The Stratigraphic and Structural Controls of the Uranium Deposits on Long Mountain, Fall River County, South Dakota

By W. A. Braddock

Trace Elements Investigations Report 425

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

AEC-887/5

June 24, 1955

Mr. Robert D. Nininger, Assistant Director
Division of Raw Materials
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Bob:

Transmitted herewith are three copies of TEI-425, "The stratigraphic and structural controls of the uranium deposits on Long Mountain, Fall River County, South Dakota," by William A. Braddock, December 1954.

We are asking Mr. Hosted to approve our plan to publish this report as a Geological Survey bulletin.

Sincerely yours,

John H. Eric
for W. H. Bradley
Chief Geologist

Geology and Mineralogy

This document consists of 23 pages,
plus 7 figures.
Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

THE STRATIGRAPHIC AND STRUCTURAL CONTROLS OF THE URANIUM DEPOSITS ON LONG MOUNTAIN, FALL RIVER COUNTY, SOUTH DAKOTA*

By

William A. Braddock

December 1954

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

USGS - TEI-425

GEOLOGY AND MINERALOGY

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THE STRATIGRAPHIC AND STRUCTURAL CONTROLS OF THE URANIUM DEPOSITS ON LONG MOUNTAIN, FALL RIVER COUNTY, SOUTH DAKOTA

By William A. Braddock

ABSTRACT

Numerous occurrences of uranium have been found in the Long Mountain area, Fall River County, S. Dak. Correlation diagrams prepared from drill cores obtained from the U. S. Atomic Energy Commission indicate that the uranium is most abundant in two sandstone units, separated by mudstone in the Lakota sandstone of Early Cretaceous age. The lower uraniferous unit is composed of thick beds of very fine- to fine-grained sandstone with a few interfingering lentils of mudstone. The upper uraniferous unit is composed of interfingering beds of very fine-, fine-, and coarse-grained sandstone and mudstone.

The uranium deposits on Long Mountain and in the area to the west are most numerous in a northeast-trending zone about a mile wide between two normal faults. The deposits between these faults are in two groups of different trend; the northern group has been incompletely explored.

The sedimentary structures of the upper and lower mineralized sandstone between the faults have controlled the deposition of uranium and vanadium.

INTRODUCTION

Uranium deposits were discovered in the Black Hills first in Craven Canyon on the west side of Long Mountain, Fall River County, S. Dak., in June 1951, (Page and Redden, 1952). Subsequently, other deposits were found in the sandstones of Early Cretaceous age around the southwestern rim of the Black Hills. This area is now called the Edgemont mining district. Minor occurrences of uranium have also been found in the Deadwood sandstone of Cambrian age, and in the Minnelusa sandstone and shale of Pennsylvanian age north of Hot Springs, S. Dak., (Bell and Bales, in preparation).

Since the initial discovery, mining has been carried on at many places in the district by a number of mining companies. The Division of Raw Materials of the U. S. Atomic Energy Commission has been engaged in exploratory diamond drilling in the area since the summer of 1952. As a part of this program, 198 holes were completed on the north end of Long Mountain during the winter of 1952-53. The drill core from 86 of these holes was examined by the writer for the purpose of studying the lithology and structure of the Lakota sandstone, and the relationship of these features to the uranium deposits. A geologic map (fig. 1) of part of Long Mountain was prepared by the writer; this map also includes some work by his colleagues Garland B. Gott and Henry Bell III. All analyses were made by the Denver Laboratory of the Geological Survey. During the field work, personnel of the Hot Springs office of the Atomic Energy Commission were very helpful in providing drill core data and in

assisting in other ways with the work. Special recognition is given D. E. Engstrom who assisted in making the geologic map (fig. 1). This investigation was a part of the regional study being made by the Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

STRATIGRAPHY

The rocks in the immediate vicinity of Long Mountain are of sedimentary origin and range in age from Triassic to Cretaceous. The soft shales and sandstones of the Triassic and Jurassic formations have been eroded to form a broad valley trending west to northwest across the northern part of the area. South of this valley the more resistant sandstones of the Lower Cretaceous form northwest-trending cuestas. Southward-draining tributaries of the Cheyenne River have cut through these cuestas to form steep-walled canyons separated by long north-trending ridges. Long Mountain is such a ridge and is bounded on the west side by Craven Canyon, and on the east side by Red Canyon.

Triassic and Jurassic rocks

The oldest rocks in the vicinity of Long Mountain are the red sandy shales and thin beds of gypsum of the Spearfish formation of Triassic age. This formation, approximately 400 feet thick, is well exposed in the large valley on the north side of Long Mountain.

The Sundance formation of Late Jurassic age, approximately 300 feet thick, crops out in Red and Craven Canyons. It is composed of red, yellow, and gray sandstone, gray shale, and thin beds of limestone.

The Sundance formation is overlain by the Morrison formation of late Jurassic age, which crops out around the base of Long Mountain and extends down Craven Canyon to Pictograph Mesa where it is approximately 90 feet thick (fig. 1). The lower part of the formation is composed of resistant beds of dense light-gray limestone interbedded with gray or greenish marl; the upper part is gray to greenish claystone. Much of the claystone near the top of the formation is dark gray and is similar in appearance to the gray mudstone in the Lakota formation. The claystones of the Morrison formation are generally free of silt, have a waxy luster, and contain no sandstone lenses. By comparison, the mudstones in the overlying Lakota sandstone are generally silty, have a dull luster, and contain thin irregular sandstone lenses. The thickness and lithology of the Morrison formation across Long Mountain is illustrated by figure 2; the formation is about 90 feet thick. At many localities landslides conceal the contact of the Morrison formation and the overlying Lakota sandstone.

Lower Cretaceous rocks

Inyan Kara group

The Lower Cretaceous rocks were divided by Darton (1901) in ascending order into the Lakota sandstone, the Minnewaste limestone, the Fuson shale, and the Dakota sandstone. Russell (1927) recognized that the Dakota sandstone of the Black Hills was older than the Dakota of eastern Nebraska, and introduced the name Fall River sandstone for the rocks which Darton had mapped as the Dakota sandstone.

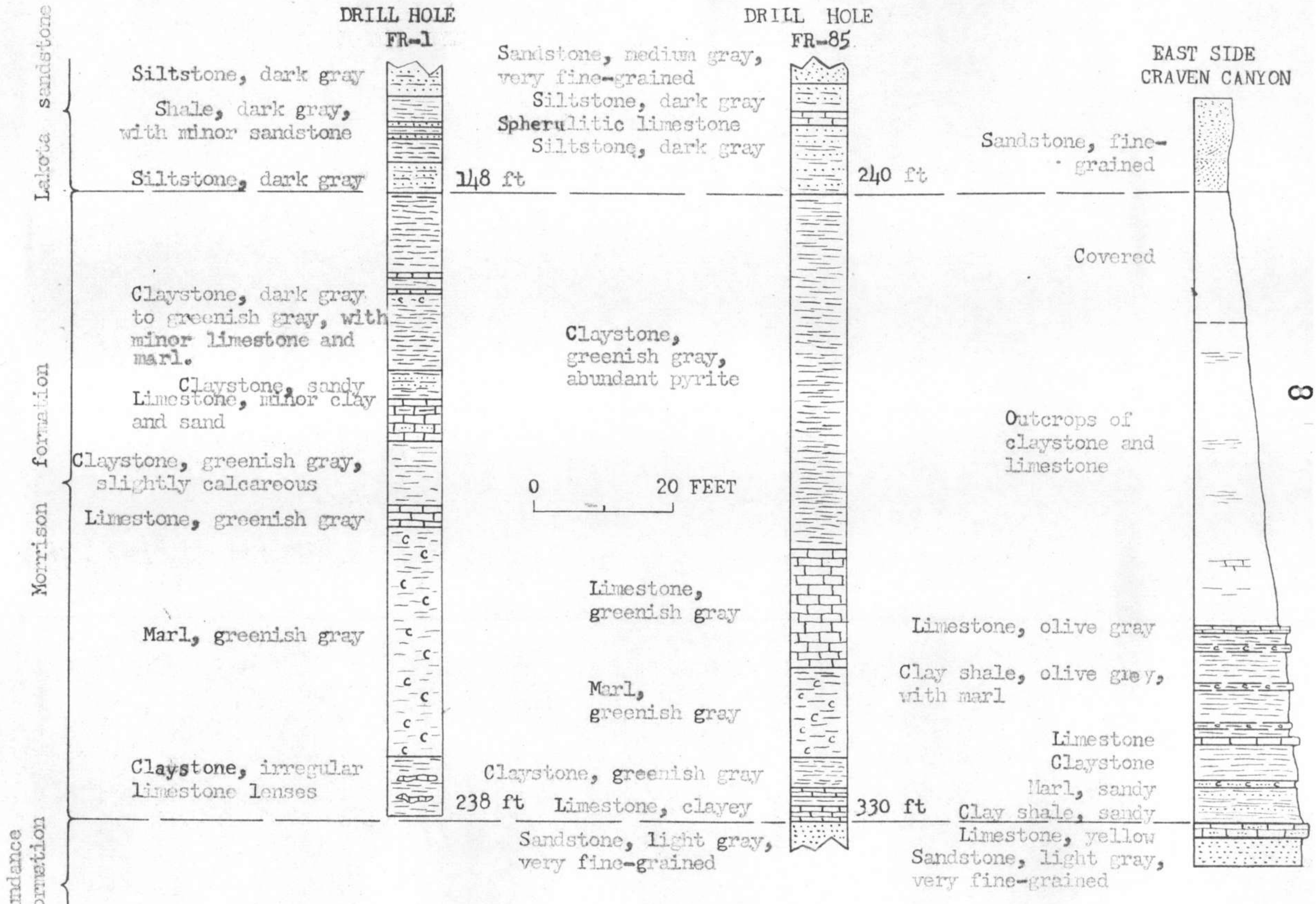

FIGURE 2, LITHOLOGY OF THE MORRISON FORMATION

Rubey (1931, and an unpublished report) recognized the difficulty of delimiting the upper and lower contacts of the Fuson formation. He classified the Lakota, Fuson, and Fall River rocks as the Inyan Kara group, an extremely variable group of rocks consisting of sandstone, minor conglomerate, thin limestones, carbonaceous mudstones, non-carbonaceous variegated mudstones, and lignites. Since 1951 members of both the Atomic Energy Commission and the Geological Survey have studied the Inyan Kara group in the Edgemont mining district, but because of the difficulty of identifying the formational boundaries as originally described by Darton, the sub-division used in their studies has been arbitrary.

Lakota sandstone.

The Lakota sandstone on the central part of Long Mountain is approximately 200 feet thick. It is composed of very fine- fine-, and medium-grained sandstone lenses interbedded with dark-gray, carbonaceous mudstone and thin limestones. A section measured on the west side of Red Canyon in sec. 29, T. 7 S., R. 3 E., contained the following units:

Character	Thickness (feet)
Covered slope except for a few exposures of very fine-grained sandstone and gray mudstone	58.0
Sandstone and interbedded mudstone. Sandstone is fine-grained, light gray.	12.0
Sandstone, fine-grained, light gray with yellow to brown limonite bands. Minor amounts of clay grains, numerous silt and carbonaceous seams, and occasional large calcareous concretions. Mostly massive, but thin bedded near the top	49.0

Character	Thickness (feet)
Covered slope except for occasional outcrops of interbedded medium-gray siltstone and very fine-grained sandstone	51.0
Sandstone, fine-grained, light gray with yellowish limonite bands.	28.0
Total	198.0

Lithologic unit.-- The principal lithologies noted in drill cores are described briefly below. Sandstone type 1 is a fine- to very fine-grained, well-sorted sandstone composed predominantly of sub-rounded quartz grains with minor amounts of chert, clay grains, and feldspar. It is light gray, yellow, or pink. In the drilled area it is thick bedded to thinly cross-bedded and ranges from 1 to 80 feet in thickness. It is the most prominent and abundant rock type. Those sandstones which under the hand lens appear to contain less than 5 percent of clay grains, rock fragments, and chert grains have been included in sandstone type 1.

Sandstone type 2 is a fine- to coarse-grained, light-gray, pink and brown rock. The degree of sorting decreases as the grain size increases. The composition varies, but the important constituents are subangular quartz, chert, rock fragments, and clay grains and galls. Many of the clay grains contain shards of devitrified volcanic glass which are recognizable in thin sections. This type of sandstone is found at the base of sandstone type 1, and is interbedded with mudstones. At many localities sandstone type 1 grades into sandstone type 2.

Sandstone type 3 is light to medium gray, very fine-grained, and contains appreciable quantities of interstitial clay and silt. Minor amounts of calcareous cement are common. In most places the sandstone contains cross-beds and seams of dark-gray siltstone and carbonaceous material and is interbedded with mudstone. The sandstone rarely exceeds 20 feet in thickness.

Mudstones consisting of siltstone and claystone are abundant as lenses interbedded with the various types of sandstones. The siltstones and claystones are generally difficult to separate because of the gradational amounts of silt and the similarity of color, but the over-all structural features of these lenses make them a characteristic unit. The mudstones are irregularly interbedded with the sandstones and with thin beds of limestone. The bedding within the mudstones is commonly irregular and appears crumpled. These units are generally carbonaceous and locally plant remains are abundant. Gypsum-rich veins occur along joints and seams. The mudstones weather to light gray and contain abundant limonite stains. In some places hard laminated dark-gray siltstones weather into thin sheets called "paper shales."

Beds of light-gray to olive-green claystones occur in the upper part of the Lakota sandstone.

Beds of limestone and sandy limestone up to two feet thick are common in the mudstone units. The limestones are aggregates of spherulitic calcite imbedded in a matrix of gray mud. The sandy limestones are light to medium gray and contain fine-grained quartz. In many places these sandy limestones appear to be the extreme edges of lenses of sandstone. Neither type of limestone can be correlated over distances greater than 1,000 feet.

The Lakota sandstone in the explored area is approximately 200 feet thick. The percentages of the major lithologic units are:

Lithologies	Percent of total thickness
Sandstone type 1	44
Sandstone type 2	14
Sandstone type 3	12
Mudstone	30

The distribution of the major types of lithologic units are shown in figures 5 and 6. These isometric diagrams show the distribution of the lithologic types throughout the explored area. The basal unit of the Lakota sandstone in the northern and western part is a lens composed predominantly of sandstone of type 1. It is called the "lower uraniferous sandstone", and is well exposed in the prominent cliffs in Craven Canyon. This sandstone pinches out rapidly east of Craven Canyon and is not found in the southeast part of the mapped area. Overlying this sandstone is a unit composed of interbedded mudstones, limestones, and sandstones of type 3. Where the lower uraniferous sandstone is missing, this mudstone-bearing unit rests upon the Morrison formation. Above this mudstone-bearing sequence is a composite unit composed predominantly of sandstones of types 1 and 2, interbedded with mudstones and sandstones of type 3. This unit is called the "upper uraniferous sandstone." It is approximately 75 feet above the Morrison formation and is continuous throughout the drilled area. Sandstone type 2 is more abundant in this unit than in other parts of the Lakota.

Chemical composition.-- Several samples from the drill cores were spectrographically analyzed by R. C. Havens and G. W. Boyes of the Geological Survey's Denver Laboratory in an attempt to determine the chemical variations of the argillaceous rocks and sandstones of the Lakota and Morrison formations. Seven of these samples were representative of sandstones types 1 and 2. No significant difference between the two types of sandstone can be detected from these analyses. The abundance of the various elements are as follows:

Element	Abundance (percent) 1/	
	Sandstone type 1	Sandstone type 2
Si	XX.	XX.
Al	.X+ to .X	.X
Fe	X.- to .X +	X.-
Ti	.X- to .0X	.0X+ to .0X-
Mn	.0X to .0X-	.0X
Ca	.X to .0X	.0X+ to .0X
Mg	.0X+ to .0X	.X- to .0X
Na	.0X+ to 0	.0X+to 0
K	.0X+ to 0	0
B	Tr.	Tr.
Ba	.0X to .0X-	.0X to .0X-
Cr	.00X- to .000X+	.00X- to .00X+
Cu	.00X	.0X- to .00X
Ni	.00X- to .000X+	.00X+ to .00X-
Sr	.00X- to .000X	.00X- to Tr.
V	.00X to .000X+	.000X+
Y	Tr.	Tr.
Zr	.0X+ to .0X.	.0X+ to .00X+
eU 2/	0.001 to <0.001	0.001 to <0.001

Looked for but not detected: P, Ag, As, Be, Bi, Cd, Ce, Co, Dy, Er, Ga, Gd, Ge, Hf, Hg, In, Ir, La, Li, Mo. Nb, Os, Pb, Pd, Pt, Re, Rh, Sb, Sc, Sn, Ta, Th, Te, Tl, U, W, Yb, Zn.

1/ Plus and minus notations give brackets in each order of magnitude such as:

.X+	equals	.464 to 1.0 percent
.X	equals	.215 to .464 percent
.X-	equals	0.10 to .215 percent
XX.	equals	Greater than 10.0 percent
0	equals	Looked for but not detected
Tr.	equals	Near threshold amount of element

2/ eU = equivalent uranium. Analyses by Geological Survey's Denver Laboratory.

Sixty mudstone samples from drill hole FR-1 were also analyzed by Havens. The results of these analyses are tabulated in figure 7. The lithologies of the samples are as follows:

Sample 1 through 26	Morrison claystone and marl.
Sample 27 through 32	Lakota dark mudstone with minor interbedded sandstone.
Sample 33	Dark-gray mudstone
Sample 34	Dark gray mudstone with patches of light-gray sandstone.
Sample 35 through 39	Dark-gray mudstone.
Sample 43 through 60	Gray mudstone with gypsum jarosite.

The number of samples analyzed to date is insufficient to indicate the composition of the Lakota sandstone or the Morrison formation. Certain relationships shown by the analyses are worthy of mention, however. The most apparent relationship is that many of the elements are present in greater amounts in the Morrison formation than in the mudstones of the Lakota. This may be because the Morrison sediments are finer grained and therefore contain more of the constituents of the clay minerals than do the Lakota mudstone. The Morrison samples contained relatively greater amounts of Fe, Mg, Na, and K, but B, Ba, Be, Ca, Ce, Ga, La, Mn, Mo, Nd, Sr are also more abundant in the Morrison than in the Lakota.

Much of the Morrison and parts of the Lakota mudstones are calcareous. In these calcareous zones Ca, Mn, Sr, and Fe are more abundant than in the non-calcareous portions. Al, Ti, Mg, K, B, Ba, Co, Cu, Ga, La, Mo, Ni, and Sc are less abundant in the calcareous portions.

The trace metal content of both the Lakota and Morrison rocks is similar to the average metal content of sedimentary rocks as given by Rankama and Sahama (1952); cobalt and nickel, however, are slightly lower than the average for argillaceous sediments.

Fuson formation.

Along the east side of the Black Hills, the Minnewaste limestone lies between the Lakota sandstone and the Fuson formation. This limestone is not present in the Long Mountain area. Two measured sections on the west side of the Red Canyon illustrate the lithology of the Fuson formation. One section was measured on the edge of a mesa capped by massive Fall River sandstone in sec. 29, T. 7 S., R. 3 E. (not shown on fig. 1).

Character	Thickness (feet)
Covered base of Fall River sandstone	22.0
Siltstone, light gray, very hard	10.0
Covered	19.0
Sandstone, very fine-grained, white. Upper part contains hematite-colored specks and small calcareous concretions	12.0
Sandstone, fine-grained with approximately 50 percent of interstitial clay which is various shades of white, yellow, and maroon.	23.0

Character	Thickness (feet)
Sandstone, fine-grained, composed of quartz cemented with white clay and silica. Very brittle; breaks into conchoidal flakes	1.0
Sandstone, very fine-grained, composed of quartz with a minor amount of chert.	35.0
Sandstone, fine-grained, consists of alternating beds of resistant and friable sandstone that contain abundant pale green clay cement . .	11.0
Covered	10.0
Sandstone, fine-grained, well-sorted, moderate amount of pinkish clay grains and chert, Stained pink to yellow. Very friable	30.0
Total	173.0

The other section was measured along the east-west section line between sec. 32, T. 7 S., R. 3 E., and sec. 5, T. 8 S., R. 3 E.

Character	Thickness (feet)
Fall River sandstone	95.0
Covered	32.0
Sandstone, fine-grained, well-sorted, no interstitial clay. Some areas contain numerous specks of hematite	57.0
Sandstone, fine- to very fine-grained, poorly sorted with irregular areas which contain as much as 50 percent interstitial clay. Minor chert grains, abundant green clay galls. . . .	39.0
Sandstone, fine-grained, contains approximately 50 percent interstitial clay. Color ranges from green to pink	16.0
Largely covered but probably greenish-gray mudstone	30.0
Total	174.0

Fall River sandstone.

The Fall River sandstone caps the south end of Long Mountain, where it is a buff, fine- to medium-grained sandstone composed predominantly of quartz. The full thickness of the Fall River is not present in the area studied.

STRUCTURE

The rocks in the Long Mountain area are only slightly disturbed by faulting and folding. The regional dip is about $2\frac{1}{2}$ degrees to the southwest and was caused by the Black Hills uplift (fig. 3). Five faults have been found in the mapped area. Fault no. 1 (fig. 1) in sec. 18 is a normal fault that trends northeast across the north end of Long Mountain and can be followed approximately one mile to the southwest across Craven Canyon. This fault has a maximum throw of approximately 85 feet. Another fault about 1,200 feet to the north has similar type of displacement. A third fault, a few hundred feet south of fault no. 1, starts on the west side of Long Mountain, and within 1,600 feet to the northeast attains a throw of approximately 80 feet. This fault and fault no. 1 bound a small graben.

Fault no. 2, in the northwest part of sec. 30, trends approximately N. 80° E., and dies out in the area explored by drilling. Within the mapped area this fault has a maximum throw of approximately 40 feet. It has been traced to the west of the mapped area for 2,000 feet where it joins a fault that trends N. 45° E. (Bell and Bales, in preparation). A minor northeast-trending fault was mapped in the southeast corner of sec. 19.

There are two major joint sets in the area: one strikes N. 20° W., the other N. 50° E. (fig. 3). Both sets have influenced the formation of the numerous landslides on the unmapped borders of the mountain where the Lakota sandstone has slid into the valleys across the Morrison formation.

Structure contour maps of the southern part of Long Mountain were drawn on the top of the Morrison formation and the base of the upper uraniferous sandstone using the data obtained from the drill cores. The top of the Morrison formation is a gently undulating surface with a small trough trending south through the southern part of the explored area. (See fig. 3.) This trough is also outlined by the contours drawn on the base of the upper uraniferous sandstone approximately 75 feet above the Morrison formation. Reference to figure 9 will show that the lenticular nature of the lower part of this unit makes it necessary to generalize the contours. (See fig. 4.) It is possible that this trough is a flexure and is the last recognizable displacement resulting from movement along fault no. 2. The fact that the trough is expressed both on the top of the Morrison, and on the base of the upper uraniferous sandstone suggests that it is a flexure rather than two superposed channels.

ORE DEPOSITS

Prior to 1954, uranium had been produced from nine claims on or near Long Mountain. The ore bodies on these claims have not been studied in detail and will be discussed in this report only in general terms. All of the known mineralized rock found on Long Mountain occurs either in the upper or the lower uraniferous sandstone. Approximately equal amounts of ore had been produced from each sandstone unit up to January 1, 1954. The ore was produced from the lower unit only on the Pictograph mesa and from the upper unit on the Clarabell, Flora, and the Gertrude claims. Personnel of the U. S. Atomic Energy Commission discovered several bodies of uranium ore in the upper sandstone unit during their exploration of the area. All of the known carnotite deposits contain relatively low amounts of vanadium in comparison with their uranium content; the ratio is slightly higher in the deposits in the upper sandstone, as illustrated in figure 8.

The sandstone around the areas of mineralized rock is irregularly stained a distinctive purple-pink. This color is believed to be closely associated with the uranium deposits and seems to occur more frequently in the upper sandstone unit. It is found intermittently along the exposures of both sandstone units throughout the southern part of the explored area but is not found north of the line between drill holes FR-22 and FR-15. (See fig. 4.)

No occurrences of uranium minerals have been found north of the boundary of the purple-pink stained area, and only a very few scattered areas of mineralized rock are known beyond the south boundary of the explored area. Most of the known areas of mineralized rock and stained sandstone are between faults nos. 1 and 2. In addition most of the high-grade uranium deposits in the Fall River sandstone

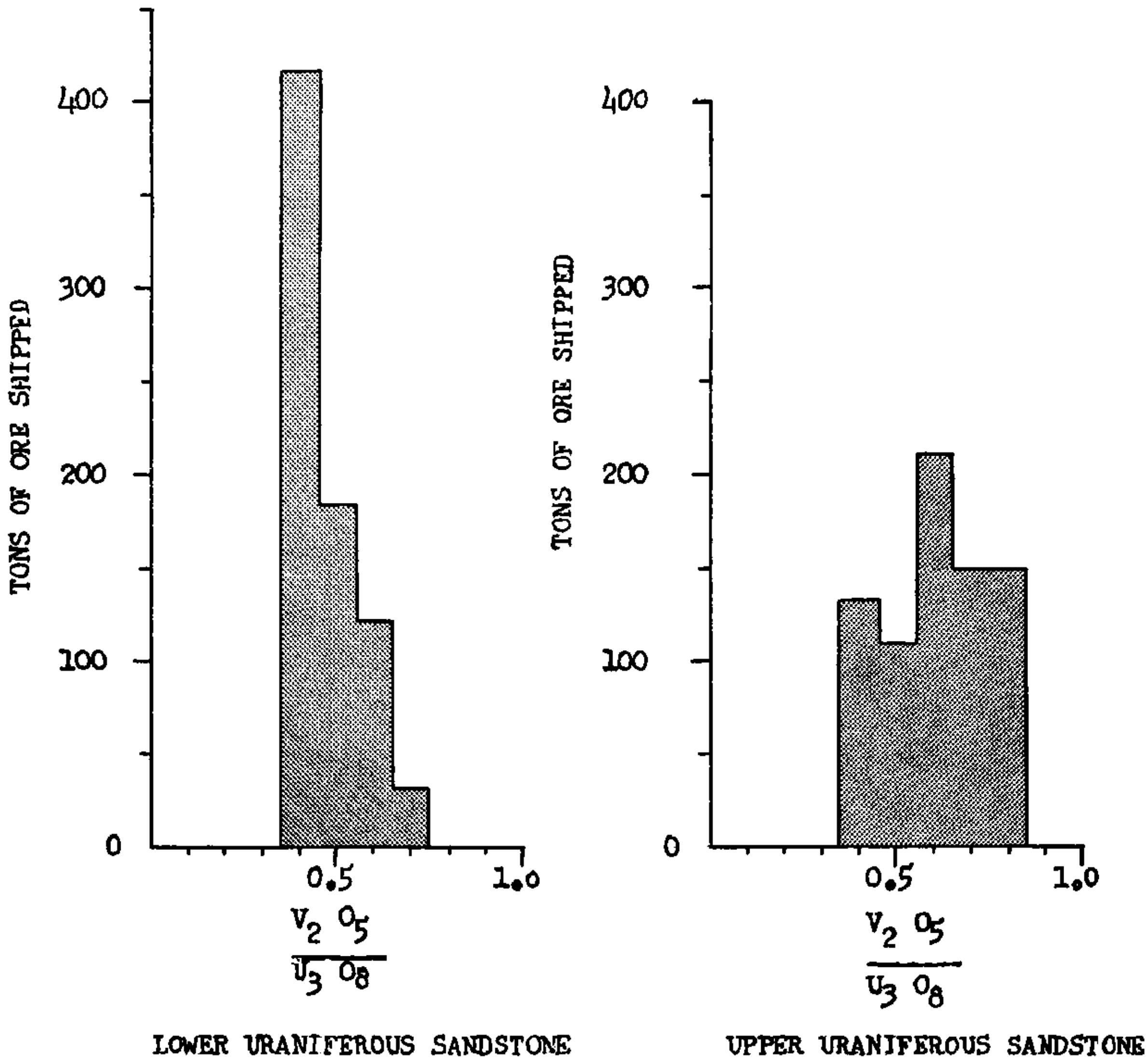

FIGURE 8.- COMPARISON OF THE VANADIUM CONTENT OF THE ORE SHIPPED FROM THE LOWER AND UPPER URANIFEROUS SANDSTONES.

in the area west of Long Mountain are between the projections of these faults. Recent diamond drilling by the Atomic Energy Commission in the Lakota sandstone on the west side of Craven Canyon has found mineralized rock a few hundred feet south of fault no. 1.

This evidence indicates that the primary control for the deposition of uranium in the Long Mountain area is a northeast-trending fracture related to faults nos. 1 and 2. Sedimentary structures probably were not the major control of ore deposits because the upper and lower sandstone units are similar in lithology and sedimentary structures throughout the barren and the mineralized areas. Between faults nos. 1 and 2, however, sedimentary structures have probably played a very important part in further localizing the deposition of uranium. The secondary control is illustrated by the fact that in the lower mineralized sandstone, in which there are a very few interfingering shale lentils and within which the permeability of the sandstone is largely uninterrupted, most of the carnotite deposits are too small to be mined. The occurrences in this lower sandstone appear to be most abundant at the boundaries between sandstone beds and around calcareous concretions (Bell and Bales, in preparation).

Minable ore bodies are more numerous in the upper uraniferous sandstone. This is probably due to the fact that this unit is lithologically much more variable than the lower unit. The correlation of the drill core data shows that the uranium minerals are more abundant in the coarser-grained part (sandstone type 2) of the unit in the areas where the sandstone interfingers irregularly with mudstones. (See figs. 5, 6, and 9.)

Within the favorable zone between faults nos. 1 and 2, the uranium deposits seem to be arranged along two northeast trends. The southernmost of these trends corresponds with fault no. 2 and includes the Pictograph and Clarabell claims, and the ore deposits found by drilling in the vicinity of holes FR-28 and FR-53. The northern trend may extend between the rim outcrops to the west of drill hole FR-30 and the ore body around hole FR-16.

SUGGESTIONS FOR PROSPECTING

The exploration by the U. S. Atomic Energy Commission has indicated that the upper uraniferous sandstone is the most favorable unit for prospecting. Much of this unit has already been explored by diamond drilling and by wagon drilling. The broad area near the center of sec. 19, however, has been explored only with seven drill holes. This area on the basis of present knowledge must be considered as favorable for additional exploration.

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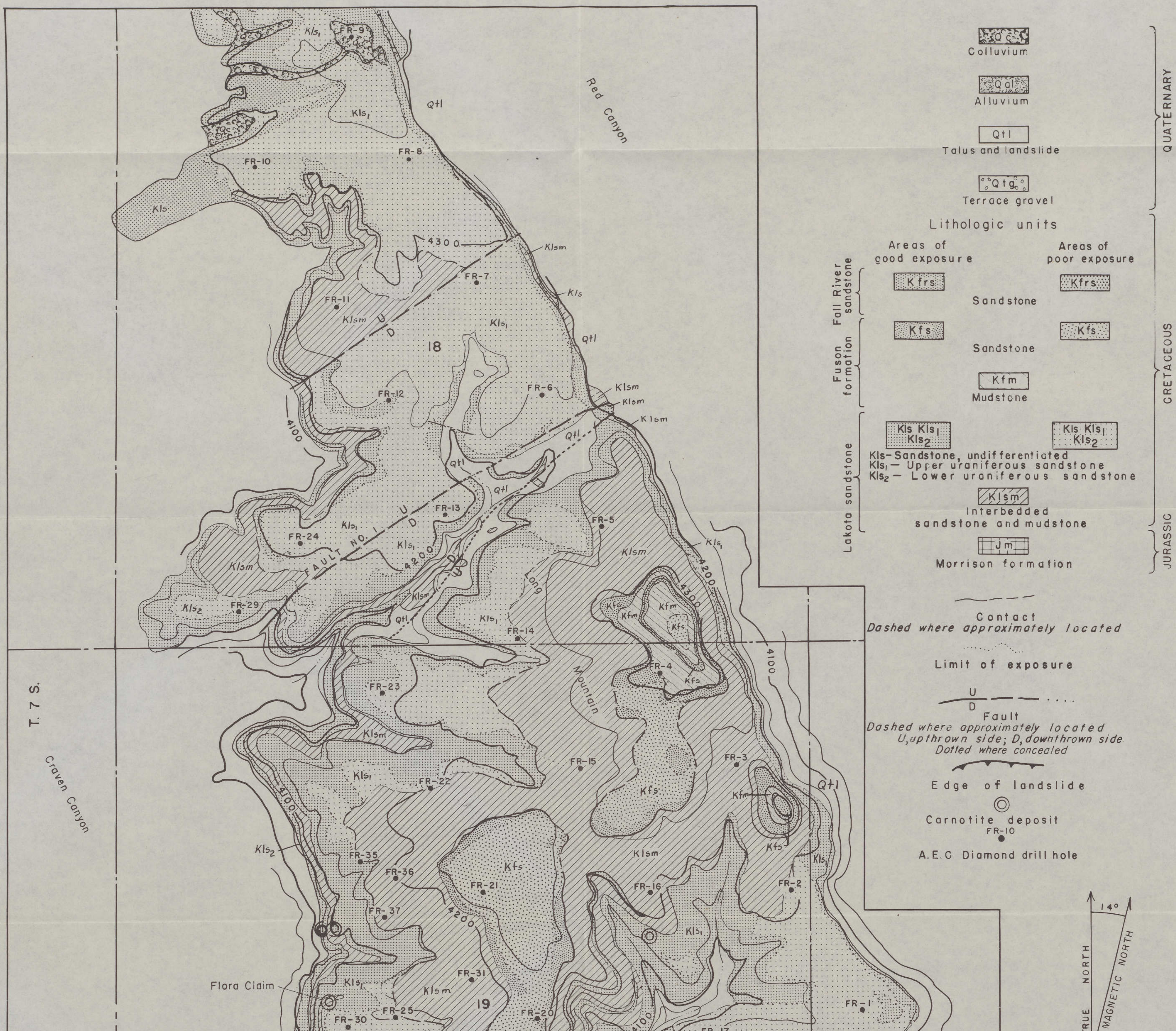

Geology by W.A. Braddock, G.B. Gott, D.E. Engstrom, and Henry Bell III, 1953

FIGURE 1.- GEOLOGIC MAP OF PART OF LONG MOUNTAIN, FALL RIVER COUNTY, SOUTH DAKOTA.

0 600 1200 1800 2400 FEET

Contour interval 50 feet
Datum is mean sea level

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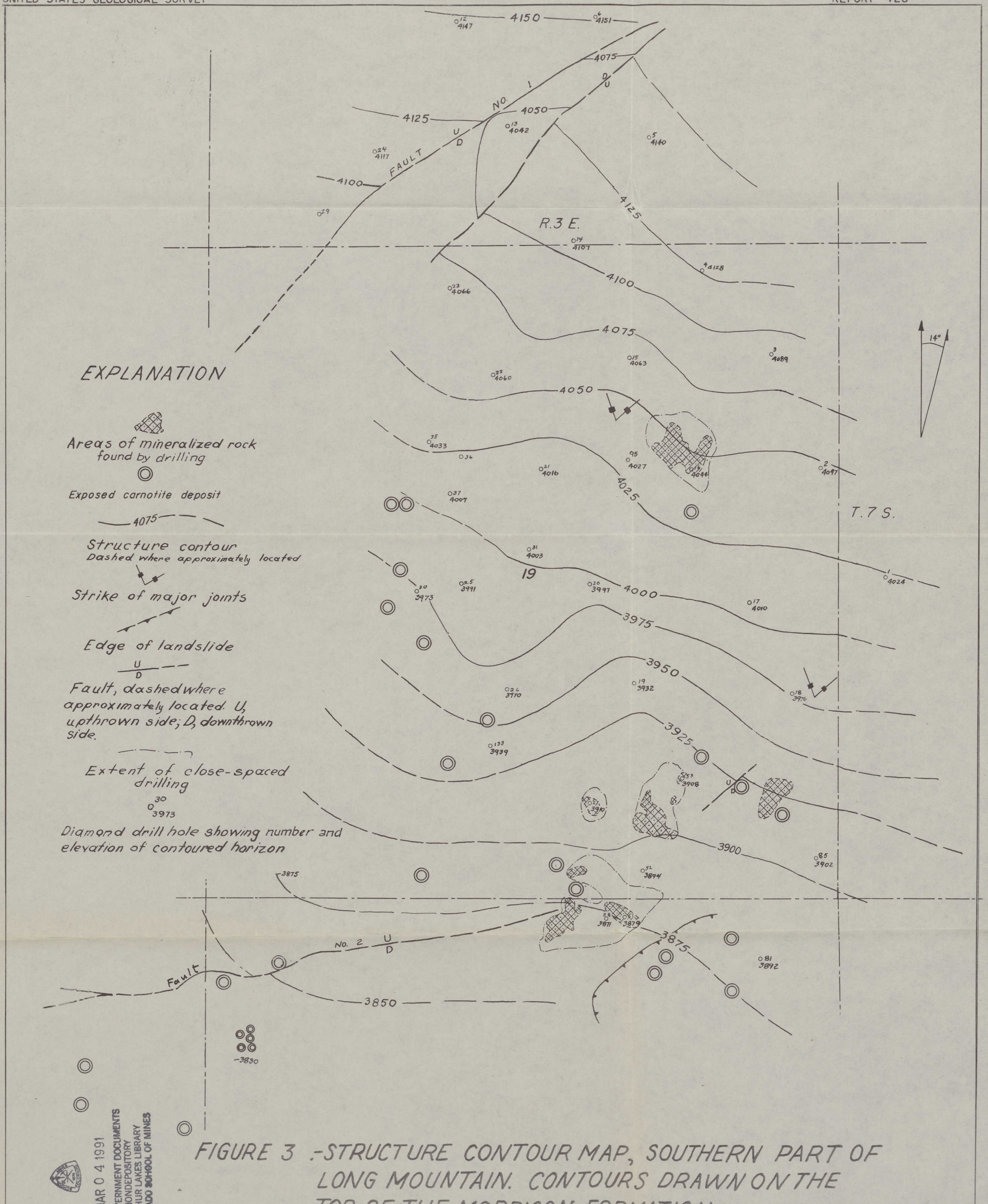

FIGURE 3 .-STRUCTURE CONTOUR MAP, SOUTHERN PART OF LONG MOUNTAIN. CONTOURS DRAWN ON THE TOP OF THE MORRISON FORMATION.

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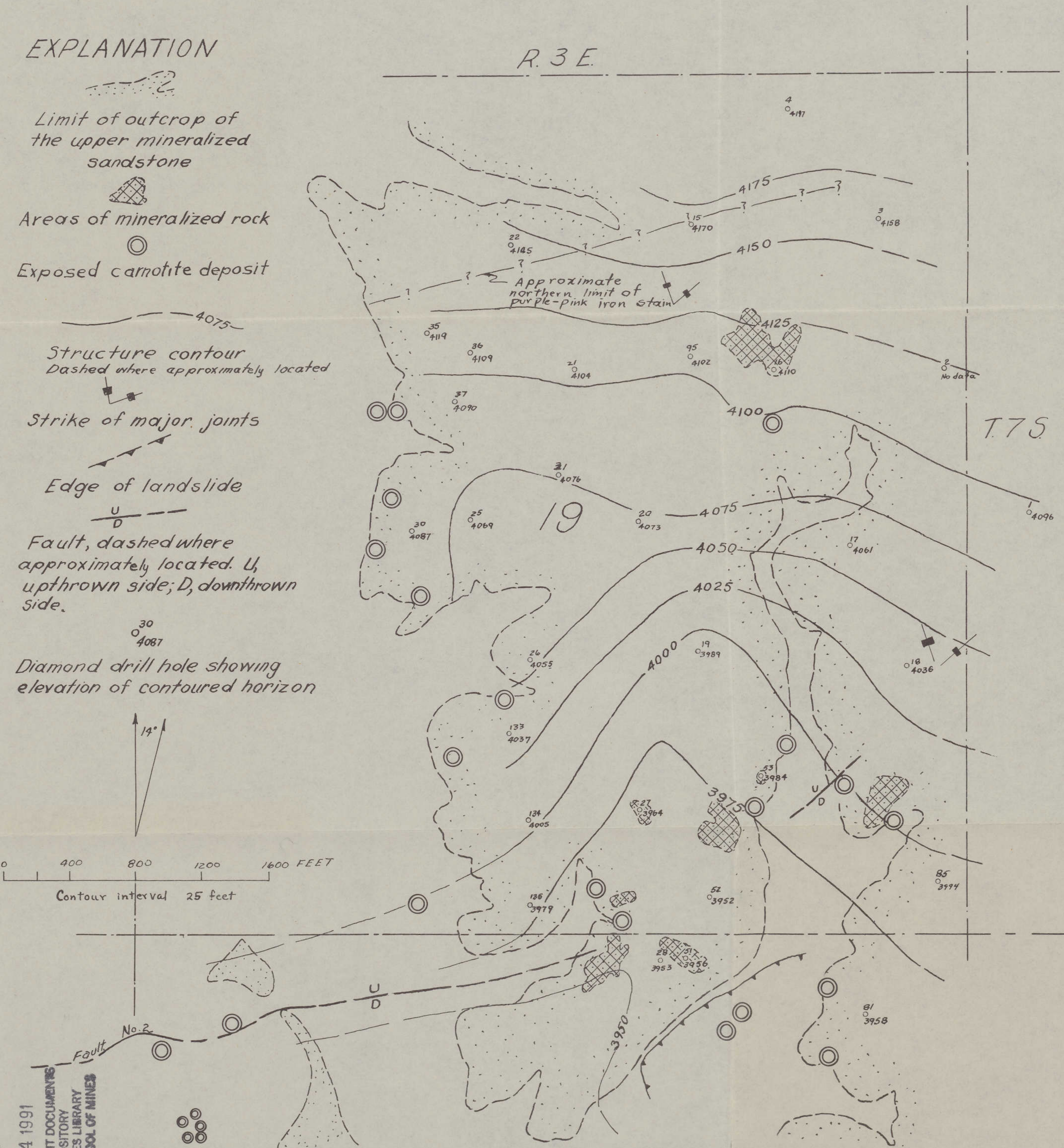

FIGURE 4.-STRUCTURE CONTOUR MAP, SOUTHERN PART OF LONG MOUNTAIN. CONTOURS DRAWN ON THE BASE OF THE UPPER URANIFEROUS SANDSTONE.

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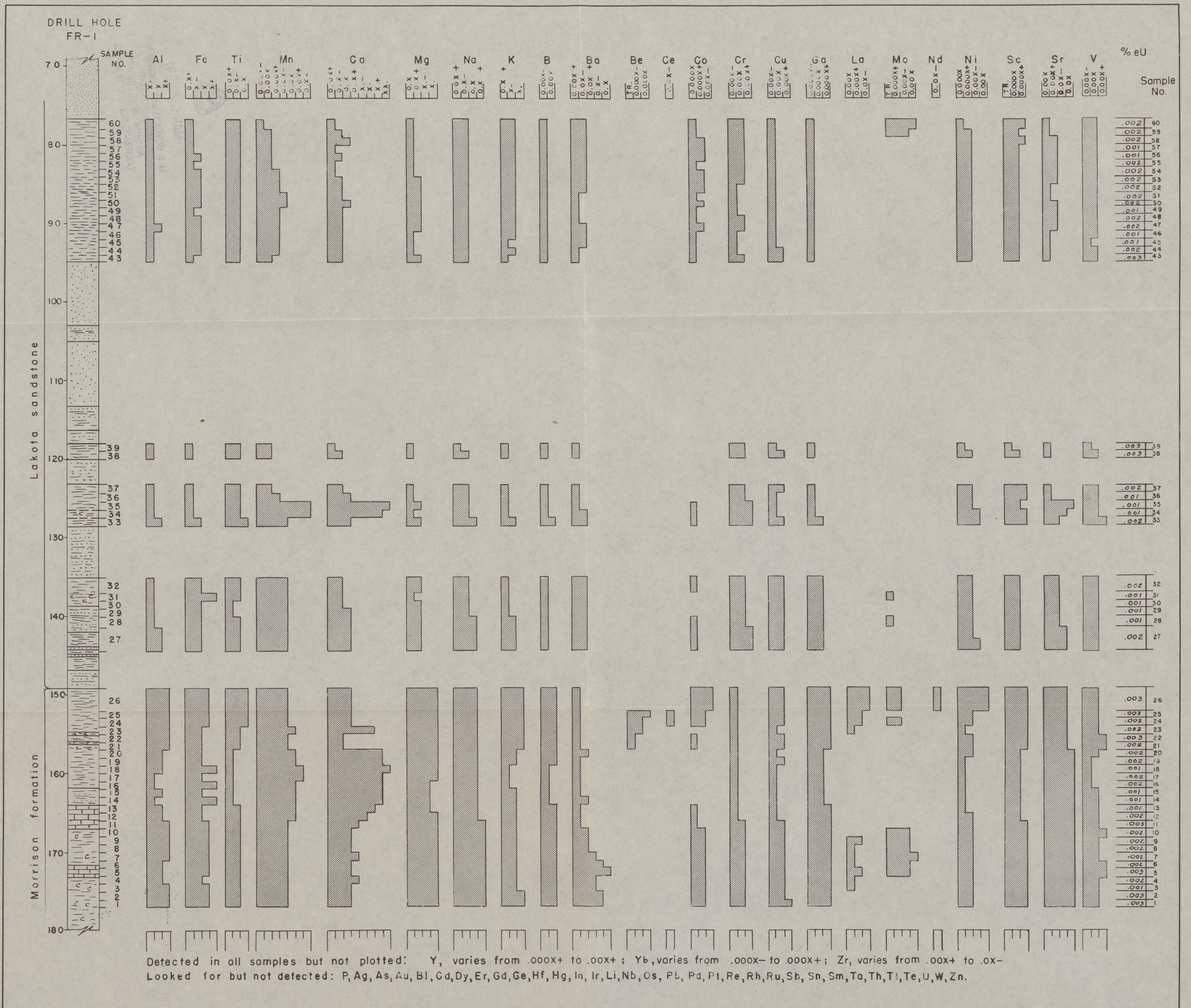
FIGURE 5.- CORRELATION DIAGRAM, NORTH PART OF LONG MOUNTAIN, FALL RIVER COUNTY, SOUTH DAKOTA

FIGURE 6.- CORRELATION DIAGRAM, MIDDLE PART OF LONG MOUNTAIN, FALL RIVER COUNTY, SOUTH DAKOTA



R. C. Havens, Spectrographer

FIGURE 7.-SPECTROGRAPHIC ANALYSES OF SOME SHALES IN DRILL HOLE FR-1

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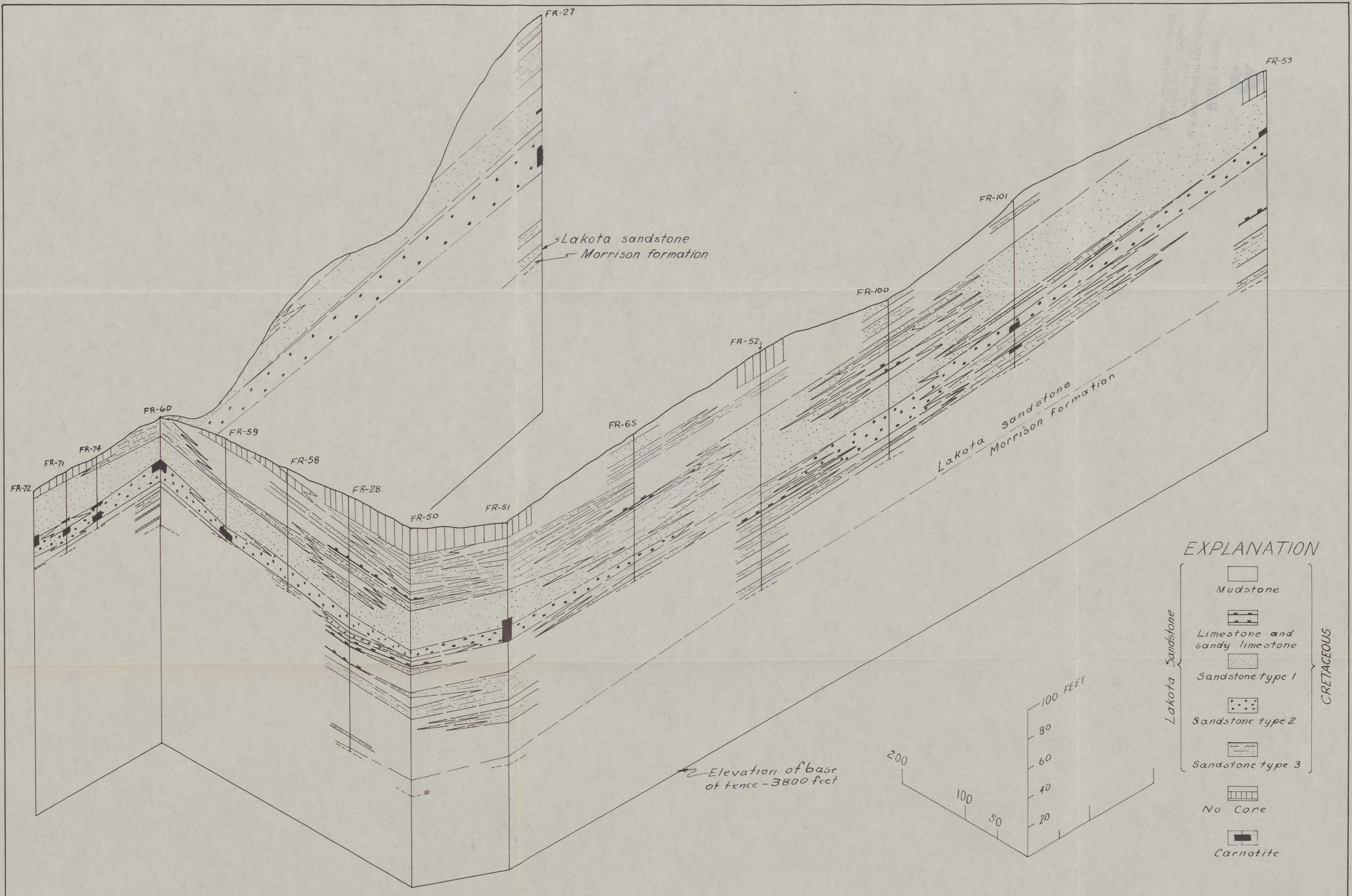

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FIGURE 9. - LITHOLOGIC VARIATIONS WITHIN THE UPPER URANIFEROUS SANDSTONE