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Geology of the Burdock Quadrangle Fall River and Custer Counties South Dakota

GEOLOGICAL SURVEY BULLETIN 1063-F

Prepared on behalf of the U.S. Atomic Energy Commission

Schnabel—GEOLOGY, BURDOCK QUADRANGLE, FALL RIVER AND CUSTER COUNTIES, S. DAK.—Geological Survey Bulletin 1063-F

Geology of the Burdock Quadrangle Fall River and Custer Counties South Dakota

By ROBERT W. SCHNABEL

GEOLOGY AND URANIUM DEPOSITS OF THE SOUTHERN BLACK HILLS

GEOLOGICAL SURVEY BULLETIN 1063-F

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[Plates are in pocket]

GEOLOGY OF THE BURDOCK QUADRANGLE, FALL RIVER AND CUSTER COUNTIES, SOUTH DAKOTA

By Robert W. Schnabel

ABSTRACT

The Burdock quadrangle is on the southwest flank of the Black Hills uplift in Fall River and Custer Counties, S. Dak. The quadrangle is underlain by sedimentary rocks of Jurassic, Cretaceous, and Quaternary ages. The pre-Quaternary rocks dip gently toward the southwest.

Uranium deposits in the quadrangle are confined to the Fall River and Lakota formations of the Inyan Kara group of Cretaceous age and are presumed to have been deposited from ground-water solutions moving through permeable sandstones in these formations.

INTRODUCTION

The Burdock quadrangle lies between lat 43°22′30″ and 43°30′ N. and long 103°52′30″ and 104° W. in the foothills on the southwest flank of the Black Hills uplift in South Dakota. Most of the quadrangle is in Fall River County, but an area about 1½ miles wide along the north edge is in Custer County (fig. 39).

Total relief within the quadrangle is about 1,300 feet. The southwestern part of the quadrangle is relatively flat; much of it is covered by alluvium in the valley of the southeastward-flowing Cheyenne River. The northeastern part of the quadrangle is relatively rugged and has steep-walled canyons, some of which are as much as 500 feet deep. Annual rainfall is 13 to 15 inches, enough to support a sparse growth of grass and sagebrush in areas of low relief and a thin growth of pines on the steeper slopes. Principal industries in the area are cattle raising and uranium mining; also, some sand and gravel are produced from small pits in the alluvium of the Cheyenne River for use outside the area.

In 1951, deposits of uranium were discovered along Craven Canyon in the adjoining Edgemont NE quadrangle (Page and Redden, 1952). Since that time, many small deposits and a few containing from 10,000

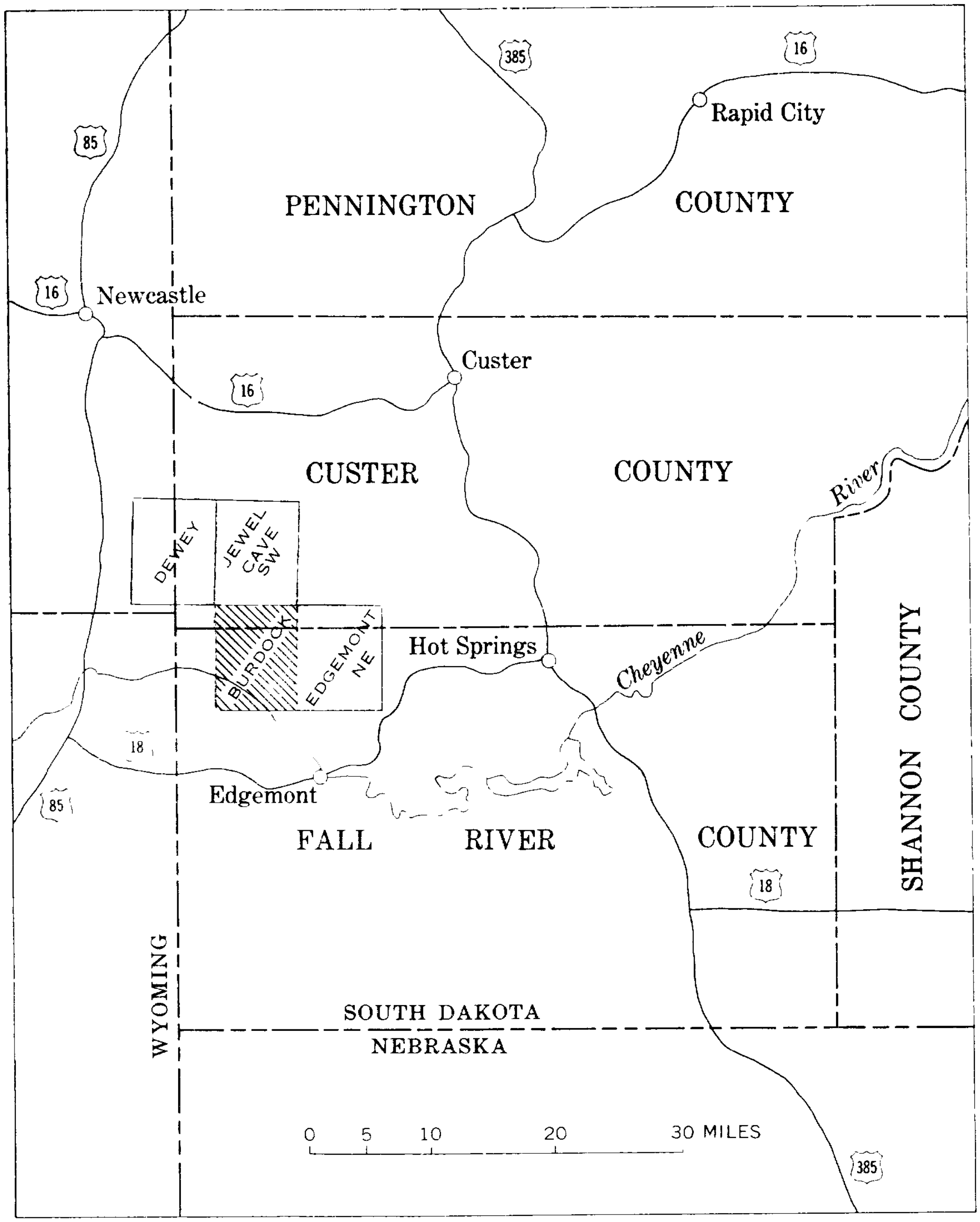

FIGURE 39.—Index map showing location of the Burdock and some adjoining quadrangles.

to 50,000 tons of ore have been found in the southern Black Hills. In 1952, the U.S. Geological Survey began a program of geologic investigations in the southern Black Hills on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission. This report is the result of that part of the program carried out in the Burdock quadrangle.

Geologic mapping of the quadrangle was originally done at a scale of 1:7200 on enlargements of the published topographic base map. The resulting maps were published in five parts that cover all but the southwest sixth of the quadrangle (Schnabel, 1958a, b, c; Schnabel and Charlesworth, 1958a, b). Plate 17 is a reduction of the original maps.

STRATIGRAPHY

The Burdock quadrangle is underlain by consolidated sedimentary rocks of Jurassic and Cretaceous age which are overlain in wide areas by unconsolidated alluvial and terrace deposits of Quaternary age (pl. 17). The consolidated rocks include the Sundance and Morrison formations of Jurassic age, and the Lakota, Fall River, Skull Creek, Mowry, and Belle Fourche formations of Cretaceous age.

The depositional environment in which these formations were deposited has been varied. It ranges from the normal marine environment in which the Sundance formation was deposited through a probable lacustrine environment during Morrison time; from the fluvial, lacustrine, marshy, and possibly eolian environments in which the Lakota and Fall River formations were deposited, to a normal marine environment during the deposition of the Skull Creek, Mowry, and Belle Fourche shales. A period of intense erosion followed the Black Hills uplift, and alluvial deposits representing stages in the downcutting during this erosion are present throughout much of the quadrangle.

JURASSIC ROCKS

SUNDANCE FORMATION

The Sundance formation of Late Jurassic age consists of a sequence of marine sandstone and shale which crops out in an area of about 1½ square miles in the northeastern part of Burdock quadrangle. Much of the formation is composed of easily eroded siltstone and mudstone. The formation, therefore, forms a gentle slope inside the hogback of the resistant rocks of the Inyan Kara group. The lower contact of the Sundance formation is not exposed in the Burdock quadrangle. In the few places where the upper contact could be observed, the formation seems to be conformable with the overlying Morrison formation.

Darton (1899) defined the Sundance formation to include 60 to 400 feet of greenish shale, buff sandstone, and red beds underlying the Morrison formation (then known as the Beulah shales), and overlying the Spearfish formation. Darton and O'Harra (1909), in their description of the Belle Fourche quadrangle, which is about 60 miles north of Burdock, stated that "* * * the type locality is above Sundance not far southeast of this quadrangle." Imlay (1947) divided the Sundance formation into five members which are, from bottom to top, the Canyon Springs sandstone member, the Stockade Beaver shale member, the Hulett sandstone member, the Lak member, and the Redwater shale member. Of these members the upper four are exposed in the Burdock quadrangle.

STOCKADE BEAVER SHALE MEMBER

The upper 20 feet of the Stockade Beaver shale member is exposed in the headwaters of a small canyon in secs. 28 and 33, T. 6 S., R. 2 E. (pl. 17). In this exposure the member consists of light to dark-greenish-gray, poorly fissile, argillaceous shale. The shale grades upward into the overlying Hulett sandstone member. Ripple-marked sandstone beds become progressively thicker and more abundant upward, but shale beds similar to those in the Stockade Beaver member persist far into the Hulett sandstone member. The contact between the members was chosen where the ratio of shale to sandstone is about 1:1.

HULETT SANDSTONE MEMBER

The Hulett sandstone member is about 45 feet thick where it is exposed in the head of a small unnamed canyon in the northeastern part of the quadrangle in secs. 28 and 33, T. 6 S., R. 2 E. (pl. 17). At the base the member consists of 10 to 15 feet of thin, interbedded, ripple-marked sandstone and light-olive-gray to light-greenish-gray shale that grades upward into a sandstone unit 20 to 25 feet thick in the middle of the member. The top of the member is a light-greenish-gray shale, about 5 to 10 feet thick.

The sandstone in the Hulett member is very fine grained, light yellowish gray, and well sorted. The individual grains are angular and are mostly quartz but include some feldspar; there are many small black flakes of biotite. The sandstone is generally slightly calcareous.

The lower contact of the Hulett sandstone member with the underlying Stockade Beaver shale member is conformable and gradational, and the upper contact, although very poorly exposed, seems to be gradational with the overlying Lak member.

LAK MEMBER

The Lak member is in parts of secs. 28 and 33, T. 6 S., R. 2 E., in the northeast corner of the Burdock quadrangle (pl. 17). It is very poorly exposed; one or two small outcrops of reddish-brown siltstone are in a few of the stream valleys. The member seems to be about 70 feet thick. This measurement is in general agreement with more accurate measurements made in adjacent quadrangles.

As nearly as can be determined from the composition of the soil formed on it, the Lak member consists mainly of red or maroon, very fine grained sandstone or siltstone and red mudstone. Both the top and the bottom of the unit are covered, but in the adjoining Edgemont NE and Jewel Cave SW quadrangles it is conformable with the overlying Redwater shale member and with the underlying Hulett sandstone member (G. B. Gott and W. A. Braddock, written communication, 1957).

REDWATER SHALE MEMBER

The Redwater shale member is exposed in the bottoms of canyons and at the base of Pilger Mountain is secs. 28, 29, 30, 31, 32, and 33, T. 6 S., R. 2 E., in the northeastern part of the Burdock quadrangle (pl. 17). The Redwater shale member is poorly exposed and in most places it is covered by a deep accumulation of talus derived from overlying rocks of the Morrison formation and Inyan Kara group.

Small outcrops of the Redwater shale member and fragments in talus indicate that the member consists of pale-olive-gray to greenish-gray shale interbedded with light-greenish-gray glauconitic sandstone and light-yellowish-gray sandstone.

Neither the top nor the bottom of the Redwater shale member is well exposed in the Burdock quadrangle. The thickness of 170 feet interpreted for the unit is, however, in agreement with measurements made in the adjoining Edgemont NE and Jewel Cave SW quadrangles. In those quadrangles the Redwater shale is conformable with both the overlying Morrison formation and the underlying Lak member.

MORRISON FORMATION

The Morrison formation of Late Jurassic age is intermittently exposed throughout an area of about 1½ square miles in the bottoms of canyons and along the base of Pilger Mountain in the northeastern part of the Burdock quadrangle. The formation is nearly everywhere covered by a deep accumulation of talus derived from the overlying rocks of the Inyan Kara group. Scattered exposures suggest that it consists of a sequence of light-greenish-gray shale and claystone interbedded with light-gray limestone. The upper and lower contacts are nowhere well exposed, but the formation seems to be conformable with both the overlying Lakota formation and the underlying Sundance formation. The thickness of the Morrison formation in the Burdock quadrangle seems to be about 100 feet, although a variation from this thickness of as much as 25 feet is possible.

Early workers in the Black Hills referred to the Morrison formation as the Beulah shales, Beulah clays, or the *Atlantosaurus* beds. After examining the Morrison formation in the Front Range of Colorado and other areas, however, Darton (1901a) was persuaded that the formation in the Black Hills was correlative with the Morrison forma-

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tion in other parts of the Western United States. He accordingly changed the name from Beulah shales to Morrison formation.

CRETACEOUS ROCKS

INYAN KARA GROUP

The Inyan Kara group includes the Lakota and Fall River formations of Early Cretaceous age. It consists of a series of sedimentary rocks of fluvial, lacustrine, and possibly eolian origin, which crop out over much of the eastern half of the Burdock quadrangle (pl. 17).

The formations in the Inyan Kara group were originally mapped by Darton (1901b) as, in ascending order, the Lakota sandstone, the Minnewaste limestone, the Fuson formation, and the Dakota sandstone. Russell (1927, 1928) concluded that the unit mapped as the Dakota sandstone by Darton in the Black Hills was not correlative with the Dakota sandstone as defined and mapped away from the Black Hills, and he renamed the unit the Fall River formation. Rubey (1930), who worked in the northern Black Hills, proposed that the Inyan Kara group include the Lakota sandstone, the Fuson formation, and the Fall River sandstone.

Mapping in parts of the southern Black Hills at a scale of 1:7200 has shown that the contact between the Lakota sandstone and the Fuson formation is difficult to determine in areas where the Minnewaste limestone is absent. Similar difficulties were found by K. M. Waagé (1959) in the northern, eastern, and western Black Hills. As a result of these difficulties and the confusion, and misuse of names arising therefrom, Waagé dropped the name Fuson formation, and included all of the pre-Fall River Inyan Kara rocks in the Lakota formation. In this revision he retained, as members, the Fuson and the Minnewaste limestone of Darton. Later, Post and Bell (1961) defined the Chilson member as those rocks in the Lakota formation below the Minnewaste limestone member.

Mapping by field parties of the U.S. Geological Survey in the southern, western, and northern Black Hills has shown that several thick channel sandstones extend over much of the area. These sandstone beds have been given number designations in a composite cross section drawn from the mapping (Mapel and Gott, 1959). The sandstones designated S_1, S_3, S_4, and S_5 are present in the Burdock quadrangle.

LAKOTA FORMATION

In the Burdock quadrangle, the Lakota formation of Early Cretaceous age consists of a series of sandstone, mudstone, limestone, and interbedded sandstone and mudstone of fluvial, lacustrine, and possibly eolian origin. Plate 18 shows the stratigraphic relations of rock types in the Lakota formation in part of the quadrangle. The formation has been divided into, in ascending order, the Chilson member, the Minnewaste limestone member, and the Fuson member.

Both the lower and upper contacts of the formation are poorly exposed throughout most of the quadrangle. The lower contact has been chosen where the lowest carbonaceous or silty bed of the Lakota formation is in contact with the noncarbonaceous, nonsilty beds of the upper part of the underlying Morrison formation. The upper contact has been chosen where the variegated mudstones in the upper part of the Fuson member and in the upper part of the S_4 sandstone channel, or the S_4 sandstone are in contact with the overlying carbonaceous interbedded sandstone and siltstone of the Fall River formation.

Where the Lakota formation is exposed in the Burdock quadrangle, it ranges in thickness from about 200 to about 350 feet. The diagram in plate 18 suggests that it thins to the west.

CHILSON MEMBER

The Chilson member of the Lakota formation is a 150- to 250-foot-thick sequence of thick channel sandstone separated by lenses and beds of carbonaceous interbedded sandstone and mudstone. Although the sandstone beds form two discrete units over most of the Burdock quadrangle, they coalesce in parts of secs. 4, 5, 8, and 9, T. 7 S., R. 2 E., as well as in the adjoining Edgemont NE quadrangle. For this reason, and because they are lithologically similar, they have been designated as a single unit—the S_1 sandstone. The relations between the S_1 sandstone and the interbedded sandstones and mudstones are shown on plate 18.

Interbedded sandstone and mudstone

The interbedded sandstone and mudstone consists of a series of thin, discontinuous, fine- to medium-grained, crossbedded light-gray sandstone beds interlaminated with dark-gray to black, highly carbonaceous, laminated mudstone and shale. The individual sandstone and mudstone beds are generally less than 1 foot thick, although locally individual sandstone beds thicken to as much as 20 feet. No similar thickening of the mudstone or shale beds was seen.

Within the interbedded sandstone and mudstone sequence there are one or more relatively thin "leathery" shale beds. These shale beds are very resistant to erosion, and crop out consistently over relatively wide areas. Where they are present they serve as useful marker beds. Discontinuity of exposures made it impossible to determine whether this rock forms a single continuous bed over the whole quadrangle, but in all places the shale beds seem to be stratigraphically between the two S_1 sandstone beds. The black "leathery" shale is rich in organic matter and will burn freely in air. Thin sections show that much of the organic material is in the form of structureless microscopic spherical waxy blebs.

Nearly all the carbonaceous material in the interbedded sandstone and mudstone sequence except the waxy blebs in the "leathery" shale is in the form of small unidentifiable plant fragments. The abundance of these fragments suggests that the sequence was probably deposited in a swampy or marshy environment, possibly on flood plains marginal to the stream channels in which the S_1 sandstone was deposited.

S_1 sandstone

Thick crossbedded, channel-type sandstones are widespread in the Chilson member in the southwestern Black Hills. These sandstones have been designated the S_1 sandstone (Mapel and Gott, 1959).

In the Burdock quadrangle the S_1 sandstone consists of three separate beds. The lowest bed crops out only in sec. 5, T. 7 S., R. 2 E. It reaches a maximum thickness of about 50 feet and seems to occur only in sec. 5. The upper beds are widespread throughout the quadrangle and are contiguous only in parts of secs. 4, 5, 8, and 9, T. 7 S., R. 2 E. The higher sandstone bed seems to be truncated to the southwest by the Minnewaste limestone member and the Fuson member; the lower bed pinches out to the northwest.

The S_1 sandstones are massive- to thick-bedded, light-yellowish-gray, fine- to medium-grained, nearly pure quartz sandstones. Locally they contain discontinuous carbonaceous mudstone beds ranging from a few inches to a few feet in thickness. Crossbedding is well defined at most places but there seems to be no preferred orientation, and crossbeds that dip in many different directions were observed in most exposures. Nearly everywhere the S_1 sandstones are fine to medium grained, have small local accumulations of coarser material, and are moderately well sorted (fig. 40).

The S_1 sandstones are generally nearly pure quartz, and have only minor amounts of other minerals. Locally, however, they contain accumulations of clay in the forms of both fine interstitial material and clay grains or galls. Locally the sandstone is cemented with calcite or silica. Much of the sandstone contains secondary silica as overgrowths on the quartz grains. Carbonaceous material in the form of macerated plant fragments is common in the S_1 sandstones.

The complexity of the crossbedding in the sandstones, and their broad channellike shape when viewed as a whole in the southern Black Hills suggest that they may have been deposited as a series of channel fills from many small streams, or from one or more large meandering or anastomosing streams.

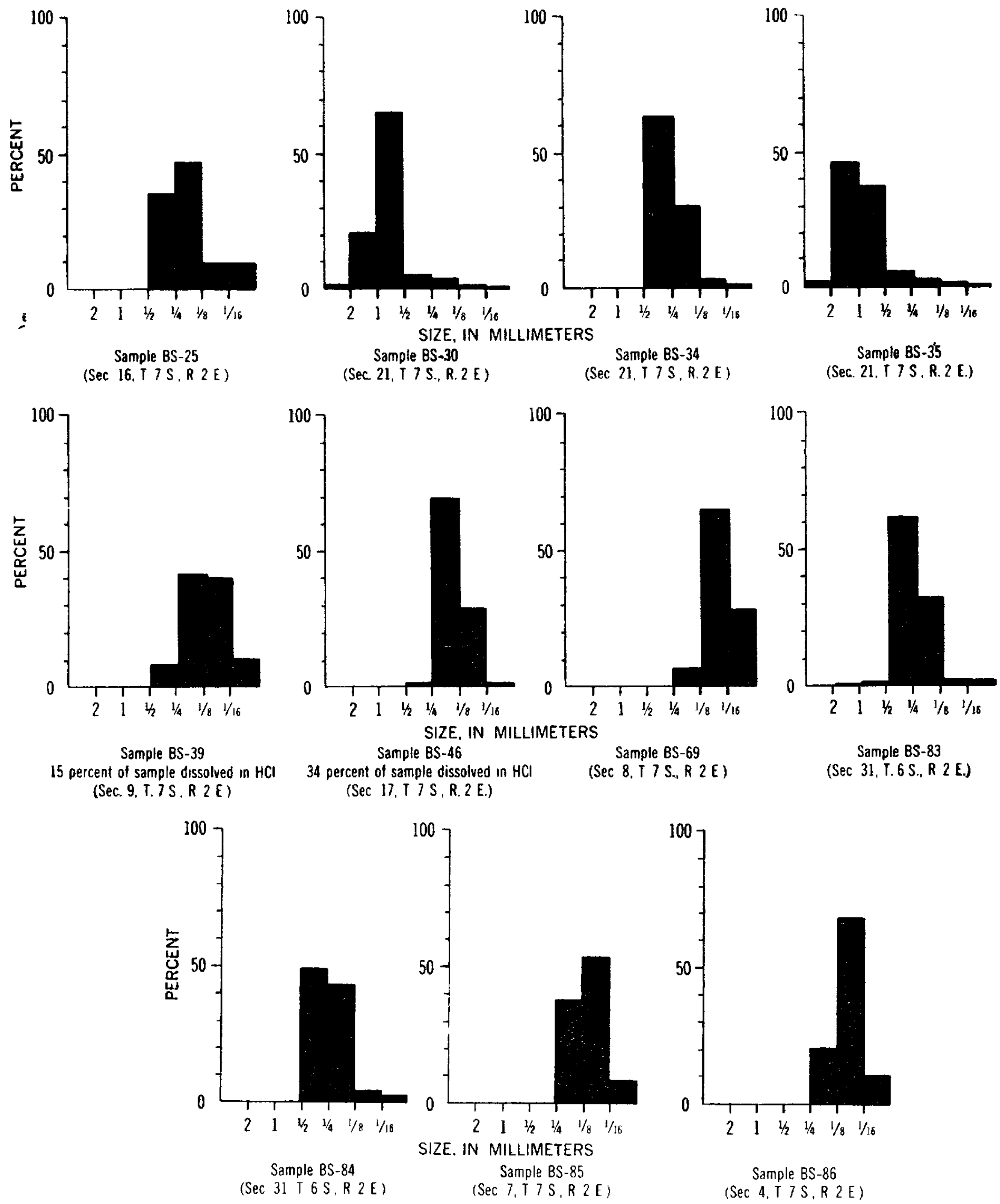

FIGURE 40.—Size analyses of samples of the S_1 sandstone from the Chilson member of the Lakota formation.

MINNEWASTE LIMESTONE MEMBER

The Minnewaste limestone member of the Lakota formation consists of a series of relatively thin, impure limestones which crop out as discontinuous lenticular beds over much of the northeastern part of the Burdock quadrangle. The limestone is resistant, forms well-defined low benches, and is generally well exposed. The member reaches a maximum thickness of about 25 feet in the north-central part of sec. 4, T. 7 S., R. 2 E.

The Minnewaste limestone member is light gray to medium gray, and generally presents a gnarled appearance that is probably due to differential solution by surface water. Locally, fractures in the limestone are filled with calcite crystals that occasionally attain a maximum length of as much as 1 inch.

Size analyses of the residues obtained from the leaching of six samples of the limestone in dilute hydrochloric acid are given in figure 41. Most of the impurities in the limestone are in the form of quartz sand or silt although some clay-sized material is present. Many of the quartz grains are well rounded and pitted. This evidence suggests that they may represent windblown material, or that they have been etched by carbonate-rich solutions.

Remains of fresh-water sponges have been found in the Minnewaste limestone member in the Angostura Reservoir quadrangle (J. J. Connor, oral communication). These fossils, in addition to the irregular distribution and lenticular shape of the limestone, suggest that the limestone was deposited in ponds or small lakes.

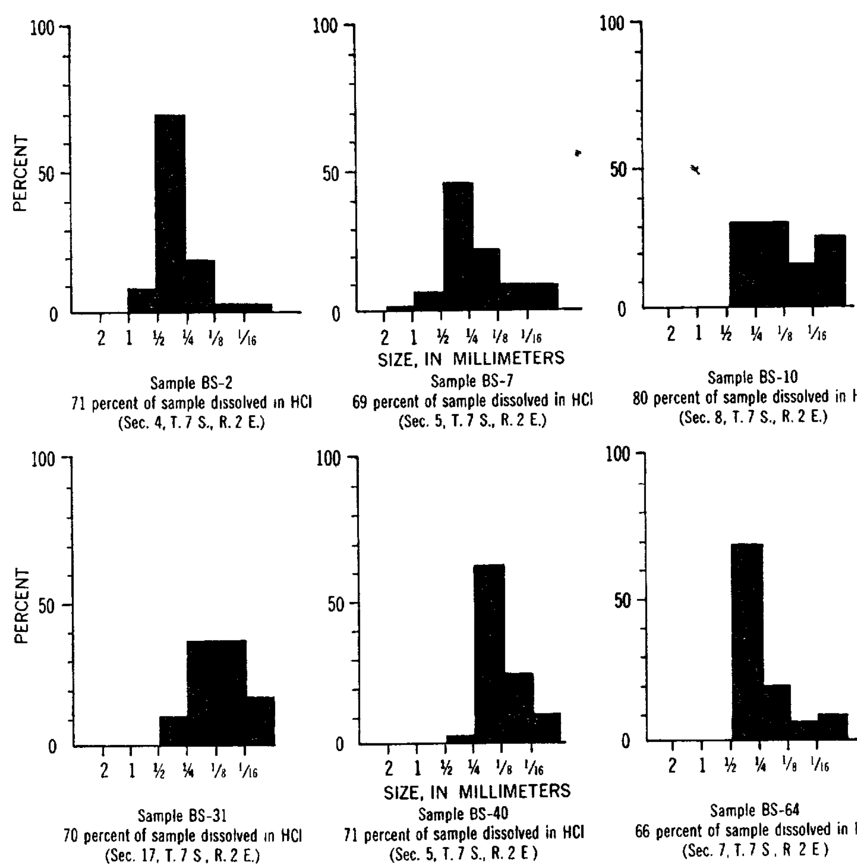

FIGURE 41.—Size analyses of residues from samples of the Minnewaste limestone member of the Lakota formation.

FUSON MEMBER

In the Burdock quandrangle, the Fuson member of the Lakota formation consists of a sequence of sandstone and variegated mudstone. Nearly everywhere in the quadrangle variegated mudstone is the predominant rock type. Locally, however, the sandstone beds reach varying degrees of prominence, and in some places form the whole Fuson member. Three distinctive sandstone bodies are present. The lowest, the S_3 sandstone, is present only in the northern part of the quadrangle. The middle sandstone, a white massive sandstone, occurs in two lenses—one in the northern part and one in the east-central part of the quadrangle. The uppermost sandstone, the S_4 sandstone, is a thick channel sandstone in the northeastern part of the quadrangle. The thickness of the Fuson member ranges from about 100 to about 200 feet in the Burdock quadrangle.

Variegated mudstone

The variegated mudstone of the Fuson member is a distinctive brightly colored rock with shades of red and green predominating, although locally it is gray and white. Outcrops of the mudstone are rare; it generally forms gentle slopes and imparts its colors to the soils formed on the slopes.

Where it is exposed, the mudstone is massive and shows almost no trace of bedding. It disintegrates into small irregular polyhedrons one-fourth to one-half inch in their longest dimensions. It is composed largely of clay- and silt-size particles of quartz; locally, accumulations of sand-size grains occur. Most of the larger grains are well rounded and have pitted or etched surfaces.

No carbonaceous debris or silicified plant material has been found in the mudstone in the Burdock quadrangle, although silicified logs have been found in the adjoining Edgemont NE quadrangle.

The fine grain size and absence of bedding and carbonaceous material suggest that the mudstone was deposited as an accumulation of windblown material under oxidizing conditions. It is possible, however, that the mudstone accumulated in a lacustrine environment and was later subjected to oxidizing processes.

S_3 sandstone

The S_3 sandstone is a channel-type sandstone that is extensive along the west rim of the Black Hills. Only the southernmost edge of this sandstone extends into the Burdock quadrangle, and outcrops are confined to secs. 29, 30, 31, 32, and 33, T. 6 S., R. 2 E., and secs. 25 and 36, T. 6 S., R. 1 E., along the north boundary. The sandstone reaches a maximum thickness of about 50 feet in the quadrangle, but pinches out within a mile of the north edge (pl. 17).

The S_3 sandstone is underlain by as much as 50 feet of variegated mudstone in the westernmost exposures. It is underlain by interbedded sandstone and mudstone of the Chilson member on Pilger Mountain, although in a few places 1 or 2 feet of variegated mudstone occurs between the interbedded sandstone and the S_3 sandstone. The S_3 sandstone is overlain by the white massive sandstone along the north border of the quadrangle. In the exposures farther into the quadrangle it is overlain by variegated mudstone, and in a few exposures along the west side of Pilger Mountain the S_4 sandstone rests directly on the S_3 sandstone.

Throughout most of the quadrangle the sandstone is well sorted and consists largely of well-rounded quartz grains, and some interstitial clay and clay grains. Locally, admixtures of very coarse grains are present, and clay galls and grains are distributed erratically through the unit. Size analyses of two samples are given in figure 42. The sandstone contains some carbonaceous material in the form of minute flecks, but nowhere was this observed to be particularly abundant. Crossbedding is locally well developed, but no particular preferred orientation of the crossbeds was observed in the Burdock quadrangle.

White massive sandstone

Over much of the Burdock quadrangle (pl. 17) the middle part of the Fuson member is occupied by a white to very light gray, very fine grained, massive sandstone. The sandstone forms two lenses; one is present in most of the east-central part of the quadrangle, the other is along the north quadrangle boundary and extends north into the Jewel Cave SW quadrangle. The lens in the east-central part of the quadrangle forms a lenticular body that reaches a maximum thickness of about 50 feet in the south-central part of sec. 8, T. 7 S., R. 2 E. It pinches out to the northeast and southwest. It thins to the northwest, but because it is buried under younger rocks it is not known if the sandstone persists in that direction. The lens along the north boundary of the quadrangle is thickest in the north, and pinches out about 1,000 feet south of the quadrangle boundary.

The white massive sandstone is composed mainly of fine to very fine quartz sand and silt particles (fig. 42). The larger grains are well rounded and have pitted or frosted surfaces. The smaller grains are rounded to angular and many show fractured surfaces. In most places the sandstone is not stratified. A rude bedding is developed, however, near the thin edges of the unit in some places, as in the north-central part of sec. 7, T. 7 S., R. 2 E. No carbonaceous material was observed in the white massive sandstone. In the NW cor. sec. 16, T. 7 S., R. 2 E., some of the white massive sandstone is cemented with

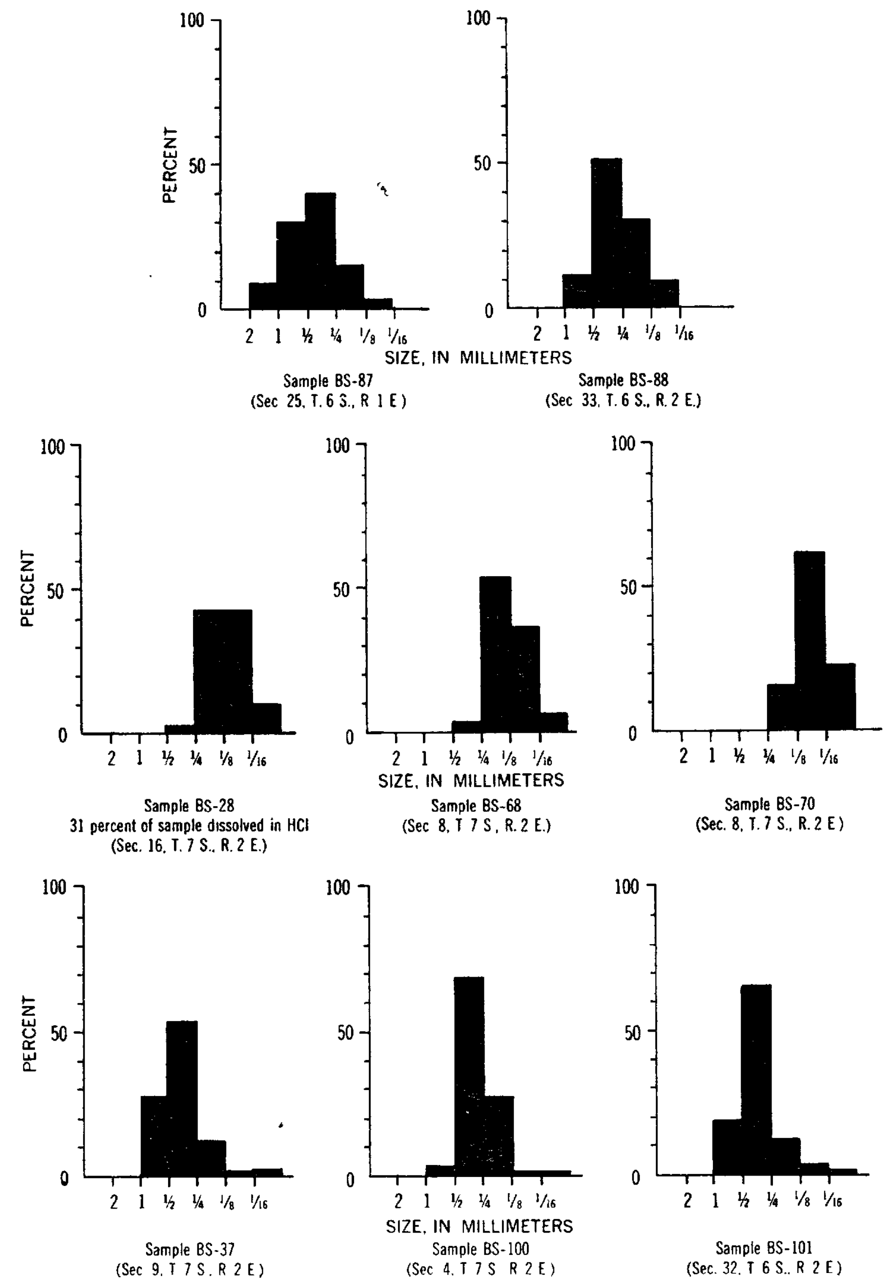

FIGURE 42.—Size analyses of samples of the S_3 (top row), white massive (middle row), and S_4 (bottom row) sandstones from the Fuson member of the Lakota formation.

calcium carbonate to form rounded nodules as much as 10 inches in diameter.

The white massive sandstone may have accumulated as a lacustrine or eolian deposit. The general lack of bedding and of carbonaceous material implies to the writer that the unit is more likely an eolian deposit in a subaerial environment. Formation of bedding in the unit was probably inhibited by a vegetative growth that was completely destroyed by oxidation both during and subsequent to the accumulation of the sand. The white color of the rock suggests lack of iron in the original sediments.

S_4 sandstone

The S_4 sandstone is a conspicuous channel-type sandstone that is exposed over much of the southern Black Hills. It fills erosional irregularities cut into lower beds in the Fuson member. Locally it replaces all other beds in the Fuson member and rests directly on the Minnewaste limestone member. The unit is of major economic importance because uranium has been mined from it in the Edgemont NE and Flint Hill quadrangles.

The S_4 sandstone ranges from 0 to about 100 feet in thickness in the Burdock quadrangle. In most places the S_4 sandstone is a light-yellowish-gray, medium-grained, crossbedded sandstone locally stained to shades of red and brown by iron oxide minerals. Patches of fine sand occur locally, and lenses of coarse-grained sandstone are abundant. The sandstone is composed almost wholly of rounded to well-rounded quartz grains and interstitial clay-sized particles (fig. 42). In the E½ sec. 16, T. 7 S., R. 2 E., the sandstone is cemented by calcium carbonate in the form of small round nodules; similar cementation was not observed elsewhere in the Burdock quadrangle although it is typical of the sandstone over wide areas in the adjoining Edgemont NE quadrangle. In the NE¼ sec. 16, T. 7 S., R. 2 E., the lower part of the S_4 sandstone contains a few silicified logs about 1 foot in diameter. These logs are alined with their long dimension parallel to the trend of the sandstone.

The channellike shape of the S_4 sandstone, the crossbedding, and the orientation of the logs at its base suggest that the sandstone was deposited in a fluvial environment.

Variegated mudstone above S_4 sandstone

In the northern and east-central parts of the Burdock quadrangle the S_4 sandstone is overlain by a very poorly exposed variegated mudstone unit that reaches a thickness of about 50 feet on the west side of Pilger Mountain. A similar mudstone is present locally above the sandstone in the Edgemont NE quadrangle. There, better exposures and information obtained from drill cores indicate that the mudstone is a late phase of the accumulation of the S_4 sandstone, and that it probably is in part derived from reworking of older mudstones of the Fuson. It seems likely that the mudstones above the S_4 sandstone in the Burdock quadrangle originated in the same manner as the mudstones above the S_4 sandstones in the Edgemont NE quadrangle.

FALL RIVER FORMATION

The Fall River formation of Early Cretaceous age is exposed over wide areas in the Burdock quadrangle. The formation consists of three units: the lowest unit is an interbedded sandstone and carbonaceous siltstone with a few thick sandstone beds; the middle unit consists of interbedded sandstone and mudstone with abundant thick channel sandstones; the upper unit consists of a thin variegated mudstone at the base and interbedded sandstone and mudstone above. The interbedded sandstone and mudstone in the middle and upper unit are lithologically similar and are discussed below as a single rock type.

The lower contact of the Fall River formation has been defined in the Black Hills area by Waagé (1959, p. 52) as a transgressive disconformity. In the Burdock quadrangle this contact has been chosen at the base of the carbonaceous interbedded sandstone and siltstone unit where it is in contact with the underlying non-carbonaceous variegated mudstones of the Fuson member and the upper part of the S_4 sandstone. In a few places, as in the east side of secs. 4, 9, and 16, T. 7 S., R. 2 E., channel sandstones of the Fall River formation have scoured through the interbedded sandstone and siltstone. In those places the basal contact of the Fall River formation has been placed at the base of the sandstone beds where they are in contact with the S_4 sandstone. The upper contact of the Fall River formation is gradational with the overlapping Skull Creek shale. It has been placed at the top of the highest sandy unit in the Fall River formation. Both the upper and the lower contacts of the Fall River formation are difficult to locate in the field as they are bounded by soft beds that disintegrate easily. In most places the boundaries were chosen arbitrarily. The Fall River formation is about 150 feet thick in the Burdock quadrangle.

INTERBEDDED SANDSTONE AND SILTSTONE

In most of the Burdock quadrangle, the lower part of the Fall River formation is composed of an interbedded sandstone and siltstone unit that has an average thickness of about 50 feet. The unit consists of a series of thin-bedded sandstones interbedded with carbonaceous siltstones and some mudstones; most of the carbonaceous material is in the form of macerated plant fragments.

The interbedded sandstone and siltstone unit is similar in many respects to the overlying interbedded sandstone and mudstone unit. In general, however, it is more silty and carbonaceous than the overlying beds. On the weathered surface the interbedded sandstone and siltstone has a brownish cast, whereas the overlying interbedded sandstone and mudstone tends to be gray. The distinction between the two units is rather fine and it is difficult to make. It was attempted because many small uranium deposits in the adjoining Edgemont NE quadrangle occur in the interbedded sandstone and siltstone.

In a few places sandstone beds in the interbedded sandstone and siltstone are more than 10 feet thick. Such a sandstone bed has been mapped in parts of sec. 36, T. 6 S., R. 1 E. See plate 17.

INTERBEDDED SANDSTONE AND MUDSTONE

Throughout the Burdock quadrangle most of the Fall River formation consists of a sequence of thin sandstone beds interlayered with carbonaceous mudstone. Where the thick channel sandstone units are not present, a variegated mudstone divides the interbedded sandstone and mudstone into two units. The lower unit is about 50 feet thick and the upper is about 30 feet thick.

The interbedded sandstone and mudstone are soft and disintegrate easily. They generally form smooth, soil-covered slopes; good exposures are rare. In general, the unit consists of sandstone beds a few inches to a few feet thick interlayered with carbonaceous mudstone of equivalent thickness. Locally the lower unit contains some siltstone and it is in one of these silty facies that the Freezeout mine is located.

VARIEGATED MUDSTONE

A variegated mudstone, with shades of red and gray predominating, is in the upper part of the Fall River formation in the Burdock quadrangle. The unit is generally about 20 feet thick although lack of good exposures makes precise measurement impossible. It is overlain in most places by about 30 feet of interbedded sandstone and mudstone.

The variegated mudstone is a thin-bedded unit that otherwise has many characteristics of the mudstone in the Fuson member of the Lakota formation. Although poorly exposed, the mudstone generally imparts its color to the soil formed on its slopes and thus serves as a useful marker bed in the Fall River formation. Toward the north quadrangle boundary, however, its value for this purpose is less because overlying and underlying mudstones assume similar colors.

S_5 SANDSTONE

A series of thick channel-type sandstones that occur at about the same stratigraphic position within the middle interbedded sandstone and mudstone have been designated the S_5 sandstone. The thickest exposures of this sandstone in the Burdock quadrangle are along the northern boundary in secs. 25, 26, 35, and 36, T. 6 S., R. 1 E., and in secs. 29 and 32, T. 6 S., R. 2 E. These exposures are interpreted to be part of a major channel within the S_5 unit. Other exposures of the S_5 sandstone within the quadrangle are interpreted to have formed in tributaries to this main channel.

The S_5 sandstone is fine to medium grained, dark yellow gray to buff, iron stained, crossbedded, and massive. It is composed mainly of well-rounded to moderately well rounded quartz grains and varying amounts of interstitial clay. In most places the sandstone contains abundant flakes of mica. In many places it contains abundant iron-oxide concretions; and on the top of Pilger Mountain in sec. 29, T. 6 S., R. 2 E. the sandstone is cemented by silica.

CRETACEOUS MARINE SHALES

A series of dark marine shales overlie the Inyan Kara group in Burdock quadrangle. They include, in ascending order, the Skull Creek shale and the Mowry shale of Early Cretaceous age and the Belle Fourche shale of Late Cretaceous age.

N. H. Darton (1901b) originally considered these shales to be part of one formation which he called the Graneros shale. He later recognized the Mowry shale member and considered it correlative with a unit of the same name that he had mapped in the Bighorn Mountain area (Darton, 1909). Collier (1923) later divided the Graneros formation into five members which he called, in ascending order, the Skull Creek shale, the Newcastle sandstone, the Nefsy shale, the Mowry shale, and the Belle Fourche shale. Rubey (1929) discarded the term "Nefsy shale" and included the rocks which Collier had called the Nefsy shale in the lower part of the Mowry shale. Reeside (1944) raised the members of the Graneros formation to the rank of formations and assigned an Early Cretaceous age to the Skull Creek shale. Cobban and Reeside (1952) considered the Mowry shale and the Newcastle sandstone as Early Cretaceous.

SKULL CREEK SHALE

The Skull Creek shale of Early Cretaceous age is a black marine shale that is exposed in a strip 1 to 1½ miles wide that extends from the southeast corner to the northwest corner of the quadrangle. Over much of this area the formation is covered by unconsolidated alluvial and terrace deposits. The Skull Creek shale is in gradational contact with the underlying Fall River formation. Inasmuch as the Newcastle sandstone, which normally overlies the Skull Creek shale, is not present in the Burdock quadrangle, the contact between the Skull Creek shale and the overlying Mowry shale is probably discomformable. The disconformity, however, is not apparent and the contact has been chosen principally on the basis of a color change from the black of the Skull Creek shale to the gray of the overlying Mowry shale.

Measurements of the thickness of the Skull Creek shale are difficult because of the wide outcrop area and because individual outcrops are so obscure that reliable measurements of dip and strike cannot be made. A thickness of about 150 feet, however, fits the observed data and is in general agreement with more precise measurements made in nearby areas.

The Skull Creek shale is a uniform black fissile marine shale which yields small, smooth, dark-gray to black chips on weathering. In the NW¼NW¼ sec. 32, T. 7 S., R. 1 E., two zones of relatively small, oval mangano-siderite concretions are near the base of the formation. Locally, cone-in-cone structures are abundant in oval calcareous concretions near the top of the Skull Creek shale.

Sandstone dikes crop out as long narrow ridges in the upper part of the Skull Creek shale and in the lower part of the Mowry shale in secs. 10 and 11, T. 7 S., R. 1 E. In thin section the sandstone dikes appear to be composed almost wholly of grains of quartz but they also contain small amounts of feldspar, principally microcline, and biotite and glauconite. The dikes are composed of grains 1 to 3 mm in diameter and the interstices are filled with fragments 0.1 mm and smaller. The general appearance of the rock suggests that it has been subjected to grinding pressures, and it may even be said to have a "cataclastic" texture.

The "cataclastic" texture of the rock suggests that the dikes may have been forcibly emplaced into the shale. Whether they were derived from sandstone in the Fall River formation below or from sandstone in the lower part of the Mowry shale above is unknown. In general the sandstones in the Newcastle and in the lower part of the Mowry contain some glauconite (D. A. Brobst, oral communication, 1959). Glauconite has not been observed in the sandstones in the Fall River formation, nor does the sandstone of the Fall River contain as much feldspar as is contained in the dike rocks. This evidence suggests that the sandstone dikes were introduced from the overlying sediments rather than from sandstone in the Fall River formation.

MOWRY SHALE

The Mowry shale of Early Cretaceous age is a dark- to medium-gray siliceous shale which is present under much of the west and southwest portions of the Burdock quadrangle (pl. 17). In most of this area the formation is covered by unconsolidated deposits of alluvium and terrace gravels. The Mowry shale is probably in disconformable contact with the underlying Skull Creek shale in the Burdock quadrangle inasmuch as the Newcastle sandstone which separates the two formations to the north and southeast is not present in the area. The Belle Fourche shale apparently conformably overlies the Mowry shale. A complete section of the Mowry is not exposed in Burdock quadrangle, but in the Dewey quadrangle to the northwest the formation is about 150 feet thick (D. A. Brobst, written communication, 1958).

The Mowry shale has been differentiated from the overlying and underlying formations largely on the basis of a color difference. The Mowry shale is a lighter shade of gray in most places than is either the Belle Fourche shale or the Skull Creek shale. In most places the Mowry shale contains abundant fish scales, and it is generally more siliceous than the overlying and underlying formations. Both features aid in identifying individual exposures as part of the Mowry.

BELLE FOURCHE SHALE

The Belle Fourche shale, a black marine shale of Late Cretaceous age, is exposed in the south-central and in the northwestern parts of the Burdock quadrangle (pl. 17). It probably also occurs over a large part of the southwest corner of the quadrangle, but there it is buried by unconsolidated alluvial deposits. Only the lower 90 to 100 feet of the formation is exposed in the quadrangle. The formation rests with apparent conformity on the underlying Mowry shale.

QUATERNARY ROCKS

Rocks of Quaternary age are present over about one-half of the Burdock quadrangle. They include the Recent alluvium along most of the major streams in the quadrangle, an older alluvium in the southwestern part of the quadrangle that has been surficially modified by wind, and higher terrace gravels that may represent stages of downcutting of the major streams, and that might represent deposits formed during Tertiary time.

Most of the Quaternary rocks are unconsolidated deposits of sand and gravel derived from the rocks surrounding the Black Hills. In many places they are composed mainly of fragments derived from the consolidated sediments exposed immediately upstream. In other places they are composed largely of fragments of Paleozoic rocks, mainly limestones and cherts found closer to the center of the Black Hills uplift.

The surface of the older alluvium in the southwest corner of the quadrangle is a series of shallow depressions elongated in a northwest direction. The deposits on the mounds between the depressions are poorly sorted and seem to be the same as those in the bottom of the depressions. This evidence suggests the removal of material by wind rather than an accumulation of windblown deposits.

STRUCTURE

The structure of the rocks in the Burdock quadrangle is simple (pl. 17). In general the rocks dip from 2° to 4° SW throughout most of the quadrangle. A small fold in the northeastern part of the quadrangle represents part of the closure of an anticlinal fold that extends into the Edgemont NE quadrangle to the east and into the Jewel Cave SW quadrangle to the north. Over large areas in the southwestern part of the quadrangle the structure has been interpreted from meager data and it may be much more complex than is shown by the structure contours.

A few faults with small displacement, generally less than 10 feet, ocur in parts of the quadrangle. Well-defined vertical joint systems are particularly evident in the thin sandstone beds in the thin-bedded rocks of the Fall River formation. In most of the quadrangle the joint systems strike N. 75°–85° E. and N. 35°–45° E.

ECONOMIC GEOLOGY

URANIUM DEPOSITS

GENERAL FEATURES

Uranium ore has been mined principally from two mines, the Triangle mine in the NE¼ sec. 34, T. 6 S., R. 1 E., and the Freezeout mine in the SW¼ sec. 36, T. 6 S., R. 1 E., but many occurrences of uranium minerals have been prospected within the quadrangle. The ore minerals occur as impregnations in sandstone, siltstone, and mudstone beds, generally but not consistently in a carbonaceous environment. The uranium and vanadium minerals from these deposits that have been identified are uraninite, fourmarierite(?), carnotite, and tyuyamunite. Although positive identifications have not been made, corvusite and rauvite are probably also present in some of the deposits.

The uranium minerals that have been observed are restricted to the S_5 sandstone and sandy or silty facies in the lower interbedded sandstone and mudstone unit near the edge of the S_5 sandstone in the Fall River formation, and the upper part of the S_1 sandstone in the Chilson member of the Lakota formation.

As of 1960 none of the known deposits in the S_1 sandstone was economically significant. These deposits are along Driftwood Canyon near the east side of the quadrangle and are made up of erratic disseminations of yellow minerals through a relatively pure quartz sandstone. In some places the yellow minerals are localized around carbonaceous material; in other places the minerals are not associated with carbonaceous material.

The Triangle deposit, which contains the largest known uranium reserves in the quadrangle, had not been discovered at the time the quadrangle was being mapped. The deposit is in the edge of the S_5 sandstone, channel sandstone, and most of the mineralized rock is about at the present water table. The portal of the mine is in the alluvium along Pass Creek.

The Freezeout mine and many small prospects, some of which have produced a few tons of ore, occur in the lower interbedded sandstone and mudstone unit of the Fall River formation. Inasmuch as the Freezeout mine was the only mine of economic significance in the quadrangle while areal mapping was in progress, it was studied in some detail.

FREEZEOUT MINE

The Freezeout mine is in the southwestern part of sec. 36, T. 6 S., R. 1 E. At the time of mapping it consisted of two main adits, one about 300 feet long, the other at least 50 feet long, and an opencut about 100 feet wide, 400 feet long, and 50 feet deep in the deepest part. The mine was mapped at a scale of 1 inch equals 20 feet for the longer adit. The walls and floor of the opencut were covered by debris washed from above or by mine waste; the shorter adit was filled with water at the time of mapping. The results of the mapping are shown on plate 19.

The uranium deposit at the Freezeout mine is in a silty facies of the lower interbedded sandstone and mudstone unit of the Fall River formation. Four different rock types, each a stratigraphic subunit, were mapped in the main adit of the mine. The lowest of these subunits is a thin-bedded to laminated siltstone with dark carbonaceous layers alternating with light, less carbonaceous layers. In general, the light layers are coarser grained than the dark layers. The lowest siltstone is medium gray to dark gray except where it is stained by iron oxides or where a "bloom" of bright-colored uranium minerals has formed on it. Through most of the lower subunit, where it is exposed in the mine, there are vertical or nearly vertical carbon-filled branching, tubular structures that probably represent fossil rootlets. The fossil rootlets terminate abruptly at the top of the subunit and extend downward through the entire thickness of the subunit exposed in the mine, about 4 feet.

The lower subunit is overlain by a subunit 1 to 2 feet thick that in places is a laminated carbonaceous siltstone and in other places is a massive siltstone or very fine grained sandstone. Locally a few very small lenses of medium- to coarse-grained sandstone occur in the massive parts of the subunit. In some places the massive parts of the subunit appear to have been deposited in scours cut into the laminated parts, and in other places the converse appears to be true. Throughout most of the mine the sandstone and siltstone subunit is heavily stained with red iron oxides; the unstained parts are medium gray to dark gray.

A carbonaceous claystone bed about 2 inches thick overlies the sandstone and siltstone subunit throughout most of the mine. It extends into the back of the mine about 80 feet from the portal, and is not identifiable in the opencut because similar claystone beds are in the overlying rocks. This bed, designated the "C" bed on plate 19, was used to determine the structure of the rocks exposed in the mine.

The uppermost subunit exposed in the mine is a series of very fine grained sandstone and siltstone beds separated by thin claystone beds much like the "C" bed. In general, the subunit contains less carbonaceous material and is coarser grained than the underlying rocks. About 3 feet of the upper subunit is exposed in the underground workings, and similar rock types are about 20 feet thick in the opencut.

Most of the uranium minerals in the Freezeout mine are in pods and lenses in the lower subunit, although some occur at the thin edges of siltstones above the lower bed.

Ore-bearing parts of the mine walls were delineated with a Geiger counter. The probe was held in contact with the mine wall, and a reading of 1 mr per hour was taken as the lower limit of the ore-grade material. The ore is distributed in irregularly shaped pods and lenses throughout the lower thin-bedded siltstone (pl. 19). Local accumulations of ore also occur in the laminated siltstone and sandstone where coarser rocks pinch out into finer rocks.

Irregular pod- and lens-shaped areas on the north wall of the main adit are water saturated. Where the rock is wet, the radioactivity is uniformly high. Where the rock is dry the radioactivity varies. Much of the ore-grade material on the north wall of the mine occurs at the interface between wet and dry rock. Near the portal and in the newly opened parts of the mine, the walls are dry, and all the ore occurs in the dry rock.

The relations between the ore and wet rock on the north wall of the main adit suggest that the ore was carried into the rock by percolating ground-water solutions. The irregular shape of the ore pods indicates that the rock is differentially permeable and that the ore was deposited only in those areas reached by the ground-water solutions. The ore pods on the south wall of the main adit are shaped similarly to those on the north wall, but the rocks on the south wall are uniformly dry. This fact suggests that the adit breached the aquifer.

Chemical and radiometric analyses of ore samples from the Freezeout mine show that most of the ore is in, or is very nearly in, equilibrium. If uranium is being deposited from the waters now seeping through the mine walls, the uranium and its daughter products are being carried at virtually the same rate. Although the mine walls were wet, not enough water had accumulated in the mine to furnish a sample for analysis.

All the subunits in the Freezeout mine, except the laminated siltstone and sandstone, are locally stained with red iron oxides. Where the rocks are stained with the iron oxides, they contain practically no uranium. All the rocks exposed in the mine contain varying amounts of pyrite and carbonaceous material, but uranium ore is not concentrated selectively by either.

LOCALIZATION OF THE DEPOSITS

Uranium deposits in the Burdock quadrangle are in, or associated with, channel sandstones. Those in the Fall River formation are either in the S_5 sandstone or in thin-bedded facies of the Fall River formation along the margin of the S_5 sandstone. Those in the Lakota formation are in the upper S_1 sandstone. It seems, therefore, that the sandstones were aquifers through which uranium-bearing solutions passed and that the uranium was deposited from these solutions where the geochemical environment was favorable.

The presence of many deposits of uranium minerals in the carbonaceous and pyritiferous thin-bedded facies of the Fall River formation suggests that the reducing environment formed by the carbonaceous debris and the pyrite was not only favorable for the precipitation of uranium but also favorable for preservation of the uranium minerals after they were uplifted into the zone of oxidation.

In all probability other conditions favorable for the precipitation of uranium exist. The Triangle mine is in a relatively carbon-free part of the S_5 sandstone, although carbonaceous streaks do occur in the sandstone in the mine, and the small deposits in the S_1 sandstone are not associated with particularly carbonaceous parts of that unit. A possible explanation for the existence of these deposits is that they were precipitated at a zone of reduction formed at the surface of the water table. Indeed, the Triangle mine is at the present water table. The deposits in the S_1 sandstone may, therefore, be merely remnants of once larger deposits. Percolating ground water probably has removed some, and may have removed a large amount, of the uranium originally precipitated in the S_1 sandstone.

SUGGESTIONS FOR PROSPECTING

All the uranium in the Burdock quadrangle is associated with either the S_1 or the S_5 sandstone. The most likely possibilities for finding additional uranium in the area involve exploration with a drill in those places where these sandstones are buried by a moderately thin cover of younger rocks.

The S_5 sandstone or its equivalents probably underlie a moderately large part of the area immediately west of Bennett Canyon. The S_1 sandstone probably underlies a large part of the southeast corner of the quadrangle. The thickness of the overlying rock cover increases toward the south and west. The best places for exploration, therefore, are along an area roughly parallel to, and west of, Bennett Canyon for deposits of the S_5 sandstone; and north of the Cheyenne River from the mouth of Bennett Canyon east for deposits in the S_1 sandstone.

The large area in the northeastern part of the quadrangle, where rocks of Inyan Kara age are exposed, has probably been adequately explored.

GRAVEL DEPOSITS

Most of the Quaternary rocks in the Burdock quadrangle are composed of unconsolidated sand and gravel. These deposits occur in most of the quadrangle, and many have been used locally for road-surfacing materials.

PETROLEUM

The small anticline, locally called the Barker dome, in the northeastern part of the quadrangle extends into the adjacent Edgemont NE quadrangle. There, oil has been produced from shallow wells that penetrated the Minnelusa formation. Although the maximum closure on this dome is not within the Burdock quadrangle, some oil might be produced from the flank of the dome.

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