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Uranium-Bearing Lignite in Southwestern North Dakota

By George W. Moore, Robert E. Melin, and Roy C. Kepferle

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

URANIUM-BEARING LIGNITE IN SOUTHWESTERN NORTH DAKOTA*

By

George W. Moore, Robert E. Melin,
and Roy C. Kepferle

June 1954

Trace Elements Investigations Report 463

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

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URANIUM-BEARING LIGNITE IN SOUTHWESTERN NORTH DAKOTA

By George W. Moore, Robert E. Melin, and Roy C. Kepferle

ABSTRACT

Uranium-bearing lignite was mapped and sampled in the Bullion Butte, Sentinel Butte, HT Butte, and Chalky Buttes areas in southwestern North Dakota. The uraniferous lignite occurs at several stratigraphic positions in the Sentinel Butte member of the Fort Union formation of Paleocene age. A total of 261 samples were collected for uranium analysis from 85 localities. Lignite containing as much as 0.045 percent uranium, 10.0 percent ash, and 0.45 percent uranium in the ash was found although the average is lower. Inferred reserves for the four areas examined are estimated to be about 27 million tons of lignite in beds about 2 feet thick and containing more than 3000 tons of uranium. The lignite averages more than 30 percent ash in the surface samples. The principal factor that seems to influence the uranium content of lignite beds is their stratigraphic position below the overlying rocks of the White River group of Oligocene age. All of the uranium-bearing beds closely underlie the base of the White River group. Although this relationship seems to be the controlling factor, the relative concentration of uranium may be modified by other conditions. Beds enclosed in permeable rocks are more uraniferous than beds in impermeable rocks, and thin beds have a higher content of uranium than thick beds. In addition, thick lignite beds commonly have a top-preferential distribution of uranium. These and other factors suggest that the uranium is secondary and that it was introduced by ground water which had leached uranium from volcanic ash in the overlying rocks of the White River group. It is thought that the uranium is held in the lignite as part of a metallo-organic compound.

INTRODUCTION

Deposits of uranium-bearing lignite were examined in the Bullion Butte, Sentinel Butte, HT Butte, and Chalky Buttes areas in southwestern North Dakota during 1953 by the U.S. Geological Survey on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission (fig. 1).

The common association of uranium with carbonaceous material has long been recognized, and at least one deposit of uranium-bearing coal has been known for 80 years (Berthoud, 1875). Other deposits of uranium-bearing coal were discovered in 1946 in the Red Desert, Sweetwater County, Wyoming, by Slaughter and Nelson. Later work by Wyant and Beroni (1950) resulted in the discovery of additional uraniferous lignite beds in North and South Dakota.

Each of the three areas investigated is dominated by one or more high buttes. Sentinel, Bullion, and HT (Black) Buttes each rise more than 500 feet above surrounding gently rolling plains. HT Butte, with an altitude of 3,468 feet, is the highest point in North Dakota. The uranium-bearing lignite lies at most places near the tops of the buttes. All of the areas are fairly accessible. U.S. Highway 85 passes through the Chalky Buttes area and U.S. Highway 10 passes within 3 miles of Sentinel Butte. The nearest rail shipping points are 12 miles south of the Chalky Buttes area at Bowman and 3 miles north of Sentinel Butte at the town of Sentinel Butte. Bullion Butte is about 30 miles by county-maintained road from the town of Sentinel Butte.

Previous geologic mapping in these areas was done by Leonard (1908), Leonard and Smith (1909), and Hares (1928). Later Beroni and Bauer (1952) sampled and described uranium-bearing lignite in the Sentinel and Bullion Butte areas. Deposits of uraniferous lignite in nearby parts of South Dakota

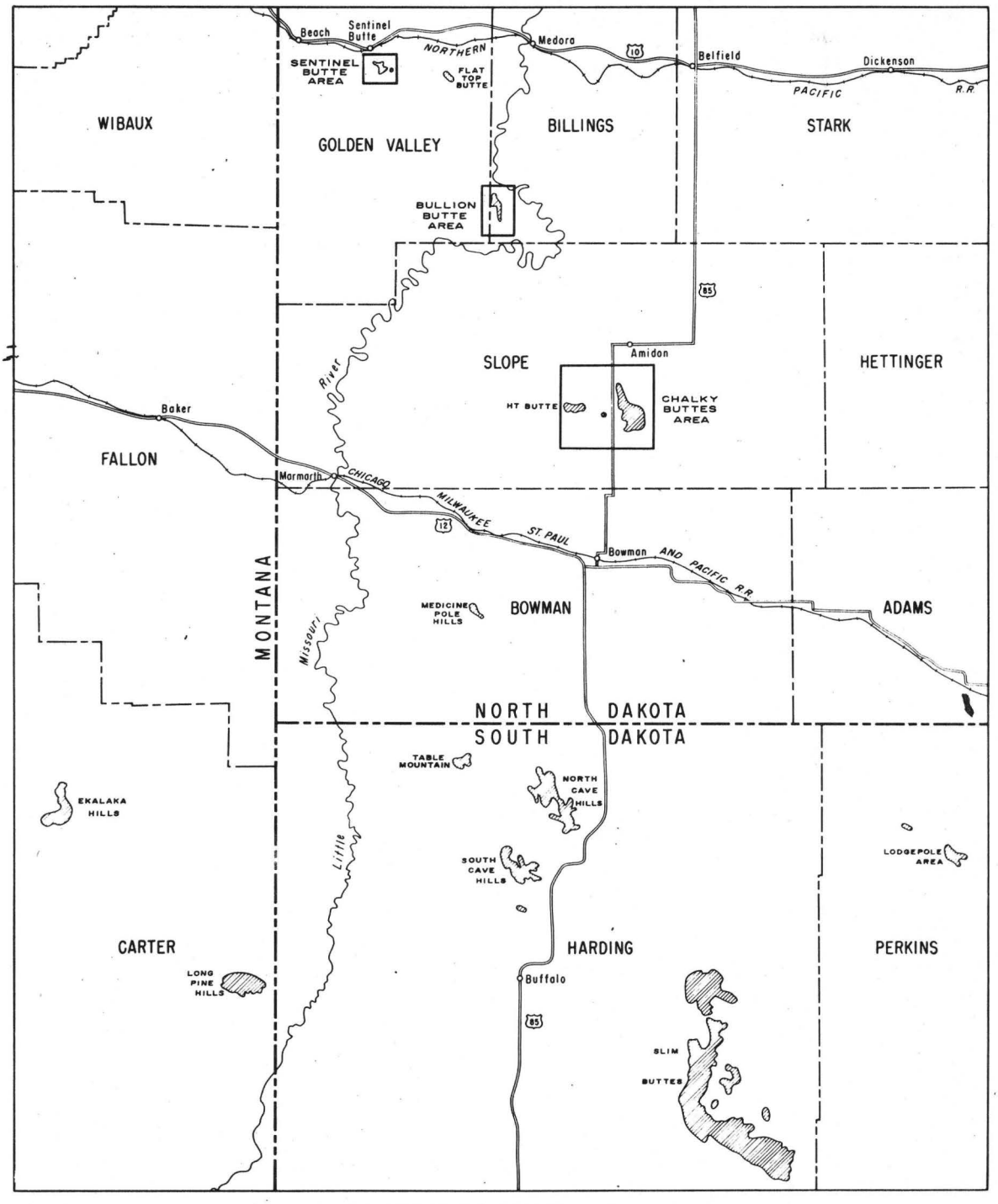


FIGURE 1.-INDEX MAP SHOWING AREAS DESCRIBED IN THIS REPORT AND OTHER AREAS OF URANIUM-BEARING LIGNITE IN NORTH DAKOTA, SOUTH DAKOTA, AND MONTANA.

have a similar geologic setting and are described by Denson and others (1950).

J. R. Gill organized the present field party and participated in the early stages of the work. Unpublished data on the uraniferous lignite deposits of South Dakota by N. M. Denson, G. O. Bachman, and H. D. Zeller were made available and permit the placing of the North Dakota deposits in their regional setting. Personnel of the U. S. Geological Survey Trace Elements Denver Laboratory analyzed the rock and water samples collected during the present study.

STRATIGRAPHY

The rocks exposed in the Sentinel, Bullion, and Chalky Buttes areas are of continental origin. The uranium-bearing lignite is in the upper part of the Fort Union formation of Paleocene age. The Fort Union formation is divided into the Ludlow, Tongue River, and Sentinel Butte members in ascending order. Only the upper two, the Tongue River and Sentinel Butte members, crop out in the mapped areas. The White River group of Oligocene age, which is made up of the Chadron and Brule formations, unconformably overlies the Fort Union formation.

Stratigraphic sections of the rocks exposed in the Sentinel, Bullion, and Chalky Buttes areas are shown in figure 2.

Tertiary rocks

Fort Union formation

Tongue River member.--The Tongue River member of the Fort Union formation of Paleocene age is the oldest rock unit exposed in each of the three areas mapped. A total thickness of 600 feet is assigned to the member by

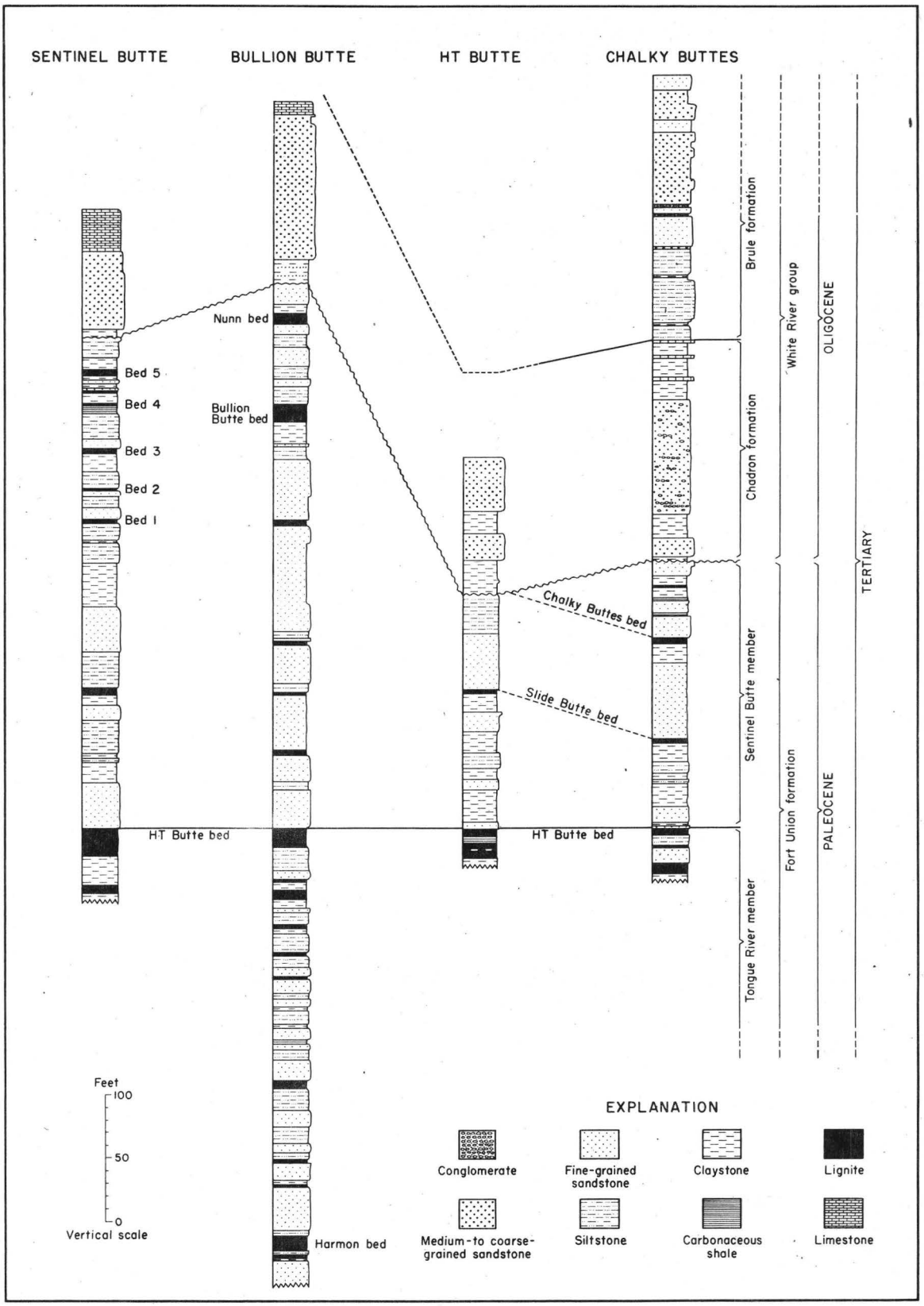


FIGURE 2-STRATIGRAPHIC SECTIONS OF ROCKS ASSOCIATED WITH URANIUM-BEARING LIGNITE IN SOUTHWESTERN NORTH DAKOTA.

Hares (1928, p. 47). The Tongue River is made up dominantly of light yellowish-gray very fine-grained sandstone and siltstone with lesser amounts of claystone, carbonaceous shale, and lignite. The contact between the Tongue River and the overlying Sentinel Butte member is placed arbitrarily at the top of the HT Butte lignite bed.

Sentinel Butte member.--The uranium-bearing lignite deposits in the areas studied are in the Sentinel Butte member of the Fort Union formation. This unit overlies the Tongue River member and is considered to be of Paleocene age (Brown, 1948). The Sentinel Butte member ranges in thickness from about 430 feet at Bullion Butte to 170 feet at HT Butte owing to an erosion surface that truncates the rocks progressively from northeast to southwest.

The Sentinel Butte member is composed principally of siltstone and very fine-grained sandstone. In addition, claystone, lignite, and carbonaceous shale make up a somewhat larger part of the total than they do in the Tongue River member, and the over-all color is darker than the Tongue River.

A vertebrate fossil identified by J. R. Macdonald, South Dakota School of Mines, as Champsosaurus sp. was found in the Chalky Buttes area about 180 feet stratigraphically above the base of the Sentinel Butte member and 18 feet below the overlying Chadron formation in the SE¼ sec. 15, T. 134 N., R. 101 W. Champsosaurus is one of the last of a primitive order of water-dwelling reptiles that appeared in Permian time and did not survive the Eocene.

Chadron formation

The Chadron formation, the lower formation of the White River group of Oligocene age, is about 170 feet thick and in each of the areas investigated

unconformably overlies the Sentinel Butte member of the Fort Union formation of Paleocene age. Twenty-five miles to the east, where a greater thickness of the underlying rocks has been preserved, the Chadron rests on the Golden Valley formation of Eocene age (Benson, 1951). At most places examined the formation consists of a basal unit of light greenish-gray sandy claystone about 20 feet thick; a middle unit of yellowish-gray coarse-grained locally conglomeratic sandstone about 100 feet thick; and an upper unit of light olive-gray bentonitic claystone and white freshwater limestone about 50 feet thick. Fossil fish have been described from some of the limestone beds (White, 1883). The middle sandstone unit forms the caprock on Sentinel, Bullion, and HT Buttes. The top of the Chadron formation is marked by the uppermost limestone bed in the section.

Brule formation

The Brule formation, about 210 feet thick, is the upper formation of the White River group and is exposed only in the Chalky Buttes. The basal 100 feet are dominantly grayish orange-pink tuffaceous siltstone. Mammal remains were collected about 20 feet above the base of the Brule formation in the NW$\frac{1}{4}$ sec. 31, T. 134 N., R. 100 W. These have been identified by M. J. Hough of the U. S. Geological Survey. The collection is regarded as Whitneyan in age.

Miohippus sp. parts of two lower jaws
Hyracodon sp. lower molar
Eporeodon ? lower jaw fragment
Protoceras ? lower jaw fragment
Leptomeryx sp. parts of three lower jaws
Leptauchenia sp. anterior portion of skull and jaws, mandible, posterior portion of skull
Cedromus ? upper tooth
Eumys sp. portions of three lower jaws

Paleolagus sp. portions of four lower jaws
Paradjidaumo ? n. sp. ? portions of three lower jaws
Prosciurus sp. lower jaw fragment

About 100 feet above the base of the Brule formation there is an erosion interval marked by a 9-foot bed of conglomerate. Above this bed the rocks are principally dusky yellow-green medium- to coarse-grained sandstone which could be upper Oligocene or younger.

Quaternary deposits

Surficial material

Deposits of terrace gravel as much as 10 feet thick are present on the flanks of Bullion Butte at an altitude of 220 feet above the Little Missouri River. These deposits were not mapped. Landslide material derived mostly from the White River group is common along the sides of the buttes. These deposits were mapped in the Chalky Buttes area but were not mapped in the Bullion Butte and Sentinel Butte areas. Deposits of alluvium and slope-wash occur along the major streams and on many of the hills, but none of this material was mapped.

STRUCTURE

The rocks in the areas investigated lie on the northeast flank of the Cedar Creek anticline, a low narrow uplift trending northwest through the southeast corner of North Dakota. The rocks dip to the northeast into the Williston Basin at about 25 feet per mile. No faults have been recognized in the mapped areas.

URANIUM-BEARING LIGNITE

All of the uranium-bearing lignite beds in the three areas studied are in the Sentinel Butte member of the Fort Union formation. The relative stratigraphic position of the lignite beds is shown by figure 2, and their areal distribution is shown by the geologic maps, figures 3, 5, and 7. The discussion of uranium distribution is based on 85 measured sections of the uraniferous beds from which 261 samples were collected for uranium determination. Samples were also submitted for analysis from the underlying non-radioactive beds.

Bullion Butte area, Billings and Golden Valley Counties, North Dakota

The most radioactive lignite bed in the Bullion Butte area is referred to in this report as the Nunn bed, named from the Nunn Ranch in Sec. 6, T. 137 N., R. 102 W. The bed crops out on the upper slopes of the butte about 400 feet stratigraphically above the base of the Sentinel Butte member. It is the stratigraphically highest lignite bed exposed in the area. The Nunn bed ranges in thickness from 3 to 12 feet, averages 5 feet in thickness, and underlies an area of about 500 acres. The highest concentration of uranium found in the bed is 0.036 percent. The average uranium content of the bed is variable, being greatest at the places where it is thin and decreasing where the bed is thick. The quantity of uranium contained in the bed per square unit of area remains approximately the same, however, so that the thickness of the bed may be taken as an inverse measure of its relative grade. The uranium is not evenly distributed through the lignite bed but is commonly concentrated in the upper part, the grade decreasing downward. A similar top-preferential distribution of uranium

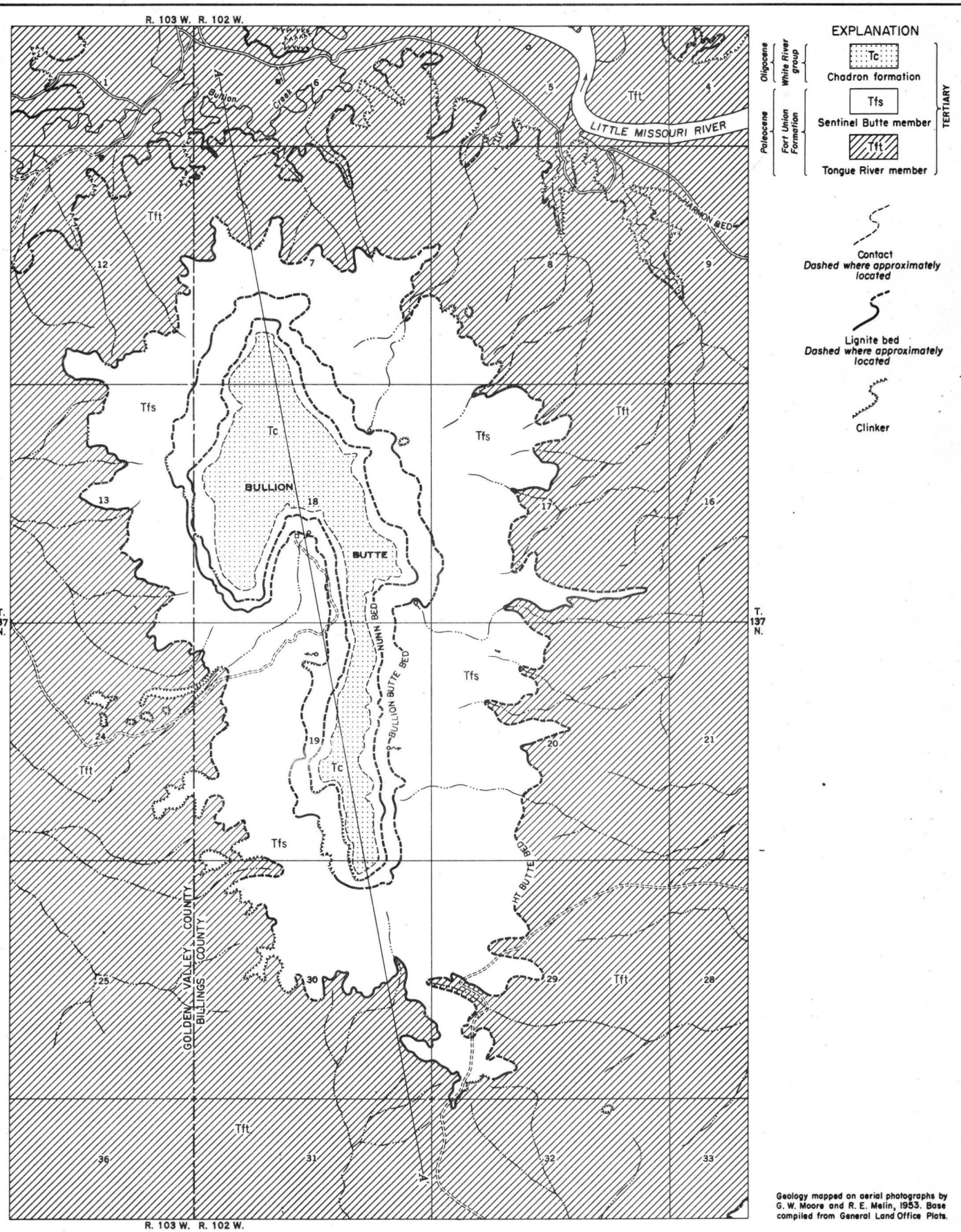


FIGURE 3-GEOLOGIC MAP OF THE BULLION BUTTE AREA, BILLINGS AND GOLDEN VALLEY COUNTIES, NORTH DAKOTA

0 ½ 1 Mile

in thick radioactive lignite beds was noted by Denson and others (1950) in nearby parts of South Dakota.

The Bullion Butte lignite bed, 60 feet stratigraphically below the Nunn bed, is slightly radioactive at some places in the Bullion Butte area. This bed ranges in thickness from 7 to 22 feet and averages 11 feet. The top 1 or 2 feet of the Bullion Butte bed locally contain concentrations of as much as 0.007 percent uranium, but the lower part contains less than 0.001 percent. Other lignite beds in the Bullion Butte area are non-uraniferous.

The Nunn bed contains an inferred reserve of about 4,210,000 short tons of lignite, and 300 short tons of uranium. The bed has an average thickness of 4.8 feet. The average uranium content of the lignite is 0.007 percent. The average ash content of the lignite is about 20 percent and the ash contains an average of 0.037 percent uranium. The Bullion Butte bed contains an inferred reserve of about 16,160,000 tons of lignite, but no uranium reserves are assigned to it. Maps of the Nunn and Bullion Buttes beds are shown in figure 4.

Sentinel Butte area, Golden Valley County, North Dakota

Five uranium-bearing lignite beds crop out near the top of Sentinel Butte. These beds from oldest to youngest are numbered 1 through 5 (figure 5). They are all in the upper part of the Sentinel Butte member of the Fort Union formation.

The upper bed, bed 5, which closely underlies the Chadron formation, has the greatest uranium content per unit area, though lower beds locally have a higher percent uranium. Within a bed the vertical distribution of uranium is somewhat irregular, the greatest concentrations occurring near

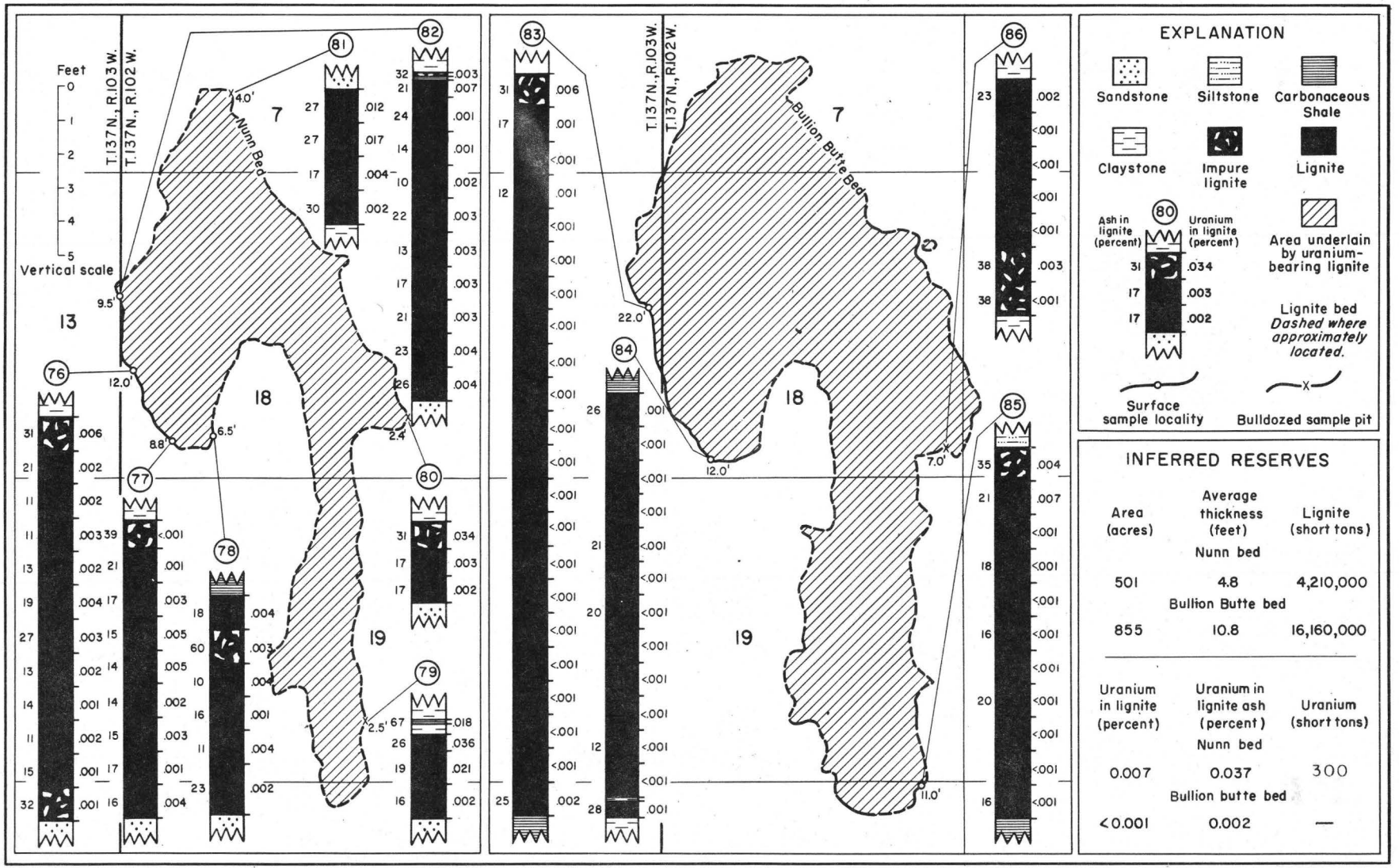


FIGURE 4-RESERVES OF URANIUM-BEARING LIGNITE IN THE BULLION BUTTE AREA, BILLINGS AND GOLDEN VALLEY COUNTIES, NORTH DAKOTA.

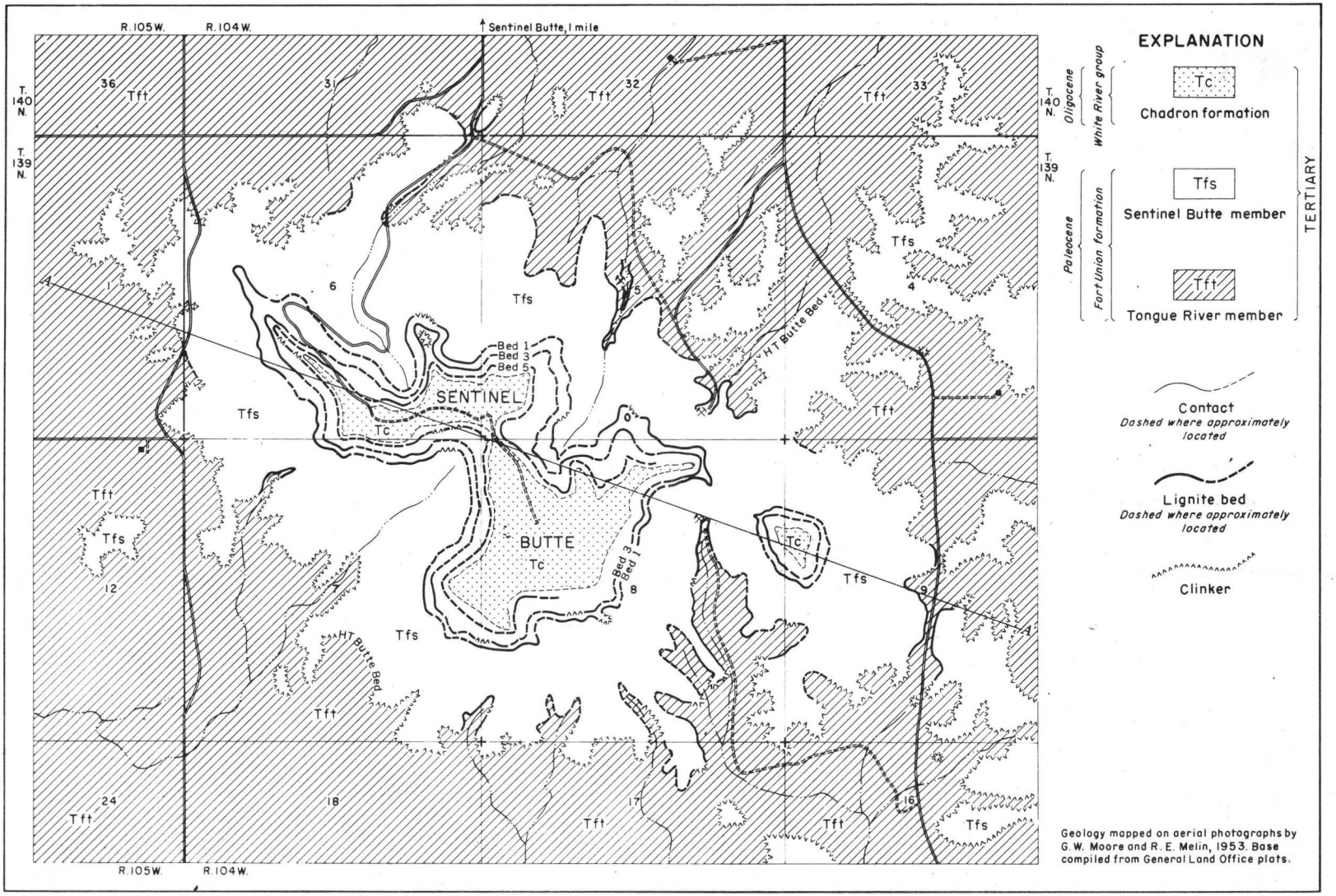


FIGURE 5 —.GEOLOGIC MAP OF THE SENTINEL BUTTE AREA, GOLDEN VALLEY COUNTY, NORTH DAKOTA

the tops of the thicker beds, but in the beds 2 feet or less in thickness the greatest concentrations occur near the base.

Lignite beds in the lower part of the Sentinel Butte member as well as in the underlying Tongue River member contain less than 0.001 percent uranium.

Lignite beds 1 through 5 contain a total inferred reserve of about 5,000,000 short tons of lignite and 300 short tons of uranium. The lignite contains an average of about 0.007 percent uranium, 32 percent ash, and 0.022 percent uranium in the ash. The average thickness of the lignite beds is about 2.5 feet. Figure 6 shows the extent of the individual lignite beds and the sampled sections and analytical data on which the reserve estimates are based. Inferred reserves of the individual beds also are shown.

Chalky Buttes area, Slope County, North Dakota

In the Chalky Buttes area, Slope County, North Dakota, two beds of uranium-hearing lignite occur in the lower part of the Sentinel Butte member of the Fort Union formation. They are here named the Chalky Buttes bed and the Slide Butte bed (fig. 7) from exposures on the respective buttes. These beds underlie a total of 8 square miles and make up the largest area known to be underlain by uraniferous lignite in North Dakota.

The Chalky Buttes bed underlies only the northern part of Chalky Buttes (fig. 8). In the southern part of the area the bed has been removed by pre-Chadron erosion. The bed ranges in thickness from 0.5 to 4 feet and averages about 2 feet. Itsuranium content varies considerably, reaching a maximum of 0.018 percent near the place where the lignite bed is truncated by the Chadron formation. The inferred reserves of the Chalky Buttes bed in

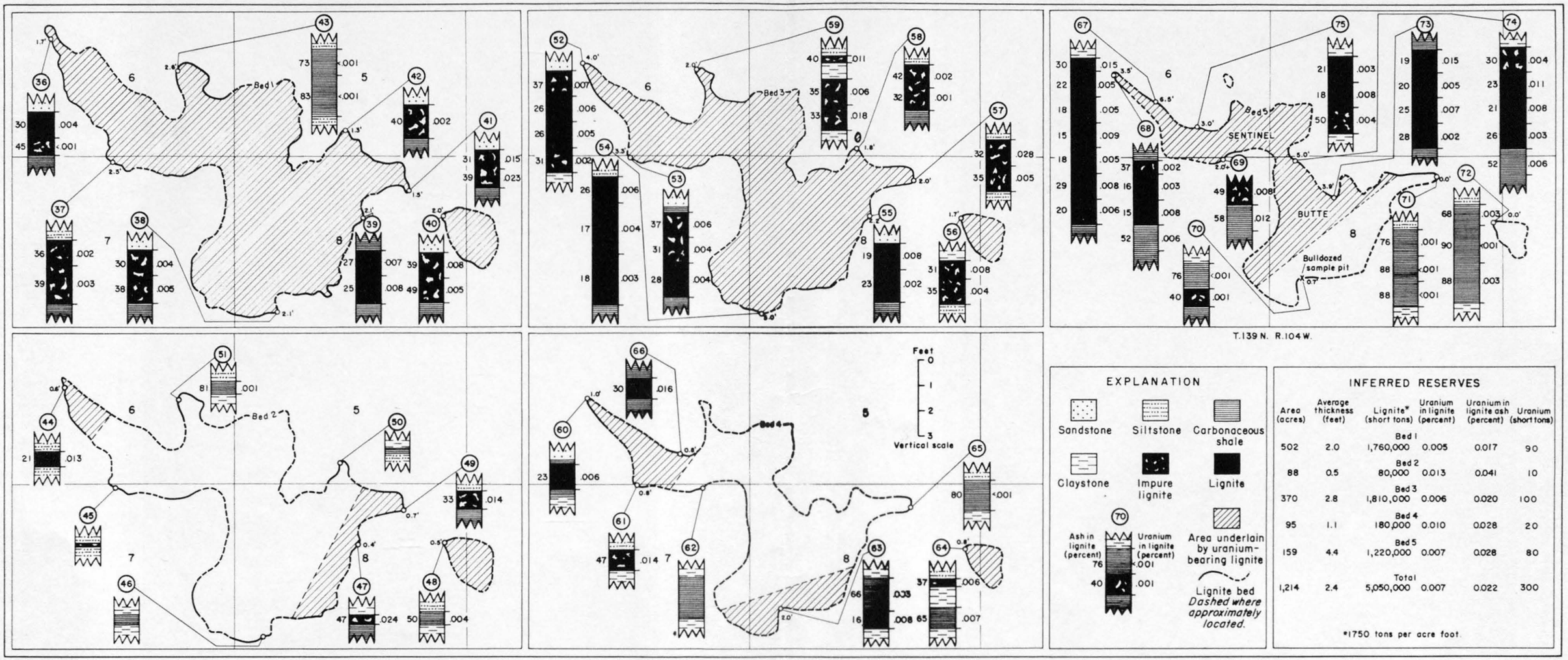


FIGURE 6.- RESERVES OF URANIUM-BEARING LIGNITE IN THE SENTINEL BUTTE AREA, GOLDEN VALLEY COUNTY, NORTH DAKOTA.

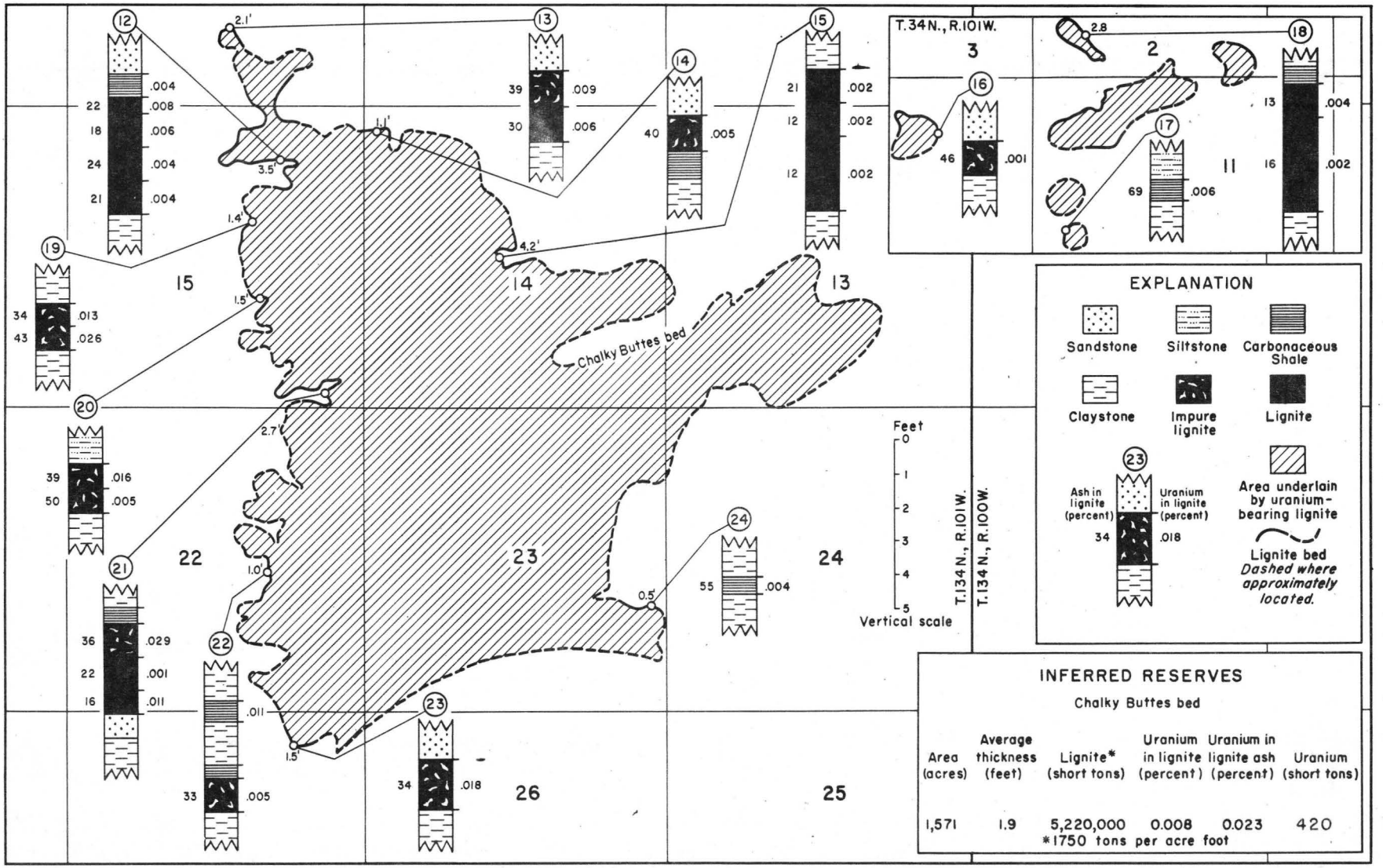


FIGURE 8 -RESERVES OF URANIUM-BEARING LIGNITE IN THE NORTHERN PART OF THE CHALKY BUTTES AREA, SLOPE COUNTY, NORTH DAKOTA.

the northern part of the Chalky Buttes area amount to 5,220,000 short tons of lignite and about 420 short tons of uranium. The lignite contains an average of 0.008 percent uranium and 30 percent ash. The uranium in the ash averages about 0.023 percent.

The Slide Butte bed is 80 feet stratigraphically below the Chalky Buttes bed and 70 feet above the base of the Sentinel Butte member. It is the stratigraphically highest bed at HT and Slide Buttes and in the southern part of Chalky Buttes. The Slide Butte bed has a maximum thickness of 7 feet and an average thickness of about 2 feet. A sample from this bed collected at the east end of HT Butte contains 0.045 percent uranium, 10 percent ash, and 0.45 percent uranium in the lignite ash. The average uranium content of the bed, however, is considerably less, and in the northern part of Chalky Buttes, where the overlying Chalky Buttes bed is present, the uranium content is as low as 0.003 percent.

In the southern part of the Chalky Buttes area (fig. 9), the Slide Butte bed contains an inferred total of about 10,000,000 short tons of lignite and about 2,230 short tons of uranium. The average uranium content of the lignite is about 0.022 percent; the ash content is about 30 percent and the ash contains about 0.063 percent uranium. Of the above reserves, about 2,900,000 short tons of lignite containing about 460 short tons of uranium has an overburden of less than 30 feet and could be recovered by strip mining. The lignite that could be recovered by stripping averages about 2.6 feet in thickness and has an average uranium content of 0.016 percent. The average ash content is about 25 percent and the ash contains about 0.06 percent uranium.

In the HT Butte area, including both HT Butte and Slide Butte, the Slide Butte bed has inferred reserves of about 2,500,000 short tons of

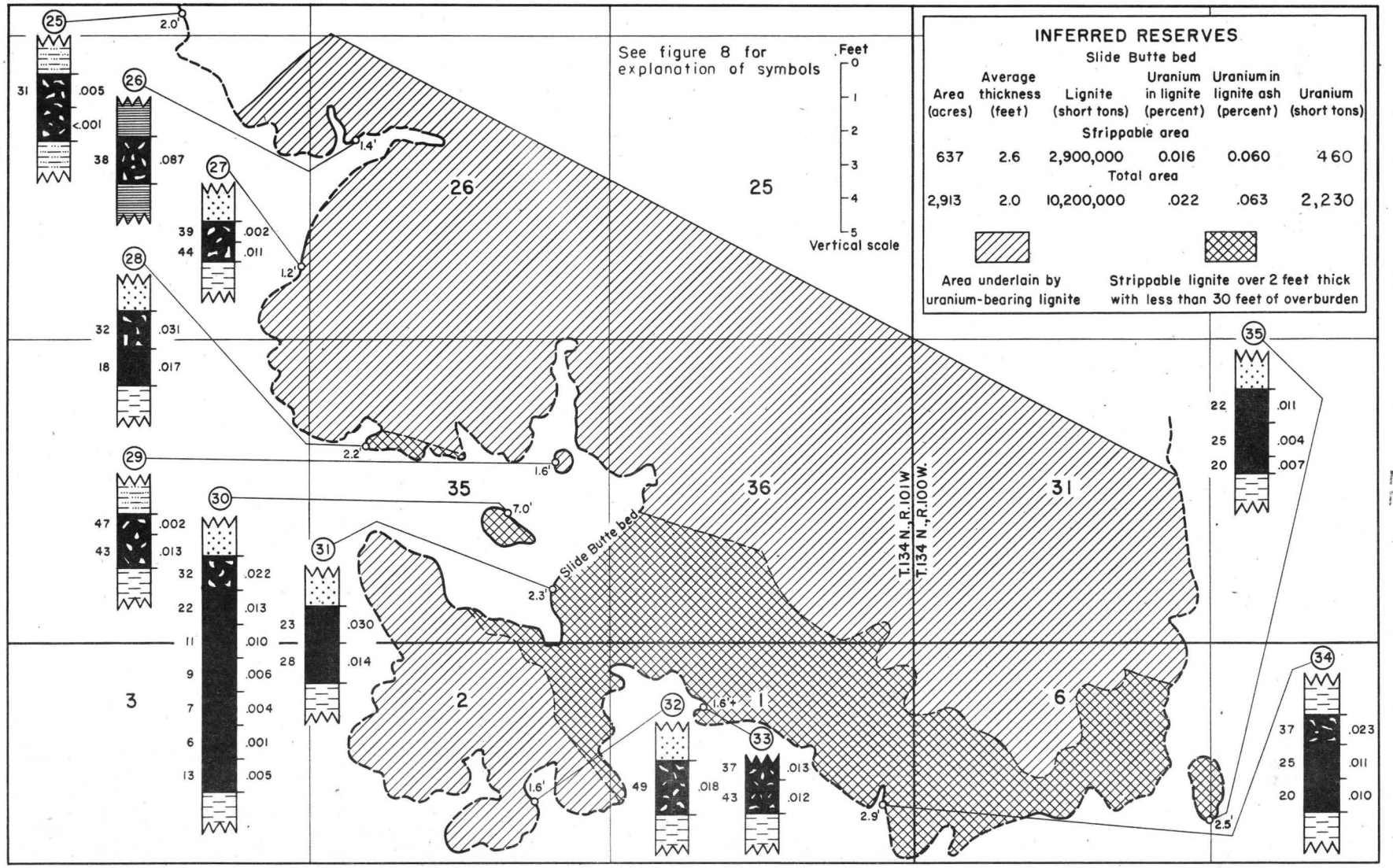


FIGURE 9-RESERVES OF URANIUM-BEARING LIGNITE IN THE SOUTHERN PART OF THE CHALKY BUTTES AREA, SLOPE COUNTY, NORTH DAKOTA.

lignite containing about 400 short tons of uranium (fig. 10). The lignite is about 2 feet thick on both buttes and contains about 20 percent ash. On HT Butte the lignite contains about 0.015 percent uranium and 0.075 percent uranium in the ash. On Slide Butte, however, which contains about 230,000 short tons of lignite and 50 short tons of uranium, the lignite contains about 0.024 percent uranium and 0.12 percent uranium in the ash.

SUMMARY OF RESERVES OF URANIUM-BEARING LIGNITE

The inferred reserves of lignite and uranium in the areas investigated in southwestern North Dakota are summarized in table 1. A total of 6,990 acres are underlain by 27,220,000 tons of lignite in beds averaging 2.3 feet in thickness. This lignite contains 3,650 short tons of uranium with an average of 0.013 percent uranium in the lignite and 0.045 percent uranium in the lignite ash.

Except for a small area in the Chalky Buttes, all of the lignite beds examined would have to be mined by underground methods. About 2,900,000 tons of lignite in the Chalky Buttes area contains about 460 tons of uranium and lies under less than 30 feet of overburden.

ORIGIN OF THE URANIUM

Two principal hypotheses have been proposed to explain occurrences of uranium in the lignite beds of North and South Dakota. Denson, Bachman, and Zeller (1950), working in South Dakota, noted that radioactive lignite beds, irrespective of their ages, closely underlie tuffaceous rocks of the White River group. Largely on the basis of this and the fact that greater concentrations of uranium occur in the upper parts of the stratigraphically highest

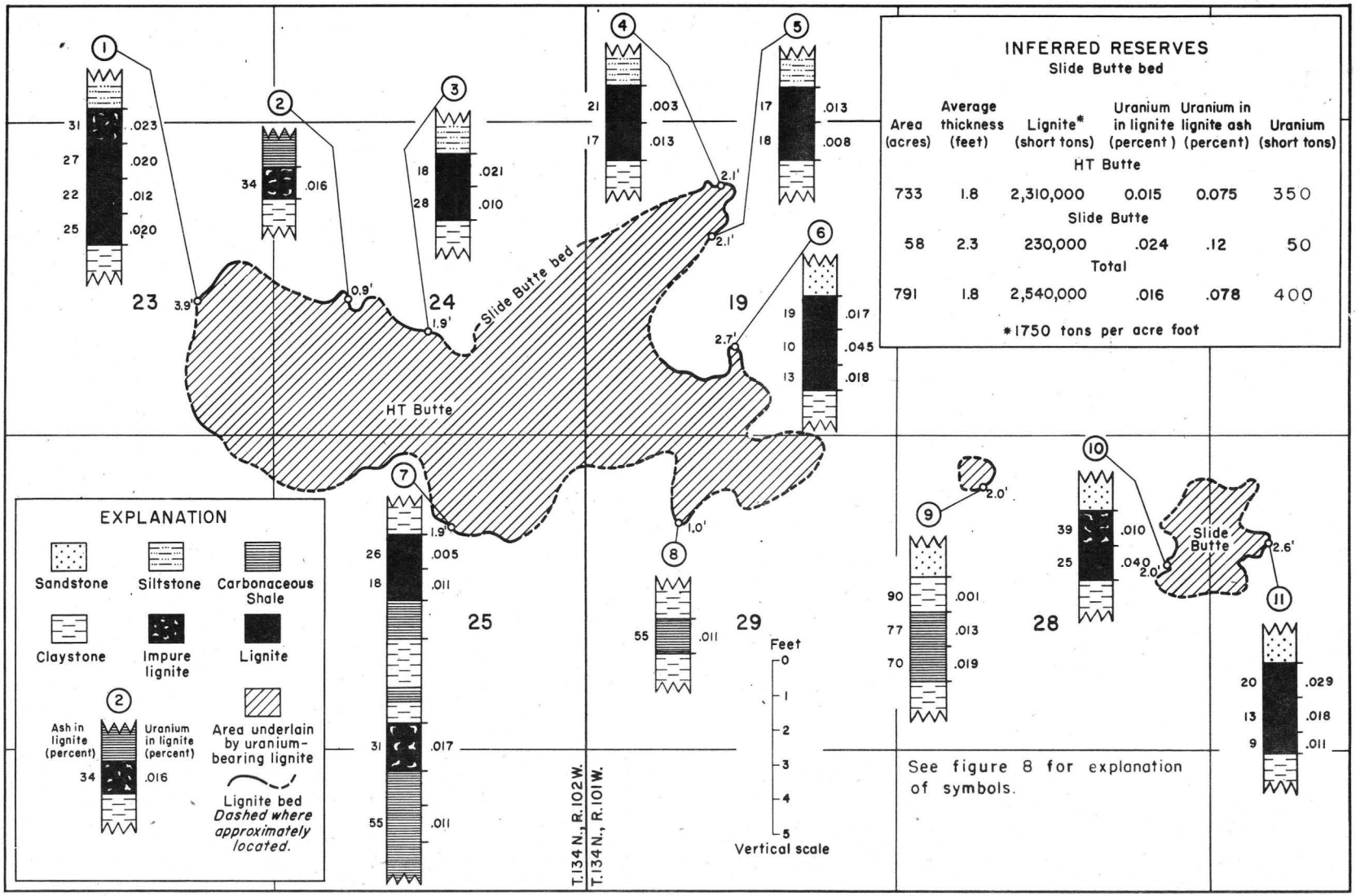


FIGURE 10-RESERVES OF URANIUM-BEARING LIGNITE IN THE HT BUTTE AREA, SLOPE COUNTY, NORTH DAKOTA.

0 1/2 1 Mile

Table 1.--Summary of inferred reserves of uranium-bearing lignite in southwestern North Dakota

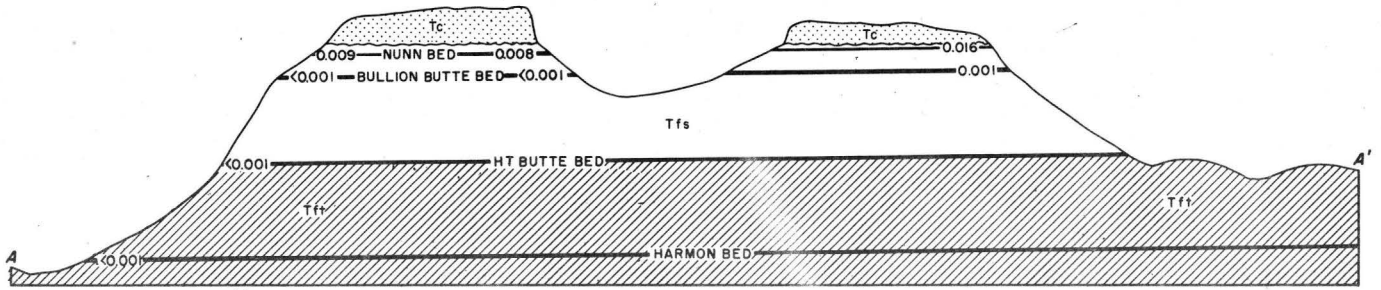
Area (acres)	Average thickness (feet)	Lignite (short tons)	Uranium in lignite (percent)	Uranium in lignite ash (percent)	Uranium (short tons)
		HT Butte, Slope County, N. Dak.			
733	1.8	2,310,000	0.015	0.075	350
		Slide Butte, Slope County, N. Dak.			
58	2.3	230,000	0.024	0.12	50
		Chalky Buttes, Slope County, N. Dak.			
		Lignite under less than 30 feet of overburden			
(637	2.6	2,900,000	0.016	0.060	460)
		Total lignite including that under less than 30 feet of overburden			
4,484	2.0	15,420,000	0.017	0.049	2,650
		Bullion Butte, Billings and Golden Valley Counties, N. Dak.			
501	4.8	4,210,000	0.007	0.037	300
		Sentinel Butte, Golden Valley County, N. Dak.			
1,214	2.4	5,050,000	0.007	0.022	300
TOTAL 6,990	2.3	27,220,000	0.013	0.045	3,650

lignite bed, they concluded that uranium was leached by ground water from volcanic ash of the White River group and overlying Arikaree formation and was introduced into the lignite after coalification.

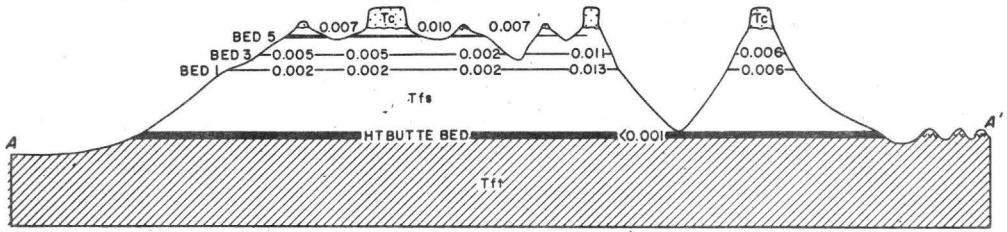
Beroni and Bauer (1952), who studied the uraniferous lignite at Sentinel and Bullion Buttes, suggested that the uranium was extracted from surface waters by organic material or by living organisms which later were carbonized to form the lignite. They suggested that the uranium was derived from volcanic ash deposited contemporaneously with the lignite and now represented by beds of bentonitic claystone and siltstone found at several stratigraphic horizons within the Sentinel Butte member of the Fort Union formation.

Evidence accumulated during the present investigation seems to support the hypothesis of origin advanced by Denson, Bachman and Zeller.

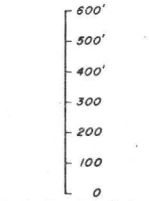
Figure 11 illustrates local variations in the areal distribution of uranium in lignite beds at Bullion, Sentinel, and Chalky Buttes. Generally, the lignite bed which directly underlies rocks of the White River group is more radioactive than other beds lower in the same stratigraphic sequence. Thus, at Bullion Butte, the Nunn bed is uranium-bearing, the underlying Bullion Butte bed contains only minor amounts of uranium locally, and beds below the Bullion Butte bed are non-uraniferous. At Sentinel Butte, bed 5 is the stratigraphically highest lignite bed and contains the most uranium at the west end of Sentinel Butte, but at the east end of the butte where bed 5 lenses out the uranium content of underlying beds 3 and 1 is markedly increased. Similarly at Chalky Buttes, the Slide Butte bed contains only small amounts of uranium where it is overlain by the Chalky Buttes bed, but much larger amounts where the Chalky Buttes bed has been removed by pre-Chadron erosion.



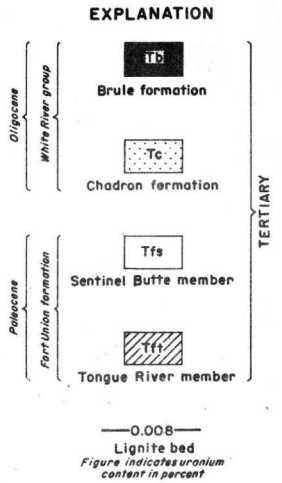
BULLION BUTTE—NOTE THAT THE GREATEST CONCENTRATION OF URANIUM OCCURS IN THE LIGNITE BED DIRECTLY BELOW THE CHADRON FORMATION

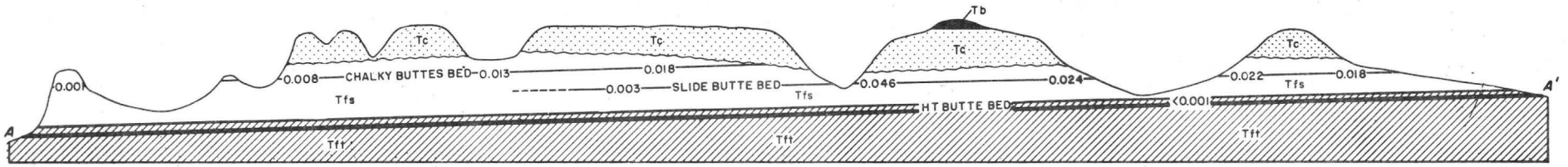


SENTINEL BUTTE—NOTE THAT WHERE THE STRATIGRAPHICALLY HIGHEST LIGNITE BED LENSES OUT, THE URANIUM CONTENT OF THE LOWER BEDS IS GREATER



Vertical scale in feet





CHALKY BUTTES—NOTE THAT WHERE THE UPPER LIGNITE BED IS TRUNCATED BY THE CHADRON FORMATION, THE URANIUM CONTENT OF THE LOWER BED IS GREATER

FIGURE 11.—STRUCTURE SECTIONS THROUGH BULLION, SENTINEL, AND CHALKY BUTTES, SOUTHWESTERN NORTH DAKOTA

0 2 Miles

Figure 12 is a graphic section of the Slide Butte bed showing the top-preferential distribution of uranium typically displayed by thick uranium-bearing lignite beds in the three areas studied. The distribution pattern suggests not only that the uranium is secondary, but that most of the uranium was introduced from above. A slight increase of uranium at the base of the bed is not uncommon, and many of the thinner lignite beds are most uraniferous at their bases. A reversal of the top-preferential distribution pattern might be explained if the coal bed itself acted as an aquifer.

The amount of uranium deposited seems to have been affected in part by the permeability of rocks enclosing the lignite beds. Beds with relatively large uranium content commonly are overlain by permeable beds of sandstone. The Slide Butte bed, which is one of the most uraniferous lignite beds studied, is overlain by a bed of sandstone 60 feet thick in the area in which it is most uraniferous, and the several thin beds of uranium-bearing lignite exposed in the Sentinel Butte area are associated with permeable rocks.

Perhaps the most convincing argument for the origin of uranium from the rocks of the White River group might be made by considering the regional relations between the White River group and the underlying uranium-bearing lignite. Figure 13 is a block diagram showing the truncation of Paleocene and upper Cretaceous rocks by the unconformity at the base of the White River group, and the relation of uraniferous lignite to this erosion surface. At Sentinel and Bullion Buttes, near the northwestern corner of the area shown by the diagram, the White River group overlies the Sentinel Butte member of the Fort Union formation. Here only the lignite in the upper part of the Sentinel Butte member contains uranium. As successively older beds of lignite are cut out beneath the pre-White River unconformity, the next lower bed in the stratigraphic sequence becomes uraniferous so that at Slim Buttes

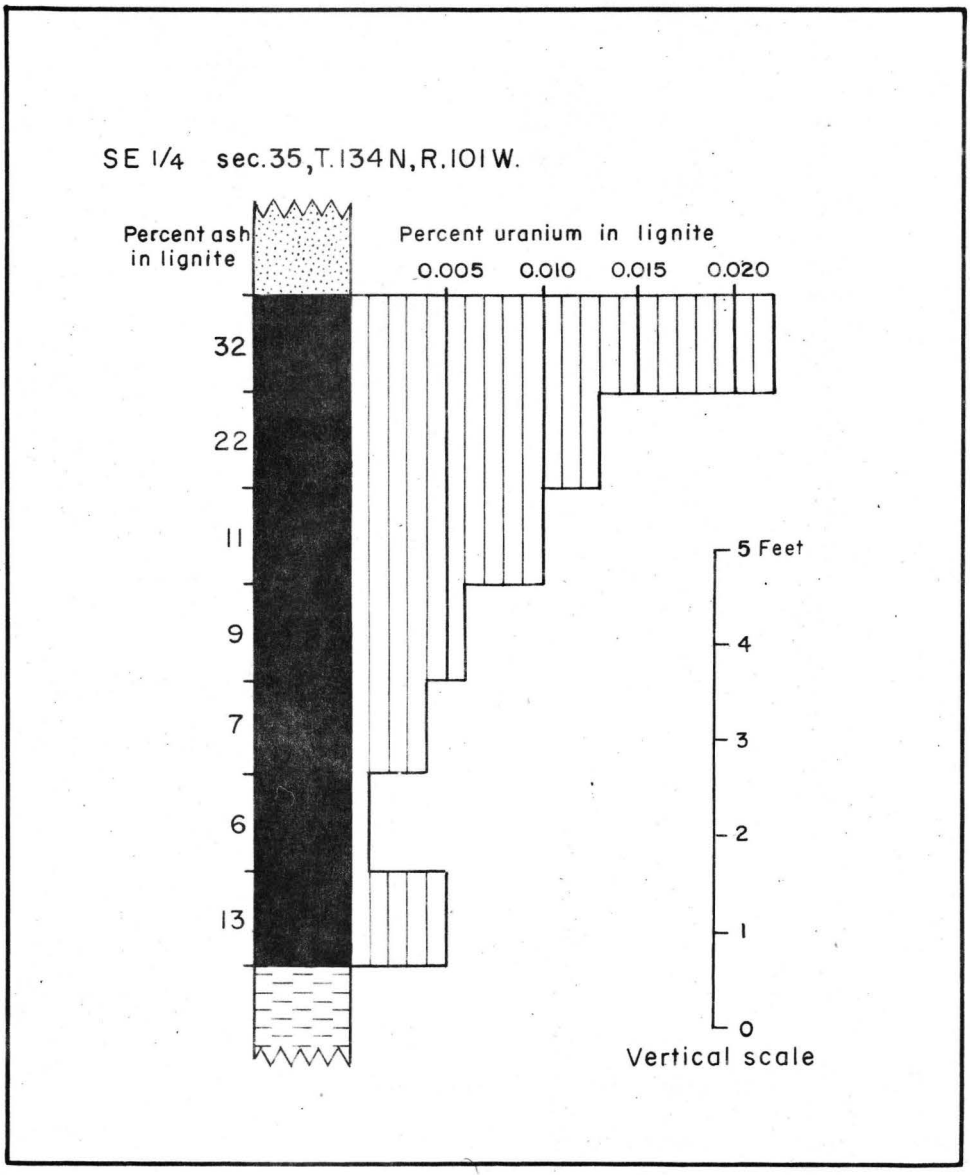


FIGURE 12-GRAPHIC SECTION OF THE SLIDE BUTTE LIGNITE BED AT CHALKY BUTTES, NORTH DAKOTA, ILLUSTRATING TOP-PREFERENTIAL DISTRIBUTION OF URANIUM.

EXPLANATION

Oligocene and Miocene

Twa — White River group and Arikaree formation

Paleocene

Fort Union formation

Tfs — Sentinel Butte member

Tft — Tongue River member

Tfl — Ludlow member

TERTIARY

Upper Cretaceous

Khf — Fox Hills and Hell Creek formation

Kp — Pierre shale

CRETACEOUS

Lignite bed

Uranium-bearing lignite bed

Rainy Buttes

Chalky Buttes

Bowman

Cannonball River

Grand River

NORTH DAKOTA

SOUTH DAKOTA

Bullion Butte

HT Butte

Sentinel Butte

Beach

Medicine Pole Hills

North Cave Hills

Slim Buttes

Little Missouri River

MONTANA

Baker

Long Pine Hills

Ekalaka Hills

Ekalaka

0 10 20 30 40 50 Miles

Approximate horizontal scale

4000'

3000'

2000'

1000'

0'

Vertical scale in feet

NORTH

After data by N.M. Denson, G.O Bachman, and H.D Zeller

FIGURE 13 —.BLOCK DIAGRAM SHOWING RELATIONSHIP OF RADIOACTIVE LIGNITE BEDS TO THE BASE OF THE WHITE RIVER GROUP IN NORTH AND SOUTH DAKOTA

in South Dakota rocks of the White River group overlie a uranium-bearing bed near the base of the Ludlow member of the Fort Union formation. At the south end of Slim Buttes thin lenticular beds of lignite in the Hell Creek formation of upper Cretaceous age are also radioactive.

Northeast of the area shown by the diagram the White River group unconformably overlies the Golden Valley formation of Eocene age (Benson, 1951). In the NW¼ sec. 31, T. 139 N., R. 97 E., Stark County, N. Dak., the Golden Valley formation contains a lenticular bed of lignite 0.6-foot thick which crops out within 10 feet stratigraphically of the base of the White River group. This lignite bed contains 0.12 percent uranium, 6.1 percent ash, and 1.9 percent uranium in the ash. Thus, lignite beds having a stratigraphic range of over 1,000 feet and ranging in age from Eocene to upper Cretaceous, may contain uranium, but they are uraniferous only where closely overlain by rocks of the White River group.

Denson and others (1950) noted that ground water from the White River group contains unusually large amounts of uranium. Later detailed sampling of water in the Slim Buttes area added corroborative evidence (Gill and Moore, 1954). Two spring water samples from the Chadron formation collected during the present investigation contain 29 and 10 parts per billion uranium at Chalky Buttes in the NW¼ sec. 31, T. 134 N., R. 101 W. and at HT Butte in the SE¼ sec. 24, T. 134 N., R. 102 W. By way of comparison, Judson and Osmond (1953) obtained an average of only 0.4 parts per billion uranium from 42 well samples in Wisconsin, and the uranium content of the ocean is about 1 part per billion (Koczy, 1950).

MODE OF OCCURRENCE OF URANIUM IN LIGNITE

Ewing and others (1950) have shown that the uranium in lignite from Sentinel Butte, North Dakota, is not associated with mineral matter in the lignite but is related to organic constituents. Breger and Deul (1952), on the basis of ion-exchange studies of uranium-bearing lignite from Slim Buttes, South Dakota, have further demonstrated that the uranium is held as a metallo-organic compound. In additional laboratory studies, non-uraniferous lignite from Slim Buttes was found to extract 99 percent of the uranium from a 200 parts per million solution of uranyl sulfate (Moore, 1954). Under the same conditions wood (white pine) extracted only 40 percent of the uranium suggesting that uncoalified organic material is a less effective extracting agent for uranium than lignite.

The graphic section of the Slide Butte bed shown by figure 7 indicates a remarkable agreement between the ash content and uranium content of the lignite, the layers high in ash having the most uranium. A similar relationship between ash and uranium seems to exist in many of the other uraniferous lignite beds studied. It is thought that other impurities were introduced into the lignite with the uranium, but since the ash content of the lignite varies directly with the freshness of the sample, and since all of the lignite beds were sampled at weathered outcrops, no consistent ash-uranium correlation can be demonstrated.

The simple top-preferential distribution of uranium in thick lignite beds observed when 1-foot vertical samples through the beds are compared is in part modified when beds are sampled in greater detail. If samples are a fraction of a centimeter to several centimeters thick, variations in uranium content are found between individual samples which do not always reflect

their position in the bed. This fact suggests that certain coal constituents may have a greater affinity for uranium than other components. J. M. Schopf and others have made extensive petrographic studies of lignite from the Slim Buttes area, South Dakota, to determine the nature of the uraniferous constituents. Preliminary results of these studies show that no quantitive correlation exists between uranium content and the coal petrologic constituents that are normally determined for coal classification (Schopf and Gray, 1954). These writers note, however, that the samples richest in uranium contain relatively large amounts of humic matter resulting from decomposition and microbial decay suggesting that plant material that has been most subjected to decay is the most receptive to uranium emplacement. It is also possible, however, that variations in permeability of the coal constituents may have controlled the movement of uranium-bearing solutions within the lignite beds thereby causing variations in uranium content not directly related to the chemical nature of the coal constituents.

LITERATURE CITED

Benson, W. E., 1951, Geologic map of North Dakota southwest of the Missouri River: U.S. Geol. Survey.

Berthoud, E. L., 1875, On the occurrence of uranium, silver, and iron in the Tertiary formations of Colorado Territory: Acad. Nat. Sci. Philadelphia, Proc., v. 27, p. 363-365.

Brown, R. W., 1948, Correlation of Sentinel Butte shale in western North Dakota: Am. Assoc. Petroleum Geol., Bull. v. 32, p. 1265-1274.

Hares, C. J., 1928, Geology and lignite resources of the Marmarth field, southwestern North Dakota: U.S. Geol. Survey Bull. 775.

Koczy, Gerta, 1950, Further uranium determinations on sea water samples: Akad. Wiss. Wien, math. -naturwiss. Kl., Sitzungsber., Abt. IIa, v. 158, p. 113-122.

Leonard, A. G., 1908, Geology of southwestern North Dakota with special reference to the coal: N. Dak. Geol. Survey fifth bienn. rept., p. 27-114.

Leonard, A. G., and Smith, C. D., 1909, The Sentinel Butte lignite field, North Dakota and Montana: U.S. Geol. Survey Bull. 341, p. 15-35.

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

White, C. A., 1883, On the existence of a deposit in northeastern Montana and northwestern Dakota that is possibly equivalent with the Green River group: Am. Jour. of Sci., v. 125, p. 411-414.

UNPUBLISHED REPORTS

Beroni, E. P., and Bauer, H. L., 1952, Reconnaissance for uraniferous lignites in North Dakota, South Dakota, Montana, and Wyoming: U.S. Geol. Survey Trace Elements Inv. Rept. 123.

Breger, I. A., and Deul, Maurice, 1952, Status of investigations on the geochemistry and mineralogy of uraniferous lignites: U.S. Geol. Survey Trace Elements Inv. Rept. 284.

Denson, N. M., Bachman, G. O., and Zeller, H. D., 1950, Summary of new information on uraniferous lignites in the Dakotas: U.S. Geol. Survey Trace Elements Memo. Rept. 175.

Ewing, R. A., Adam, H. W., Miles, F. W., Bearse, A. E., and Richardson, A. C., 1950, Recovery of uranium from North Dakota lignite: Battelle Memorial Inst., BMI-237.

Gill, J. R., and Moore, G. W., 1954, Carnotite-bearing sandstone in Cedar Canyon, Slim Buttes, Harding County, South Dakota: U.S. Geol. Survey Trace Elements Inv. Rept. 411.

Judson, Sheldon, and Osmond, Kenneth, 1953, The possible use of ground water radioactivity as a prospecting tool for uranium, and the role of ground water in the geochemistry of uranium: U.S. Atomic Energy Comm., Contract no. AT(11-1)-178.

Schopf, J. M., and Gray, R. J., 1954, Microscopic studies of uraniferous coal deposits--a progress report: U.S. Geol. Survey Trace Elements Inv. Rept. 408.

Slaughter, A. L., and Nelson, J. M., 1946, Trace elements reconnaissance in South Dakota and Wyoming: U.S. Atomic Energy Comm. Raw Materials Operation, unpublished topical report.

Wyant, D. G., and Beroni, E. P., 1950, Reconnaissance for trace elements in North Dakota and eastern Montana: U.S. Geol. Survey Trace Elements Inv. Rept. 61.

DISCUSSION AND PLANS

Detailed investigations of uranium-bearing lignite in southwestern North Dakota were undertaken to obtain information on the potentialities of these areas as sources of uranium in accordance with the recommendations made by the U.S. Geological Survey (Beroni and Bauer, 1952). These recommendations were amplified in a letter (AEC 247/3) dated August 22, 1952, from H. M. Bannerman, Acting Chief Geologist, to Dr. Merritt and in Dr. Merritt's reply dated September 3, 1952, to the Chief Geologist.

The data obtained by detailed studies in the Bullion Butte, Sentinel Butte, HT Butte, and Chalky Buttes areas substantiate the previously expressed opinion that these areas are not as favorable for the possible production of uranium from lignite as the Slim Buttes area in South Dakota and the Red Desert area in central Wyoming.

Because of surface weathering, a lignite deposit and its uranium potentialities cannot be evaluated completely from samples of surface outcrops alone. Core samples are necessary to obtain adequate data on ash content and possible utilization characteristics of the lignite. However, the lignite beds described in this report are so thin that it seems unlikely that they are of immediate interest as a source for uranium. For that reason, no physical exploration is planned or recommended at this time.

UNPUBLISHED REPORT

Beroni, E. P., and Bauer, H. L., 1952, Reconnaissance for uraniferous lignites in North Dakota, South Dakota, Montana, and Wyoming: U.S. Geol. Survey Trace Elements Inv. Rept. 123.