HIGH-GRADE URANIFEROUS LIGNITES IN HARDING COUNTY, SOUTH DAKOTA

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ABSTRACT

Lignite beds, the uranium content of which ranges between 0.10 and 10 percent, were discovered in Harding County, northwestern South Dakota during the summer of 1954, and economically significant reserves have since been found. The lignite field lies in the Missouri Plateau section, unglaciated, of the Great Plains province between the Black Hills uplift and the Williston basin.

The uranium deposits are in thin lignitic beds of the Tongue River and Ludlow members of the Fort Union formation of Paleocene age. Uranium occurs principally in a urano-organic complex. Meta-autunite and other uranium minerals also occur as coatings on fracture surfaces in the richest deposits.

Only weathered lignite deposits are known; the deeper unweathered zones have not yet been explored. Proximity to aquifers, joints at one deposit, and amount of degradation of the coal are factors that have been observed to control uranium deposition. Epigenetic origin of the uranium is favored by most observers. Other hypotheses regarding source are leaching of overlying weakly uraniferous tuffaceous beds and a modified hydrothermal origin.

INTRODUCTION

Lignite beds of Paleocene age, containing uranium in amounts ranging between 0.1 and 10 percent, were discovered in northwestern South Dakota during the summer of 1954. Many economically significant additional discoveries were made during the rest of the year. Physical exploration and the exploitation of known deposits have been undertaken only to a limited extent; as a consequence, details concerning geology, mode of occurrence, and habit of deposits are as yet incomplete.

Weakly radioactive lignites were studied by the U. S. Geological Survey in northwestern South Dakota and adjacent areas as early as 1948. A core drilling project was carried out between 1951 and 1953 which resulted in calculation of reserves of 47 million tons of uraniferous lignite containing 0.005 percent uranium (Gill, 1954).

This report, however, concerns only the lignitic deposits discovered in 1954 and 1955 containing 0.10 percent or more uranium. Discoveries of such material have been made principally in Harding (the north westernmost) County, S. Dak., with scattered discoveries of unknown potential in adjacent areas of North Dakota and Montana. Inferred reserves approximate 100,000 tons containing more than 0.10 percent U_3O_8 and a potential of a million tons of similar grade is possible.

GEOGRAPHY

Harding County is located in the unglaciated portion of the Missouri Plateau section of the Great Plains province. The rolling topography of the plains is interrupted by steep-walled buttes and mesas, notably North and South Cave Hills, Table Mountain, and Slim Buttes (fig. 142). These features stand 300–500 feet above the surrounding plains.

The western part of Harding County drains north into the Little Missouri River; the eastern part drains eastward and empties into the Grand and Cannonball Rivers, both tributary to the Missouri River. The plains are grass covered and almost devoid of trees although parts of the larger mesas support a moderate growth of pine. Stock grazing is the most important occupation.

Buffalo, S. Dak. (population 350), is the county seat and largest town in Harding County. It is served from north and south by U. S. Highway 85 and from east and west by State Highway 8. Nearest rail connections are the Milwaukee Road, 52 miles to the north at Bowman, N. Dak., and the Chicago and Northwestern, 73 miles to the south at Belle Fourche, S. Dak.

STRATIGRAPHY

The stratigraphic section exposed in Harding County includes rocks of Cretaceous, Tertiary, and Quaternary age. Figure 143 shows the Harding County portion of the geologic map of South Dakota published by the U. S. Geological Survey with minor modifications. Cretaceous rocks are not discussed in detail as they have no known bearing on the uraniferous lignite problem.

FORT UNION FORMATION (PALEOCENE)

Lignite beds containing more than 0.10 percent U_3O_8 are found at several horizons in the Ludlow member and at two horizons of the Tongue River member of the Fort Union formation of Paleocene age.

The Ludlow and Tongue River members consist predominantly of dark-yellow and gray, fluviatile soft sandy shales and shales with scattered resistant massive sandstone units, particularly in the Tongue River member.

The Ludlow member intertongues, in the eastern part of Harding County, with the marine Cannonball member which is non-lignite-bearing. The Tongue River member, of which the resistant basal massive sandstone unit makes the rimrock on the Cave Hills and Table Mountain, is absent in the Slim Buttes. Pre-Oligocene erosion stripped the Tongue River member in the southern part of the area before deposition of the Oligocene White River group. The Sentinel Butte shale member of the Fort Union formation was similarly removed and is not present in Harding County. Significant uranium discoveries have been made recently in the Sentinel Butte shale member in North Dakota.

WHITE RIVER GROUP (OLIGOCENE)

The White River group (figs. 143–147) unconformably overlies the Fort Union formation in Harding County. From 40 to 200 feet thick, it is composed of light-gray, yellow-brown, and pink bentonitic clay; sandstone containing devitrified ash; and limestone lenses.

ARIKAREE FORMATION (MIOCENE)

The Arikaree formation forms the caprock of the Slim Buttes and several of the smaller buttes and mesas in the southern part of Harding County. It consists of about 200 feet of tuffaceous sandstones. The unit is more radioactive than any other formation of the area and is several times more uraniferous (0.0015 percent U) than average sedimentary rocks (Denson, Bachman, and Zeller, 1956).

STRUCTURE

Harding County, S. Dak., lies between the Black Hills uplift to the south and the Williston basin to the north. The Cedar Creek anticline trends approximately S. 60° E. across Montana toward the point where North Dakota, South Dakota, and Montana join. The anticline flattens and loses its identity between the Cave Hills and Slim Buttes in Harding County, S. Dak. Regional dip is 30–40 feet a mile northeastward into the Williston basin.

Jointing is a common feature in the indurated sandstones of the Cave Hills. Significant faulting has not been observed in the Cave Hills but has been noted in Slim Buttes. The Slim Buttes faults trend approximately N. 75° W., dip vertically, and have caused displacements of as much as 200 feet. Seismic surveys by private companies have indicated as many as 10 such faults with displacements between 40 and 200 feet,

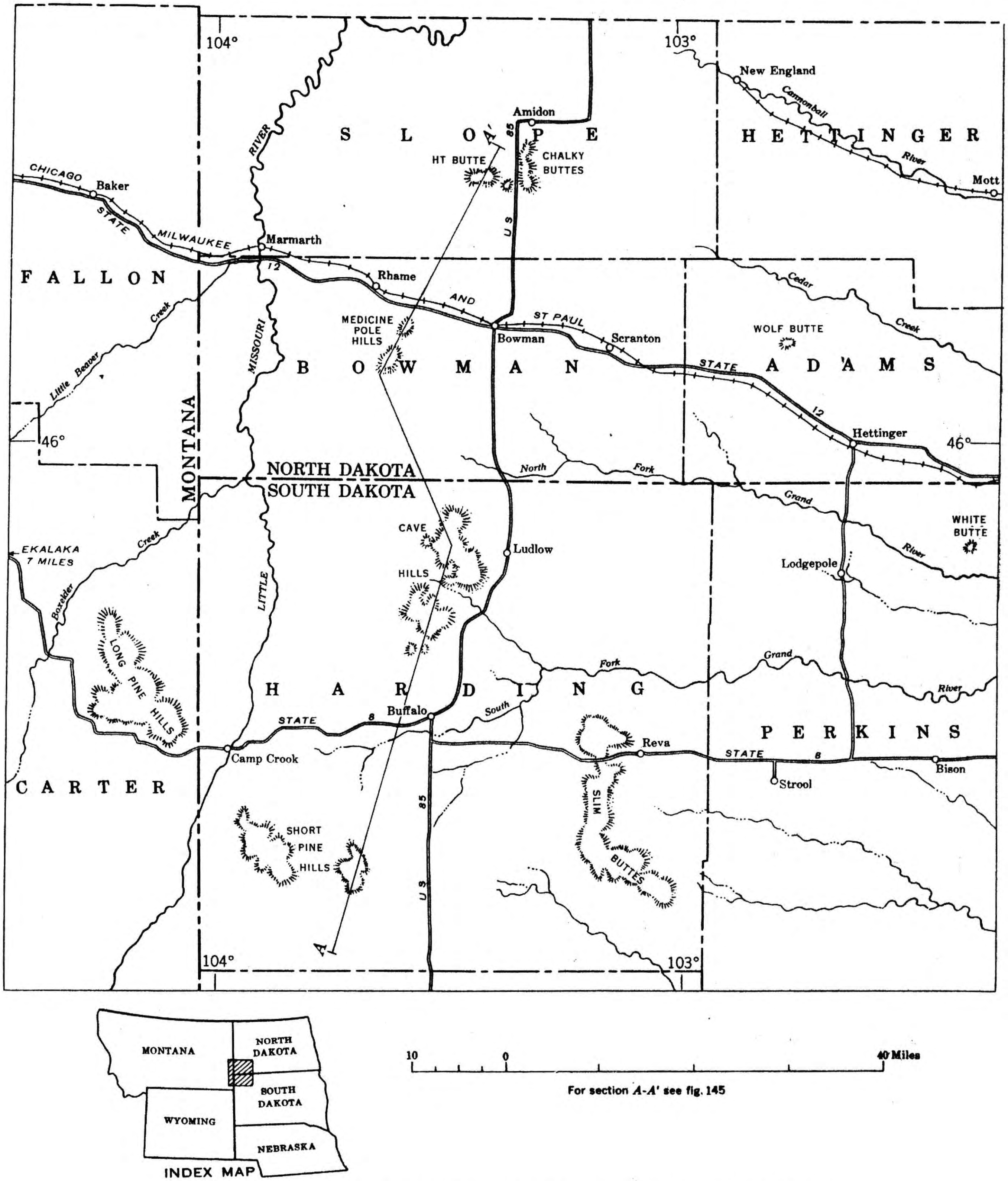

FIGURE 142.—Index maps of uraniferous lignite in contiguous parts of North Dakota, South Dakota, and Montana.

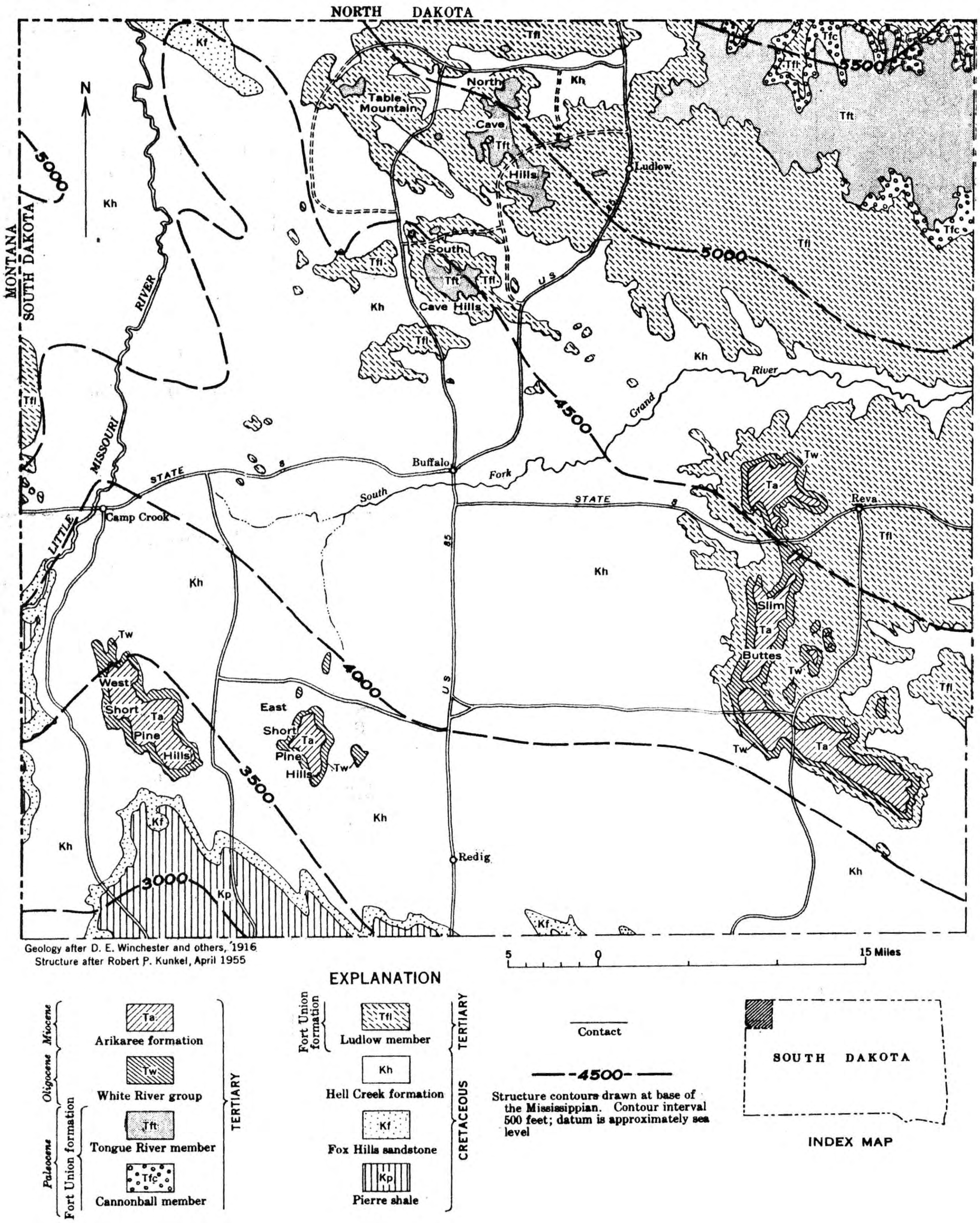

FIGURE 143.—Geologic map of Harding County, S. Dak.

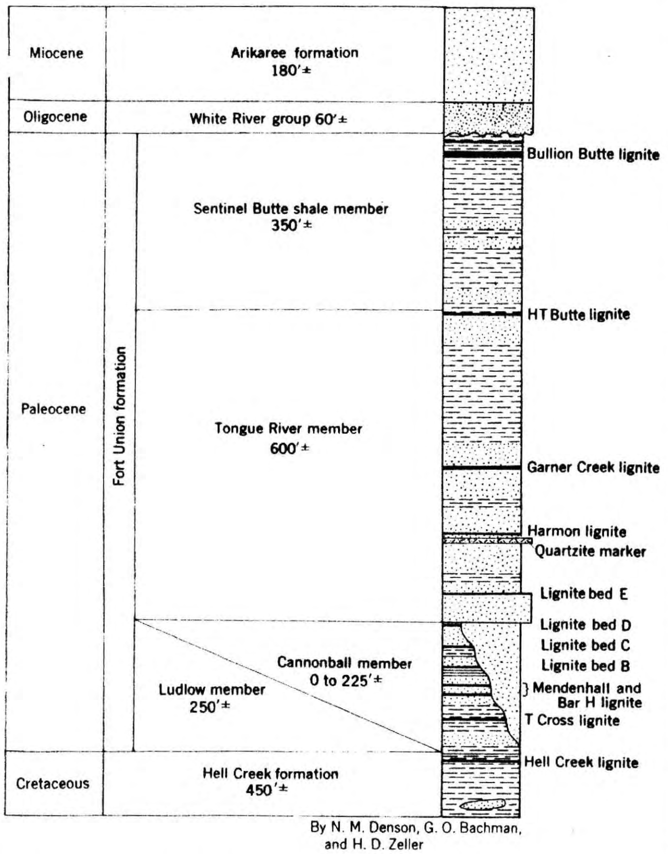

FIGURE 144.—Generalized partial columnar section showing stratigraphic position of principal coal beds in Harding County, S. Dak., and adjacent areas.

across a 1-mile section. The direction of displacement is not consistent, but creates a horst and graben system.

Landsliding and slumping characterize the slopes of Slim Buttes and are common in the Cave Hills. Many of the lignitic units are involved, making stratigraphic correlation difficult in many areas.

MINERALOGY

COAL PETROGRAPHY

Limited petrographic work has been done on the strongly weathered abundantly uraniferous lignitic material from the Cave Hills. Specimens from most of the uraniferous lignite outcrops do not burn under a blowpipe flame. Moisture content differs, but the average of more than 500 tons shipped as uranium ore is approximately 32 percent. Lot samples range between 20 and 50 percent moisture. No unweathered material has yet been collected.

Auger drilling, which produced only fair to poor samples, indicated that the abundantly uraniferous lignitic material exists, and is reasonably consistent, as far as 350 feet horizontally from the outcrop and under a maximum overburden of 75 feet. Although no proximate or ultimate analyses are available from the thin uraniferous lignitic beds, extensive work has been done on the thicker beds having a uranium content of about 0.005 percent. Averages of 5 samples of weathered and 5 of unweathered lignite from the Mendenhall and Olesrud (or Bar H) beds (near the middle of the Ludlow member) are as follows:

Proximate analysis (as revised)

	Unweathered Percent	*Weathered Percent*
Moisture	34.1	45.6
Volatile matter	24.6	22.8
Fixed carbon	29.2	15.4
Ash	12.4	16.2

Ultimate analysis

	Unweathered Percent	*Weathered Percent*
Hydrogen	6.2	6.3
Carbon	37.5	23.7
Nitrogen	0.5	0.5
Oxygen	42.3	52.0
Sulfur	1.4	1.3
Ash	12.2	16.1
Btu	6,220	3,530

Weight of the lignitic material in place is assumed to be 1,750 wet short tons per acre foot or 27.3 cubic feet per ton.

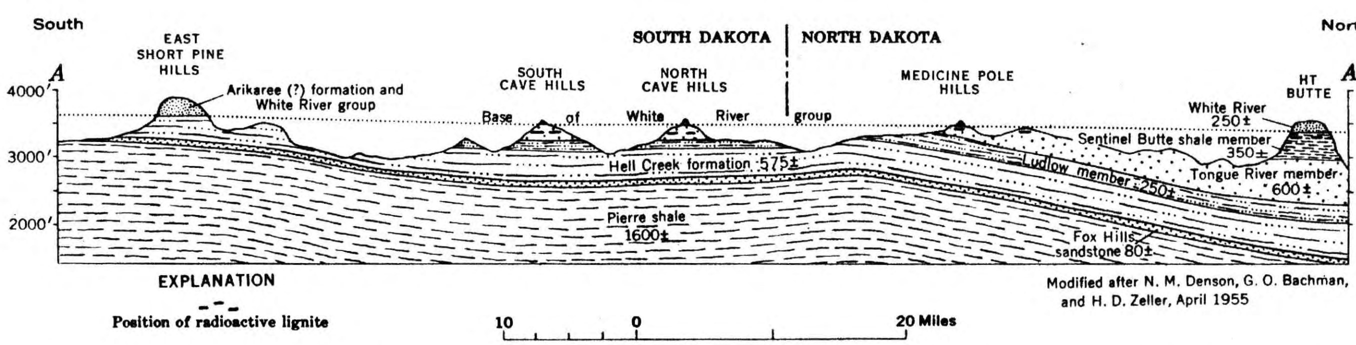

FIGURE 145.—Section from Short Pine Hills in Harding County, S. Dak., to HT Butte in Bowman County, N. Dak., showing relation of lignitic beds to base of the White River group. Figures following formation names refer to thickness of the formation, in feet.

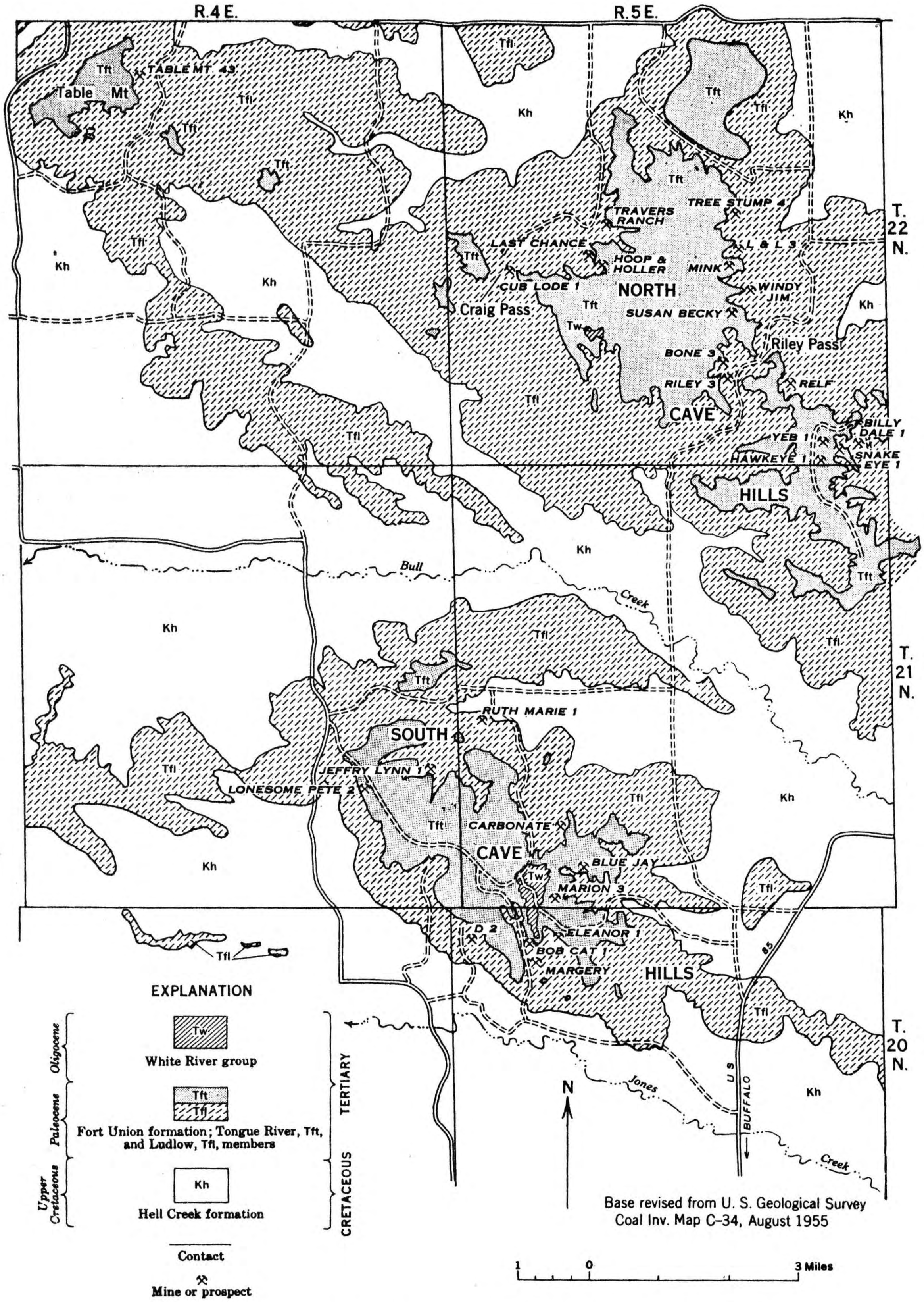

FIGURE 146.—Location of mines and prospects, Cave Hills, Harding County, S. Dak.

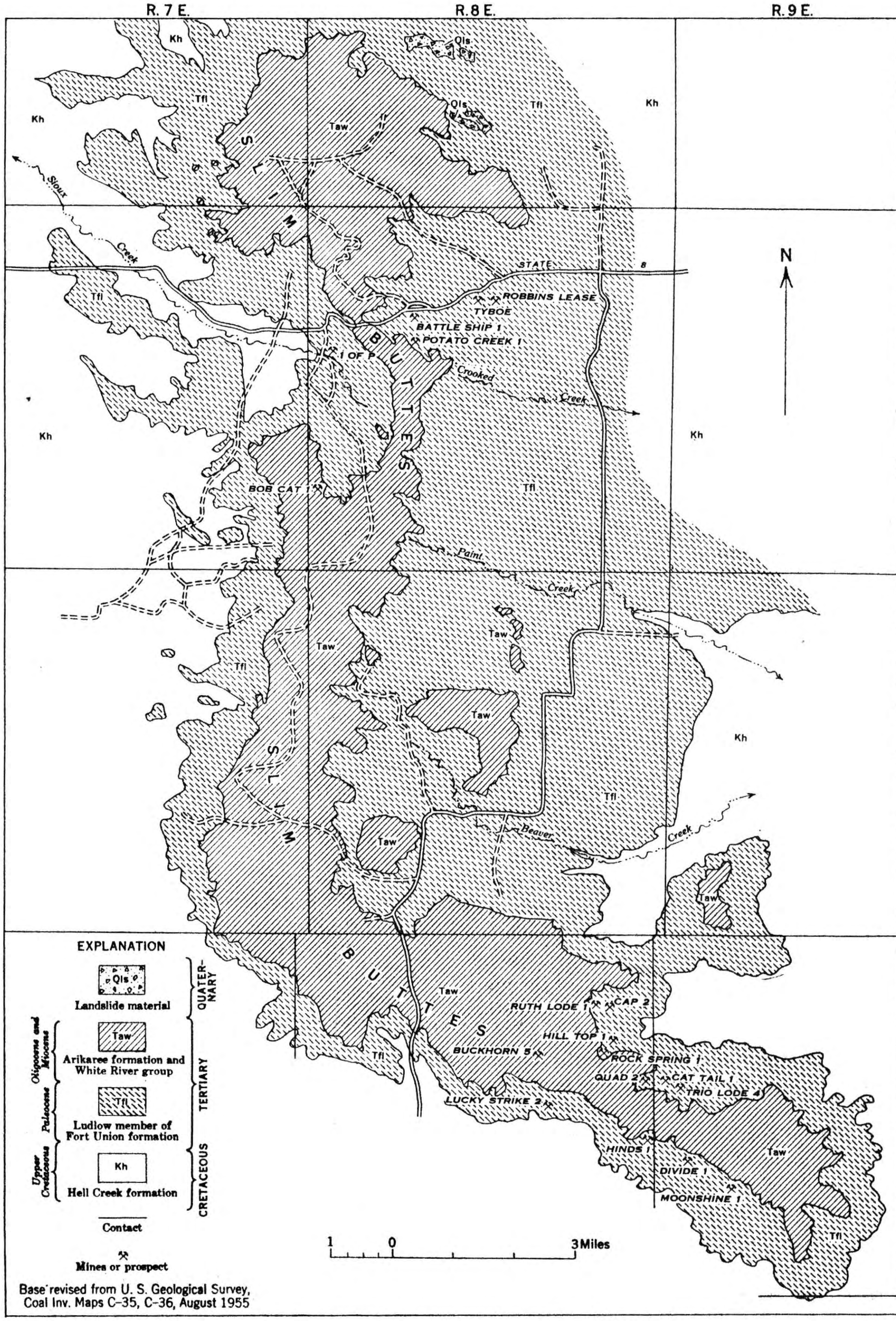

FIGURE 147.—Location of mines and prospects, Slim Buttes, Harding County, S. Dak.

URANIUM IN THE COAL

Average, maximum and minimum assays of uranium, vanadium and calcuim carbonate in the first 600 dry short tons of lignitic uranium ore shipped from Harding County are as follows:

	Average (percent)	Maximum (percent)	Minimum (percent)
U_3O_8	0.39	0.86	0.10
V_2O_5	.05	.07	.00
$CaCO_3$	3.0	10.8	1.2

Uranium in amounts up to 0.85 percent chemical U_3O_8 has been found in carbonaceous siltstone (in the Ludlow member) overlying a weathered black lignitic bed ("B" bed) which is essentially barren. It has been found also in Harding County in amounts up to 2.4 percent U_3O_8 in brown fissile lignitic material, in amounts up to 0.36 percent U_3O_8 in different grades of dull-black powdery lignite, in amounts up to 8.0 percent U_3O_8 in semilustrous weathered black lignitic material, and up to 3.5 percent in red, ashed material. The dull powdery material is characteristically the lowest in uranium; and the semilustrous material, the highest. At several localities where the semilustrous material is fractured into ½-inch cubes, greenish fluorescent uranium minerals, principally meta-autunite, are visible. Metatorbernite and metazeunerite have been identified also (J. R. Gill, and J. W. Gruner, personal communication). I. A. Breger and others (1955) have shown that most of the uranium is associated with the organic constituents of the coal, rather than with its inorganic constituents. They established that the uranium is not held in the coal by ion exchange but is in the form of organouranium complexes or compounds soluble at a pH of less than 2.18. The same authors found no discrete uranium minerals in the low-grade (0.005 percent U) material studies.

No correlation between uranium content and standard coal petrographic constituents has been noted (Schopf and Gray, 1954) in the lignite containing a few thousandths to a few hundredths of 1 percent uranium. The ash content, however, is higher in some of the more uraniferous layers. This may be a result of introduction of other materials along with the uranium.

The correlation between microscopic plant materials, degradation products, and uranium has also been investigated (Schopf and Gray, 1954) in the same type of material. No direct correlation was found between any single coal component and the uranium content. These authors conclude that none of the samples owe their high or low uranium content to their relative position within the bed, a conclusion borne out by field relationships.

OTHER MINERALS IN THE COAL

The most common accessory mineral in the lignitic material is analcite, which occurs as small spheroids and rosettes less than 1 millimeter in diameter, in differing amounts with no apparent relationship to the quantity of other minerals. No consistent vertical concentration has been noted within a given lignite bed, and the areal extent of the analcitic zones is unknown. Analcite is not confined to the lignite but is a common accessory constituent of the surrounding clastic beds. The analcite must form in alkaline water and it therefore seems improbable that the analcite is of sygenetic origin but must have been introduced subsequent to coalification (Denson, Bachman, and Zeller, 1956).

Limonite and jarosite in small masses, seams, and veinlets commonly cut across the bedding of the lignite units. Pyrite is common in the concretionary masses. There is no apparent correlation between the iron minerals and the uranium content.

Gypsum in seams and veinlets is common and appears to have been the latest mineral formed.

Semiquantitative spectrographic analyses have been made on about 25 samples of ashed lignite from the Cave Hills. The amount of ash ranged from 30 percent to 50 percent. Arsenic and molybdenum were found in the ash in maximum concentrations of 3.2 percent and 1.4 percent, respectively. A plot of uranium, arsenic, and molybdenum values indicates that all three elements tend to form peaks together (J. R. Gill, oral communication).

Copper, phosphate, and fluorine were determined in samples of uraniferous carbonaceous siltstone overlying a lignitic bed in the Lonesome Pete claim in South Cave Hills (fig. 146).

DISTRIBUTION OF URANIFEROUS LIGNITE

Individual lignite units extend over areas of several square miles and may cover several tens of square miles. Sufficiently detailed stratigraphy has not been worked out to assure correlations in all cases.

Lignites containing more than 0.10 percent uranium are characteristically 10–14 inches thick but are exceptionally 30–36 inches thick. Lignites more than 10 feet thick exist in the area but are not known to contain more than trace quantities of uranium.

Although many of the beds probably containing uranium are regional in extent, uranium deposits are known only in certain areas. Lack of exploration seriously limits adequate determination of the distribution, and only a few areas are presently known to contain mineralized patches larger than an acre. At least 3 areas of approximately 10 acres each are estimated to be at least 50 percent mineralized.

Uraniferous lignitic units are known in Harding County through approximately 400 feet of the Tongue River and Ludlow members of the Fort Union formation. Local exposures of the uranium-bearing lignite are believed to be the result of local erosion and do not constitute a limit of the favorable horizons.

The uppermost units of important uranium content in Harding County are the "E" and "F" beds of the Tongue River member (fig. 144). The "F" bed is locally uraniferous in the Riley Pass area of North Cave Hills, (fig. 146) where it lies approximately 15 feet stratigraphically above the "E" bed. The "E" bed lies immediately above the basal massive cliff-forming sandstone of the Tongue River member. It is exposed over most of the top of North Cave Hills in thicknesses of 1–2 feet.

In Cave Hills the "D" and "C" beds of the Ludlow member are uraniferous locally. The "D" bed lies at or close to the top of the Ludlow member and beneath the lower massive Tongue River sandstone unit (fig. 144). The "C" bed lies within 100 feet of the top of the Ludlow member.

In Slim Buttes all known uraniferous lignite beds are confined to the Ludlow member. Pre-Oligocene erosion removed the Tongue River member and truncated the Ludlow, which dips gently northward. Thus, the White River group overlies progressively lower sections of the Ludlow to the south. Several lignitic beds are known to be uraniferous in the Slim Buttes from the northern extremity nearly to the southern tip. Detailed stratigraphy of the deposits has not yet been worked out sufficiently to assign each deposit to a specific bed. The Slim Buttes deposits are, however, at lower horizons than those exposed around the periphery of the Cave Hills.

MODE OF OCCURRENCE

Abundantly uraniferous lignite beds are not necessarily the uppermost of a stratigraphic series as early observations indicated. The deposits at Carbonate claims and those near the Travers Ranch in Cave Hills, the Ruth Lode in Slim Buttes (fig. 143), and the deposits at Table Mountain are examples where two or more barren lignitic beds overlie the most uraniferous bed. Although preference of uranium for the top, within lignitic units, has been noted in some of the low-grade (± 0.005 percent U) beds, field evidence concerning high-grade (± 0.10 percent U) deposits shows no consistently preferred horizon of the most uraniferous part within a bed.

Proximity to aquifers is believed by the writers to be an important factor in mineralization of the lignite. The "E" bed of the Tongue River member at Cave Hills is in direct contact with the permeable underlying basal massive sandstone. It is overlain directly in some localities by a highly impermeable mudstone, and elsewhere such mudstone units occur only a few feet stratigraphically above the "E" bed. No uraniferous deposit of economic potential is known where highly impermeable beds enclose the lignite completely.

At Craig Pass (fig. 146) brown lignitic material predominates, and encloses black lignitic lenses and seams. Transition zones, a fraction of an inch in thickness, surrounding the black material are the most radioactive parts.

Structural control of uranium deposition has not been observed, but insufficient study precludes any conclusion. A broad basin in the vicinity of Riley Pass (fig. 146) contains several of the large deposits. The rock exposures are particularly extensive in this area; and this, not structural control, may be the reason why there are so many deposits in this basin. Strong joint control has been observed at the Carbonate group in North Cave Hills, but not elsewhere. At this deposit, 2 joints in argillaceous lignite, 2–3 feet apart, are filled with 1 or 2 inches of limonite-stained non-carbonate-bearing clastic rocks. The lignite between the joints and slightly less than a foot on either side is highly radioactive. Radioactivity decreases rapidly 3–4 feet from the joints. At two other exposures on the carbonate group high radioactivity is associated with joints.

All known deposits are at shallow depths, and all are confined to weathered lignitic material, although weathering in itself is not believed to have an important bearing on the uranium content. No deep exploration has yet penetrated fresh lignite.

Chemical assay of the lignite commonly shows 2 times as much uranium as is indicated by the radioactivity assay. In two deposits in highly carbonaceous siltstone, however, the chemically determined uranium was less than that indicated by the radioactivity assay.

In view of the above relationships, the authors believe that the uranium was brought to the lignitic beds by solutions whose predominant direction of movement was lateral. A syngenetic theory of origin does not fit observed facts, and it does not appear logical that such locally abundant uranium content can be attributed to clastic deposition. Predominant vertical movement of mineralizing solutions is difficult to prove in view of many extensive overlying impermeable units and the presence at several localities of 1–4 barren lignitic units of comparable quality overlying the abundantly uraniferous unit. The presence of relatively large amounts of arsenic and molybdenum (at Cave Hills, As, 3.2 percent; Mo, 1.4 percent), however, is strongly suggestive to some observers of a modified hydrothermal origin, in which hydrothermal solutions mixed with ground waters would have moved, for considerable distances, through sedimentary rocks of diverse character. An alternative hypothesis of origin (Denson, Bachman and Zeller, 1956) states that the uranium was derived by leaching of weakly uraniferous (0.0015 percent U) tuffaceous beds of the Arikaree formation and the White River group and transported by downward perculating waters to the present host beds.

DESCRIPTION OF INDIVIDUAL DEPOSITS

Of the 3 uranium deposits described below, 1 is in the Tongue River member and 2 are in the Ludlow member. These are the best known and are in geologic environments typical of most deposits.

BILLY DALE GROUP

The Billy Dale group comprises 3½ claims, located on parts of 3 buttes rising 300 feet above the surrounding plain immediately east of North Cave Hills (fig. 146).

Only rocks of the Tongue River member are exposed in the area. The "E" bed lies on the surface of the basal massive sandstone, a surface marked by small swells and swales 1–4 feet in extent with a maximum relief of 6 inches. The uranium-bearing "E" bed is overlain by a maximum of 75 feet of sandstones and shales. The "F" bed, which is present on part of the buttes, is mineralized to ore grade locally. Regional dip is less than 0.5° to the northeast. Jointing is sparse; faulting has not been observed.

A measured section from the top of the butte to the lower massive sandstone underlying the "E" bed is as follows:

	Feet
Sandstone, pink to gray, very fine- to fine-grained, poorly sorted thin-bedded, slabby, moderately indurated; contains sparce carbon specks; weathers reddish-brown	1
Not exposed	51
Lignite ("F" bed), distintegrated, blocky to powdery black, discontinuous and lenticular. Spotty mineralization	0. 5–0. 8
Mudstone, dark-gray, fissile; contains abundant weathered analcite particles; abundant iron stain occurs on weathered surfaces	5
Sandstone, medium-gray, very fine-grained, well-sorted, poorly indurated, heavily iron-stained, permeable. Some carbon specks and sparse analcite particles near contact with overlying mudstone	4
Sandstone, light-gray, very fine- to fine-grained, thin-bedded, permeable; contains abundant carbon trash, sparse analcite, and some mica flakes. Intense limonite stain along bedding planes	3
Lignite ("E" bed), 6–14 inches of black to brownish-black	1
Sandstone, medium-gray to brown, intensely limonite-stained, very fine- to coarse-grained, thick to massively bedded, locally crossbedded. Base marks the base of Tongue River member	70

The uraniferous zone on the Billy Dale group of claims is exposed for about 90 feet along the outcrop and 30 feet into the butte from the rim. The "E" bed can be followed completely around the butte, which covers about 11 acres of 1 claim above that horizon. Abnormal radioactivity is noted on all "E" bed outcrops around a large butte and at many places on the nearby hills.

The "E" bed, in the stripped area, is entirely black, weathered lignite, 9–10 inches thick. Some of the lignite is powdery, granular, and dull; the rest is composed of cubes less than one-half an inch in size with semilustrous surface. The cubes have the higher uranium content and locally exhibit on the fracture surfaces a yellow-green fluorescent uranium mineral, tentatively identified as meta-autunite. Picked samples assay up to 10 percent chemical U_3O_8.

Unlike the noncombustible lignite in many of the other uranium deposits, the material at Billy Dale claim burns with abundant smoke. Analcite is conspicuously rare at this deposit. Limonite and jarosite veinlets and stringers and clay stringers are moderately abundant.

Radiometric assays of samples from the property range from 1.17 percent eU_3O_8, in black strongly weathered lignite, to 0.07 percent eU_3O_8 in black powdery lignite. In general the chemical assays are twice as high as the radioactivity assays. An 8-ton shipment containing some barren rock assayed 0.10 percent chemical U_3O_8, but a cleaner 9-ton shipment contained 0.86 percent chemical U_3O_8. A reserve of several thousand tons, with an average grade of more than 0.5 percent U_3O_8, is estimated for this deposit.

HILLTOP MINE

The Hilltop mine is in the southern part of Slim Buttes (fig. 147), approximately 75 feet below the base of the Arikaree formation cap. Local relief is 250–300 feet.

The deposit lies in and close to the base of the Ludlow member. Only the lower beds of the Ludlow were left in this area after pre-Miocene erosion. Slumping is extensive in the vicinity of the Hilltop mine, but the deposit itself is in undisturbed strata. The complete section of the White River group is not present in the area, as indicated by the proximity of the Ludlow member to the Arikaree formation. Dip of sediments in this vicinity is less than 50 feet per mile to the north.

The uraniferous zone, which has been traced for several hundred feet along the hillside, consists of 10–16 inches of brownish-black to black, weathered, powdery lignite containing lenses of hard semilustrous material of conchoidal fracture. Peacock irridescence, grading into a dark-brown coating, is present on fracture surfaces. Abundant limonite and some jarosite are present locally. Gypsum seams, commonly one-eighth of an inch thick, are present throughout the bed, and gypsum crystals as much as 2 inches thick occur in the upper part of the bed. No analcite was observed. A green micaceous mineral, commonly exhibiting green fluorescence, has been noted on cleat faces but is rare. Chemical assays as high as 5.0 percent U_3O_8 have been obtained from picked samples.

The mineralized zone is overlain by several feet of interbedded mudstones and unconsolidated sandstones and directly underlain by more than 2 feet of brown peaty impermeable mudstone. An incomplete section measured immediately above and below the uraniferous lignitic bed is as follows:

	Feet
Mudstone, medium-gray to black, fissile; contains abundant carbon trash and casts of woody material. A thick brown coating present on fracture surfaces, and gypsum occurs as fracture fillings. Mudstone exhibits blocky fracture	5
Sandstone yellowish-brown to light-gray, thin-bedded, silty to very fine-grained, limonite-stained; interbedded with mudstone; 1- to 2-inch gypsum rosettes on fracture surfaces. Bottom foot is fine-grained unconsolidated permeable sandstone with sparse carbon seams near top and abundant limonite stain near base	4
Mudstone, light- to medium-gray, interbedded with light-brown to gray very fine-grained sandstone, containing carbon specks and some gypsum. Sandstone capped by 3 inches of dark-gray fissile mudstone	3
Lignite, uraniferous, 10–16 inches thick	1
Mudstone, medium-gray to black, fissile, peaty; contains a high percentage of carbon specks, flakes, and seams. Jarosite and limonite occur as stringers. Gypsum present as fracture fillings	3
Mudstone, medium- to dark-gray; contains sparse carbon specks and some jarosite stringers. Slope below concealed	2

More than 300 tons averaging 0.33 percent U_3O_8, 0.04 percent V_2O_5, and 3.4 percent $CaCO_3$ have been shipped from the Hilltop mine.

LONESOME PETE CLAIM

The Lonesome Pete claim is in sec. 26, T. 21 N., R. 4 E., along the western side of South Cave Hills (fig. 146). Local relief is approximately 250 feet.

The lower massive sandstone of the Tongue River member caps the hills in this area, but the "E" bed is not present in the vicinity. The Ludlow member makes up the lower slope of the South Cave Hills.

The mineralized unit is just above the "B" bed of the Ludlow; that is, approximately 110 feet below the contact of the Ludlow and the Tongue River. Two, and possibly three, barren lignite beds overlie this deposit.

Regional dip is approximately 40 feet per mile to the northeast; heavy slumping in the Ludlow masks local structural features. Jointing is moderately spaced, but faulting has not been observed.

A section measured from the caprock of the lower massive sandstone of the Tongue River member to the "B" bed is as follows:

	Feet
Sandstone, brown, fine- to medium-grained, thin-bedded to massive, locally crossbedded. Heavy iron staining imparts a faint banded appearance. Tends to weather into slabs near the top; the more massive-bedded lower part weathers with characteristic wind-eroded pits	35
Covered slope; contains the contact between Tongue River member and underlying Ludlow member. "D" bed may be present at contact	20
Sandstone, light-gray, silty to very fine-grained, massively bedded, friable. Heavy iron stain present on blocky surfaces; small ironstone concretions, partly altered to limonite are abundant. Thin beds of greenish-gray fissile mudstone containing carbon seams present throughout. Abundant weathered analcite associated with discontinuous carbonaceous seams ½–2 inches thick. A prominent heavily iron-stained joint strikes N. 50° W	18
Mudstone, medium- to dark-gray; contains some carbon seams. Abundant gray-weathered analcite particles associated with the carbon seams. Limonite and jarosite present in short stringers ½–2 inches thick	8
Lignite, black, earthy; contains abundant gray- to white-weathered analcite particles and some woody, fibrous material. Jarosite stringers present. Lignite bed pinches and swells, and is nonradioactive. Probably an unnamed bed of only local extent	1.2
Siltstone, gray to reddish-gray, sandy; contains abundant weathered analcite particles and some carbon trash. Abundant carbon flakes and a few mudstone partings occur in lower part. Jarosite present on fracture surfaces	2–4
Lignite, "C" bed, black, earthy; contains abundant white-weathered analcite particles and jarosite. Iron minerals commonly occur as stringers and masses with a jarosite core and limonite halo. No abnormal radioactivity	3
Sandstone, medium-gray to buff, very fine-grained; interbedded with siltstone and mudstone. Some massive pyrite and sparse pyrite crystals associated with carbon in the mudstone. Abundant carbon flakes and specks occur in the sandstone, together with traces of analcite, near top of unit	10
Sandstone, medium-gray to brown, very fine- to fine-grained, poorly consolidated, exhibits iron stain in thin bands. Abundant carbon associated with iron staining. Near the base, lenses of buff to medium-brown hard very calcarous, very fine- to fine-grained sandstone, 1–1½ feet thick, some with abundant carbon	15
Sandstone, light-gray, very fine- to medium-grained, friable massive; contains small ironstone concretions with limonite halos	35

Uraniferous zone	Feet
Clay, medium-gray, sandy; contains small rounded particles of unidentified black mineral	0. 7–1. 2
Mudstone, medium-gray, sandy; contains same rounded black particles. Radioactive	0. 5
Clay, green to greenish-gray; contains limonite and jarosite stringers	0. 8
Mudstone, medium-gray to black, sandy; contains abundant rounded particles of black mineral; richest part of ore zone	0. 3
Claystone, medium-gray; contains abundant limonite as stringers and stain	0. 4
Lignite ("B" bed), earthy, black; contains some white- to gray-weathered analcite particles. Limonite and jarosite occur as stringers. Upper part radioactive at this locality. Lower slope concealed	11. 0

The Lonesome Pete group represents a type of deposit distinct from the uraniferous lignites. The mineralized zone constitutes 6 inches to 2 feet of discontinuous carbonaceous mudstone and claystone, less than a foot above the "B" lignite bed of the Ludlow member. No uranium minerals are visible except at the exposed rim where weathering and oxidation have reached an advanced stage. The mineralized beds, under a few inches of cover, exhibit no oxidation and are gray to black. No uranium minerals have been identified from it although chemical assays of 0.85 percent U_3O_8 are common. Pyrite nodules are abundant; carbon content is about 5 percent.

A bulk sample (100 pounds) gave the following results:

eU_3O_8, 0.85 percent; chemical U_3O_8, 0.85 percent; V_2O_5, 0.03 percent; $CaCO_3$, 7.6 percent; Cu, 0.02 percent. Phosphate, in the amount of 12–13 percent and fluorine in the amount of 1.5 percent were determined from another bulk sample.

The ore zone was exposed by mining operations for 550 feet along the bed and into the hill about 30 feet. The beds constituting the mineralized zone were revealed to pinch and swell unpredictably as they were exposed. Thirty feet from the outcrop, the uppermost gray sandy clay bed, described in the measured section, pinched out completely at one point in the mine. The 4 radioactive beds, whose aggregate thickness ranges between 1 and 2 feet, have been combined to make a product whose grade was more than 0.10 percent U_3O_8. The stratigraphically lowest radioactive bed consists of about 4 inches of medium-gray to black sandy mudstone with abundant rounded particles (1–3 mm) of black carbonaceous material. This is the richest part of the ore zone, with channel samples assaying as much as 0.85 percent chemical U_3O_8. A bed of medium-gray claystone, 3 inches thick and containing abundant limonite stringers and stains, separates the uraniferous mudstone from the underlying "B" lignite bed. Although less than 2 feet of the lignite has been uncovered, auger holes indicate that the bed ranges between 4 and 21 feet in thickness. The upper 2 feet consists of earthy, black-weathered lignite containing some analcite particles. Limonite and jarosite occur as stringers. The "B" bed is essentially barren at this claim.

SUMMARY AND CONCLUSIONS

Uraniferous lignite and carbonaceous siltstone represent a significant reserve of uranium source material in western North and South Dakota. The biggest known deposits are located in Harding County, S. Dak., but the area of potential deposits extends many miles into North Dakota and Montana.

Uranium deposits are found in the thin lignitic beds of all members of the Fort Union formation of Paleocene age. Although the stratigraphically highest lignite bed is not necessarily the most uraniferous, the known deposits are all within 200 feet of the pre-Oligocene erosion surface. Possibly pre-Oligocene weathering of the coals facilitated deposition of uranium in the lignites. Although some deposits show no oxidation, most have some oxidized minerals.

Chemical assays of lignite are commonly higher in uranium than the radiometric assays; the reverse is true of assays made of uraniferous carbonaceous shale or siltstone. Although a few uranium minerals have been identified, the uranium is overwhelmingly in association with the coal constituents. Visible minerals are a guide to high-grade parts of a deposit.

Deposits of several thousand tons in size are known at present, but the limits of the deposits have not been firmly established.

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