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# The General Geology of Uranium in Southwestern North Dakota

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### **ABSTRACT**

During the summer of 1955 a radiometric and general geological survey of uranium deposits located mainly south of the eastward flowing course of the Little Missouri River and west of the 102nd meridian indicated that uranium in lignite is present in sufficient quantity at certain localities to warrant detailed investigations as to ore potential. Most of the deposits appear along the west side of the north-south trending divide between the drainage of the Little Missouri River on the west and the drainage of the Cannonball, Heart and Knife Rivers to the east.

Radioactive lignite beds in greatest number lie stratigraphically near the base of the Sentinel Butte member of the Tongue River formation in the Tertiary Fort Union group of sediments. Radioactive carbonaceous material present other than lignite is: (1) crudely bedded "coal" ranging from lignite to sub-bituminous and often associate with selenite crystals and the yellow mineral jarosite; (2) black lignite fragments, not bedded but associated in lenses with conglomeratic material suggestive of nearby carbonaceous strata eroded, transported and redeposited; (3) very fine powdery light duff-like black carbonaceous material—probably the result of extensive weathering of coals or lignite; (4) chocolate-brown carbonaceous shaly beds; (5) partly decomposed matted plant fibers having no visible mineral or rock characteristics. To a lesser extent sandstones and siltstones and rarely, clays and limestones may be radioactive. Field evidence indicates uranium in the lignite to be of epigenetic

emplacement in accord with theory advanced by N. M. Denson of the U.S. Geological Survey which describes disseminated uranium in Oligocene White River strata to be removed in solution by downward percolation of waters through pervious beds until uranium is abstracted and held by the highest of underlying lignite beds. The remarkable affinity of urani um for carbon has been discussed by Breger and others. Localities of uranium deposits examined are designated on maps and the Lutheran Church (T. 137N., R. 100W.) and Sentinel Butte (T. 139N.,

R. 104W.) localities discussed in detail. The development of North Dakota lignites as ore awaits blocking of

enough reserves by drilling and an acceptable processing method to support properly a nearby mill and buying station.

## INTRODUCTION

This report presents the results of a reconnaissance survey of the uranium-bearing rocks of southwestern North Dakota. The field information was gathered during the summer of 1955, and, although most of the deposits known at that time were examined, a number of new localities of interest are reported to have been found since then.

The eastern edge of the area in North Dakota which is currently of most interest in regard to uranium and radioactive products lies approximately along the 102nd meridian, or approximately 60 miles west of Bismarck. A northern boundary may be assigned to the easterly-flowing course of the lower Little Missouri River while portions of the North Dakota-Montana and North Dakota-South Dakota state lines delineate the west and south boundaries. The entire western third of the State is of general interest for uranium prospects but specifically most work by all observers has been concentrated in the south-west corner of North Dakota bounded by U. S. Highway 10 on the north and U. S. Highway 85° on the east. It is the latter area with which this report is most closely connected although certain localities beyond its bounds are discussed.

The general physical aspect of southwestern North Dakota is that of a gently southeastward sloping uneven plain which is sharply incised and dissected in its western and northern parts into badlands country. The region thus consists of two drainage areas: An eastern slope area of generally rolling appearance, broken here and there by low buttes and drained primarily by the Cannonball, Heart and Knife Rivers, and a western drainage area occupied by the north-flowing Little Missouri River and its complex of short, steep, east and west flowing tributary streams. The two drainage areas are separated by a north-south trending divide loacted generally between 10 to 20 miles east of the Little Missouri River (see Figure 1).

Rainfall in the region is usually less than 15 inches a year and runoff and evaporation rates are high. The soil with exception of certain portions of the badlands is utilized for dry land farming and ranches, and is primarily classified as marginal to submarginal in character. Over wide areas the vegetation is largely confined to grasses and low brush, but portions of the badlands contain very little or no vegetation. Exposures of bedrock are commonly found in the western but are relatively scarce in the eastern sectors of the region.

Although a number of hard-surfaced highways traverse the area (see Figure 1) and most of the terrane is readily accessible in ordinary weather, heavy rains or winter conditions render extensive travel over much of the area impracticable. The principal towns of Dickinson, Belfield, Medora, and Beach are located along the east-west through line of the Northern Pacific Railroad which parallels U. S. Highway 10, whereas Hettinger, Bowman, and Marmarth of the south and southwestern part of the area lie along the Chicago, Milwaukee, and St. Paul Railroad which traverses diagonally the extreme southwestern corner of North Dakota.

## PREVIOUS GEOLOGIC INVESTIGATIONS

In the year 1862, F. B. Meek and F. V. Hayden (1862, p. 433) named the Fort Union rocks and described the general geology of a portion of western North Dakota and adjacent territory. In 1908, A. G. Leonard contributed much information concerning the sequence, extent, and thickness of lignites and associated strata of southwestern North Dakota. The lignites which lie above the Ludlow formation and beneath the 22 Fox Hills formation foot thick lignite bed which is found near the base of Sentinel Butte in Golden Valley County were indicated by Thom and Dobbin (1924) to be the same in stratigraphic position as the Tongue River beds of the Sheri-

indicated, were thus designated as Tongue River and classified as a member unit of the Fort Union formation. Four years later, C. J. Hares (1928) presented maps and descriptions of the geology and lignite resources of the Marmarth coal field. Since 1951 a number of reports with accompanying maps have been compiled, both by the Federal and North Dakota pear identical to and in the same stratigraphic position as the Colgate Geological Surveys.

In 1952, W. E. Benson of the United States Geological Survey completed an open file report on the geology of the Knife River area. Fisher of the North Dakota Geological Survey in that year and 1953, mapped and described the geology of portions of McKenzie and Golden Valley Counties. Caldwell (1954) of the North Dakota Geological Survey described the surface structure of western Stark County and adjacent areas. During the last three years numerous articles, charts and maps have been published by the Atomic Energy Commission and the United States Geological Survey which pertain to uranium in Tertiary sandstone and lignites of South Dakota, Montana, and North Dakota. Of particular interest is the coal investigation map C-33 by N. M. Denson and others (1955).

Field work was begun June 15 and completed August 28, 1955. The localities reported to be radioactive were examined and the location of the deposits plotted on county road maps of a scale of 1 inch to a mile. Where possible, the stratigraphic position and general geologic relationship of each deposit to the region was noted. Representative scintillometer readings were recorded at all localities where readings of .03 milliroentgens per hour (MR/HR) were observed. Deposits which showed marked radioactivity were sampled and the samples analyzed radiometrically in the field. Stratigraphic sections were measured at Sentinel Butte, Flat Top or Square Butte, Bullion Butte, Black or H. T. Butte, White Butte and at a number of localities near Medora. A Jacob's staff and Abnev hand level were used to measure the sections and the thickness of the sections was usually checked by means of a Paulin altimeter. Elevation control when necessary was obtained by carrying elevation lines from bench marks into the areas to be investigated. Some of the more accessible and easily located bench marks are here listed:

ocalities	Specific Location	Elevation above mean sea leve
wn of Beach	Railway Station	2,769
wn of Golva	Top of rail in front of railway station	
	elevation by railroad survey	2,799
wn of Sentinel Butte	Railway Station	2,722
wn of Medora	West side of two-storey brick school	2,271
wn of Belfield	Railway Station	2,592
wn of Amidon	Northeast corner of Cour House lawn	2,908
ack or H. T. Butte	West end of top.	3,468
wn of Bowman	East face foundation of High School.	2,974
wn of Marmarth	Top of rail in front of railway station	2,712

pany "Scintillator" Model No. 111B, and assays run with the same instrument employing an assay cup. Background readings with this instrument generally varied from .009 to .023 milliroentgens.

The general field practice in exploration was to examine uranium localities and recorded claims and leases. A continual radiometric observation along the access roads of the localities of interest was kept and any unusually high reading recorded on the proper county road map and field notebooks. The area was then examined on foot with the scintillometer held one foot from the ground or closer if "hot spots" were found. The search was made in a series of parallel traverses about five feet apart. Where practicable the reported localities were searched by jeep and foot traverse. Areas where readings were approximately 0.3 MR/HR or greater were examined minutely and samples taken of the radioactive material. The radiometer was recalibrated at least three times daily by means of a standard radiation disc supplied by the instrument manufacturer. In general it was found that the highest background count occurred at midday and early in the afternoon. Background count is caused by local un- "shale" and underlying Tongue River member is best observed in the eastimportant ground and atmospheric radiations. The true reading caused ern portion of the south unit of Theodore Roosevelt National Memorial by the rocks examined is the instrument reading minus the background Park. Here a marked color change from lighter colored beds below to darkcount generally prevalent for the area at that particular time of day. er colored beds above occurs. This color change is at a marked indentation Back-ground count may vary at the same locality and the same time of in the profile of the bluffs which rise abruptly from the Little Missouri day on different days. Careful observation of instrument behavior over River valley. A kind of natural platform, flat or "shelf" has been devela number of days enables the operator to set up adequate comparative oped approximately 275 feet above the river that is readily observable

Examination of a number of outcrops was greatly facilitated by the use of a jeep, and a short-handled shovel was found very useful in trenching the coals in order to obtain less weathered samples than those of the

## **ACKNOWLEDGEMENTS**

Personal attention by Dr. Wilson M. Laird, State Geologist, to equipment and details which considerably aided the writer and his family to live comfortably in the field is greatly appreciated. Early in the field season, Mr. Miller Hansen, Assistant State Geologist of the North Dakota Geological Survey saved much time by orienting the writer to certain field relationships of the strata. Somewhat later, Mr. James Gill of the United States Geological Survey further demonstrated the stratigraphic relationships of the White River formation to the underlying rocks. Professor N. N. Kohanowski of Grand Forks and Dr. Donald Towse of Dickinson contributed a number of interesting ideas in discussions considering the mode of origin and deposition of uranium in the sediments. Assistance n the field was ably provided by Mr. Robert Roehrich, a student at the University of North Dakota. Mr. John Jay, supervisor of Theodore Roosevelt Park provided temporary office space at the south unit of the Park and he and other members of his staff were helpful and considerate in many ways. The writer is also grateful to numerous people living in the surveyed area who aided in locating radioactive deposits and furnished other useful information and acts of kindness which greatly facilitated the work and helped make the field study thoroughly enjoyable.

## **STRUCTURE**

The exposed rock sequences of southwestern North Dakota have a regional dip to the northeast of a few feet per mile. Local dips outline a number of broad basins, domes, arches, and troughs of low structural relief. This general regional aspect is broken by a structure of considerable size and depth which clearly involves rocks down to the Precambrian basement or crystalline complex. This structure is the Cedar Creek anticline which lies for the most part in southeast Montana, but extends south and somewhat eastward across the Montana line into southwesternmost North Dakota. The structure is evident because the older Cretaceous rocks are exposed and flanked by younger Tertiary rocks which dip away to the east and west of the older rock exposures.

Ten miles southwest of Dickinson in western Stark County is the center of a large shallow structural basin marked by local rough topography known as the Little Badlands which occupies an area of over 55 square miles. Considerable White River strata near the center of the basin have been preserved from erosion because of the inward dip of the rocks.

The stratigraphy of the region has been described by numerous writers, notably Leonard (1908), Hares (1928), Brown (1948), and Benson (1952). The rock exposures range in age from late Cretaceous to Recent geologic time.

The lowest and hence the oldest rock strata exposed in the southwestern portion of North Dakota are the dark marine shales of the Pierre formation of Late Cretaceous age. Exposures of the upper 400 feet of these rocks (Hares, 1928, p. 15) are found in extreme western portions of Bowman County. The Pierre outcrop area may in part be recognized in that the soil derived from the Pierre is very poor for farming and ranching, and travel on the Pierre when it is wet is often difficult because of the sticky black gumbo that develops on its surface. Ground water in the formation tends to be alkaline and numerous selenite and calcite crystals occur in the shale bed.

Bordering the low, rounded, slightly vegetated hills and smooth valleys of the Pierre is more rugged terrane of steep-sided, flat-top buttes,

stone beds rest on and thus are younger than the Pierre. The lowest of the sandstone sequences varies from about 40 to 85 feet thick and is known as the Fox Hills formation of Cretaceous age. The main sandstones which partly comprise the upper portion of the Fox Hills formation apsandstone in eastern Montana which crops out on both sides of the Cedar Creek anticline. In North Dakota then, the upper, partly marine, gray massive cross-bedded sandstone 15 to 45 feet thick is designated the Colgate member of the Fox Hills sandstone. It is separated from the lower portion of the Fox Hills by a thin shale (Dobbin and Reeside, 1929, p. 15).

Hell Creek formation Above the Fox Hills is the Hell Creek formation which consists of about 575 feet of alternating dark-gray to brown sandstones, shales, bentonitic clay, and in the lower 200 feet, thin, impure lignite beds (Kepferle and Culbertson, 1955). The Hell Creek strata were formerly designated as the basal beds of the Tertiary (Hares, 1928, p. -4) but the presence of fossil remains of the dinosaur Ceratops established the age as Cretaceous (Wilmarth, 1936, pp. 937-8). The lignites of the Hell Creek are not known by the writer to contain any significant amount of radioactive material. but sandstone in the Long Pine Hills of southeastern Montana was reported by J. R. Gill (1954, p. 154) to contain an estimated 0.2% of eU.

Ludlow formation and Cannonball formation Lying on the Hell Creek strata are sediments of the Tertiary System. The basal Tertiary is represented by the Ludlow formation which is about 250 feet thick and which crops out in a belt 6 to 18 miles wide east and north of the Pierre, Fox Hills and Hell Creek formations which flank the Cedar Creek anticline as described. The Ludlow consists of dark shales, slightly indurated light-brown to gray sandstones, and contains in its basal portions thin lignite beds. To the east and southeast the continental Ludlow beds interfinger with marine strata of equivalent age known as the Cannonball formation. The Ludlow and the Cannonball each in a different area is a basal formation of the Fort Union group of sediments, and are equivalent in age with Tullock and Lebo shale members of the Fort Union beds of eastern Montana. The Tongue River formation, which contains the Sentinel Butte shale member in its upper part, lies on the Ludlow and the Cannonball and completes the Fort Union group of strata. All of the Fort Union sequence except the Cannonball contains lignite and has uranium potential.

### Tongue River formation

A large portion of the rocks exposed in southeastern North Dakota are of the Tongue River formation. Fisher (1953) has reported the Tongue River to be from 745 feet to 1010 feet thick in McKenzie County and vicinity. Kepferle and Culbertson (1955) state the thickness to be from 400 to 600 feet in Slope and Bowman Counties exclusive of about 350 feet of the Sentinel Butte "shale" which many other investigators include. The Tongue River may be described as a series of rather soft, yellowish to light tan clayey sandstone and siltstone beds containing harder more massive lenses of sandstone. The light-colored beds characteristically alternate with darker beds of lignite, coal and shales. In certain localities some of the lignite has burned and rocks overlying the former lignite beds are often baked and oxidized to a bright red or pink color. Such rocks are termed "clinker" or "scoria". The Tongue River is generally described as being readily distinguished from overlying and underlying beds by its lighter color, all though coals are more numerous in the Tongue River than in strata above and below. This lighter color is ascribed to the larger amount of contained sandy material (Brown, 1948).

However, observations in the Medora area indicate that the Sentinel Butte shale member, although distinctly darker in color than other Tongue River strata, appears to contain much sand and silt of a light olive drab color. The writer is of the opinion that the Sentinel Butte shale member in this area contains more sand than the lower portion of the Tongue River. The contact or horizon of separation between the Sentinel Butte in a number of places and upon which the darker Sentinel Butte beds very well developed at certain locations and has the appearance of an incompletely developed plateau level. Several miles to the west is a general clinker level lying between and near Sentinel and Square Buttes which was indicated by Leonard (1908, p. 108) as being the horizon of separation between his middle member and his upper member of the Tongue River since respectively designated by others as the Tongue River formation and Sentinel Butte shale in this area.

The uranium occurs in only a very few of the large number of lignite beds in the Fort Union group of sediments. But these are mainly found in the Tongue River formation. Associated with the lignites, whether they are radioactive or not, are often concentrations of selenite and the vellow minerals jarosite and limonite. In certain localities where good exposures exist, four or five well-defined thin lignite beds may occur in as many tens of feet vertically. Locally certain resistant sandstones of the Tongue River range up to 40 feet in thickness and on the slopes of many buttes form distinctive ledges and "steps". The sandstones, however, do not appear to extend laterally as resistant units for any great distance and hence are mot usually used for mapping purposes except in conjunction with other beds.

Often the sandstones exhibit the phenonmenon of "case hardening" in which the surfaces exposed to weathering become harder than the interior of the rock mass. The condition is believed to be induced primarily by the concentration of calcium carbonate and silica in the outer pores of the rock as a result of evaporation of mineral bearing moisture from within the rock. Iron oxide and certain clay minerals may be concentrated in the same manner near the surface and still further cement and harden

Concretions are common. The largest of these are frequently subspherical or log-like in form and usually consist of rocks darker in color and harder than the enclosing sediments. Because they are often much more resistant to disintegration by weathering action than adjacent rock material, they frequently are concentrated at or near the surface of the ground or are found as the resistant pinnacles of small conical buttes. Both the log-like and subspherical type of concretions seem to occur in most abundance near the central portion of the Tongue River formation.

The Tongue River strata like many other continental sequences are often difficult to map because of the lenticular nature of the beds. Considerable difficulty is found in tracing key zones more than a few miles. Many sequences of the lithology, although of different stratigraphic position, are so alike in general aspect, that misidentification can readily

The most important sequence of rocks in the Tongue River formation in respect to uranium are the low grade lignites. These lignites vary from Pleistocene age. a fraction of an inch to 40 feet in thickness and may vary considerably both in composition and thickness within a short distance. Further, they may join with others or separate into a number of individual beds. Neverthe-less, because of the more lenticular nature of the other kinds of associated rocks such as sandstone and sandy clays, the lignite layers are the best marker beds the geologist may follow from one locality to another. For this reason then, and because they have been especially studied as a been designated by name, letter or number, and these designations appear rich, appear on the diagrams.

Mapping, however, is complicated by missing intervals stripped out by erosion and intervals which are covered by soil or other sediments. The very number of lignitic beds in certain sequences makes it easy to jump inadvertently from one bed to another. Despite these difficulties certain areas have been mapped and described with some precision (Leonard, 1908; Hares, 1928; Benson, 1951, 1952; Fisher, 1953 and others).

The lignitic beds may be recognized by a number of different features. Where the seams are freshly and cleanly exposed they appear dark in the "breaks" is a problem which further exploration should solve. It is color and contrast strongly with the almost universally lighter- colored of note that to date little radioactivity has been reported to occur on the and deep gullies that reflect the outcrop pattern of the sandstones more adjacent beds of other rock types. However, throughout a large portion eastern slope.

dan, Wyoming coal field. These lignite bearing beds in North Dakota then resistant to erosion than the Pierre Shales. These predominantly sand- of the region the lignite beds are usually not readily seen but are often at least partly covered by slump or wash from higher layers of other rocks. In the badlands area, however, where the general topography is rough and the slopes of the buttes and breaks are often steep, certain lignite beds may be traced hundreds of yards or even several miles.

> Although a covered bed may be a foot or less in thickness, its position may be often ascertained by an indentation in the profile of a slope. The presence of lignite grains on a slope suggests a lignite seam at the same or higher level. Springs are commonly associated with lignite outcrops. Water working downwards through overlying sediments contacts the lignite and its underclay and then spreads laterally along the lignite bed until it intercepts the surface of the ground. Tracing a series of springs along a hillside may accurately locate the position of a lignite seam. Where "clinker" or red "scoria" occurs, following the burned beds will often lead to an unburned portion of the lignite. The lignite needs oxygen in order to continue burning and when enough depth of overlying rock material prevents air from feeding the fires, the burning of the seam ceases. Thus unburned and burned lignites merge laterally.

## Golden Valley formation

Lying conformably on the Fort Union group of strata, the Golden Valley formation, named by Benson and Laird in 1947, occurs primarily in patches in the eastern and northern portion of the region. Its areal extent has not been entirely delimited on a state-wide basis but its thickness varies from 0 to at least 200 feet. Named from exposures near the town of Golden Valley, Mercer County, North Dakota, the formation consists of two members. The lowest member 20-25 feet thick, consists largely of clays with some minor beds of siltstone and sandstone. Near the middle of the lower member there is a persistent white to light-gray clay bed which is characteristically stained yellow to orange by iron oxide. The upper member 175 feet thick in the type area, consists of light-gray to vellow and brown micaceous silts and sands with a few lenses of gray clay and lignite. The Golden Valley contains plants, some of which are identical to those in certain Montana beds determined to be Eocene in age by means of diagnostic Eccene vertebrate fossils. The Golden Valley is um "in favor" of uranium. The opposite condition may also exist. thus considered to be of Eocene age.

Scattered outcrops of Oligocene and possible Miocene age occur on many of the higher buttes and areas, particularly in the northern and eastern portions of the region. These outcrops are of strata considered equivalent to the White River formation named by Meek and Hayden in 1858, and consist of two distinct lithologic sequences. In the Little Badands (Figures 1 and 2), the White River sediments are light-gray to light purplish gray in color, poorly consolidated, and eroded to small steep-sided barren or slightly vegetated buttes. The lower-most bed is often a yellowish-gray clay which ranges from a few feet to 40 feet in

Locally, irregular lenses of conglomerate containing water-worn pebbles lie at the top of the clay, but more often the clay is blanketed by a distinctive somewhat silty darker clay which apparently swells when wet, leaving when dry a minutely cracked "puffy" clay encrustation a few inches thick. Such clay beds are often referred to as "bentonitic clays" although it is not generally thought that the clay minerals, montmorillonite or beidellite (the common clay minerals of the swelling type of bentonite), are major constituents of the clay.

Above the clay, which in places is at least 35 feet thick, a sequence of clay, calcareous and silty beds with an over-all light purplish gray appearance predominates. The strata are generally so variable in thickness and lithology that matching or correlation of the beds from one locality to another can only be accomplished in a general way. A similar sequence of beds is found at Chalky Buttes. At the latter locality, however, the beds do not lie on Tongue River rocks, but rest on a thick massive micaceous brown sandstone which dips to the south. This sandstone is the same as that which caps H. T. Butte a few miles to the west and which probably correlates with a massive cliff forming brown sandstone 70 to 105 feet thick that lies at or near the top of Sentinel, Square, Bullion, Black and Rainy Buttes. Each of these buttes is an isolated erosional remnant of a former plateau that has been and is being extensively carried away by the headward and lateral dissection of stream drainage.

Although sandstones of similar appearance but of considerably less thickness are common in Tongue River and Golden Valley strata, the thick sandstone of the high buttes is assigned to the White River largely rest in mounded and conical topographic forms, or buttes. The "shelf" is because of the presence of a light-green colored ash-clay just below the sandstone which is more like the general lithology of the White River than the Tongue River beds, in which no similar rocks are known to occur. Further, the basal portion of this thick sandstone in Sentinel, Square, and Bullion Buttes, contains a conglomerate of light green clay nodules of pebble to cobble, and even larger size which appears identical to the underlying green clay bed. The sequence of strata suggests an abrupt change of environmental conditions after deposition of the carbonaceous beds of the Tongue River or the introduction of different material from a new source, or a combination of both factors. The writer believes that the latter explanation best fits the data.

Overlying the thick sandstone at Sentinel Butte is a calcareous greenish ash-clay conglomerate about 40 feet thick near the top of which is 11/2 to 3 feet of hard white argillaceous or clayey limestone which contains fresh water fish fossils. Beds similar to the hard white limestone were observed on the north outlier of the Killdeer Mountains. White River clay beds such as are well exposed on the Chalky Buttes characteristically erode into a badland topography of steep sloping hills and deep gullies. The slopes are often difficult to walk on because of the frequent presence of numerous pebbles which lie on top of the hard clay and offer treacherous footing. These clays seem to be very similar to the Brule clay of western South Dakota and eastern Wyoming and that of the type locality and similarly often contain abundant land vertebrate fossil remains.

Scattered thin irregular lenses of loose rounded pebbles composed of much dark chert and other resistant siliceous materials are often found in the higher portions of the region. The pebbles appear to be the same as those found in the conglomerates of the White River and may be largely derived by erosion of White River beds. Such deposits are probably of Miocene and later age and may be equivalent in part at least to Flaxville

North of the region the continental glaciers of the Pleistocene epoch have left much glacial debris which partly masks the underlying Tertiary rocks. Recent and modern stream deposits, slump and landslide debris, and some windblown material constitute the youngest sediments of the

Near the North Dakota-Montana State boundary close to the towns of Carlyle and Ollie, Montana there is an area of low hummocky hills which are largely covered by grass. Trenching of these hills reveals that they are largely composed of an unconsolidated sand and a clay pebble "conglomerate" in which irregular "pods" or lenses of "trashy" lignite are found. The lignite appears to have been derived from nearby beds, transported, and redeposited. These deposits are probably either Pliocene or

## URANIUM OCCURRENCE

## Geographical Location

The location of the principal radioactive deposits examined are shown on the accompanying diagram (Figures 1 and 2). In many cases a number of deposits close together are represented by a single dot. In other cases a dot may represent more than one radioactive bed in a given lofuel source, a number of lignite beds of unusual thickness and extent have cality. Only deposits examined by the writer and his assistant, Mr. Roeh-

Within the area studied, the largest number of interesting radioactive localities appear to lie in a north-south belt about 20 miles wide which includes the divide between the east-trending streams and the Little Missouri River on the west. A considerable number of the radioactive finds examined and reported, appear in a roughly linear trend along the eastern slope of the Little Missouri badlands, which also marks the western edge of the divide. Whether this trend is real and dependent upon geological factors or is subjective because of the relative ease of exploration along

### Limitations of Exploration Methods

On the eastern slope well-exposed bedrock is comparatively rare and the ground is extensively covered with soil. Since the radioactivity given off by uranium and its daughter or break-down products may readily be blanketed by a few feet of soil, even where uranium exists instruments may not record any significant readings over background count in covered areas. These areas even though they may contain high grade deposits will logically be the last to be explored and exploited. It can readily be seen that trends which appear to be geological, may, at an early stage of exploration be more apparent than real.

The instruments used in exploration for uranium, principally geiger counters and scintillometers, do not read directly in terms of uranium content of the examined material. Rather, they merely record its radioactivity. Thus, a reading may represent uranium with or without its normally associated radioactive daughter products; the daughter products or fraction of daughter products alone, or simply radioactivity from another source such as cosmic rays or an A or H bomb explosion.

In practice, scintillometer readings taken in the field commonly include cosmic rays and miscellaneous unimportant emanations from the ground and atmosphere. It is only when the readings rise above the general level of this "background count" that localization of radioactive maand .27% chemically. This same lignite and some others have caught fire terial is nearby. Field results show that localized uranium is almost alin the past an dhave burned to form a "scoria" or "clinker" on a ways present wherever the radioactive reading is at least double the background count. Because radioactive readings do not indicate the actual because of the red color of the "scoriaceous" material and the talus slope amount of uranium present but only the radioactivity that would occur if at its base. Coal ash or clinker from near the base of the scoria gave a a given amount of uranium and normally associated daughter products reading up to .4MR/HR on outcrop and .057% eU in radiometric and were present, the expression eU or Ue, meaning uranium equivalent is

Only precise chemical analyses will furnish the prospector with an accurate determination of the amount of uranium in the rocks. Such analyses can only be made readily in laboratories set up for that purpose, If chemical analysis shows more uranium in a sample to be present than radiometric assay would indicate the sample is said to be out of equilibri-

were observed. Radioactivity on Sentinel Butte thus occurs in limestone, Another factor which often confounds the prospector is "mass effect". coal, clinker ash and some clay. The question, however, as to whether po-Relatively small amounts of radioactive materials scattered over a contentially profitable uranium deposits occur at Sentinel Butte is still open. siderable area may cause the radiometer to give a reading comparable to that of a high grade deposit of very limited areal extent. This effect is terrane north and south, an area known as the Lutheran Church property termed "mass effect" and can be reasonably evaluated in the field only lies at the edge of the Little Missouri "breaks" (see Figure 4). The radioactive strata here consist of two lignite beds, the uppermost about one

The instruments employed, although built for field use, are neverthe-less very delicate and may readily get out of adjustment and give erroneous readings. Common causes of instrument error are; improper calibration, rundown batteries, excessive dampness in insstrument, radioactive dust adhering to or within the instrument and a break or "open" in the wiring leading from the probe to the main portion of the instrument. Instruments should be frequently checked against certain standard conditions or against other instruments.

Areas to be explored should be methodically checked. This is best done by dividing the area off in squares and checking off each square as it is carefully surveyed. The most efficient method of generall exploration in an area of low topographic relief is by flying a sensitive scintillometer close to the ground. This method has been responsible for the largest number of deposits discovered in the active lignite areas to date. Air reconnaissance is by no means infallible, however, and close coverage is best conducted on the ground. The exploration of covered areas necessitates extensive drilling, examination of cores and rock chips from drilling and the recording of radioactivity of subsurface rocks by lowering instruments into the drilled holes or by examination of the subsurface by means of open cuts, drifts, or shafts.

### Stratigraphy of the Uranium-Bearing Rocks

Radioactive rocks have been reported to occur in all of the Tertiary units with the exception of the Cannonball formation. The most consistently radioactive and hence principal strata of interest are the upper lignite beds of a thick series of lignites which lie stratigraphically near the central portion of the Tongue River formation. Radioactive outcrops of these beds may be examined at localities situated principally between Medora

The radioactive lignites and carbonaceous materials are of six prim-

eral jarosite.

- (2) crudely bedded "coal" ranging from lignite to sub-bituminous and often associated with selenite crystals and the yellow min-
- (3) black lignite fragments not bedded but associated in lenses with conglomeratic material,—suggestive of nearby carbonaceous strata eroded, transported, and redeposited.
- (4) very fine powdery, light duff-like black carbonaceous materialprobably the result of extensive weathering of coal or lignite. (5) chocolate-brown carbonaceous shaly beds.
- (6) partly decomposed matted plant fibers having no visible mineral or rock characteristics.

Although the carbonaceous beds command the most interest in regard to uranium, other rock types in places are notably radioactive. Many sandstones such as the Tongue River sandstones of the Moody Plateau south of Medora and east of the Little Missouri, the Medicine Pole hills. the Sand Hills just outside of the town of Buffalo Springs, and a large number of buttes of Tongue River or Golden Valley rocks in the Grassy Buttes-Gorham area show considerable radioactivity. Very often, however, because of mass effect, sandstones which give relatively high readings in the field produce very low readings in radiometric hand sample analysis. The Oligocene White River limey ash clay beds om Sentinel Butte and on the Killdeer Mountains are abnormally radioactive. Certain local clays have yielded significant readings. None of these lithologies seem, in reconnaissance field examination, to have the potential of the more radioactive lignites, although near Ollie, Montana just across the line from North Dakota, a considerable area of carnotite type ore bearing sandstone

## Origin of the Uranium in the Sediments

Laboratory experiments indicate that uranium and carbon have a remarkable affinity and probably combine in coals and lignites as an organo-uranium compound or complex (Breger and Duel, 1955). Laboratory data applied to field conditions suggest that moving ground water containing uranium in solution contacts lignite beds which abstract the uranium. Norman M. Denson of the United States Geological Survey has suggested that the radioactive volcanic ash material contained in the White River beds is the source of the uranium. Under the influence of gravity, radioactive charged waters percolate downward through pervious sands and other beds to an impervious layer. If carlbonaceous beds such as lignites lie above the impervious layer, the uranium in solution is retained by the carbon of the lignite. There is much field evidence to

Other men have postulated that the uranium may have been emplaced by solution, vapor or ionic migration from below. Some see evidence to support the view that uranium concentration has more tham a coincidental occurrence with structural "highs". Still other thinking suggests that the uranium may have been deposited contemporaneously with the sediments instead of migrating into the sediments at a post depositional date. Many variations and combinations of these ideas are current.

The mineralogy of the uranium in the lignites is complex. Field checks of radioactivity along the outcrops demonstrate rapid lateral and vertical changes in intensity within a few inches to a few feet, although the top, middle or basal portion of a bed may show the most radioactivity. Despite apparent "centers" of high radioactivity or "hot spots" less than an inch in diameter, no uranium minerals are generally visible to the eye. Although on the Moody Plateau and near Ollie a "bloom" of autunite and meta-autunite is visible on many lignite fragments, crushing, seiving, and microscopic analysis of uraniferous lignite from the Memdenhall bed of South Dakota has been reported by Breger and Duel (1955) as not revealing any centers of radioactivity in the examined material. Two Representative Localities

## One of the most interesting localities in respect to variety of strati-

graphy and radioactive occurrence is Sentinel Butte (See Figure 3) which lies about three miles south of the town of that name in Golden Valley

County. The top of the butte is nearly flat and occupies approximately Commission and the United States Geological Survey have fielded a num-450 acres. Although largely grassed over, the upper surface has lying ber of observers in the region, there is a great amount of work yet to be on it much cloudy agate and a large patch of rounded stream gravels and pebbles containing much chert. Below these loose surface materials is 10

A number of major problems exist. One of the foremost difficulties at present in the development of lignites as uranium ore is that to date no official announcement has been made of an economic process to extract uranium from lignite at a cost comparable to that of processing the carnotite type ores now largely employed. Uranium-bearing lignite, although it may assay the same as carnotite type ore (0.1% uranium oxide or more), has not been acceptable by the mills except in quantities suitable only for experimental or pilot plant operations. There are a number of other problems, primarily of an economic or legal aspect which must be solved before the production of uranium ore in North Dakota can become base. Below the base of the sandstone is two or three feet of thick light-

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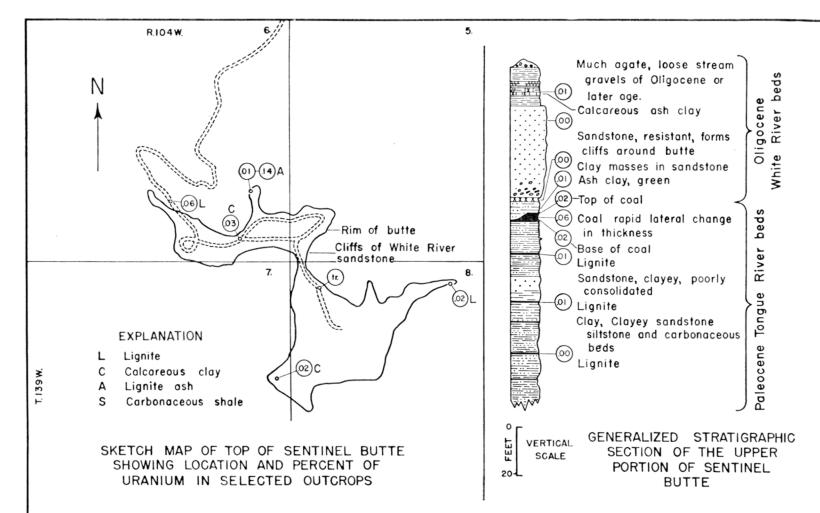
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in the Fall Creek area, Bonneville County, Idaho: U. S. Geol. Survey Circular eral geology of southwestern North Dakota. Although the Atomic Energy



to 40 feet of light-gray ashy beds which contain some green clay con-

glomerate. Near the base of the sequence two and one-half feet of white

clay limestone occur in irregular beds two to five inches thick. This lime-

stone gave a reading of .042 MR/HR in a prospect pit and assayed .05%

Ue radiometrically. Chemical assay indicated .03% uranium oxide (U<sup>3</sup>O<sup>3</sup>).

Below these beds is a thick light brown sandstone which is relatively re-

sistant to erosion and which outlines the top of the butte. The lower eight

feet of this 95 foot thick sandstone contains light-green clay masses from

pebble to cobble size which becomes densely conglomeratic towards the

green ash clay. The beds from this ash clay upward to the top of the butte

butte where the lower beds become covered. Near the top of the sequence

.048 MH/HR and one sample of which assayed at 0.3% radiometrically

northward extending ridge of the butte. The ridge is very conspicuous

.08% chemical assay. Coal beds of the upper portion of the sequence be-

low the thick bed are generally a few feet thick and a few feet apart

stratigraphically. These respectively assay radiometrically .07, .03, .04,

.01, MR/HR and chemically .02, .01, .01, .00% progressively down section.

A map of the top of the butte showing radiometric and chemical analyses

Below the central portion of the exposed sequence no radioactive beds

In section 34 of Township 137 North, Range 100 West, and adjacent

half to one and a half feet, and the lower bed about two to three feet in

thickness. The two beds are separated by a somewhat carbonaceous fine-

grained sand bed one half to three feet thick. These beds lie under an

overburden of very fine-grained pervious sand containing no bedded lig-

nites which varies from 0 to 185 feet in thickness. The lower lignite,

which is underlain by a clay, is the more radioactive of the two. Readings

along the outcrop at the "breaks" are exceptionally high for the region

and it appears that the radioactivity in the same beds may be extensive

since an outcrop of the two lignites appears on the east side of the divide

in a silage pit and is also strongly radioactive (see Figure 4). If drilling

and chemical analysis of the samples proves the beds beneath the over-

burden to be as rich in uranium as the outcrops generally appear, this

and there seems little doubt but that new localities will be discovered as

prospecting and exploratory drilling continues. The scope of this report

does not include detailed descriptions of all of the areas examined, but

um occurrence as observed in the field and their relationships to the gen-

permits only an outline of some of the more significant features of urani-

Other areas in North Dakota of apparent importance are known

area should be one of considerable interest.

are all thought to be of the White River formation.

readings appears in Figure 3.

FIG. 3 SKETCH MAP AND GENERALIZED STRATIGRAPHIC COLUMN OF TOP PORTION OF SENTINEL BUTTE T.139N. R.104W

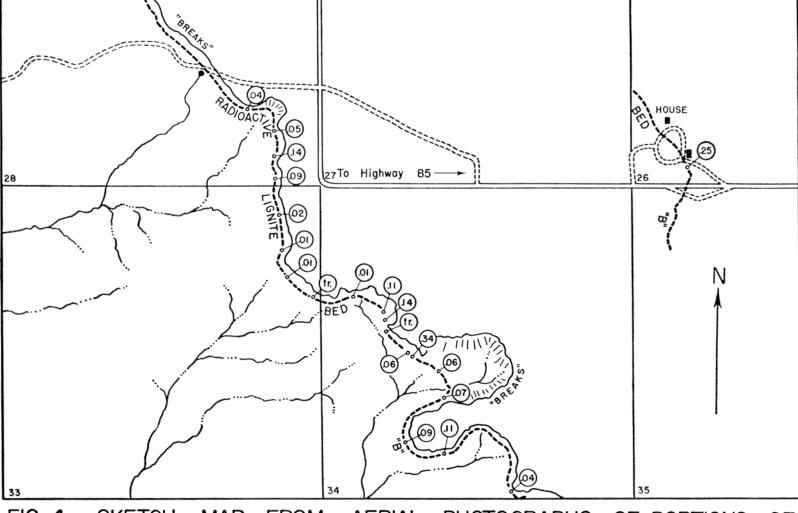
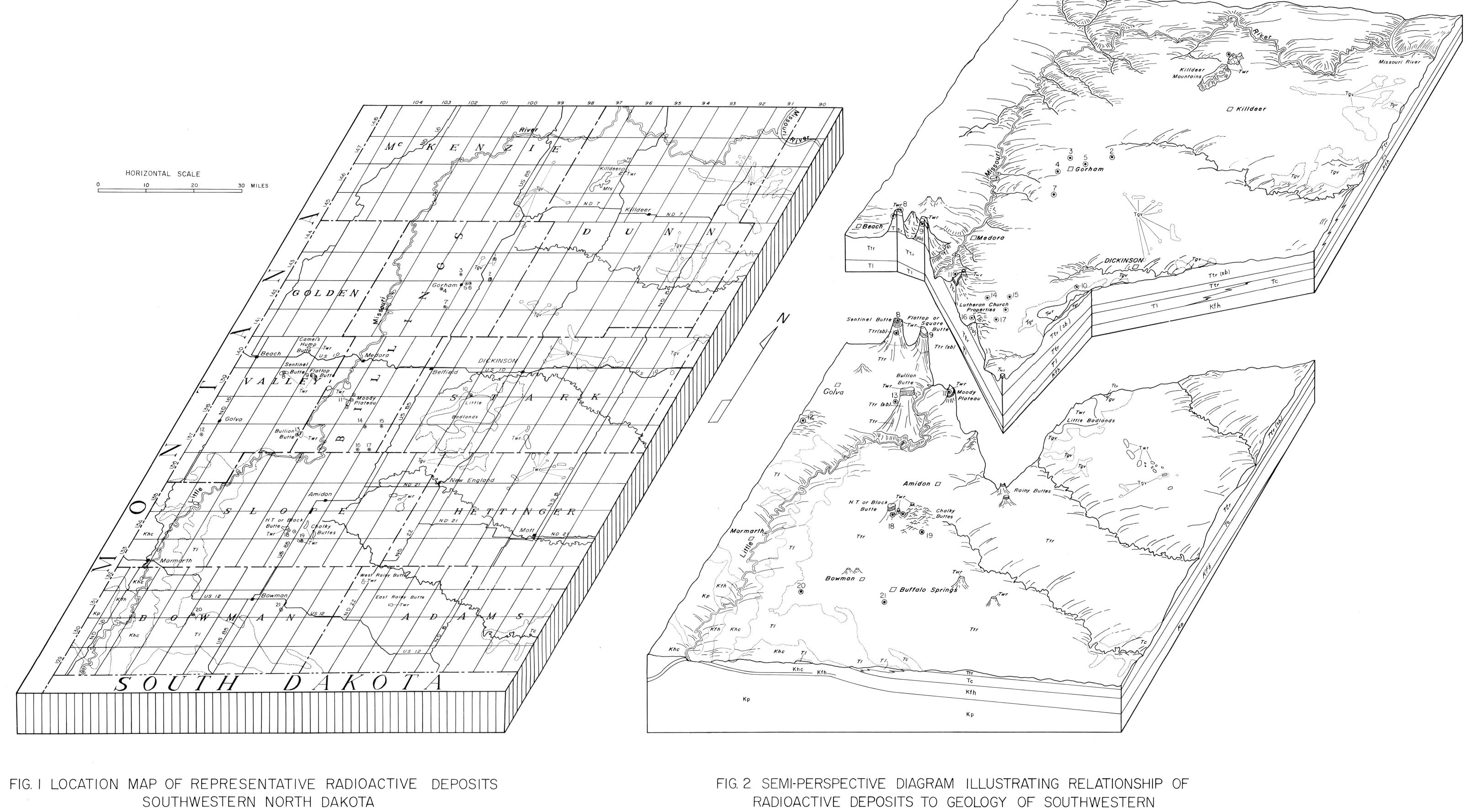


FIG. 4 SKETCH MAP FROM AERIAL PHOTOGRAPHS OF PORTIONS OF T.137N., R.100W.

SHOWING PERCENT URANIUM IN RANDOM SAMPLES OF PRINCIPAL EXPOSED RADIOACTIVE LIGNITE BED IN LOCALITY



# EXPLANATION

DEPOSIT NUMBER	PRINCIPAL ROCK TYPE	LOCATION	DEPOSIT NUMBER	PRINCIPAL ROCK TYPE	LOCATION
I.	SANDSTONE	T.143N., R.99W., SEC. 10	l I.	SANDSTONE & COAL	T. 138N., R. 101W., SEC. 6
2.	SANDSTONE	T.143N., R.99W., SEC. 36	12.	SANDSTONE & COAL	T. 137 N., R.10 6W., SEC. 14
3.	SANDSTONE	T.143N., R.100W., SEC. 26	13.	COAL & CLÁY	T.137 N., R.103W., SEC.13
4.	SANDSTONE	T.142 N., R.100 W., SEC. 10	14.	LIGNITE	T. 137 N., R. 100W., SEC. 6
5.	SANDSTONE	T.142N., R.99W., SEC. 6	15.	LIGNITE	T. 137 N., R. 100W., SEC. 2
6.	SANDSTONE	T.142N., R.99W., SEC. 5	16.	LIGNITE	T. 137 N., R. 100W., SEC. 3
7.	SANDSTONE	T. 142 N., R. 100W., SEC. 36	17.	LIGNITE	T. 137 N., R. 100 W., SEC. 3
8.	LIGNITE, CLAY,	T. 139N., R.104W., SEC. 5	18.	LIGNITE	T. 134N., R. 101W., SEC. 19
	LIGNITE ASH '	,	19.	LIGNITE	T. 133N., R. 101W., SEC. 1
9	LIGNITE, CLAY	T. 139N., R. 103W., SEC. 9	20.	SANDSTONE	T. 131N., R. 103W., SEC. 3
10.	LIGNITE'	T. 139N., R. 97 W., SEC. 31	21.	SANDSTONE	T. 131N., R.101W., SEC. 2
		•			

### NORTH DAKOTA EXPLANATION Location of radioactive deposits Tongue River formation White River formation Hell Creek formation Ludlow formation—inter-tongues with marine Golden Valley formation Fox Hills formation Sentinel Butte shale member of the Tongue River formation Cannonball formation of same age Pierre formation

VERTICAL SCALE

FEET

1500

1000

500

2000 TI