Uranium Deposits in Fall River County South Dakota

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A CONTRIBUTION TO THE GEOLOGY OF URANIUM

URANIUM DEPOSITS IN FALL RIVER COUNTY, SOUTH DAKOTA

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ABSTRACT

In 1951 uranium deposits containing carnotite were discovered in the southern Black Hills near Edgemont, Fall River County, S. Dak. Many carnotite deposits have since been found in sandstones in the Inyan Kara group of Early Cretaceous age, and uranium-bearing material has been discovered in the Minnelusa sandstone of Pennsylvanian age and the Deadwood formation of Cambrian age in the southern Black Hills. Ore has been produced only from the Inyan Kara group, mostly within an area of about 30 square miles along the southwest flank of the Black Hills uplift between Dewey and Hot Springs, in Custer and Fall River Counties. In addition, occurrences of uranium in other parts of the Black Hills and the surrounding area are known or reported in sedimentary, igneous, and metamorphic rocks of pre-Cambrian to Tertiary age.

The lowermost and uppermost formations of the Inyan Kara group—the Lakota and Fall River sandstones—contain the productive uranium deposits. These terrestrial formations are composed predominantly of massive sandstone lenses with thin units of thinly bedded sandstone and mudstone, but locally they contain abundant mudstone and thinly bedded sandstone. The massive sandstone lenses commonly overlap and truncate underlying lenses. Iron stain, carbonaceous material, thin seams of gypsum, ripple marks, concretions, and fossil roots are common in the mudstone and thinly bedded portions of these formations.

Some high-angle normal faults of small displacement are found in the area containing the largest number of uranium occurrences in the Inyan Kara group. Although no ore deposits seen were cut by faults, high-angle fractures parallel to and at right angles to the faults contain carnotite for short distances.

The productive uranium deposits are most common where the Lakota and Fall River sandstones locally contain a large proportion of mudstone and thinly bedded sandstone. Other deposits are in the massive sandstone lenses of the Lakota sandstone and in the thin units between the lenses.

Although carnotite is the most conspicuous and important mineral in most deposits, corvusite is an important constituent of some deposits. Other uranium minerals in the deposits are tyuyamunite, rauvite, and autunite. Ore produced in 1952 from the Fall River and Lakota sandstones contained about 0.2 percent of U_3O_8 and 0.6 percent of V_2O_5. In general, deposits in the Fall River and Lakota sandstones contain about the same percentage of U_3O_8, but the deposits in the Fall River sandstone appear to have a higher percentage of vanadium. The grade of individual deposits, however, is highly variable. Most deposits are small, but a few have yielded as much as a thousand tons of ore.

INTRODUCTION

The first discovery of carnotite in South Dakota was in Craven Canyon, 8 miles north of Edgemont, Fall River County, S. Dak. (fig. 32), in June 1951 (Page and Redden, 1952). Additional discoveries have since extended the area of known occurrences. All the known commercial uranium deposits in the southern Black Hills are in the Inyan Kara group of Early Cretaceous age (fig. 33).

Several hundred lode claims have been staked for uranium in Fall River County, mostly in the Harney National Forest, although numerous discoveries have been made on privately owned ground.

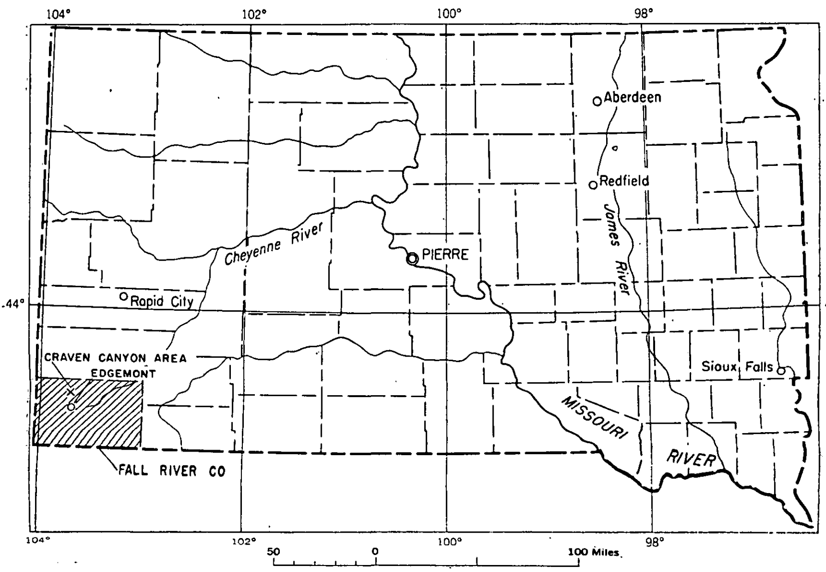

FIGURE 32.—Index map of South Dakota showing the location of Craven Canyon area, Fall River County.

Not all claims are known to contain occurrences of radioactive material, and only a few contain uranium deposits of ore grade.

Most of the ore produced from the area was shipped by railroad to mills in Colorado until December 1952 when an ore-buying station was established at Edgemont by the Atomic Energy Commission. Shipping points on the Chicago, Burlington & Quincy Railroad, which passes through Edgemont, are easily accessible by dirt roads and United States Highway No. 18–85A. Mining has been done with shovels and wheelbarrows in open pits and short adits. Bulldozers and front-end loading machines have been used to remove soil cover, expose ore deposits, and load the mined material on trucks.

The first comprehensive geologic work in the area was done by N. H. Darton and others of the U. S. Geological Survey between 1898 and

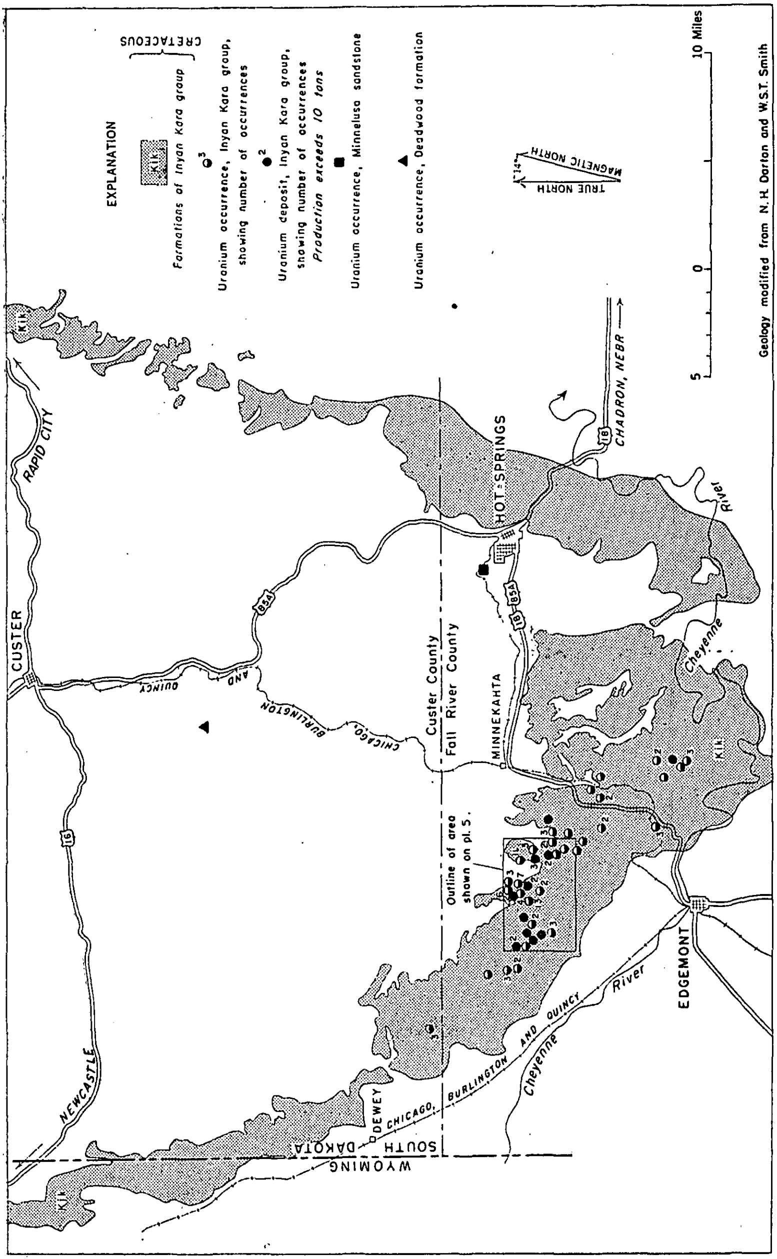

FIGURE 33.—Map showing outcrop pattern of formations of the Inyan Kara group, and distribution of uranium occurrences, southern Black Hills, S. Dak. and Wyo.

1925 (Darton, 1904, 1902; Darton and Smith, 1904; Darton and Paige, 1925), and subsequently many other geologic studies have been made for special purposes. In 1951 the U. S. Geological Survey (Page and Redden, 1952) and the Atomic Energy Commission described [1] the first uranium deposits discovered. Later these agencies contributed to the knowledge of the district through geologic mapping, core drilling, and radioactivity reconnaissance using airborne equipment and equipment mounted on automobiles.

During 1952, the writers, assisted by J. D. Ryan and R. B. Taylor, made detailed geologic and topographic maps of two areas, at a scale of 1:1,200, one in Craven Canyon and one in Red Canyon (pls. 3 and 4). Preliminary mapping of an area including the areas mapped in detail was completed at a scale of 1:24,000 (pl. 5). Many prospects and mines were studied and mapped. These geologic investigations have been directed toward the development of criteria for the recognition of ground favorable for the occurrence of uranium deposits.

The writers wish to express their thanks to the many prospectors, mining companies, and private property holders who, without exception, cooperated and gave freely of their time, assistance, and information. The work of the Geological Survey was carried out in behalf of the Division of Raw Materials, Atomic Energy Commission, and the writers wish to thank Howard Stafford and his associates of Hot Springs, S. Dak., for their material assistance and for access to data collected in their studies.

REGIONAL SETTING

The pre-Cambrian, Paleozoic, and Mesozoic rocks of the Black Hills area were uplifted in Laramide time into a domal structure about 60 miles wide and 120 miles long trending northwest. Subsequent erosion exposed a central crystalline core around which the sedimentary rocks now form a plateau, hogbacks, and cuestas.

The oldest sedimentary rocks lie on the pre-Cambrian core, and outward from the center of the uplift the sedimentary rocks are progressively younger. In the southern Black Hills these formations are, in ascending order: the Deadwood formation of Cambrian age, the Englewood and Pahasapa limestones of Mississippian age, the Minnelusa sandstone of Pennsylvanian age, the Opeche formation and Minnekahta limestone of Permian(?) age, the Spearfish formation of Triassic(?) age, the Nugget(?) sandstone, Gypsum Springs formation, Sundance formation, Unkpapa sandstone, and Morrison formation of Jurassic age, and the Lakota sandstone, Minnewaste limestone, Fuson shale, and Fall River sandstone of Early Cretaceous age.

[1] Baker, K. E., Smith, L. E., and Rapaport, Irving, 1952, Carnotite deposits near Edgemont, South Dakota: U. S. Atomic Energy Commission, Div. of Raw Materials, RMO-881.

Some of the characteristics of the formations from the Cambrian to Lower Cretaceous are summarized in the stratigraphic chart (p. 216–217). Upper Cretaceous and Tertiary rocks are extensively exposed over wide areas adjacent to the Black Hills uplift. Some of these rocks include tuff and volcanic debris that contain small amounts of uranium.[2]

From 5 to 10 miles east of Red Canyon and Craven Canyon in the southern Black Hills, two north-trending flexures are superimposed on the main domal structure. Within the area mapped, however, the Cretaceous rocks strike nearly east and dip from 1° to 2½° to the south. Faults with large displacements are not common in the southern Black Hills, but the pre-Cambrian rocks contain northeast-trending zones of structural weakness. The more competent sedimentary beds are highly jointed. Several high-angle northeast-trending faults of small displacement have been found in the area mapped. Most faults in the map area have a displacement of 10 to 20 feet, but one fault has a displacement of as much as 75 feet. Most of the faults are in the Craven Canyon area where uranium occurrences are most numerous, but none of the faults mapped cut a uranium deposit. In Craven Canyon more than 200 fractures in the Lakota sandstone were measured. These have dominant strikes of N. 11° W. and N. 75° E. and dip at high angles. The strike of these fractures is approximately parallel to or at right angles to the trend of the faults mapped. Some fractures near uranium deposits are filled with calcite, but none are radioactive. In the Red Canyon area a poorly exposed fracture zone contains traces of yellow uranium minerals.

The most conspicuous topographic feature of the southern Black Hills is the broad valley eroded in soft red shales between the older and harder Paleozoic rocks lying on the crystalline core of the Black Hills and the Cretaceous sandstones that form prominent hogbacks and cuestas around the margin of the uplift. Remnants of Tertiary sedimentary rocks in this valley and isolated gravel deposits on the plateau and encircling hogbacks indicate that the entire Black Hills area may have been covered by Tertiary rocks.

Uranium occurrences in the Black Hills area are known or reported in pre-Cambrian, Cambrian, Pennsylvanian, Cretaceous, and Tertiary rocks. In the northern Black Hills, autunite has been identified in the Deadwood formation (Vickers, 1953) and in Tertiary monzonite intrusives. Uraniferous fluorite veins have been found in both intrusive and sedimentary rocks of the Bear Lodge Mountains near Sundance, Wyo. A highly radioactive breccia has been reported from a fault zone in metamorphic rocks of pre-Cambrian age near Keystone

[2] 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.

General section from Cambrian to Lower Cretaceous formations in the southern Black Hills, S. Dak.

[Modified from Darton and Paige]

System	Series	Group and formation		Thickness (feet)	Character and topographic expression	Outcrop distribution and variation in thickness
Cretaceous.	Lower Cretaceous.	Inyan Kara group.	Fall River sandstone.	60–125	Sandstone, light-brown, uranium-bearing, medium-grained; with some lenticular thin-bedded sandstone, mudstone, and carbonaceous seams. Forms cliffs, hogbacks, and cuestas.	Extensive outcrops. Massive sandstones variable in thickness; in some localities mudstones and thin sandstone units predominate.
			Fuson shale.	30–150	Shale, sandy; and white, greenish-gray, and red sandstone. Forms slopes usually covered by talus. Not easily separated from Fall River and Lakota sandstones in area of this report.	Variable in thickness; in general thicker northeast and east of Hot Springs.
			Minnewaste limestone.	0–25	Limestone, light-gray, uniform, pure.	Absent west of Minnekahta, although isolated outcrops of limestone near top of the Lakota sandstone may represent the Minnewaste limestone.
			Lakota sandstone.	200–485	Sandstone, light brown, lenticular, uranium-bearing; in part conglomeratic with gray shales, carbonaceous seams, and coal. Forms the lower part of hogbacks and cuestas.	Extensive outcrops. Sandstones variable in thickness; in some localities mudstone and thinly bedded sandstones form a proportionately large part of the formation.
Jurassic.	Upper Jurassic.	Morrison formation.		0–100+	Shales and clays, gray, massive; with some thin sandstones and limestones.	Absent in southeast and east where the Unkpapa sandstone is present.
		Unkpapa sandstone.		0–225	Sandstone, white and purplish, massive. Forms steep-rounded slopes.	Crops out east and south of Hot Springs, in general where the Morrison formation is absent.
		Sundance formation.		248–267+	Shales and siltstones, gray: with some maroon sandstones and thin limestones. Forms low slopes.	Extensive outcrops.
	Middle Jurassic.	Gypsum Springs formation.		0–30	Gypsum predominantly, with some shales.	Crops out for short distance in extreme northwest portion of area.
	Lower Jurassic.	Nugget(?) sandstone.		0–29	Sandstone, salmon- to brick-red. Forms cliffs and steep slopes.	Outcrops restricted to area north of Red and Craven Canyons.

Triassic (?).		Spearfish formation.	400–500	Shales, red, sandy; with gypsum beds as much as 30 feet thick. Very soft and easily eroded. Forms broad valley.	Extensive outcrops. Slightly thicker in western part of the area.
Permian (?).		Minnekahta limestone.	50±	Limestone, light-gray with purplish tint, slabby. Bedding commonly contorted. Forms small cliffs; contains hot springs.	Extensive outcrops.
		Opeche formation.	75–115	Sandstone, shaly, red; and purplish shales. Forms steep slopes.	Outcrops restricted.
Pennsylvanian.		Minnelusa sandstone.	600±	Sandstone, reddish, uranium-bearing; with some limestones, red and gray shales and carbonaceous seams. Forms rocky ridges and canyon walls.	Extensive outcrops over broad areas; usually covered by soil and alluvium.
Mississippian.		Pahasapa limestone.	300–630	Limestone, light-colored, massive; contains vast caverns. Forms plateaus and cliffs.	Extensive outcrops over broad areas.
		Englewood limestone.	30–60	Limestone, pale-pink to buff, slabby; with shale locally at base. Forms slopes.	Extensive outcrops; usually covered in part by talus.
Cambrian.		Deadwood formation.	4–100	Sandstone, light-colored, quartzitic, uranium-bearing; some conglomerate and shale.	Extensive outcrops; usually covered in part by talus.

in the central Black Hills. South and west of the Black Hills near Lusk, Wyo., uranophane and other secondary uranium minerals have been found in sulfide veins cutting pre-Cambrian and Cambrian rocks (Wilmarth and Johnson, 1954). Uranophane and carnotite-type minerals also occur in sandstones of Tertiary age near Pumpkin Buttes, Wyo. (Love, 1952). Some uranium-bearing material in the Inyan Kara group has been mined near Carlile, Wyo., and other deposits are being explored near Aladdin, Wyo. North of the Black Hills there are uranium-bearing lignites at Slim Buttes and other nearby areas.[3]

URANIUM-BEARING FORMATIONS

In the southern Black Hills the Inyan Kara group contains the only productive uranium deposits, but the Deadwood formation and the Minnelusa sandstone also contain uranium-bearing material.

The Deadwood formation, in some places where it is a coarse-grained iron-stained quartzite, contains uranium-bearing material.

The Minnelusa sandstone contains uranium-bearing black shale, sandstone, and limestone in Hot Brook Canyon, north of the town of Hot Springs (fig. 33). Here red and gray sandstone, limestone, and shale, some thin coaly shale, and thin dark-gray petroliferous siltstone are exposed in the upper part of the formation.

The Inyan Kara rocks are extremely variable terrestrial deposits. The uppermost formation of this group is the Fall River sandstone. This formation is predominantly a massive, crossbedded sandstone, from 60 to 125 feet thick, containing thin lenses of gray mudstone. In the area between Craven Canyon and Coal Canyon, however, the Fall River sandstone is chiefly interbedded mudstones and thin lenses of crossbedded sandstone. These thin lenses of sandstone are only 25 feet thick in places. Where these lenses thicken they tend to become massive and crossbedded, with large, thick concave cross strata. Where the lenses are thin they are thinly bedded or laminated and there are commonly abundant macerated carbonized plant remains on the bedding surfaces. Within the sandstone there are zones of angular charcoal fragments. Fossil roots, worm tubes, ripple marks, and concretions of calcite, pyrite, and limonite are common where the formation is chiefly interbedded mudstone and sandstone. Iron stain is prominent particularly where the sandstone lenses are very thinly bedded and plant remains are abundant. Pyrite is common in drill cores as fine-grained disseminated crystals and as nodules in carbonaceous layers. Thin layers of gypsum and films of jarosite are common in the mudstone.

[3] Beroni, E. P., and Bauer, H. L., Jr., 1952, Reconnaissance for uraniferous lignites in North Dakota, South Dakota, Montana, and Wyoming: U. S. Geol. Survey Trace Elements Inv. Rept. 128.

The lowest formation of the Inyan Kara group is the Lakota sandstone. It is a thick-bedded white to pale-brown sandstone with some gray mudstone, carbonaceous shale, and thin coal seams. Massive lenses of crossbedded sandstone are well exposed in the bottom of Craven Canyon. These lenses are as much as 70 feet thick. Some of the lenses are conglomeratic in the lower parts, and the thin lenses may be coarse-grained throughout. The lenses overlap and truncate the underlying lenses. Parallel banding of manganese stain in the massive sandstone has been found in some places adjacent to thinly laminated units. In Craven Canyon, a lens of carbonaceous shale, parts of which weather into paper-thin laminations, thickens from less than an inch to as much as 30 feet within a distance of a mile and a half. The thicker parts of this bed contain coal reportedly of bituminous grade (Stone, 1912). In the Red Canyon area, the Lakota sandstone has been divided into three units: an upper unit composed chiefly of mudstones with some thin lenticular sandstone; a middle unit of cliff-forming fine- to medium-grained crossbedded sandstone with some mudstone; and a lower unit of thin mudstone and sandstone. Plate 6 shows these units as mapped; however, it seems unlikely that these divisions can be distinguished in other areas. Plate 4 shows sandstone lenses and mudstone in the two upper units of this division. The Minnewaste limestone and the Fuson shale of the Inyan Kara group do not contain commercial uranium deposits.

ORE DEPOSITS

DISTRIBUTION

Fall River County uranium deposits have been found in the Fall River and Lakota sandstones in the area between Dewey and a point in Chilson Canyon about 3 miles east of United States Highway No. 18–85A. The deposits have been found in both the Fall River and Lakota sandstones in the Craven and Red Canyon area (pl. 5), but in the area west of Craven Canyon they have been found mostly in the Fall River sandstone. In Chilson Canyon the deposits are mostly in the Lakota sandstone southeast of United States Highway No. 18–85A. Some uranium-bearing black shale and limestone have been found in the Minnelusa sandstone at good exposures in Hot Brook Canyon about 2 miles north of Hot Springs.

SIZE AND SHAPE

The uranium- and vanadium-bearing material in the Inyan Kara group occurs as small impregnations in sandstone and mudstone. Little is known of the size and shape of these deposits. One of the large uranium and vanadium deposits has been mined for a length

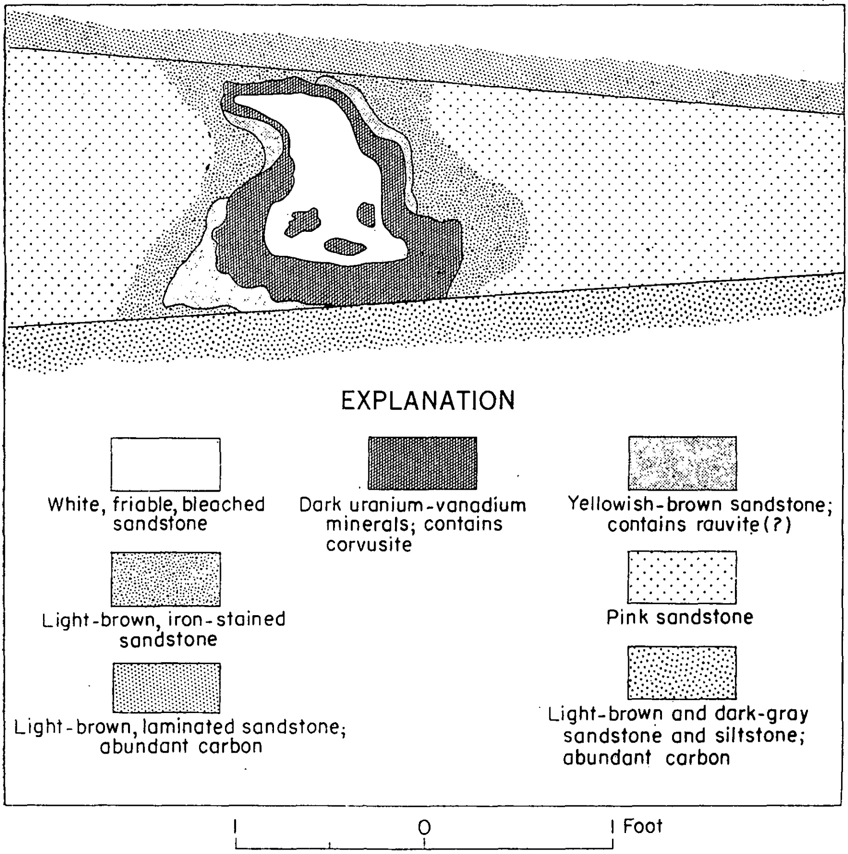

FIGURE 34.—Cross section of a pod of ore minerals in the Fall River sandstone.

of 170 feet and a width of 50 feet. This deposit has produced over 1,000 tons of ore, and several others are nearly as large. In Craven Canyon, exposures of carnotite in the Lakota sandstone are as much as 60 feet long and range from a few inches to a few feet thick. Some of the numerous smaller exposures in this area have been tested, but none has produced more than 150 tons of ore.

Most ore deposits are essentially parallel to the bedding, but a few cut across the bedding. Most ore deposits have gradational boundaries, but some in the Fall River sandstone have sharp boundaries. A small deposit at one locality in the Fall River sandstone is roughly elliptical, or pod-shaped, in cross section; the long diameter measures about 1 foot, 7 inches and the short diameter, 1 foot 2 inches (fig. 34). The length of this pod is unknown.

In the Lakota sandstone small fractures cutting ore deposits are filled with high-grade yellow uranium minerals for a vertical extent of as much as 12 feet.

In Hot Brook Canyon where the upper part of the Minnelusa sandstone is well exposed there are outcrops of radioactive shale as much as 1,000 feet long. Most of the radioactive beds are less than 1 foot thick, although one is more than 3 feet thick.

MINERALOGY

Carnotite, $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$, and its calcium analog tyuyamunite, $Ca(UO_2)_2(VO_4)_2 \cdot nH_2O$, are the most conspicuous and important ore minerals in the Inyan Kara group. A black mineral that has an X-ray pattern identical with corvusite, $V_2O_4 \cdot 6V_2O_5 \cdot xH_2O$, has been found, and other dark uranium and vanadium minerals, as yet unidentified may also be present. Some hand specimens contain sparsely disseminated carnotite, abundant stain resembling limonite, and as much as 5 percent V_2O_5. X-ray studies indicate that the brown stain is not limonite but may be a uranium and vanadium mineral, perhaps rauvite, $CaO \cdot 2UO_3 \cdot 5V_2O_5 \cdot 16H_2O$. These ore minerals coat sand grains and fill the interstices of sandstone. Yellow uranium minerals also stain sandstone in thin irregular concentric bands and halos around deposits and fractures in the Lakota sandstone, fill joints, and coat the surfaces of fractures. This material has been identified at a few places as tyuyamunite. It often contains more uranium by chemical assay than equivalent uranium by radiometric analysis. Other minerals of sparse occurrence are autunite, $Ca(UO_2)_2(PO_4)_2 \cdot 10\text{–}12H_2O$, and hewettite, $CaO \cdot 3V_2O_5 \cdot 9H_2O$. Various states of hydration of these minerals are known, and metahewettite and metatyuyamunite have been identified from these deposits. It is very difficult to distinguish between carnotite, tyuyamunite, and metatyuyamunite in the field. These minerals will be referred to as carnotite, therefore, unless they have been identified in the laboratory. A grass-green stain similar to that found by prospectors on the Colorado Plateau occurs as long streaks or splotches on the surface of rocks.

Pink sandstone is commonly associated with the ore deposits. The color, probably caused by small amounts of hematite, is abundant near deposits containing dark uranium and vanadium minerals. This pink stain may be analogous to the hematite commonly found with pitchblende veins in Canada (Lang, 1952, p. 25–27) and perhaps to the hematite noted by Gruner (1952, p. 16) in experiments in synthesizing of pitchblende. Also white bleached sandstone is commonly associated with dark uranium and vanadium minerals (figs. 34 and 35).

Some yellow uranium minerals and an unidentified green radioactive mineral have been found in coaly shale and limestone of the Minnelusa sandstone, but radioactive shales are much more extensive than

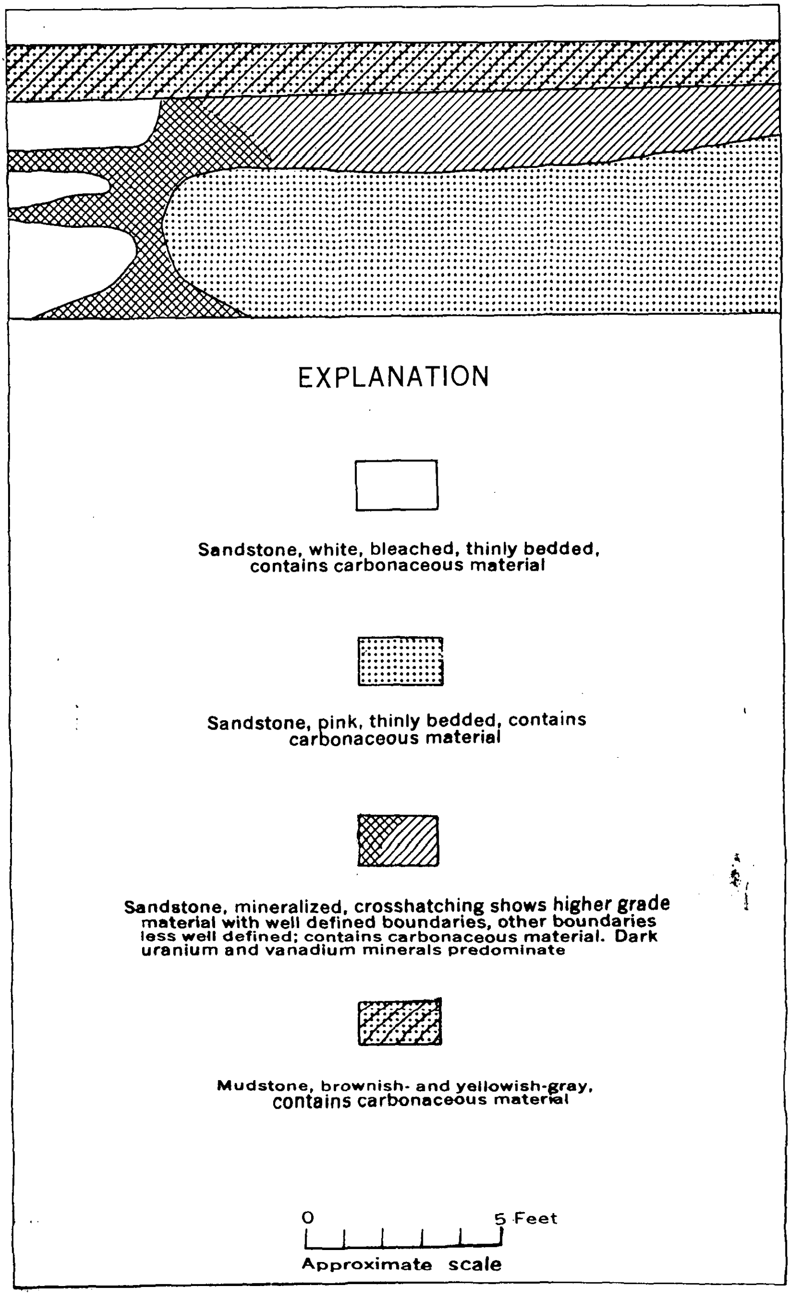

FIGURE 35.—Sketch showing relationship of white and pink sandstone to mineralized rock in a deposit in the Fall River sandstone.

the megascopic yellow and green minerals. These deposits may contain uranium-bearing material similar to that in other radioactive lignites and black shales.

During 1952, ore produced from deposits in the Inyan Kara group averaged 0.22 percent U_3O_8 and 0.6 percent V_2O_5; a ratio of about 3 parts V_2O_5 to 1 part U_3O_8. Although nearly the same tonnage was produced from the Fall River and Lakota sandstones, the ratio of V_2O_5 to U_3O_8 in ore from the Fall River sandstone was 4 to 1, whereas the ratio of V_2O_5 to U_3O_8 in ore from the Lakota sandstone was 2 to 1. The ratio of V_2O_5 to U_3O_8 in individual deposits, however, is highly variable and some deposits in the Lakota sandstone have a grade and ratio about equal to deposits in the Fall River sandstone. Within any one deposit the ore minerals are unevenly distributed. The grade of any sample, therefore, is not necessarily representative of the grade of the mine face or the deposit.

Although the mine workings are not extensive, it appears that in some deposits carnotite is more abundant near the outcrop, and dark uranium and vanadium minerals predominate a few feet below the surface. Ore having a grade of about 0.4 percent U_3O_8 and 1.4 percent V_2O_5 has been produced from deposits consisting chiefly of dark uranium and vanadium minerals. Some ore deposits in the Lakota sandstone contain only carnotite with some high-grade fracture fillings and concentric irregular banding of yellow minerals. Ore produced from these deposits commonly has a grade of about 0.3 percent U_3O_8 and 0.2 percent V_2O_5.

LOCALIZATION OF DEPOSITS

Most of the ore deposits in the Inyan Kara group seem to be localized in or near thinly bedded sandstone. West of Craven Canyon, deposits in the Fall River sandstone are chiefly in the mudstone and thinly bedded sandstone facies of the formation. The deposits seem to be associated with the sides and bottoms of sandstone lenses where the lenses are very thinly bedded or laminated and where there are concentrations of iron stain and plant fragments (fig. 36).

The deposits in the Lakota sandstone in Craven Canyon are in thinly laminated sandstone and mudstone beds, and in massive sandstone lenses directly above and below such beds (pl. 7). Small fractures in the massive sandstone lenses are filled and coated with carnotite. These deposits appear to be most common where the sandstone lenses thin or are truncated by an overlying lens.

In other places deposits in the Lakota sandstone seem to be localized where this formation is proportionally high in thinly bedded sandstones and mudstones.

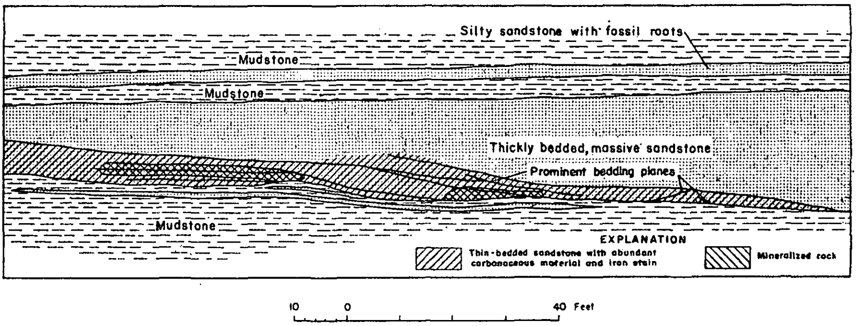

FIGURE 36.—Generalized section of part of a sandstone lens in the Fall River sandstone.

ORIGIN

The origin of the uranium deposits in Fall River County, S. Dak., is unknown. However, the uranium and vanadium apparently was deposited by ground waters in two different environments. Ore deposits containing dark uranium and vanadium minerals and the concretionary type of deposit illustrated by figure 34 occur in an environment of thinly bedded sandstone and mudstone. The sandstone and mudstone contain thin seams of gypsum, pyritized plant material, and various types of concretions. Ore deposits containing dark uranium and vanadium minerals in this environment seem to be older than deposits containing only carnotite.

Deposits containing only carnotite occur in an environment of thinly laminated sandstone, mudstone, and massive sandstone lenses (pl. 7). A relatively recent period of mineralization is suggested for these deposits by two factors: uranium in excess of the equilibrium state in the yellow uranium minerals found in fractures in the massive Lakota sandstones, and the presence of bands of the uranium and iron minerals parallel to fractures and plant remains, suggesting that these minerals were introduced by ground-water solutions after lithification and subsequent fracturing of the host rocks.

The localization of many of the uranium deposits near the edges of truncated sandstone lenses and in or near units of interbedded sandstone and mudstone possibly indicates that the mineral-bearing solutions were trapped by the overlying sandstone lenses or by the less permeable mudstones and subsequently precipitated their mineral content.

SUGGESTIONS FOR PROSPECTING

The most favorable areas for prospecting in the Inyan Kara group of formations seem to be where the Fall River and Lakota sandstones are thinly bedded and contain large amounts of mudstone, abundant iron stain, and carbonized plant remains. Pink sandstone may be a helpful guide in finding ore deposits.

Results of geologic mapping suggest that in the area west of Craven Canyon the Fall River sandstone is favorable for prospecting, whereas in the area east of Red Canyon the Lakota sandstone seems to be favorable. Between Craven and Red Canyons the Fall River and Lakota sandstones both consist of massive sandstone lenses with minor amounts of mudstone. This area, therefore, is considered less favorable than the areas to the east and west. Plate 5 shows the two areas considered to be favorable for finding large uranium and vanadium deposits.

DESCRIPTION OF SELECTED AREAS

AREA BETWEEN CRAVEN CANYON AND COAL CANYON

The area between Craven Canyon and Coal Canyon contains uranium and vanadium deposits in the Fall River sandstone. This area, the western part of plate 5, is only partly mapped geologically; however, the mapping completed indicates the ore deposits are near the base of the Fall River sandstone where this formation is predominantly mudstones and thin sandstones. At the Coal Canyon claim (pl. 5, no. 1) the uranium is in thinly bedded sandstone at the base and apparently at the side of a sandstone lens. This lens is well exposed on the south side of a west-trending ridge that is about 250 feet wide. The lens thickens within a distance of 150 feet from 12 feet on the west to 23 feet at the eastern exposures. This lens extends southward as far as the Coal Canyon No. 14 claim (pl. 5, no. 2) and perhaps farther. The poor exposures and the thin lenticular character of the sandstones have made it nearly impossible to correlate definitely the mineralized sandstone at the Coal Canyon claim with the ore-bearing sandstones at the Get Me Rich No. 1 claim (pl. 5, no. 4), the Ridgerunner No. 3 claim (pl. 5, no. 3), or the Virginia C. No. 2 claim (pl. 5, no. 5). However, the ore deposits on all these claims are in thinly bedded sandstone that is overlain and underlain by brownish- and greenish-gray sandy mudstone containing some thin sandstone beds, carbon, films of jarosite, and thin seams of gypsum. The carbonaceous material that is associated with ore deposits is abundant as macerated plant fragments on bedding planes and as fragments of charcoal as much as one-fourth inch in diameter. On the Coal Canyon claim, a bed 4 feet thick of very fine grained silty sandstone contains abundant fossil roots.

The sandstones containing the ore deposits are highly fractured. Some closely spaced fractures are filled with calcite near the ore deposits on the Coal Canyon claim. Some poorly exposed high-angle northeast-trending normal faults are near the ore deposit on the Trail Fraction claim (pl. 5, no. 6). The displacement along these faults ranges from less than a foot to 10 or 20 feet, but one fault southeast of the ore deposit on the Trail Fraction claim has a displacement of as much as 75 feet.

The uranium and vanadium deposits in the area between Coal Canyon and Craven Canyon contain predominantly carnotite, tyuyamunite, and metatyuyamunite, but in some deposits a large percentage of the ore consists of the dark uranium and vanadium minerals corvusite and rauvite. The ore minerals are parallel to bedding planes in sandstone, but at some places they cut sharply across the bedding. Some streaks of ore have gradational boundaries, but others have distinct boundaries. Areas of bleached white friable sandstone and yellowish-brown and pink iron stain (fig. 35) adjoin concentrations of high-grade ore. On the south side of the Coal Canyon claim is a small distinctive pod of ore (fig. 34). In the center of this pod is a bleached white friable medium- to fine-grained sandstone surrounded by high-grade dark uranium and vanadium minerals and light-brown and pink iron stain. Selected samples of the dark ore-grade material assay 0.62 percent equivalent uranium, 1.05 percent uranium, and 7.7 percent V_2O_5.

Most of the deposits in the area between Coal Canyon and Craven Canyon have been mined by opencut methods, but the Coal Canyon claim has been mined by an adit with side drifts. Several of the deposits produced over a hundred tons of ore in 1952, and one deposit produced over a thousand tons. In November 1952 the largest deposit had been exposed for about 170 feet and had been mined for a maximum width of about 50 feet. The thickness of ore at some places was 4 feet. The grade of the ore produced in 1952 from deposits in the area between Coal Canyon and Craven Canyon was 0.22 percent U_3O_8 and 0.8 percent V_2O_5, a ratio of about 4 parts V_2O_5 to 1 part U_3O_8. The grade of ore within individual deposits and from one deposit to another is highly variable. Those deposits that have a large percentage of dark uranium and vanadium minerals in the ore may have a ratio of V_2O_5 to U_3O_8 of as much as 7 to 1, whereas ore from deposits containing mostly carnotite may have a ratio of V_2O_5 to U_3O_8 of 1.5 to 1. Deposits within 3 or 4 feet of the surface such as the deposit on the Trail Fraction claim seem to contain mostly carnotite, whereas deeper deposits seem to contain larger proportions of dark uranium and vanadium minerals.

CRAVEN CANYON

The uranium deposits in Craven Canyon are in the Lakota sandstone. The outcrops of the Morrison formation and the Lakota sandstone in part of Craven Canyon are shown in plate 3. A mudstone lens, a carbonaceous shale lens, and seven individual sandstone lenses within the Lakota sandstone have been mapped (pl. 7). The sandstone lenses are as much as 70 feet thick but overlap and truncate underlying lenses. Between the thick lenses of massive sandstone are units consisting of alternating thinly bedded sandstone and mudstone. These units are as much as 4 feet thick but commonly are much thinner. The thinly bedded alternating sandstone and mudstone between the sandstone lenses are represented in plate 7 by the lines separating individual sandstone lenses. These units contain macerated carbonized plant remains, light-brown and pink iron stain, and uranium deposits. Halos and thin concentric irregular bands of yellow uranium minerals in the massive sandstone lenses surround deposits in the thinly bedded units. These halos and bands are particularly common where fractures in the massive sandstone lenses cut deposits in the thinly bedded units. These fractures may be filled with uranium minerals for a vertical extent of as much as 12 feet. Fractures in the Lakota sandstone are common in Craven Canyon; more than 200 were measured in the area of plate 3. These fractures have dominant strikes of N. 11° W. and N. 76° E. and dip at high angles. The strike of these fractures is approximately parallel to, or at right angles to, the strike of normal faults.

The higher grade carnotite deposits in Craven Canyon are in the thinly bedded units consisting of sandstone and mudstone, and the lower grade deposits are in the massive sandstone lenses directly above and below. Many of the deposits seem to be more abundant in places where a massive sandstone lens thins or is truncated by an overlapping lens. In plate 7, sandstone lenses II and III are truncated by lens IV. The trace of the intersection of the erosion surface and the east edge of lens III trends about N. 15° W. Most of the deposits in the thinly bedded units between these sandstone lenses are within 300 feet of the line along which the lens is truncated. At one place within sandstone lens IV, plate 7, uranium-bearing material has been found where there is no continuous erosional diastem but only a discontinuous thin layer of thinly bedded sandstone. However, the uranium-bearing material is low grade and the deposits appear to be small. Most ore deposits within the thinly bedded units are essentially parallel to the bedding but a few cut across the bedding.

Deposits in the thinly bedded units contain carnotite, but the halos, concentric irregular bands, and fracture fillings contain tyuyamunite. The tyuyamunite commonly contains more uranium than equivalent uranium. No dark uranium and vanadium minerals have been found in the deposits in Craven Canyon.

There are numerous exposures of mineralized sandstone in Craven Canyon (pl. 3), but few have been mined. One is as much as 60 feet long and ranges from a few inches to several feet thick. Deposits on the Flora, Gertrude, Imogene, Dagmar, Clarabelle, and Clarabelle No. 4 claims (pl. 5, nos. 7–10) have been tested by opencut methods or by short adits. The untested deposits on the Pictograph claim (pl. 5, no. 11) in Craven Canyon are similar in character to and probably are similar in size and grade to the deposits that have been mined. The deposits tested on the Dagmar and Imogene claims were found to extend only a few feet beyond the outcrop, although one deposit has produced over 100 tons of ore. The grade of this ore in 1952 was 0.32 percent U_3O_8 and 0.2 percent V_2O_5. Some of the mineral deposits in this area have been described by Page and Redden (1952).

RED CANYON

The uranium deposits in the Red Canyon area are in the Lakota sandstone. This formation in Red Canyon has been divided into three units: an upper unit composed chiefly of mudstone with some thin lenticular sandstone, a middle unit of cliff-forming fine- to medium-grained crossbedded sandstone with some mudstone; and a lower unit of thin mudstone and sandstone (pl. 6). Plate 4 shows several sandstone lenses and thick units of mudstone in the two upper units of this division in part of the Red Canyon area. Most of the uranium deposits are in the cliff-forming crossbedded sandstone unit (pl. 6), but the largest deposit, on the Hot Point No. 3 claim, is in thinly bedded sandstone. This thinly bedded sandstone is cross laminated, contains seams of sandy mudstone, carbonized plant material, and fragments of charcoal, and has a light-brown and pink iron stain. Detailed geologic mapping suggests that in this area the Lakota sandstone contains more mudstone in proportion to sandstone than in Craven Canyon, and that the proportion of mudstone increases to the east. The sandstones in this area are fractured, and a poorly exposed fracture zone contains traces of carnotite.

Although ore from the Hot Point No. 3 mine contains dark uranium and vanadium minerals, carnotite is the most important ore mineral. The ratio of V_2O_5 to U_3O_8 is about 1 to 1. Most of the ore contains only carnotite finely disseminated in sandstone, but some ore is light brown with small splotches and streaks of corvusite, and some is white to pale gray with a few nodules of corvusite surrounded by carnotite. Some ore may also contain rauvite. Small fragments of charcoal, carbon on bedding planes, and some gypsum are found in the ore. The distinctive pink iron stain commonly associated with ore deposits is very abundant in the barren sandstone near ore in the Hot Point No. 3 mine.

Less than a hundred tons of ore has been produced from the Hot Point No. 3 mine. Most of this ore came from a stope 30 feet long, 15 feet wide, and about 3 feet high parallel to the bedding. Talus blocks of high-grade ore containing only carnotite have been mined at the discovery pit on the Hot Point No. 1 claim. Also on the Hot Point No. 1 claim, some carnotite in several thin layers in a fine-grained poorly cemented sandstone has been mined from a small opencut. Near this opencut, soil containing small fragments of carnotite-bearing sandstone was high enough in grade to be shipped as ore.

Although the Hot Point No. 3 mine has produced only a little ore, it is a significant mine because of the presence of corvusite in thinly bedded sandstone. About a mile and a half to the east where the Lakota sandstone is proportionately high in thinly bedded sandstone and mudstone, several large deposits have produced ore averaging about 0.19 percent U_3O_8 and 0.4 percent V_2O_5 and containing a high percentage of dark uranium and vanadium minerals. The ore from these deposits is similar in character to ore from deposits in the Fall River sandstone that contain dark uranium and vanadium minerals. This suggests that similar environments in the Lakota sandstone and Fall River sandstone were favorable for the deposition of the richer deposits containing dark uranium and vanadium minerals.

HOT BROOK CANYON

The Minnelusa sandstone in Hot Brook Canyon contains uranium-bearing material outcropping in secs. 10 and 15, T. 7 S., R. 5 E. Black Hills meridian, about 2 miles north of Hot Springs (figs 33 and 37). The upper part of the Minnelusa sandstone, the Opeche formation, and the Minnekahta limestone are exposed in Hot Brook Canyon. These formations are folded into a north-trending anticline that is cut by Hot Brook Canyon. The upper part of the Minnelusa sandstone in this area consists of red and gray sandstone, limestone and shale, some thin coaly shale, and thin dark-gray petroliferous siltstone.

Some yellow uranium minerals and an unidentified greenish radioactive mineral have been found in coaly shales and in limestone in the Minnelusa sandstone, but radioactive shales are much more extensive than the megascopic yellow and green radioactive minerals. A radioactive shale exposed in a north-trending cliff face for about 1,000 feet in secs. 10 and 15 (fig. 37) is black to green, generally nonfissile, and contains thin lenses of petroliferous siltstone. This shale ranges from 2.4 to 4.4 feet in thickness, averages approximately 3 feet thick, and contains at one locality 0.012 percent equivalent uranium, 0.009 percent uranium, and 0.66 percent V_2O_5. Three radioactive coaly shale beds are exposed along the railroad cut in the southwest quarter of sec. 10, and two radioactive coaly shale beds are exposed in an east-trending cliff in the north-central part of sec. 15. Thin black fissile shale beds overlie and underlie a limestone bed at one locality and overlie a calcareous sandstone at another

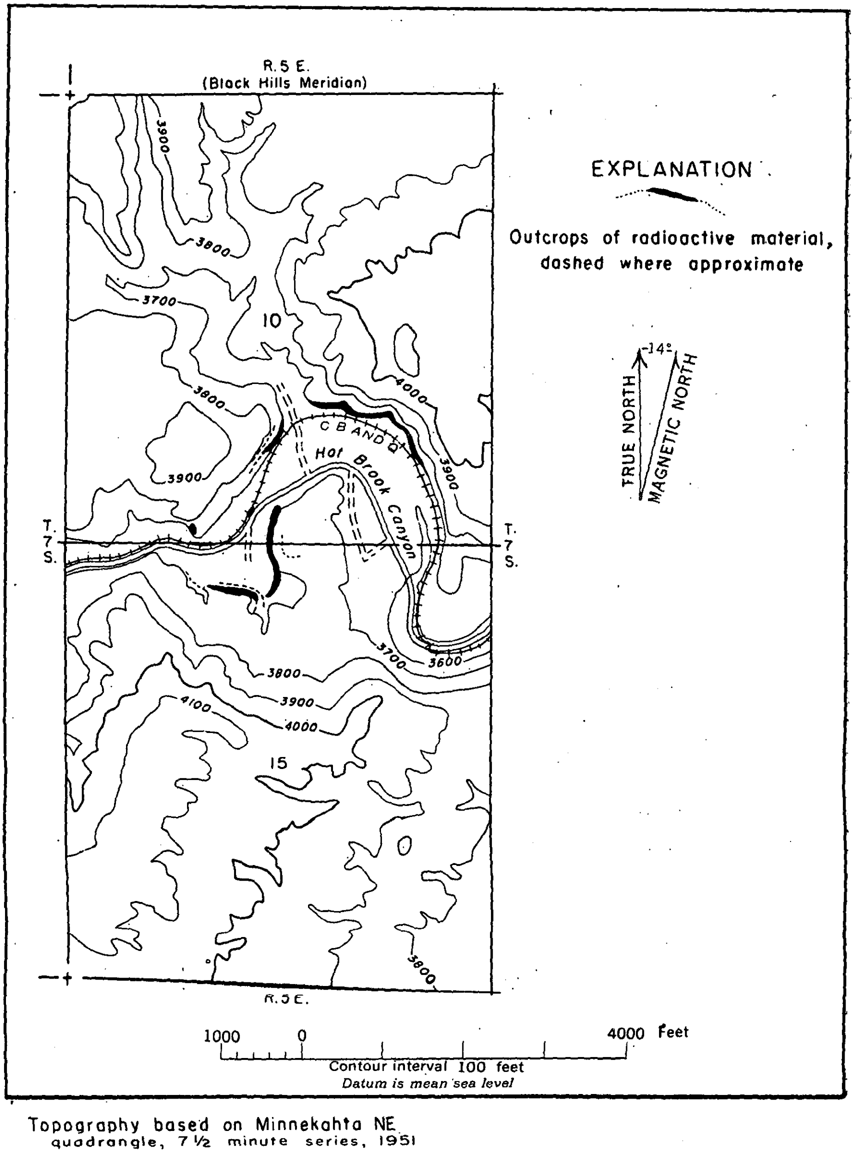

FIGURE 37.—Map of part of Hot Brook Canyon, Fall River County, S. Dak., showing outcrops of radioactive material.

locality about 2,500 feet distant. These two black fissile shale beds are exposed on the flanks of the anticline; they have not been traced from one locality to the other, but they may be correlative. A composite sample of these two black shales at each locality contained 0.036 and 0.046 percent equivalent uranium, 0.024 and 0.069 percent uranium, and less than 0.1 percent V_2O_5. The following table gives the assay results from samples of various radioactive beds in Hot Brook Canyon.

Assays of various radioactive beds in the Minnelusa sandstone, Hot Brook Canyon, Fall River County, S. Dak.

Sample no.	Thickness (ft)	Percent			Rock type and remarks
		eU [1]	U	V_2O_5	
1	1.3	0.017	0.007	0.46	Shale, black, fissile.
2	3.3	.012	.009	.66	Shale, green to black.
3	.6	.029	.027	.36	Shale, coaly.
4	.7	.018	.011	.50	Shale, coaly.
5	(2)	.52	.69	.36	Limestone, contains yellow radioactive mineral.
6	1.4	.012	.006	$<.1$	Sandstone, calcareous.
7 [3]	<1.0	.036	.024	$<.1$	Shale, black, fissile.
8 [3]	<1.0	.046	.069	$<.1$	Shale, black, fissile.

[1] Equivalent uranium.
[2] Grab sample.
[3] Samples 7 and 8 may be from the same beds; composite sample.

LITERATURE CITED

Darton, N. H., 1902, Description of the Oelrichs quadrangle, South Dakota-Nebraska: U. S. Geol. Survey Geol. Atlas, folio 85.

——— 1904, Description of the Newcastle quadrangle, Wyoming-South Dakota: U. S. Geol Survey Geol. Atlas, folio 107.

——— and Paige, Sidney, 1925, Description of the Central Black Hills quadrangle, South Dakota: U. S. Geol. Survey Geol. Atlas, folio 219.

——— and Smith, W. S. T., 1904, Description of the Edgemont quadrangle, South Dakota-Nebraska: U. S. Geol. Survey Geol. Atlas, folio 108.

Gruner, J. W., 1952, New data of syntheses of uranium minerals; Part I, Annual Report for July 1, 1951 to June 30, 1952: U. S. Atomic Energy Commission, Tech. Inf. Service, RMO-983, p. 16.

Lang, A. H., 1952, Canadian deposits of uranium and thorium (interim account): Geol. Survey of Canada, Econ. Geology Series no. 16.

Love, J. D., 1952, Preliminary report on uranium deposits in the Pumpkin Buttes area, Powder River Basin, Wyoming: U. S. Geol. Survey Circ. 176.

Page, L. R., and Redden, J. A., 1952, The carnotite propsects of the Craven Canyon area, Fall River County, South Dakota: U. S. Geol. Survey Circ. 175.

Stone, R. W., 1912, Coal near the Black Hills, Wyoming-South Dakota: U. S. Geol. Survey Bull. 499, p. 10.

Vickers, R. C., 1953, An occurrence of autunite, Lawrence County, South Dakota: U. S. Geol. Survey Circ. 286.

Wilmarth, V. R., and Johnson, D. H., 1954, Uranophane at Silver Cliff mine near Lusk, Wyoming: U. S. Geol. Survey Bull. 1009-A.

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