderately thin- and thick-banded. Sample TE 54.
395.06'
Coal, impure with very thick woody bands below 395.31' and below 395.71'. Sample TE 55.
395.86'
Clay, black to dark gray, highly carbonaceous. Sample TE 56.
396.37'
Siltstone, medium gray and carbonaceous with very thin coaly streaks. Sample TE 57. (0.0003U)
398.97'
Siltstone, as above. Sample TE 58. (0.0003U)
400.59'
Sandstone, fine-grained, medium gray with irregular medium-grained light gray sand lenses. Sample TE 59. (0.0002U)
401.80'
Shale, clayey, light gray with thin coaly streaks; included with shale below as Sample TE 60. (0.0003U)
402.00' (Bottom of box 5 and top of box 6)
Shale, clayey, light gray with occasional very thin coal streaks, becomes black and more coaly towards bottom. Sample TE 60. (0.0003U)
402.85'
Coal, dominantly medium-banded. Sample TE 61.
403.89'
Shale, black with a few thin coal streaks. Sample TE 62.
405.59'
Shale, black and light gray with 0.28' impure coal at base. Sample TE 63.

407.51' (Top of fifth BM Sample) ----------)
Coal, moderately thick-banded, with 0.03' fusain parting)
below 408.42'. Core slightly broken in drilling. Sample)
TE 64.)
409.32' (Bottom of fifth BM Sample)----------)
Shale, clayey, light to medium gray with very light gray
sand lenses in middle portion. Sample TE 65. (0.0003U)
411.37'
Shale, silty and fine-grained sandstone, light gray. Omitted
from TE Samples.
411.91'
Loss in drilling, 0.09', accumulated below 402.00'.
412.00' (Bottom of box 6, total depth)

Bureau of Mines Laboratory Analysis No. E 13501 (Appendix B,p.83)

APPENDIX B

PROXIMATE AND ULTIMATE ANALYSES OF LIGNITE CORES FROM THE MENDENHALL AREA HARDING COUNTY, SOUTH DAKOTA

ANALYSES BY U. S. BUREAU OF MINES

PITTSBURGH, PENNSYLVANIA

ANALYSES OF SAMPLES OF THE MENDENHALL "RIDER"

Hole no.	Thickness	Lab. no.	Condition 1/	PROXIMATE				ULTIMATE						
				Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	Softening temp.
SD-78	0.65	E-32880	1	20.5	29.5	14.0	36.0	3.7	25.2	0.5	32.3	2.3	3590	2380
			2	--	37.1	17.7	45.2	1.8	31.7	0.6	17.8	2.9	4510	
			3	--	67.7	32.3	--	3.3	57.9	1.2	32.2	5.4	8240	
SD-8	3.1	E-19298	1	39.0	25.5	29.5	6.0	6.9	39.2	0.5	46.4	1.0	6510	2260
			2	--	41.8	48.4	9.8	4.2	64.3	0.7	19.3	1.7	10670	
			3	--	46.4	53.6	--	4.7	71.3	0.8	21.3	1.9	11840	
	4.0	E-19299	1	45.0	21.9	27.6	5.5	7.2	35.5	0.4	50.9	0.7	5850	2250
			2	--	39.9	50.0	10.1	4.1	64.2	0.8	19.5	1.3	10640	
			3	--	44.3	55.7	--	4.5	71.3	0.9	21.9	1.4	11830	
K-26	2.4	E-24658	1	40.1	29.9	17.2	12.8	--	--	--	--	1.9	4130	--
			2	--	50.0	28.6	21.4	--	--	--	--	3.1	6880	
			3	--	63.6	36.4	--	--	--	--	--	4.0	8760	
	3.5	E-24659	1	39.6	24.8	14.7	20.9	--	--	--	--	1.6	3320	--
			2	--	41.0	24.3	34.7	--	--	--	--	2.7	5490	
			3	--	62.8	37.2	--	--	--	--	--	4.1	8410	
SD-24	1.1	E-33312	1	27.6	22.8	16.4	33.2	4.3	24.8	0.5	35.2	2.0	3560	2220
			2	--	31.5	22.7	45.8	1.7	34.2	0.7	14.9	2.7	4920	
			3	--	58.0	42.0	--	3.1	63.2	1.3	27.3	5.1	9070	

1/ 1 = as received; 2 = moisture free; 3 = moisture and ash free.

ANALYSES OF SAMPLES OF THE MENDENHALL "RIDER"

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	PROXIMATE: Volatile matter	PROXIMATE: Fixed carbon	PROXIMATE: Ash	ULTIMATE: Hydrogen	ULTIMATE: Carbon	ULTIMATE: Nitrogen	ULTIMATE: Oxygen	ULTIMATE: Sulphur	British thermal units	Softening temperature
SD-24(cont.)														
	6.3	E-33313	1	29.8	25.2	28.4	16.6	5.6	37.4	0.4	38.3	1.7	6250	2030
			2	--	35.9	40.4	23.7	3.3	53.3	0.6	16.6	2.5	8900	
			3	--	47.1	52.9	--	4.4	69.8	0.8	21.8	3.2	11660	
USGS-4	0.6	D-68859	1	43.8	24.1	13.5	18.6	--	--	--	--	1.7	3100	2180
			2	--	42.9	24.0	33.1	--	--	--	--	3.1	5510	
			3	--	64.1	35.9	--	--	--	--	--	4.6	8230	
	1.7	D-68860	1	45.9	20.7	11.9	21.5	6.2	18.6	0.3	51.5	1.9	2680	2130
			2	--	38.3	22.0	39.7	2.1	34.5	0.6	19.7	3.4	4950	
			3	--	63.4	36.6	--	3.5	57.2	1.0	32.6	5.7	8200	
USGS-16	8.4	D-71570	1	41.8	22.0	26.1	10.1	6.9	34.7	0.4	47.1	0.8	5790	2100
			2	--	37.9	44.8	17.3	3.8	59.7	0.8	17.0	1.4	9950	
			3	--	45.8	54.2	--	4.6	72.2	0.9	20.6	1.7	12030	

ANALYSES OF SAMPLES OF THE MENDENHALL BED

Hole no.	Thickness	Lab. no.	Condition[1/]	PROXIMATE: Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	ULTIMATE: Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	Softening temperature
SD-1	1.7	E-32380	1	34.4	23.5	29.6	12.5	6.0	36.2	0.5	42.3	2.5	6090	1990
			2	--	35.9	45.1	19.0	3.3	55.2	0.8	17.8	3.9	9280	
			3	--	44.3	55.7	--	4.1	68.2	0.9	22.0	4.8	11460	
	2.1	E-32381	1	36.3	23.6	30.0	10.1	6.2	36.7	0.4	44.4	2.2	6120	1970
			2	--	37.1	47.1	15.8	3.4	57.6	0.7	19.1	3.4	9600	
			3	--	44.1	55.9	--	4.1	68.4	0.8	22.6	4.1	11410	
	8.7	E-32382	1	41.0	23.7	27.8	7.5	6.8	35.9	0.4	48.0	1.4	6060	2140
			2	--	40.1	47.1	12.8	3.8	60.8	0.7	19.5	2.4	10270	
			3	--	46.0	54.0	--	4.4	69.7	0.8	22.4	2.7	11770	
SD-2	1.45	E-32387	1	18.0	23.4	29.2	29.4	4.2	37.0	0.5	26.4	2.5	6070	2210
			2	--	28.5	35.7	35.8	2.6	45.1	0.6	12.8	3.1	7400	
			3	--	44.4	55.6	--	4.1	70.3	1.0	19.8	4.8	11530	
	5.3	E-32388	1	32.5	26.8	31.5	9.2	6.2	41.5	0.5	41.1	1.5	6900	2050
			2	--	39.6	46.7	13.7	3.8	61.5	0.7	18.1	2.2	10220	
			3	--	45.9	54.1	--	4.4	71.2	0.8	21.1	2.5	11830	
SD-4	4.75	E-32401	1	24.9	26.0	35.4	13.7	5.5	43.8	0.6	34.6	1.8	7450	2100
			2	--	34.6	47.2	18.2	3.7	58.3	0.7	16.7	2.4	9910	
			3	--	42.3	57.7	--	4.5	71.4	0.9	20.3	2.9	12120	

1/ 1 = as received; 2 = moisture free; 3 = moisture and ash free.

ANALYSES OF SAMPLES OF THE MENDENHALL BED

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	PROXIMATE: Volatile matter	PROXIMATE: Fixed carbon	PROXIMATE: Ash	ULTIMATE: Hydrogen	ULTIMATE: Carbon	ULTIMATE: Nitrogen	ULTIMATE: Oxygen	ULTIMATE: Sulphur	British thermal units	Softening temperature
SD-4 (cont.)														
	6.55	E-32402	1	29.6	28.5	33.2	8.7	6.1	43.1	0.5	40.4	1.2	7180	2220
			2	--	40.5	47.2	12.3	3.9	61.3	0.7	20.1	1.7	10210	
			3	--	46.2	53.8	--	4.5	69.9	0.8	22.8	2.0	11640	
SD-6	5.75	E-32807	1	39.3	23.8	28.8	8.1	6.7	38.3	0.5	45.2	1.2	6360	2130
			2	--	39.2	47.5	13.3	3.9	63.0	0.8	17.0	2.0	10480	
			3	--	45.2	54.8	--	4.5	72.7	0.9	19.6	2.3	12100	
	7.85	E-32871	1	37.4	24.2	30.1	8.3	6.5	39.3	0.5	44.4	1.0	6500	2140
			2	--	38.7	43.0	13.3	3.7	62.7	0.8	18.0	1.5	10390	
			3	--	44.7	55.3	--	4.3	72.4	0.9	20.6	1.8	11980	
SD-14	1.1	E-32888	1	31.0	19.8	19.6	29.6	4.8	25.1	0.4	36.9	3.2	3920	2040
			2	--	28.7	28.4	42.9	2.0	36.4	0.6	13.4	4.7	5680	
			3	--	50.2	49.8	--	3.5	63.8	1.1	23.4	8.2	9940	
	6.0	E-32889	1	42.0	23.2	26.1	8.7	6.8	35.0	0.4	48.1	1.0	5690	1970
			2	--	40.0	45.0	15.0	3.6	60.3	0.7	18.6	1.8	9810	
			3	--	47.1	52.9	--	4.3	71.0	0.8	21.8	2.1	11550	
SD-15	2.2	E-32891	1	39.7	23.7	26.2	10.4	6.6	35.9	0.5	45.6	1.0	5880	1960
			2	--	39.2	43.5	17.3	3.7	59.5	0.8	17.0	1.7	9740	
			3	--	47.5	52.5	--	4.4	71.9	0.9	20.7	2.1	11780	

ANALYSIS OF SAMPLES OF THE MENDENHALL BED

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	Volatile matter	Fixed carbon	Ash	ULTIMATE: Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	Softening temperature
SD-15 (cont.)														
	1.25	E-32892	1	38.4	22.0	26.0	13.6	6.3	33.1	0.3	44.0	2.7	5560	1910
			2	--	35.6	42.4	22.0	3.3	53.7	0.5	16.1	4.4	9020	
			3	--	45.7	54.3	--	4.2	68.8	0.7	20.6	5.7	11570	
	5.8	E-32893	1	40.5	23.1	26.4	10.0	6.7	35.1	0.4	46.8	1.0	5760	1970
			2	--	38.8	44.4	16.8	3.6	59.0	0.7	18.2	1.7	9690	
			3	--	46.7	53.3	--	4.4	70.8	0.8	21.9	2.1	11640	
SD-19	5.3	E-12615	1	42.7	22.0	25.3	10.0	6.9	34.0	0.5	46.9	1.7	5790	2010
			2	---	38.3	44.2	17.5	3.8	59.3	0.8	15.6	3.0	10110	
			3	---	46.4	53.6	--	4.7	71.9	1.0	18.8	3.6	12250	
	6.38	E-12616	1	44.9	21.9	25.5	7.7	7.2	34.1	0.4	49.8	0.8	5720	2140
			2	--	39.8	46.1	14.1	4.0	61.8	0.8	17.9	1.4	10380	
			3	--	46.3	53.7	--	4.6	71.9	0.9	21.0	1.6	12070	
SD-23	1.25	E-33310	1	37.4	22.0	26.1	14.5	6.2	33.3	0.4	42.5	3.1	5610	1940
			2	--	35.2	41.7	23.1	3.2	53.2	0.6	14.9	5.0	8960	
			3	--	45.7	54.3	--	4.2	69.1	0.8	19.5	6.4	11650	
	5.5	E-33311	1	42.0	22.8	26.8	8.4	6.9	35.3	0.4	47.8	1.2	5900	2020
			2	--	39.3	46.3	14.4	3.8	60.9	0.7	18.2	2.0	10180	
			3	--	45.9	54.1	--	4.5	71.1	0.8	21.3	2.3	11890	
SD-24	8.3	E-33314	1	29.7	25.3	29.2	15.8	5.7	38.6	0.5	38.3	1.1	6420	2080
			2	--	36.0	41.5	22.5	3.3	54.9	0.6	17.1	1.6	9130	
			3	--	46.4	53.6	--	4.3	70.8	0.8	22.1	2.0	11780	

ANALYSES OF SAMPLES OF THE MENDENHALL BED

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	PROXIMATE: Volatile matter	PROXIMATE: Fixed carbon	PROXIMATE: Ash	ULTIMATE: Hydrogen	ULTIMATE: Carbon	ULTIMATE: Nitrogen	ULTIMATE: Oxygen	ULTIMATE: Sulphur	British thermal units	Softening temperature
SD-30	0.3	E-33800	1	21.6	23.8	19.1	35.5	3.6	28.0	0.8	28.3	3.8	4210	1970
			2	--	30.4	24.3	45.3	1.5	35.7	1.1	11.5	4.9	5370	
			3	--	55.6	44.4	--	2.8	65.3	2.0	21.0	8.9	9820	
	13.4	E-33801	1	39.0	23.8	26.5	10.7	6.6	35.3	0.4	45.6	1.4	5870	1990
			2	--	39.0	43.5	17.5	3.7	57.9	0.7	17.9	2.3	9630	
			3	--	47.3	52.7	--	4.5	70.2	0.9	21.6	2.8	11670	
SD-35	8.95	E-33297	1	39.3	22.5	25.0	13.2	6.4	32.3	0.5	46.0	1.6	5330	2040
			2	--	37.0	41.3	21.7	3.3	53.1	0.8	18.4	2.7	8770	
			3	--	47.2	52.8	--	4.3	67.8	1.0	23.5	3.4	11200	
SD-36	2.2	E-33810	1	32.7	23.5	25.6	18.2	5.5	31.6	0.4	39.7	4.6	5250	1940
			2	--	34.8	38.1	27.1	2.8	47.0	0.5	15.8	6.8	7800	
			3	--	47.8	52.2	--	3.8	64.4	0.7	21.8	9.3	10690	
USGS-2	9.5	D-68851	1	37.8	24.2	27.8	10.2	--	--	--	--	1.6	6150	2060
			2	--	39.0	44.7	16.3	--	--	--	--	2.6	9880	
			3	--	46.6	53.4	--	--	--	--	--	3.1	11800	
USGS-3	6.2	D-68853	1	40.8	24.0	27.4	7.8	--	--	--	--	1.1	6260	2070
			2	--	40.5	46.4	13.1	--	--	--	--	1.8	10570	
			3	--	46.7	53.3	--	--	--	--	--	2.1	12160	
	7.8	D-68854	1	40.3	24.7	26.2	8.8	--	--	--	--	1.6	6030	2080
			2	--	41.4	43.9	14.7	--	--	--	--	2.6	10100	
			3	--	48.5	51.5	--	--	--	--	--	3.1	11840	

ANALYSES OF SAMPLES OF THE MENDENHALL AREA

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE Moisture	Volatile matter	Fixed carbon	Ash	ULTIMATE Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	Softening temperature
USGS-4	5.4	D-68864	1	42.4	24.7	24.5	8.4	--	--	--	--	1.3	5800	2150
			2	--	42.9	42.5	14.6	--	--	--	--	2.2	10060	
			3	--	50.3	49.7	--	--	--	--	--	2.6	11780	
	3.5	D-68863	1	42.4	22.9	26.2	8.5	--	--	--	--	1.4	5780	2080
			2	--	39.7	45.5	14.8	--	--	--	--	2.4	10020	
			3	--	46.5	53.5	--	--	--	--	--	2.8	11760	
	1.7	D-68862	1	41.5	24.2	27.0	7.3	--	--	--	--	0.7	6140	2180
			2	--	41.4	46.1	12.5	--	--	--	--	1.3	10480	
			3	--	47.3	52.7	--	--	--	--	--	1.4	11980	
USGS-17	0.8	D-73496	1	40.9	20.5	25.6	13.0	--	--	--	--	--	--	2130
			2	--	34.7	43.3	22.0	--	--	--	--	--	--	
			3	--	44.5	55.5	--	--	--	--	--	--	--	
	1.0	D-73497	1	43.0	21.3	27.3	8.4	--	--	--	--	--	--	2100
			2	--	37.4	47.9	14.7	--	--	--	--	--	--	
			3	--	43.8	56.2	--	--	--	--	--	--	--	
	6.1	D-73498	1	43.5	22.2	26.7	7.6	--	--	--	--	1.1	5890	2130
			2	--	39.2	47.3	13.5	--	--	--	--	2.1	10420	
			3	--	45.4	54.6	--	--	--	--	--	2.4	12050	
USGS-18	4.6	D-73909	1	43.2	21.7	24.5	10.6	6.9	33.6	0.4	47.2	1.3	5570	2050
			2	--	38.2	43.1	18.7	3.7	59.0	0.8	15.5	2.3	9800	
			3	--	47.0	53.0	--	4.6	72.7	1.0	18.8	2.9	12060	

ANALYSES OF SAMPLES OF THE MENDENHALL AREA

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	PROXIMATE: Volatile matter	PROXIMATE: Fixed carbon	PROXIMATE: Ash	ULTIMATE: Hydrogen	ULTIMATE: Carbon	ULTIMATE: Nitrogen	ULTIMATE: Oxygen	ULTIMATE: Sulphur	British thermal units	Softening temperature
USGS-18 (cont.)														
	4.4	D-73910	1	44.8	21.9	25.3	8.0	--	--	--	--	1.4	5710	2050
			2	--	39.6	45.9	14.5	--	--	--	--	2.6	10330	
			3	--	46.3	53.7	--	--	--	--	--	3.0	12080	
	0.8	D-73911	1	46.1	21.3	24.7	7.9	--	--	--	--	--	--	--
			2	--	39.6	45.7	14.7	--	--	--	--	--	--	
			3	--	46.4	53.6	--	--	--	--	--	--	--	

ANALYSES OF SAMPLES OF THE OLESRUD BED (UPPER BENCH)

Hole no.	Thickness	Lab. no.	Condition 1/	PROXIMATE: Moisture	Volatile matter	Fixed carbon	Ash	ULTIMATE: Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	Softening temperature
SD-1	4.60	E-32383	1	30.1	27.5	33.3	9.1	6.0	43.5	0.5	39.8	1.1	7230	2140
			2	--	39.3	47.6	13.1	3.8	62.3	0.7	18.5	1.6	10350	
			3	--	45.2	54.8	--	4.4	71.6	0.8	21.4	1.8	11910	
	4.05	E-32384	1	31.8	26.4	31.9	9.9	6.1	40.7	0.5	41.8	1.0	6770	2140
			2	--	38.8	46.7	14.5	3.8	59.7	0.7	19.8	1.5	9920	
			3	--	45.3	54.7	--	4.4	69.8	0.8	23.3	1.7	11610	
SD-2	3.55	E-32389	1	25.1	26.0	31.4	17.5	5.3	41.0	0.5	34.3	1.4	6760	2150
			2	--	34.7	41.9	23.4	3.4	54.8	0.7	15.8	1.9	9020	
			3	--	45.3	54.7	--	4.4	71.5	0.9	20.7	2.5	11780	
	3.3	E-32390	1	27.4	24.5	27.4	20.7	5.3	35.3	0.4	37.0	1.3	5840	2210
			2	--	33.8	37.7	28.5	3.1	48.7	0.6	17.3	1.8	8050	
			3	--	47.3	52.7	--	4.3	68.1	0.8	24.2	2.6	11260	
SD-3	5.95	E-32394	1	31.3	26.4	30.3	12.0	5.9	39.0	0.5	41.1	1.5	6440	2100
			2	--	38.4	44.1	17.5	3.6	56.8	0.7	19.2	2.2	9380	
			3	--	46.6	53.4	--	4.3	68.9	0.8	23.3	2.7	11370	
SD-3A	2.65	E-32398	1	36.9	24.9	30.9	7.3	6.4	39.6	0.5	45.3	0.9	6440	2150
			2	--	39.5	48.9	11.6	3.7	62.8	0.7	19.8	1.4	10210	
			3	--	44.6	55.4	--	4.2	71.0	0.8	22.4	1.6	11550	

1/ 1 = as received; 2 = moisture free; 3 = moisture and ash free.

ANALYSES OF SAMPLES OF THE OLESRUD BED (UPPER BENCH)

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	Volatile matter	Fixed carbon	Ash	ULTIMATE: Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	Softening temperature
SD-3A (cont.)														
	3.8	E-32399	1	38.1	26.2	29.0	6.7	6.6	38.7	0.5	46.5	1.0	6370	2420
			2	--	42.4	46.8	10.8	3.9	62.5	0.7	20.5	1.6	10280	
			3	--	47.5	52.5	--	4.4	70.0	0.8	23.0	1.8	11520	
SD-4	7.5	E-32403	1	32.1	26.9	30.7	10.3	6.1	40.1	0.5	41.7	1.3	6670	2100
			2	--	39.6	45.2	15.2	3.7	59.0	0.7	19.5	1.9	9810	
			3	--	46.6	53.4	--	4.4	69.6	0.8	23.0	2.2	11570	
SD-6	5.9	E-32872	1	36.0	20.8	23.1	20.1	6.0	30.0	0.4	41.8	1.7	5010	2140
			2	--	32.4	36.3	31.3	3.1	46.9	0.6	15.5	2.6	7820	
			3	--	47.2	52.8	--	4.5	68.3	0.8	22.6	3.8	11380	
SD-7	5.65	E-32875	1	38.3	24.5	28.2	9.0	6.6	37.3	0.4	45.7	1.0	6180	2210
			2	--	39.7	45.7	14.6	3.8	60.5	0.7	18.8	1.6	10020	
			3	--	46.4	53.6	--	4.4	70.8	0.8	22.1	1.9	11730	
SD-7B	5.6	E-32881	1	40.1	23.9	26.1	9.9	6.8	35.0	0.5	46.4	1.4	5830	2040
			2	--	39.9	43.5	16.6	3.8	58.4	0.8	18.0	2.4	9730	
			3	--	47.8	52.2	--	4.6	70.0	0.9	21.7	2.8	11660	
SD-8	5.34	E-19300	1	44.1	23.1	26.6	6.2	7.3	35.5	0.4	49.6	1.0	5920	2190
			2	--	41.2	47.7	11.1	4.2	63.4	0.8	18.7	1.8	10580	
			3	--	46.4	53.6	--	4.7	71.3	0.9	21.0	2.1	11900	
SD-9A	0.7	E-32885	1	19.2	17.6	10.0	53.2	3.3	15.5	0.3	27.6	0.1	---	2700
			2	--	21.7	12.5	65.8	1.4	19.2	0.4	13.1	0.1	---	
			3	--	--	--	--	--	--	--	--	--	---	

ANALYSES OF SAMPLES OF THE OLESRUD BED (UPPER BENCH)

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	PROXIMATE: Volatile matter	PROXIMATE: Fixed carbon	PROXIMATE: Ash	ULTIMATE: Hydrogen	ULTIMATE: Carbon	ULTIMATE: Nitrogen	ULTIMATE: Oxygen	ULTIMATE: Sulphur	British thermal units	Softening temperature
SD-9A (cont.)														
	0.4	E-323886	1	12.4	14.5	10.9	62.2	2.7	15.9	0.2	18.6	0.4	---	2520
			2	--	16.6	12.4	71.0	1.5	18.1	0.3	8.6	0.5	---	
			3	--	--	--	--	--	--	--	--	--	---	
	3.65	E-32887	1	36.2	23.9	28.0	11.9	6.2	36.9	0.4	42.4	2.2	6060	2040
			2	--	37.5	43.9	18.6	3.3	57.9	0.7	16.1	3.4	9510	
			3	--	46.0	54.0	--	4.1	71.2	0.8	19.7	4.2	11680	
SD-10	5.17	E-9832	1	44.2	20.2	25.7	9.9	7.0	32.8	0.4	49.3	0.6	5470	2020
			2	--	36.3	46.0	17.7	3.7	58.8	0.7	18.1	1.0	9790	
			3	--	44.1	55.9	--	4.5	71.4	0.8	22.1	1.2	11890	
SD-14	9.2	E-32890	1	38.7	24.3	27.0	10.0	6.5	36.1	0.4	45.4	1.6	5950	2040
			2	--	39.7	44.0	16.3	3.6	58.9	0.7	17.8	2.7	9710	
			3	--	47.5	52.5	--	4.3	70.3	0.8	21.4	3.2	11600	
SD-15	8.5	E-32894	1	39.9	22.6	24.8	12.7	6.6	32.7	0.4	46.5	1.1	5390	2070
			2	--	37.6	41.2	21.2	3.5	54.5	0.6	18.3	1.9	8970	
			3	--	47.7	52.3	--	4.5	69.1	0.8	23.2	2.4	11380	
SD-18	0.6	E-33304	1	29.9	17.9	9.6	42.6	4.4	17.0	0.5	35.3	0.2	---	2150
			2	--	25.5	13.8	60.7	1.5	24.2	0.7	12.6	0.3	---	
			3	--	--	--	--	-	--	--	--	--	---	
SD-19	7.8	E-12617	1	45.5	21.5	26.5	6.5	7.2	34.7	0.4	50.5	0.7	5820	2180
			2	--	39.4	48.7	11.9	4.0	63.6	0.8	18.4	1.3	10660	
			3	--	44.7	55.3	--	4.5	72.2	0.9	20.9	1.5	12100	

ANALYSES OF SAMPLES OF THE OLESRUD BED (UPPER BENCH)

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	PROXIMATE: Volatile matter	PROXIMATE: Fixed carbon	PROXIMATE: Ash	ULTIMATE: Hydrogen	ULTIMATE: Carbon	ULTIMATE: Nitrogen	ULTIMATE: Oxygen	ULTIMATE: Sulphur	British thermal units	Softening temperature
SD-21	0.5	E-33307	1	21.7	23.3	14.7	40.3	3.6	24.3	0.5	29.8	1.5	3200	2280
			2	--	29.8	18.7	51.5	1.5	31.0	0.7	13.4	1.9	4090	
			3	--	61.5	38.5	--	3.0	64.0	1.3	27.9	3.8	8440	
	0.95	E-33308	1	33.1	24.0	25.5	17.4	5.4	33.2	0.5	40.5	3.0	5300	1930
			2	--	35.8	38.1	26.1	2.6	49.7	0.8	16.3	4.5	7920	
			3	--	48.5	51.5	--	3.5	67.2	1.1	22.1	6.1	10720	
SD-26	5.2	E-33315	1	38.5	24.1	27.6	9.8	6.5	36.7	0.5	45.8	0.7	6110	2130
			2	--	39.2	44.9	15.9	3.7	59.8	0.8	18.7	1.1	9950	
			3	--	46.6	53.4	--	4.4	71.1	1.0	22.1	1.4	11830	
	4.0	E-33316	1	35.1	21.5	21.9	21.5	6.0	29.8	0.4	41.4	0.9	5010	2160
			2	--	33.1	33.8	33.1	3.2	45.9	0.6	15.7	1.5	7730	
			3	--	49.4	50.6	--	4.8	68.6	0.9	23.5	2.2	11560	
SD-27	3.35	E-33792	1	35.8	23.7	25.5	15.0	6.2	34.0	0.4	43.6	0.8	5590	2100
			2	--	36.9	39.8	23.3	3.5	52.9	0.7	18.4	1.2	8720	
			3	--	48.1	51.9	--	4.6	69.0	0.9	23.9	1.6	11370	
SD-28	4.6	E-33796	1	36.9	22.3	24.4	16.4	6.2	31.1	0.4	44.3	1.6	5310	2080
			2	--	35.3	38.6	26.1	3.3	49.3	0.6	18.2	2.5	8420	
			3	--	47.8	52.2	--	4.5	66.6	0.8	24.8	3.3	11380	
SD-29	6.4	E-33798	1	35.1	25.1	29.6	10.2	6.4	39.2	0.5	43.1	0.6	6480	2090
			2	--	38.7	45.6	15.7	3.8	60.3	0.7	18.5	1.0	9980	
			3	--	45.9	54.1	--	4.5	71.6	0.8	21.9	1.2	11840	

ANALYSES OF SAMPLES OF THE OLESRUD BED (UPPER BENCH)

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	Volatile matter	Fixed carbon	Ash	ULTIMATE: Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	Softening temperature
SD-30	13.4	E-33801	1	39.0	23.8	26.5	10.7	6.6	35.3	0.4	45.6	1.4	5870	1990
			2	--	39.0	43.5	17.5	3.7	57.9	0.7	17.9	2.3	9630	
			3	--	47.3	52.7	--	4.5	70.2	0.9	21.6	2.8	11670	
SD-32	2.0	E-33804	1	34.0	23.0	24.6	18.4	5.7	32.8	0.6	41.4	1.1	5200	2300
			2	--	34.9	37.3	27.8	2.9	49.7	0.9	17.0	1.7	7880	
			3	--	48.3	51.7	--	4.0	68.9	1.2	23.6	2.3	10910	
	3.0	E-33805	1	37.7	24.4	27.0	10.9	6.5	36.3	0.4	44.3	1.6	6030	2000
			2	--	39.1	43.4	17.5	3.7	58.2	0.7	17.4	2.5	9680	
			3	--	47.4	52.6	--	4.5	70.5	0.8	21.1	3.1	11730	
SD-33	4.6	E-33808	1	34.6	24.0	25.4	16.0	6.0	33.9	0.5	42.5	1.1	5430	2030
			2	--	36.7	38.8	24.5	3.2	51.8	0.8	18.0	1.7	8300	
			3	--	48.6	51.4	--	4.3	68.6	1.0	23.9	2.2	10990	
SD-36	6.85	E-33811	1	38.7	24.4	29.2	7.7	6.6	38.4	0.5	46.0	0.8	6290	2100
			2	--	39.7	47.8	12.5	3.8	62.7	0.7	19.0	1.3	10260	
			3	--	45.4	54.6	--	4.3	71.6	0.9	21.7	1.5	11730	
SD-38	6.1	E-33813	1	37.0	25.2	28.1	9.7	6.4	38.1	0.5	44.3	1.0	6230	2060
			2	--	39.9	44.8	15.3	3.5	60.5	0.8	18.3	1.6	9890	
			3	--	47.2	52.8	--	4.2	71.4	0.9	21.6	1.9	11680	
USGS-1	1.7	D-68847	1	29.2	29.1	34.4	7.3	-	--	-	--	1.2	7560	2420
			2	--	41.1	48.7	10.2	-	--	-	--	1.6	10680	
			3	--	45.8	54.2	--	-	--	-	--	1.8	11900	

ANALYSES OF SAMPLES OF THE OLESRUD BED (UPPER BENCH)

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	PROXIMATE: Volatile matter	PROXIMATE: Fixed carbon	PROXIMATE: Ash	ULTIMATE: Hydrogen	ULTIMATE: Carbon	ULTIMATE: Nitrogen	ULTIMATE: Oxygen	ULTIMATE: Sulphur	British thermal units	Softening temperature
USGS-2	6.1	D-68850	1	36.0	26.1	27.5	10.4	-	--	-	--	1.3	6370	2150
			2	--	40.8	42.9	16.3	-	--	-	--	2.1	9960	
			3	--	48.7	51.3	--	-	--	-	--	2.5	11890	
USGS-3	7.9	D-68855	1	38.2	26.0	25.2	10.6	-	--	-	--	1.4	6040	2080
			2	--	42.0	40.9	17.1	-	--	-	--	2.2	9760	
			3	--	50.7	49.3	--	-	--	-	--	2.7	11790	
USGS-17	2.7	D-73499	1	43.4	21.0	25.7	9.9	-	--	-	--	-	---	2150
			2	--	37.1	45.5	17.4	-	--	-	--	-	---	
			3	--	45.0	55.0	--	-	--	-	--	-	---	
USGS-18	4.5	D-73912	1	44.8	21.9	25.7	7.6	7.2	34.2	0.4	49.7	0.9	5690	2130
			2	--	39.7	46.5	13.8	4.0	61.9	0.8	17.9	1.6	10310	
			3	--	46.0	54.0	--	4.7	71.8	0.9	20.8	1.8	11950	

ANALYSES OF SAMPLES OF THE OLESRUD BED (LOWER BENCH)

Hole no.	Thickness	Lab. no.	Condition 1/	PROXIMATE: Moisture	Volatile matter	Fixed carbon	Ash	ULTIMATE: Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	Softening temperature
SD-1	6.15	E-32385	1	34.2	24.9	28.9	12.0	6.2	37.1	0.5	42.9	1.3	6220	2050
			2	--	37.9	43.9	18.2	3.7	56.4	0.7	19.0	2.0	9460	
			3	--	46.4	53.6	--	4.5	68.9	0.9	23.3	2.4	11570	
SD-2	4.0	E-32391	1	29.3	26.0	28.9	15.8	5.7	36.9	0.5	38.6	2.5	6190	2080
			2	--	36.7	40.9	22.4	3.4	52.2	0.6	17.9	3.5	8750	
			3	--	47.3	52.7	--	4.4	67.3	0.8	22.9	4.6	11270	
SD-3	7.35	E-32395	1	34.0	25.3	27.8	12.9	6.1	36.5	0.5	41.7	2.3	6110	2000
			2	--	38.4	42.1	19.5	3.6	55.3	0.8	17.4	3.4	9250	
			3	--	47.6	52.4	--	4.4	68.7	0.9	21.8	4.2	11490	
SD-3A	5.15	E-32400	1	35.7	25.0	29.0	10.3	6.4	37.8	0.4	43.8	1.3	6290	2060
			2	--	39.0	44.9	16.1	3.7	58.8	0.7	18.7	2.0	9790	
			3	--	46.4	53.6	--	4.4	70.0	0.8	22.4	2.4	11660	
SD-4	7.1	E-32404	1	28.6	27.6	30.8	13.0	5.7	40.6	0.5	38.8	1.4	6740	2130
			2	--	38.7	43.1	18.2	3.6	56.9	0.7	18.5	2.0	9440	
			3	--	47.3	52.7	--	4.4	69.6	0.8	22.8	2.4	11540	
SD-6	9.7	E-32873	1	39.8	23.1	26.6	10.5	6.7	35.0	0.4	46.3	1.1	5850	2080
			2	--	38.4	44.1	17.5	3.8	58.2	0.6	18.0	1.9	9710	
			3	--	46.6	53.4	--	4.6	70.5	0.8	21.8	2.3	11770	
SD-7	5.1	E-32876	1	37.9	24.6	26.8	10.7	6.6	35.4	0.4	45.0	1.9	6020	1980
			2	--	39.6	43.2	17.2	3.9	57.0	0.6	18.3	3.0	9700	
			3	--	47.9	52.1	--	4.7	68.8	0.8	22.1	3.6	11710	

1/ 1 = as received; 2 = moisture free; 3 = moisture and ash free.

ANALYSES OF SAMPLES OF THE OLESRUD BED (LOWER BENCH)

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE Moisture	Volatile matter	Fixed carbon	Ash	ULTIMATE Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	Softening temperature
SD-7B	6.8	E-32882	1	40.1	23.7	26.1	10.1	6.9	35.1	0.4	46.3	1.2	5860	2080
			2	--	39.5	43.6	16.9	4.0	58.6	0.7	17.7	2.1	9790	
			3	--	47.6	52.4	--	4.8	70.5	0.8	21.4	2.5	11780	
SD-8	5.46	E-19301	1	43.4	23.1	25.4	8.1	7.2	34.9	0.5	48.4	0.9	5900	2210
			2	--	40.9	44.7	14.4	4.3	61.7	0.8	17.1	1.7	10431	
			3	--	47.8	52.2	--	5.0	72.1	1.0	20.0	1.9	12180	
SD-10	5.5	E-9833	1	43.9	21.6	25.5	9.0	7.1	33.4	0.4	49.3	0.8	5640	2020
			2	--	38.4	45.5	16.1	3.9	59.5	0.8	18.2	1.5	10050	
			3	--	45.8	54.2	--	4.6	70.9	0.9	21.8	1.8	11970	
SD-14	9.2	E-32390	1	38.7	24.3	27.0	10.0	6.5	36.1	0.4	45.4	1.6	5950	2040
			2	--	39.7	44.0	16.3	3.6	58.9	0.7	17.8	2.7	9710	
			3	--	47.5	52.5	--	4.3	70.3	0.8	21.4	3.2	11600	
SD-15	6.65	E-32895	1	39.7	21.4	24.6	14.3	6.4	31.9	0.4	45.6	1.4	5290	2070
			2	--	35.5	40.8	23.7	3.4	52.9	0.6	17.0	2.4	8770	
			3	--	46.4	53.6	--	4.4	69.4	0.8	22.3	3.1	11490	
SD-16	5.5	E-33301	1	38.0	22.0	24.1	15.9	6.3	31.2	0.4	44.5	1.7	5250	2130
			2	--	35.5	38.8	25.7	3.3	50.3	0.6	17.4	2.7	8470	
			3	--	47.7	52.3	--	4.5	67.6	0.8	23.5	3.6	11400	
SD-18	2.35	E-33305	1	37.1	22.9	24.3	15.7	6.4	32.6	0.4	43.2	1.7	5460	2110
			2	--	36.4	38.6	25.0	3.5	51.8	0.6	16.3	2.8	8680	
			3	--	48.6	51.4	--	4.7	69.1	0.8	21.7	3.7	11570	

ANALYSES OF SAMPLES OF THE OLESRUD BED (LOWER BENCH)

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	Volatile matter	Fixed carbon	Ash	ULTIMATE: Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	Softening temperature
SD-18 (cont.)														
	1.9	E-33306	1	26.4	17.1	14.9	41.6	4.6	20.8	0.3	30.9	1.8	--	2310
			2	--	23.2	20.3	56.5	2.3	28.3	0.3	10.1	2.5	--	
			3	--	--	--	--	--	--	-	--	-	--	
SD-19	5.46	E-13500	1	44.2	22.2	25.5	8.1	7.2	33.8	0.4	49.6	0.9	5790	2130
			2	--	39.8	45.7	14.5	4.1	60.7	0.8	18.2	1.7	10370	
			3	--	46.6	53.4	--	4.8	71.0	0.9	21.3	2.0	12140	
SD-21	3.95	E-33309	1	35.7	22.9	24.2	17.2	6.2	32.0	0.4	43.0	1.2	5380	2180
			2	--	35.6	37.7	26.7	3.4	49.8	0.7	17.6	1.8	8360	
			3	--	48.6	51.4	--	4.7	67.9	0.9	24.0	2.5	11410	
SD-26	3.6	E-33317	1	36.5	21.5	22.7	19.3	6.2	30.4	0.4	42.5	1.2	5130	2180
			2	--	33.8	35.9	30.3	3.3	47.8	0.6	16.0	2.0	8070	
			3	--	48.6	51.4	--	4.7	68.7	0.8	23.0	2.8	11590	
SD-27	3.1	E-33794	1	34.4	21.6	22.2	21.8	5.8	28.7	0.4	41.5	1.8	4870	2130
			2	--	32.9	33.8	33.3	3.0	43.7	0.6	16.6	2.8	7420	
			3	--	49.3	50.7	--	4.5	65.4	0.9	25.0	4.2	11120	
SD-28	3.9	E-33797	1	35.1	23.4	25.9	15.6	6.0	36.0	0.4	40.6	1.4	5750	1990
			2	--	36.0	39.9	24.1	3.3	55.4	0.6	14.4	2.2	8850	
			3	--	47.4	52.6	--	4.3	73.0	0.8	19.0	2.9	116500	
SD-29	2.9	E-33799	1	39.7	22.8	25.6	11.9	6.6	33.5	0.4	46.1	1.5	5620	1980
			2	--	37.9	42.4	19.7	3.6	55.7	0.6	17.9	2.5	9320	
			3	--	47.2	52.8	--	4.5	69.3	0.8	22.3	3.1	11610	

ANALYSES OF SAMPLES OF THE OLESRUD BED (LOWER BENCH)

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE Moisture	Volatile matter	Fixed carbon	Ash	ULTIMATE Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	Softening temperature
SD-30	4.3	E-33802	1	36.5	23.2	24.7	15.6	6.2	32.7	0.4	43.5	1.6	5470	2120
			2	--	36.6	38.9	24.5	3.4	51.4	0.6	17.6	2.5	8610	
			3	--	48.5	51.5	--	4.5	68.2	0.8	23.1	3.4	11410	
SD-31	4.45	E-33803	1	36.8	24.0	26.1	13.1	6.4	34.4	0.4	44.0	1.7	5800	2060
			2	--	37.9	41.4	20.7	3.7	54.4	0.6	17.9	2.7	9190	
			3	--	47.8	52.2	--	4.6	68.6	0.7	22.7	3.4	11580	
SD-32	4.4	E-33806	1	39.2	23.1	25.2	12.5	6.5	33.4	0.4	45.3	1.9	5610	1940
			2	--	38.0	41.4	20.6	3.5	55.0	0.6	17.2	3.1	9230	
			3	--	47.8	52.2	--	4.4	69.3	0.8	21.6	3.9	11640	
SD-33	3.25	E-33809	1	28.2	23.8	23.3	24.7	5.2	30.2	0.4	36.1	3.4	5110	2010
			2	--	33.2	32.4	34.4	2.9	42.0	0.6	15.3	4.8	7120	
			3	--	50.6	49.4	--	4.5	64.1	0.8	23.3	7.3	10850	
SD-35	2.25	E-33298	1	39.6	22.4	27.9	10.1	6.5	35.9	0.4	46.5	0.6	5920	2130
			2	--	37.1	46.2	16.7	3.5	59.5	0.7	18.6	1.0	9790	
			3	--	44.6	55.4	--	4.3	71.4	0.8	22.3	1.2	11760	
SD-36	3.8	E-33812	1	35.8	22.0	23.4	18.8	6.1	30.9	0.3	42.4	1.5	5170	2170
			2	--	34.3	36.4	29.3	3.3	48.2	0.5	16.4	2.3	8060	
			3	--	48.6	51.4	--	4.7	68.2	0.7	23.2	3.2	11410	
SD-38	3.7	E-33814	1	32.9	23.1	24.6	19.4	6.2	31.3	0.4	39.5	3.2	5270	2020
			2	--	34.5	36.6	28.9	3.7	46.7	0.6	15.3	4.8	7860	
			3	--	48.5	51.5	--	5.3	65.6	0.8	21.5	6.8	11040	

ANALYSES OF SAMPLES OF THE OLESRUD BED (LOWER BENCH)

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE				ULTIMATE						Softening temperature
				Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	
USGS-3	5.3	D-68856	1	40.8	22.6	26.8	9.8	--	--	--	--	1.2	5940	2070
			2	--	38.3	45.2	16.5	--	--	--	--	2.1	10030	
			3	--	45.8	54.2	--	--	--	--	--	2.5	12020	

ANALYSES OF SAMPLES OF THE "Y" BED

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE				ULTIMATE						Softening temperature
				Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	
SD-1	1.7	E-32386	1	39.7	24.6	28.2	7.5	6.8	37.6	0.4	47.0	0.7	6260	2100
			2	--	40.7	46.9	12.4	3.9	62.4	0.7	19.4	1.2	10370	
			3	--	46.5	53.5	--	4.4	71.2	0.8	22.2	1.4	11840	
SD-2	1.05	E-32392	1	22.3	26.5	33.8	17.4	5.2	43.9	0.6	32.1	0.8	7350	2150
			2	--	34.1	43.5	22.4	3.5	56.5	0.8	15.8	1.0	9460	
			3	--	43.9	56.1	--	4.6	72.9	1.0	20.2	1.3	12190	
SD-3	0.95	E-32396	1	22.8	24.2	26.7	26.3	4.9	35.3	0.5	32.3	0.7	5900	2470
			2	--	31.4	34.5	34.1	3.0	45.7	0.7	15.6	0.9	7650	
			3	--	47.7	52.3	--	4.6	69.4	1.0	23.6	1.4	11610	
SD-6	0.9	E-32874	1	37.3	23.7	26.6	12.4	6.6	35.3	0.4	44.4	0.9	5990	2130
			2	--	37.8	42.3	19.9	3.9	56.3	0.6	17.8	1.5	9560	
			3	--	47.2	52.8	--	4.9	70.3	0.7	22.3	1.8	11930	
SD-7	1.1	E-32877	1	36.9	21.9	23.6	17.6	6.3	31.4	0.3	43.5	0.9	5340	2210
			2	--	34.7	37.4	27.9	3.5	49.7	0.5	16.9	1.5	8470	
			3	--	48.2	51.8	--	4.9	69.0	0.7	23.3	2.1	11750	
SD-8	0.5	E-32883	1	28.3	21.5	21.9	28.3	5.2	29.4	0.4	34.2	2.5	5010	2090
			2	--	30.0	30.5	39.5	2.9	41.0	0.5	12.7	3.4	6980	
			3	--	49.7	50.3	--	4.8	67.8	0.9	20.8	5.7	11540	

1/ 1 = as received; 2 = moisture free; 3 = moisture and ash free.

ANALYSES OF SAMPLES OF THE "Y" BED

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE				ULTIMATE						British thermal unit	Softening temperature
				Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur			
SD-15	0.95	E-32896	1	37.3	22.4	25.6	14.7	6.2	32.5	0.4	43.0	3.2		5490	1970
			2	--	35.7	40.9	23.4	3.3	51.7	0.7	15.8	5.1		8760	
			3	--	46.6	53.4	--	4.3	67.5	0.9	20.7	6.6		11430	
SD-16	1.0	E-33302	1	30.4	27.8	30.1	11.7	6.1	40.3	0.5	38.8	2.6		6810	2010
			2	--	39.9	43.2	16.9	3.9	57.9	0.7	16.8	3.8		9780	
			3	--	48.0	52.0	--	4.7	69.6	0.9	20.2	4.6		11760	
SD-27	3.75	E-33795	1	34.0	19.3	20.0	26.7	5.6	26.8	0.4	39.5	1.0		4530	2190
			2	--	29.3	30.2	40.5	2.8	40.6	0.6	14.1	1.4		6860	
			3	--	49.2	50.8	--	4.7	68.3	0.9	23.7	2.4		11530	
SD-35	1.3	E-33299	1	37.1	22.1	24.4	16.4	6.3	32.1	0.4	43.6	1.2		5380	2110
			2	--	35.1	38.9	26.0	3.5	51.1	0.6	16.9	1.9		8550	
			3	--	47.4	52.6	--	4.7	69.0	0.9	22.9	2.5		11560	
USGS-3	1.0	D-68857	1	39.1	25.1	25.7	10.1	-	--	-	--	1.5		6100	2050
			2	--	41.2	42.2	16.6	-	--	-	--	2.4		10020	
			3	--	49.4	50.6	--	-	--	-	--	2.9		12020	

ANALYSES OF SAMPLES OF THE "Z" BED

Hole no.	Thickness	Lab. no.	Location 1/	PROXIMATE				ULTIMATE						Softening temperature
				Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	British thermal units	
SD-2	1.5	E-32393	1	31.3	28.2	31.5	9.0	6.2	42.3	0.5	40.4	1.6	7080	2070
			2	--	41.0	45.9	13.1	4.0	61.5	0.8	18.3	2.3	10310	
			3	--	47.2	52.8	--	4.5	70.8	0.9	21.2	2.6	11850	
SD-3	2.1	E-32397	1	30.3	25.9	30.9	12.9	5.7	39.2	0.5	38.0	3.7	6600	2030
			2	--	37.2	44.3	18.5	3.4	56.2	0.7	15.9	5.3	9460	
			3	--	45.6	54.4	--	4.2	68.9	0.9	19.5	6.5	11600	
SD-4	2.3	E-32405	1	28.4	26.5	29.8	15.3	5.7	39.6	0.5	37.4	1.5	6650	2050
			2	--	37.0	41.7	21.3	3.6	55.3	0.7	17.0	2.1	9280	
			3	--	47.0	53.0	--	4.5	70.3	0.9	21.6	2.7	11800	
SD-7	2.2	E-32878	1	39.2	22.2	28.2	10.4	6.6	36.7	0.5	45.2	0.6	5980	2100
			2	--	36.5	46.4	17.1	3.6	60.4	0.8	17.1	1.1	9840	
			3	--	44.0	56.0	--	4.4	72.8	0.9	20.6	1.3	11870	
	0.6	E-32879	1	37.8	21.5	21.7	19.0	6.2	28.9	0.4	43.7	1.8	4870	2080
			2	--	34.5	34.9	30.6	3.3	46.5	0.7	16.0	2.9	7830	
			3	--	49.7	50.3	--	4.7	66.9	1.0	23.3	4.1	11280	
SD-8	2.0	E-32884	1	40.8	22.7	26.7	9.8	6.7	36.2	0.5	45.5	1.3	5960	2040
			2	--	38.4	45.1	16.5	3.6	61.1	0.9	15.6	2.3	10070	
			3	--	45.9	54.1	--	4.3	73.2	1.0	18.8	2.7	12060	

1/ 1 = as received; 2 = moisture free; 3 = moisture and ash free.

ANALYSES OF SAMPLES OF THE "Z" BED

Hole no.	Thickness	Lab. no.	Condition	PROXIMATE: Moisture	PROXIMATE: Volatile matter	PROXIMATE: Fixed carbon	PROXIMATE: Ash	ULTIMATE: Hydrogen	ULTIMATE: Carbon	ULTIMATE: Nitrogen	ULTIMATE: Oxygen	ULTIMATE: Sulphur	British thermal units	Softening temperature
SD-15	1.65	E-32897	1	36.7	25.4	29.3	8.6	6.5	39.5	0.5	44.3	0.6	6510	2110
			2	--	40.1	46.3	13.6	3.8	62.5	0.8	18.3	1.0	10280	
			3	--	46.4	53.6	--	4.4	72.3	0.9	21.2	1.2	11890	
SD-16	2.0	E-33303	1	31.4	22.5	23.5	22.6	5.7	31.2	0.4	38.5	1.6	5300	2140
			2	--	32.8	34.2	33.0	3.2	45.4	0.6	15.4	2.4	7720	
			3	--	48.9	51.1	--	4.8	67.8	0.9	23.0	3.5	11530	
SD-19	1.83	E-13501	1	44.9	22.9	26.9	5.3	--	--	--	--	0.6	6180	---
			2	--	41.5	48.9	9.6	--	--	--	--	1.1	11200	
			3	--	45.9	54.1	-	--	--	--	--	1.3	12390	
SD-32	1.7	E-33807	1	34.0	20.1	20.2	25.7	5.6	27.4	0.4	39.6	1.3	4520	2150
			2	--	30.4	30.7	38.9	2.8	41.5	0.5	14.4	1.9	6840	
			3	--	49.7	50.3	--	4.6	67.9	0.9	23.5	3.1	11190	
SD-35	2.0	E-33300	1	38.3	24.7	28.0	9.0	6.6	37.8	0.5	44.8	1.3	6280	2030
			2	--	40.1	45.4	14.5	3.8	61.4	0.8	17.4	2.1	10190	
			3	--	46.9	53.1	--	4.5	71.8	0.9	20.3	2.5	11920	

APPENDIX C

SEMI-QUANTATIVE SPECTROGRAPHIC ANALYSES AND CHEMICAL ANALYSES ON ASH FROM LIGNITE CORES FROM CORE HOLES SD-8, SD-10, AND SD-19, AND U. S. BUREAU OF MINES BULK SAMPLE PITS 1-5, MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA

Spectrographic and chemical analyses by Washington and Denver Trace Elements Laboratories

Spectrographic analysts: Mona Frank
Katherine E. Valentine
C. L. Waring

Chemical analysts: Joseph Budinsky
Alice Caemmerer
Irving May
Thomas Murphy
Alice Padgett
Audrey Smith
Joan Smith

Threshold Values of Elements Included in the Semi-Quantitative Spectrographic Method
Revised June 4, 1951

	Percent		Percent
Ag	0.001	Mg	0.0001
Al	0.0001	Mo	0.001
As	0.1	Mn	0.001
Au	0.01	Na*	0.001 (0.1)
B	0.001	Nd	0.01
Ba	0.0001	Ni	0.001
Be	0.0001	P	0.1
Bi	0.001	Pb	0.01
Ca	0.001	Pr	0.01
Cb	0.01	Pt	0.01
Cd	0.01	Rb	10.0
Ce	0.1	Re	0.1
Co	0.01	Sb	0.001
Cr	0.001	Sc	0.1
Cs	1.0	Si	0.0001
Cu	0.0001	Sm	0.1
Dy	0.01	Sn	0.01
Eu	0.01	Sr	0.01
Er	0.01	Ta	0.1
F	0.1**	Tb	0.1
Fe	0.001	Te	0.1
Ga	0.01	Th	0.1
Gd	0.01	Ti	0.001
Ge	0.001	Tl	0.1
Hf	0.1	Tm	0.01
Hg	0.1	U	0.1
Ho	0.01	V	0.01
In	0.001	W	0.1
K*	0.01 (1.0)	Y	0.001
La	0.01	Yb	0.0001
Li*	0.0001 (0.1)	Zn	0.01
Lu	0.01	Zr	0.001

* A second exposure is required for the high sensitivity test.

** A third exposure is required for the fluorine estimation.

Mendenhall area, Slim Buttes, Harding County, South Dakota
Mendenhall "rider"

Semi-quantitative spectrographic analyses of lignite ash.

A - over 10%; B - 1-10%; C - 0.1-1.0%; D - 0.01-0.1%;
E - 0.001-0.01%; F - 0.0001-0.001%

Core hole	TE sample number	Laboratory number	Thickness of sample (feet)	Percent ash in sample	Al	Si	Fe	Mg	Ca	Na	Ba	Sr	Mn	Ti	B	Cu	Mo	V	Cr	Ni	Pb	Co	Sc	Zr	Ga	Y	Sn	Yb	Be	Ag	Ge	La	Li	K	As	Ce	Eu	Th	Br	P	Uranium in ash (percent)1/
SD-8	1	113893	0.33	84.6	A	A	B	C	B	C	C	D	D	C	D	E	D	E	D		E	D	E	D	E	E		F	F											0.016
	2	113894	0.11	11.3	B	B	A	B	B	B	C	C	D	D	C	D	C	D	D	C	D	C	E	D	E	E	E	F	F	E	D	E				D			.[illegible]
	3	113895	0.33	10.2	B	B	A	B	B	B	C	D	C	D	C	D	C	E	D	D	E		F	D	E	E	E	F	F	F	D								.112
					0.34' lignite not analyzed																																			
	5	113897	0.5	6.8	A	B	B	B	A	B	C	C	C	D	C	D	C	E	E	E	E	D	F	D	E	E	E	F	F	F				E						.118
	6	113898	0.34	4.2	A	B	B	B	A	B	C	C	C	D	C	D	C	E	E	E	E	D	F	D	E	E	E	F	F	F				E						.119
	7	113899	0.29	7.0	A	B	B	B	A	B	C	C	C	D	C	D	C	E	E	E	E	E	F	E	E	E	E	F	F	F		E						C	.114
	8	113900	0.41	12.1	B	B	A	B	B	B	C	D	C	D	C	D	C	E	D	D	E	E	F	D	E	E		F	F											.047
	9	113901	0.4	14.1	B	B	A	B	B	B	C	D	C	D	C	D	D	E	D	D	E	E	F	D	E	E		F	F											.025
	10	113902	0.33	7.4	B	B	B	B	A	B	C	D	C	D	C	D	C	D	D	D	E	D	E	D	D	E	E	F	F	F	D									.122
USBM-3 Pit	14	81803	1.00	7.8	B	B	A	B	B	B	C	C	C	D	D	D	D	C	D	E	D	E	D	D	D	E	D	F	F	E										.11
	15	81804	1.00	14.0	B	B	B	B	B	B	C	C	C	C	C	E	D	C	E	E	D	E	E	F	D	F	E		F	F											.064
	16	81805	0.70	19.3	B	B	A	B	B	B	C	C	C	C	D	E	D	C	E	E	E	E	E	F	E	F	E	F	F	F											.029
	17	81806	1.00	11.7	B	B	B	B	B	B	C	C	C	C	C	D	D	D	E	E	E	E	E	D	E	E	E		F	F											.055
	18	81807	1.00	13.8	B	B	B	B	B	B	C	D	C	C	D	D	D	C	D	E	D	E	E	F	D	E	E		F	F											.073

1/ Uranium content based on results of chemical analyses

Mendenhall area, Slim Buttes, Harding County, South Dakota
Mendenhall bed

Semi-quantitative spectrographic analyses of lignite ash.

A - over 10%; B - 1-10%; C - 0.1-1.0%; D - 0.01-0.1%;
E - 0.001-0.01%; F - 0.0001-0.001%

Core hole	TE sample number	Laboratory number	Thickness of sample (feet)	Percent ash in sample	Al	Si	Fe	Mg	Ca	Na	Ba	Sr	Mn	Ti	B	Cu	Mo	V	Cr	Ni	Pb	Co	Sc	Zr	Ga	Y	Sn	Yb	Be	Ag	Ge	La	Li	K	As	Ce	Nd	Zn	Br	P	Uranium in ash (percent)1/
SD-19	4	111475	0.31	16.0	A	A	B	B	B	B	C	D	C	D	C	D	C	E	D	D	D	C	F	D	E	E	E	F	F	F	D	E								0.13
	5	111476	0.11	16.0	A	A	B	B	B	B	C	D	C	D	C	D	C	E	D	D	E	D	F	D	E	E	E	F	F	F	D	E								.10
	6	111477	0.25	13.7	B	B	A	B	B	A	C	C	C	D	C	E	C	E	D	D	E	D	F	D	E	E	E	F	F		D	E								.081
	7	111478	0.34	11.8	A	B	C	B	A	A	C	C	C	D	C	D	C	E	E	E	E	E	F	D	E	E	E	F	F	F	E	E	E					C		.052
	8	111479	0.33	20.0	B	B	A	B	B	B	C	C	C	D	D	D	C	E	D	D	E			E			E	F	F											.031
	9	111480	0.34	10.2	B	B	C	B	A	A	C	C	C	D	C	E	D	E	E	E	E	E	F	E	E		E		F	F		E	E								.054
	10	111481	0.30	9.2	B	B	B	B	A	A	C	C	C	D	C	D	D	E	D	E	E	E	F	E	E	E	E	F		F	E		E								.11
	11	111482	0.32	9.4	B	B	B	B	A	A	C	C	C	D	C	E	D	E	E	E	E	E	F	E	E	E			F	F			E								.16
	12	111483	0.37	26.2	B	B	A	C	C	B	D	D	D	D	D		D	E	D	D	E	E		E	E			E													.024
	13	111484	0.27	15.1	B	A	B	B	B	B	C	D	C	D	C	D	D	E	D	E	E	E		E	E	E	E	F		F			E								.094
	14	111485	0.29	12.4	B	B	B	B	B	A	C	C	C	D	C	D	D	E	D	D	E	E	F	E	E	E		F	F	F			E								.054
	15	111486	0.18	8.0	B	B	C	B	A	A	C	C	C	D	C	E	D	E	E	E	E	E	F	E	E	E		F		F			E								.074
	16	111487	0.12	11.6	B	B	B	B	B	A	A	C	C	C	D	C	E	D	E	E	E	E	E	E	D	E	E	E	F	F	F		E								.050
	17	111488	0.18	11.0	B	B	B	B	A	A	C	C	C	D	C	D	D	E	D	E	E	E	E	E	E	E		F	F	F			E								.038
	18	111489	0.22	23.8	B	A	C	B	B	B	C	D	D	D	C	E	E	E	E	E	E	E	E	E	E	E	E	F	F				E								.012
	19	111490	0.20	10.9	B	B	C	B	B	A	C	D	C	D	C	D	D	D	D	E	E	E	E	D	E	E	E	F	F	F			E								.049
												1.80 clay																													
	21	111491	0.23	18.7	A	A	B	B	B		C	C	C	D	C	D	E	E	D	E	D	E	E	E	E	E		F	F	F		E	D								.022
												0.63 loss in coring																													
	22	111492	0.36	7.9	B	B	C	B	A	A	C	C	D	D	C	D	D	E	D	E	E	D	E	E	E	E	E	F	F	F	E	E	E								.060
	23	111493	0.21	9.1	B	B	C	B	A	A	C	C	C	D	C	E	D	E	E	E		E	E	E	E	E		F	F	F			E								.029

Mendenhall area, Slim Buttes, Harding County, South Dakota
Mendenhall bed

Semi-quantitative spectrographic analyses of lignite ash.
A = over 10%; B = 1-10%; C = 0.1-1.0%; D = 0.01-0.1%;
E = 0.001-0.01%; F = 0.0001-0.001%

Sample pit	TE sample number	Laboratory number	Thickness of sample (feet)	Percent ash in sample	Al	Si	Fe	Mg	Ca	Na	Ba	Sr	Mn	Ti	B	Cu	Mo	V	Cr	Ni	Pb	Co	Sc	Zr	Ga	Y	Sn	Yb	Be	Ag	Ge	La	Li	K	As	Ce	Nd	Zn	Br	P	Uranium in ash (percent)1/
USBM-1	8	81797	0.60	36.7	B	A	A	C	B	C	C	C	D	C	D	D	D	E	E	D	E	E	E	D	F	E	F	F	F			E		D	D	D	E			0.16
					0.60 clay parting																																			
	9	81798	1.25	24.1	B	A	A	C	B	C	C	C	D	C	D	D	B	D	E	E	E	E	F	D	F	E	F	F	F		E									.039
	10	81799	1.00	19.0	B	B	A	B	B	B	C	C	D	D	D	E	C	E	E	E		E	E	E	F	E	F	F	F					D							.044
	11	81800	1.00	32.6	B	B	A	C	B	C	C	C	D	C	D	E	D	E	E	E		E	F	E	F	F	F	F						D							.028
	12	81801	1.00	16.5	B	B	A	C	B	B	C	C	D	C	D	D	D	E	E	E		E	F	D	F	E	F	F	F					D							.039
USBM-2	5	81794	1.50	26.5	B	B	A	C	B	B	C	D	D	C	E	D	C	E	E	E	E	E	E	E	F	E	F	F	F			E		C							.071
					0.50 clay parting																																			
	6	81795	1.30	20.4	B	B	A	C	B	C	C	C	D	D	D	E	D	D	E	E	E	E	E	E	E	F	E		F	F		E									.038
					0.80 clay parting																																			
	7	81796	1.50	16.5	B	B	A	B	B	B	C	C	D	D	D	E	D	E	E	E	E	E	E	E		F			F												.032

Mendenhall area, Slim Buttes, Harding County, South Dakota
Olesrud bed (Upper bench)

Semi-quantitative spectrographic analyses of lignite ash.
A = over 10%; B = 1-10%; C = 0.1-1.0%; D = 0.01-0.1%;
E = 0.001-0.01%; F = 0.0001-0.001%

Core hole	TE sample number	Laboratory number	Thickness of sample (feet)	Percent ash in sample	Al	Si	Fe	Mg	Ca	Na	Ba	Sr	Mn	Ti	B	Cu	Mo	V	Cr	Ni	Pb	Co	Sc	Zr	Ga	Y	Sn	Yb	Be	Ag	Ge	La	Li	K	As	Ce	Nd	Zn	Br	P	Uranium in ash (percent)1/
SD-10	5	109497	0.36	56.9	A	A	B	C	B	B	C	D	D	C	D	D	E	E	E	D	D	D	E	D	E	E	E	F	E											.004
					1.10 clay parting																																				
	9	109498	0.51	9.5	A	A	B	C	B	B	C		D	D	C	D	D	E	E	E	E	E		E	E	E		F	E											.027
	10	109499	0.49	7.2	B	B	B	B	A	A	C	C	D	D	C	E	D	E	E	E		E		E	E	E		F	F	F										.027
	11	109500	0.50	9.4	B	B	B	B	A	A	C	C	D	D	C	D	D	E	E	E		F		E	E	E		F	F	F										.024
	12	109501	0.46	9.0	B	B	B	B	A	A	C	C	D	D	C	E	D	E	E	E			F	E	E	E		F	F	F										.027
	13	109502	0.27	8.8	B	B	B	B	A	A	C	C	D	D	C	D	D	E	E	E		E		E	E	E		F	F	F										.027
	14	109503	0.27	10.2	B	B	B	B	A	A	C	C	D	D	C	E	D	E	E	E		D	F	E	E	E		F	F											.044
	15	109504	0.46	11.4	B	B	B	B	A	A	C	C	D	D	C	D	D	E	D	D		D	E		E	E	E	F	F	F									E	.044
	16	109505	0.40	16.4	A	A	B	B	B	B	C	C	D	D	C	D	C	E	E	D	E	C	E	E	E	E		F	F											.23
	18	109506	0.26	45.6	A	A	B	C	B	B	C	D	D	C	C	D	E	E	D	D	E	D	E	D	E	E		F	F	F	E	E								.010
					0.04 pyrite band																																				
	20	109507	0.24	73.9	A	A	B	C	C	B	C	D	E	C	D	E	E	E	E	E	E	E	E	E	E	E		F	F		E									.004
	21	109508	0.34	32.2	A	A	B	C	B	B	C	D	D	C	C	D	D	E	D	D	E	D	E	D	E	E		F	F	F	E	E		D						.015
	22	109509	0.30	7.1	B	B	B	B	A	B	C	C	D	D	C		D	E	D	E		E	E	E	E	E		F	F	F										.028
	23	109510	0.25	9.2	A	A	B	B	B	B	C	D	D	D	C	D	D	E	E	E		E	E	E	E	E		F	F	F	E									.030
	24	109511	0.21	26.8	A	A	B	B	B	B	C	D	D	D	C	D	D	E	E	D	E	D	E	E	E	E		F	F	F	E									.050
USBM-4 Pit	19	81808	1.00	36.2	B	A	A	C	B	C	C	D	D	C	E	D	C	D	E	D	E	D	F	D	F	E	F	F	F		E	E		C		E			.020
	20	81809	1.00	41.0	B	A	B	C	B	C	C	D	D	C	E	D	C	E	E	E	E	E	F	D	F	E		F	F		E			C						.027
	21	81810	1.00	21.7	B	A	A	B	B	C	C	C	C	C	D	D	D	E	E	E	E	E	F	D	F	E		F	F		E		D							.032
	22	81811	1.00	19.1	B	B	A	B	B	B	C	C	C	C	D	D	D	E	E	E	E	E	F	D	F	E		F	F				D							.033
	23	81812	1.00	16.7	B	B	A	B	B	B	C	C	C	C	D	D	D	E	E	E	E	E	F	D		E		F	F				D							.032

Mendenhall area, Slim Buttes, Harding County, South Dakota
Olesrud bed (Upper bench)

Semi-quantitative spectrographic analyses of lignite ash.
A - over 10%; B - 1-10%; C - 0.1-1.0%; D - 0.01-0.1%;
E - 0.001-0.01%; F - 0.0001-0.001%

Sample pit	TE sample number	Laboratory number	Thickness of sample (feet)	Percent ash in sample	Al	Si	Fe	Mg	Ca	Na	Ba	Sr	Mn	Ti	B	Cu	Mo	V	Cr	Ni	Pb	Co	Sc	Zr	Ga	Y	Sn	Yb	Be	Ag	Ge	La	Li	K	As	Ce	Nd	Zn	Br	P	Uranium in ash (percent)1/
USBM-5	24	81813	0.40	30.9	B	B	A	C	C	B	C	D	D	D	E	D	E	D	E	D	E	E	E	D	F	E	F	F	E	E	E		B	C		E	D			0.007
															0.40 shale parting																										
	25	81814	1.00	22.5	B	B	B	C	B	B	C	C	D	D	E	D	C	E	E	D	E	D	F	D	F	E		F	E	E	E		C			E	D			.039
	26	81815	1.00	17.4	B	B	B	C	B	B	C	C	D	C	D	D	C	E	F	D	E	D	F	D	F	E		F	E				C			E	D			.038
	27	81816	1.00	20.4	B	B	A	C	B	B	C	C	D	C	D	D	D	E	E	D	E	D	F	E	F	E		F	F		E		C			E	D			.019
	28	81817	1.00	15.5	B	B	B	B	B	B	C	C	D	C	D	D	E	E	E	D	E	D	F	E	E	E		F	F			D	C				D			.018

Mendenhall area, Slim Buttes, Harding County, South Dakota
Olesrud bed (Lower bench)

Semi-quantitative spectrographic analyses of lignite ash.
A - over 10%; B - 1-10%; C - 0.1-1.0%; D - 0.01-0.1%;
E - 0.001-0.01%; F - 0.0001-0.001%

Core hole	TE sample number	Laboratory number	Thickness of sample (feet)	Percent ash in sample	Al	Si	Fe	Mg	Ca	Na	Ba	Sr	Mn	Ti	B	Cu	Mo	V	Cr	Ni	Pb	Co	Sc	Zr	Ga	Y	Sn	Yb	Be	Ag	Ge	La	Li	K	As	Ce	Nd	Zn	Br	P	Uranium in ash (percent) 1/
SD-10	28	109512	0.44	11.9	A	A	C	B	B	B	C	C	D	D	C	D	C	E	E	E	E	D	E	D	E	E		F	F		D		E								0.048
	29	109513	0.18	12.8	A	A	C	B	B	B	C	C	D	C	C	E	C	E	E	E	E	E	E	D	E	E		F	F	F	D		E								.032
	30	109514	0.31	18.0	A	A	A	B	B	B	C	D	D	D	C	D	C	E	D	E	E	E	F	D	E	E		F	F	F	E										.052
	31	109515	0.13	12.9	A	A	C	B	B	B	C	C	D	D	C	D	C	E	E	D	D	D	E	D	E	E		F	F	F		D	D							C	.116
	32	109516	0.13	7.9	A	B	C	B	A	A	C	C	D	D	C	E	D	E	D	D		D	E	E	E	E		F	F	F			D								.036
	33	109517	0.22	16.5	A	A	B	B	B	B	C	C	D	C	C	D	C	D	D	D	E	D	E	D	E	E		F	F	F		D									.047
	34	109518	0.33	9.5	B	B	C	B	A	A	C	C	D	D	C	E	D	E	D	D		D	E	E	E	E		F	F	F											.008
	35	109519	0.27	20.2	A	A	C	B	B	B	C	C	D	C	C	D	D	E	E	D	D	E	E	E	E	E	E	F	F	F											.021
	36	109520	0.18	7.5	A	B	C	B	A	A	C	C	D	C	C	D	D	E	D	D	E	D	E	E	E	E	E	F	F	F		D	D							C	.026
	37	109521	0.19	16.2	A	A	C	B	B	B	C	C	D	C	C	D	D	E	D	D	E	E	E	D	E	E	E	F	F	F			E								.013
	38	109522	0.49	11.6	A	A	C	B	B	B	C	C	D	D	C	D	D	E	E	D	E	E	E	E	E	E	E	F	F	F			D								.023
	39	109523	0.51	18.1	A	A	B	B	B	B	C	C	D	D	C	D	D	E	D	D	E	E	F	D	E	E	E	F	F		E										.044
	40	109524	0.46	10.2	A	A	C	B	B	B	C	C	D	D	C	D	D	E	D	D	E	D	E	E	E	E		F		F	E		E								.003
	41	109525	0.46	68.8	A	A	B	B	C	C	C	D	D	C	D	E	E	E	D	D	E	D	E	E	E	E		F	F												.001
	42	109526	0.46	41.7	A	A	B	B	B	C	C	D	D	C	C	E	D	D	D	D	E	D	E	D	E	E	E	F	F		E							D			.006
	43	109527	0.46	30.0	A	A	B	B	B	B	C	D	D	C	C	D	C	E	D	D	E	D	E	E	E	E	E	F	F												.050
	44	109528	0.44	76.0	A	A	B	B	C	C	C	D	D	C	D	E	D	E	D	D	E	E	E	E	E	E		F	F												.006
	45	109529	0.35	60.4	A	A	B	B	C	C	C	D	D	C	D	E	E	E	D	D	E	E	E	E	E	E		F	F												.001
	46	109530	0.32	27.1	A	A	B	B	B	B	C	D	D	C	C	D	D	E	D	D	D	D	E	E	E	E		F	F	F											.006
	47	109531	0.22	77.5	A	A	B	B	C	C	C	D	D	C	D	E	E	E	D	E	E	E	E	D	E	E		F	F												.001

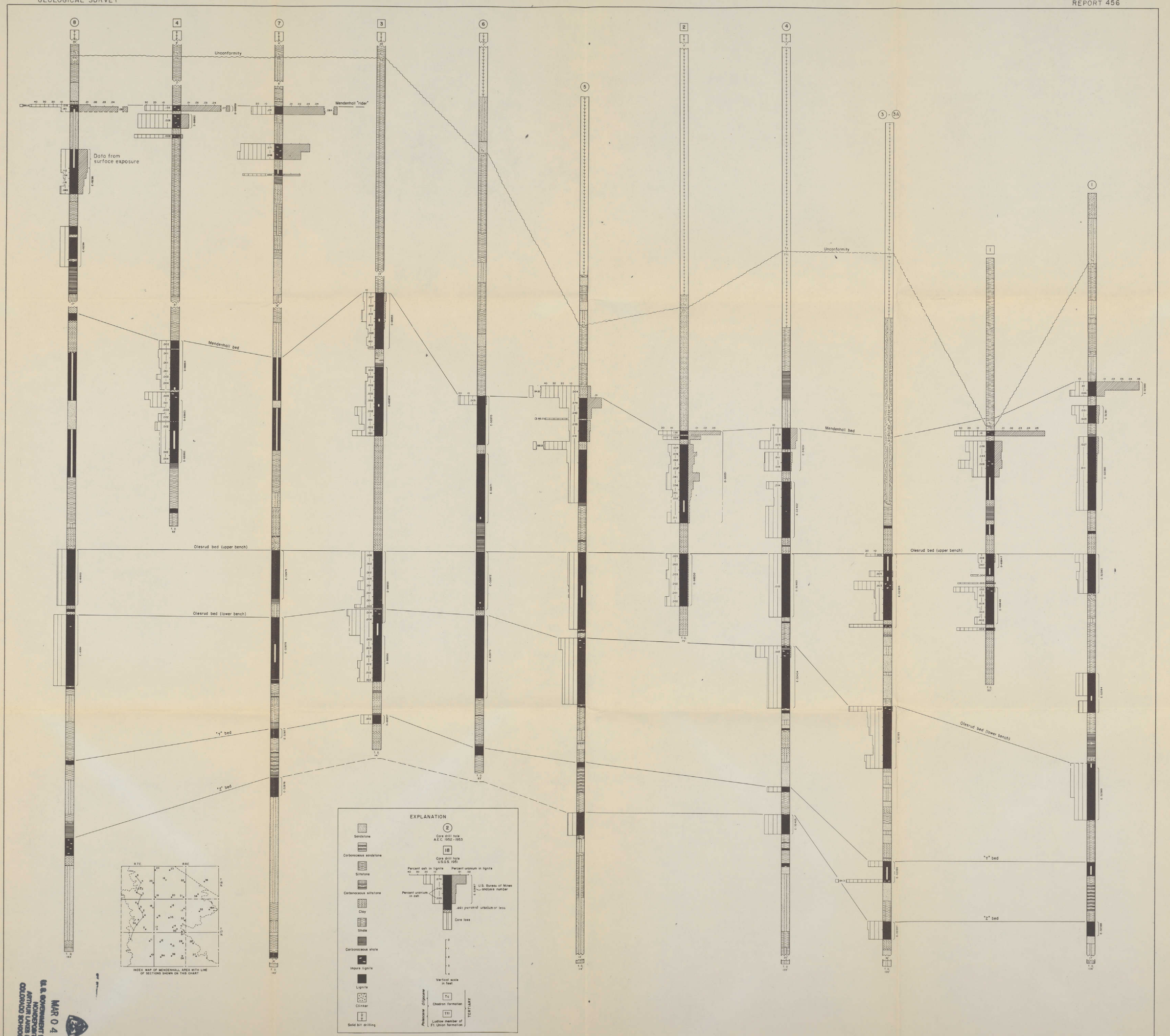

FIGURE 4.--CHART SHOWING DISTRIBUTION AND CONCENTRATION OF URANIUM IN LIGNITE CORES, MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA

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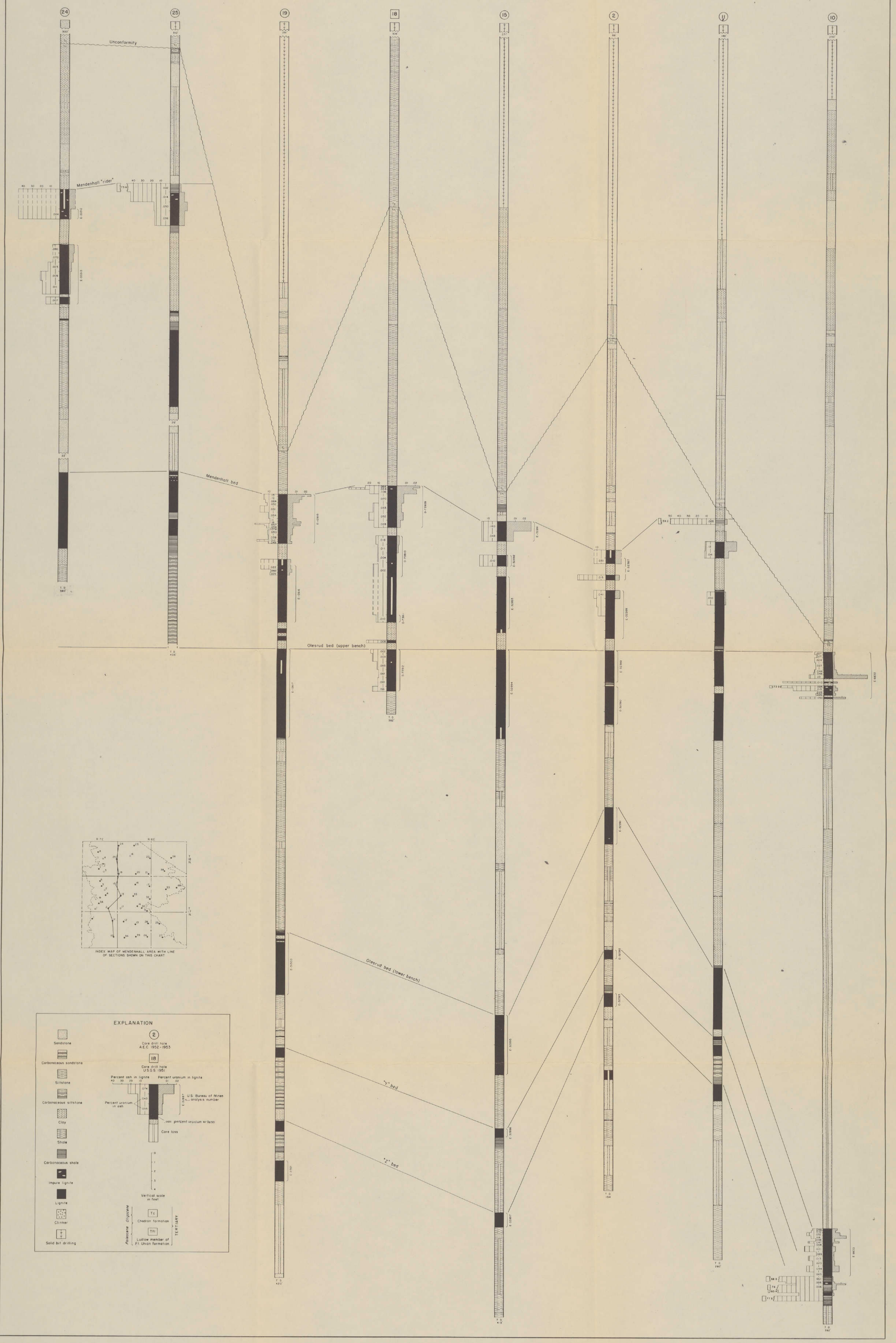

INDEX MAP OF MENDENHALL AREA WITH LINE OF SECTIONS SHOWN ON THIS CHART

EXPLANATION

- Sandstone
- Carbonaceous sandstone
- Siltstone
- Carbonaceous siltstone
- Clay
- Shale
- Carbonaceous shale
- Impure lignite
- Lignite
- Clinker
- Solid bit drilling

(2) Core drill hole A.E.C. 1952-1953

18 Core drill hole U.S.G.S. 1951

Percent ash in lignite — Percent uranium in lignite

Percent uranium in ash

U.S. Bureau of Mines analysis number

.001 percent uranium or less

Core loss

Vertical scale in feet

Paleocene, Oligocene: Tc Chadron formation; Tfl Ludlow member of Ft. Union formation — TERTIARY

FIGURE 5.--CHART SHOWING DISTRIBUTION AND CONCENTRATION OF URANIUM IN LIGNITE CORES, MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA

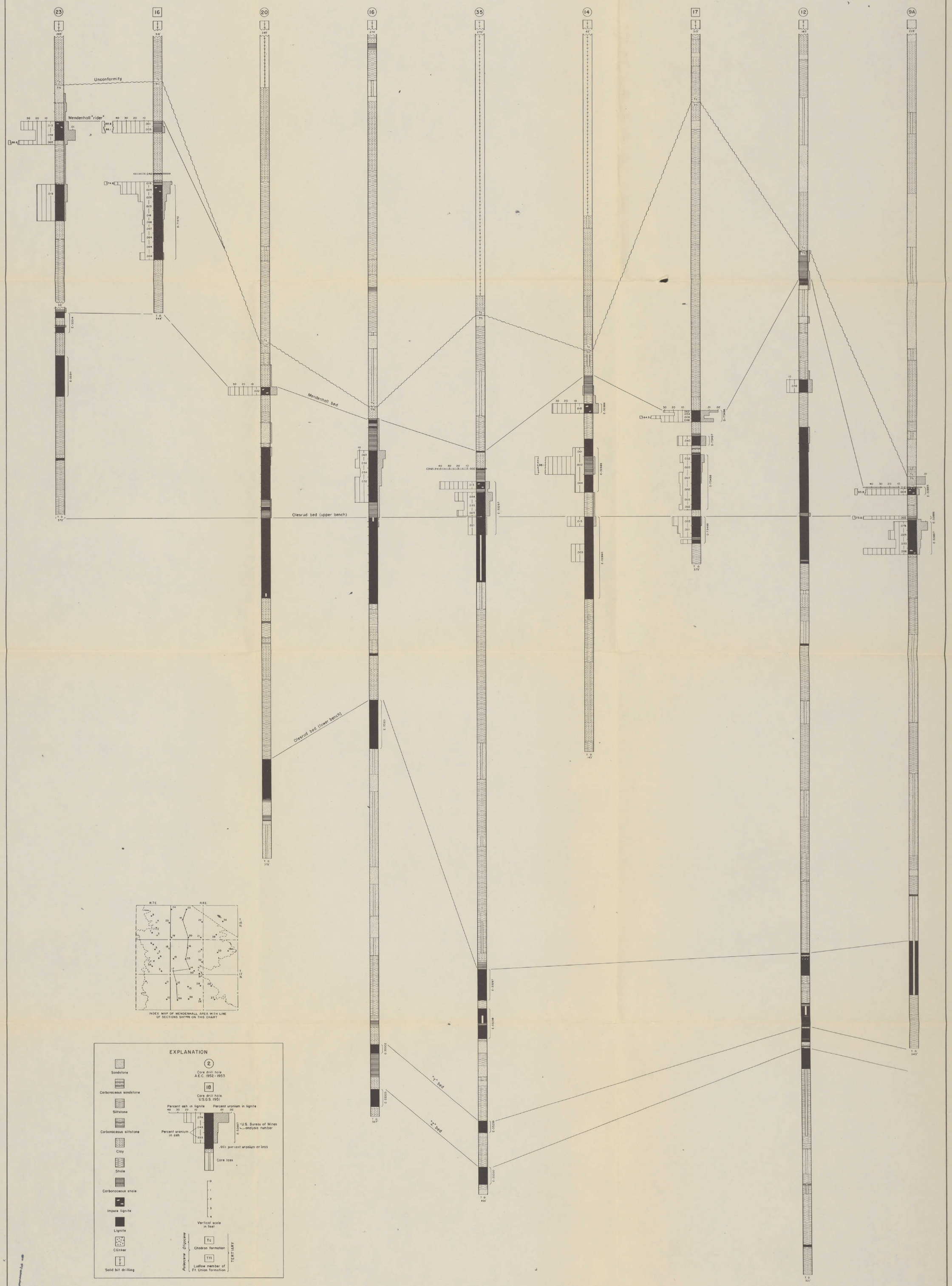

FIGURE 6.--CHART SHOWING DISTRIBUTION AND CONCENTRATION OF URANIUM IN LIGNITE CORES, MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA

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TRACE ELEMENTS INVESTIGATIONS
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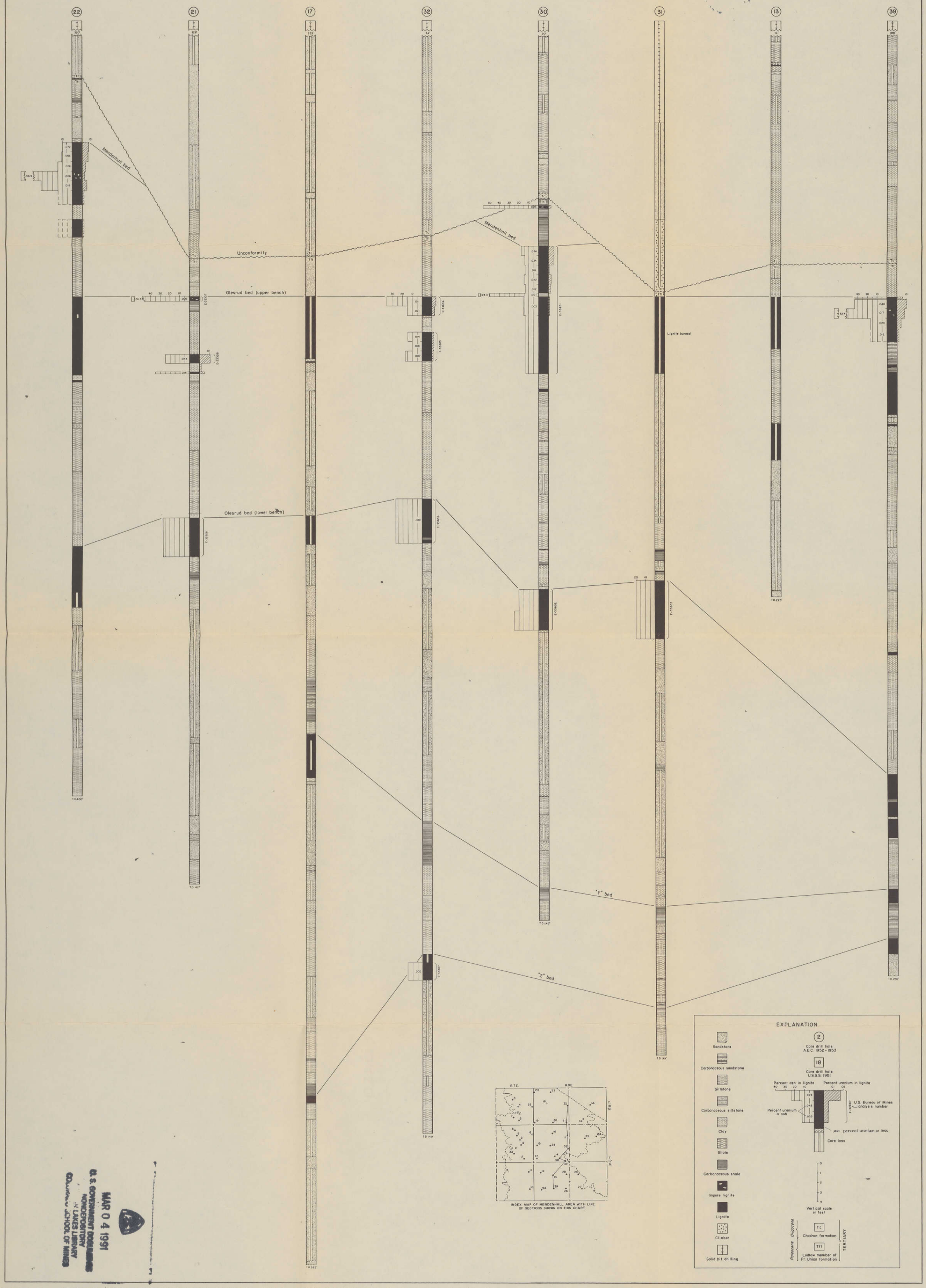

FIGURE 7.--CHART SHOWING DISTRIBUTION AND CONCENTRATION OF URANIUM IN LIGNITE CORES, MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA

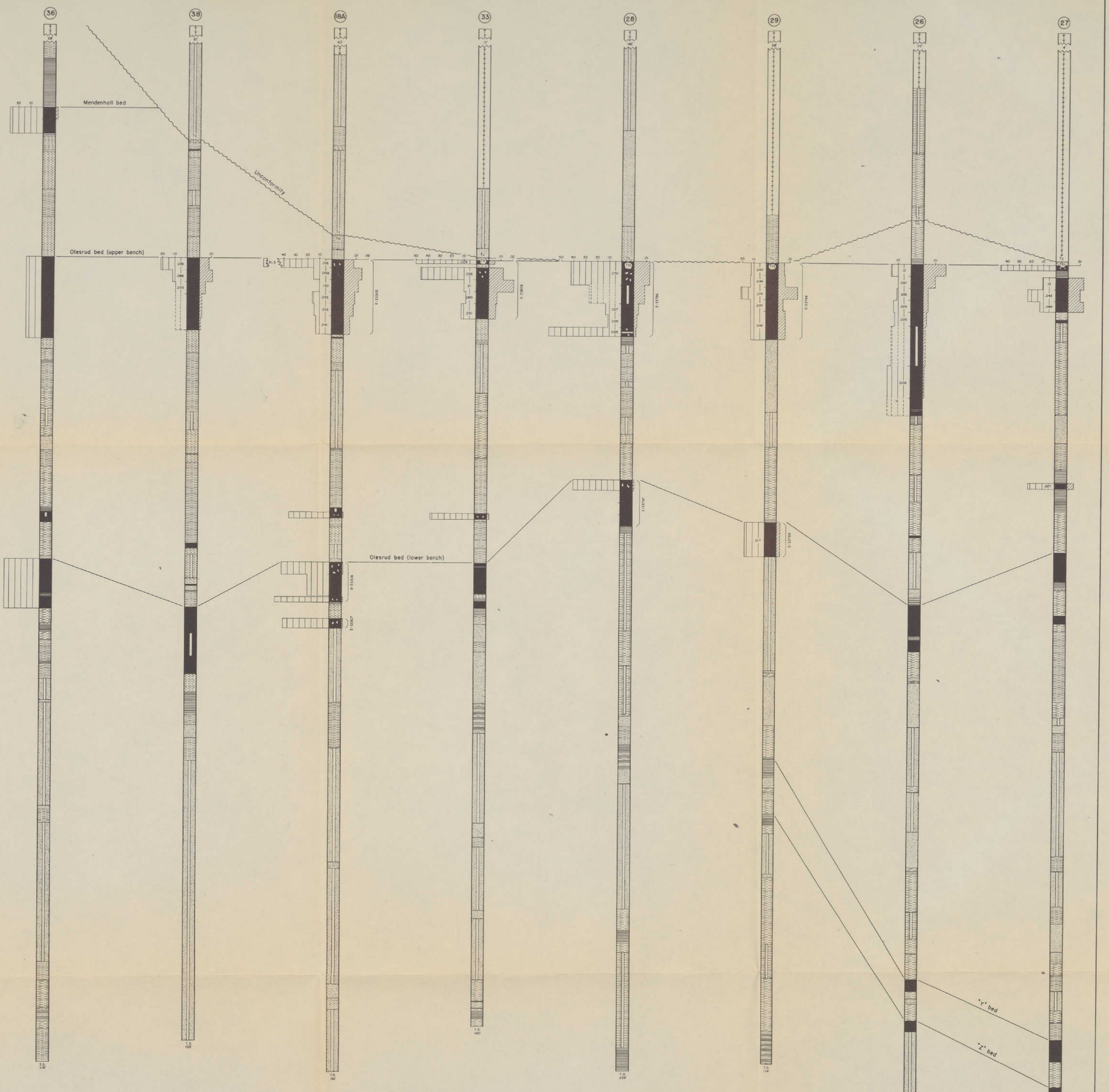

FIGURE 8.--CHART SHOWING DISTRIBUTION AND CONCENTRATION OF URANIUM IN LIGNITE CORES, MENDENHALL AREA, HARDING COUNTY, SOUTH DAKOTA