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Uranium-Bearing Coal and Carbonaceous Shale in the La Ventana Mesa Area, Sandoval County, New Mexico

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Trace Elements Investigations Report 241

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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Geology - Mineralogy

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

URANIUM-BEARING COAL AND CARBONACEOUS SHALE IN LA VENTANA MESA AREA, SANDOVAL COUNTY, NEW MEXICO*

By

James D. Vine, George O. Bachman,
Charles B. Read, and George W. Moore

January 1953

Classification cancelled by authority of Jesse C. Johnson by Jane Titcomb 10/29/54

Trace Elements Investigations Report 241

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

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By James D. Vine, George O. Bachman
Charles B. Read, and George W. Moore

ABSTRACT

Uranium-bearing coal, carbonaceous shale, and carbonaceous sandstone of Upper Cretaceous age occur on and adjacent to La Ventana Mesa, Sandoval County, New Mexico. The geologic features of the uranium deposits are described and a hypothesis for the origin and control of the uranium deposits is given. On the basis of recent sampling and analyses the uranium content in coal is found to be as much as 0.62 percent, whereas the coal ash has a uranium content that is as much as 1.34 percent.

La Ventana is 62 miles northwest of Albuquerque, New Mexico, by primary road. It is 151 miles by primary road from Durango, Colorado, where a mill for refining uranium ore is located. It is approximately 115 miles by primary and secondary roads from Grants, New Mexico, where a mill is being constructed.

In view of the grade and tonnage of the La Ventana deposits as indicated from outcrop data and because of the favorable geographic location of the area, it is recommended that consideration be given to a physical exploration program of moderate magnitude that will provide information needed to complete the evaluation of the deposits.

INTRODUCTION

Purpose and scope of the report

Uranium-bearing coal, carbonaceous shale, and carbonaceous sandstone were discovered on La Ventana Mesa, Sandoval County, New Mexico, during the summer of 1951. The occurrence was first reported to the Atomic Energy Commission by Bachman and Read (1951) and additional information on outlying areas was reported by Read (1952). The area has since been carefully mapped, 125 samples have been collected and analyzed for uranium, and it is now possible to describe and evaluate the deposits in more detail. This report describes the occurrences, discusses the possible source of uranium and its deposition in coal, and points out the need for further exploration in the area. This work was done on behalf of the Division of Raw Materials of the Atomic Energy Commission.

Geography

La Ventana Mesa is 1 mile east of La Ventana on State Highway 44 between Cuba and San Ysidro and about 65 miles northwest of Albuquerque, New Mexico. (See index map, fig. 1.) It is 151 miles by primary road from Durango, Colorado, and approximately 115 miles from Grants, New Mexico. A mill for refining uranium ore is located at Durango, Colorado, and a mill is being constructed at Grants, New Mexico.

La Ventana Mesa culminates in two buttes, a north and a south butte which are located in secs. 28, 29, 32, 33, and 34, T. 19 N., R. 1 W. on the west side of the Nacimiento Mountains. The north butte ranges in elevation from 7,200 to 7,400 feet above sea level, whereas the south butte ranges from 7,400 to 8,000 feet above sea level. As the highway adjacent to La Ventana is about 6,000 feet above sea level, the topographic relief of the area is approximately 2,000 feet. At the present time the top of the mesa can be reached only by foot. The surface of the mesa is a relatively broad area of gentle relief (fig. 2).

The climate of the area is semi-arid. The lowlands are sparsely vegetated, juniper forests grow in the intermediate uplands, and there are forests of yellow pine in the mountains. The entire area is drained by the Rio Puerco which has an intermittent flow, and small quantities of water are available from streams in the vicinity of La Ventana Mesa. Potable water is available in Cuba about 12 miles to the north, and at Warm Springs, about 12 miles south of the mesa. Cuba as well as Warm Springs provide limited living accommodations.

Field work

Geologic reconnaissance was undertaken in the vicinity of the Jemez volcanic plateau because of the occurrence there of the Bandelier tuff (R. L. Griggs, oral communication) of Pliocene (?) age. It was thought that this mildly radioactive tuff, which contains about 0.003 percent uranium, might be a source for uranium-bearing solutions. Consequently, an attempt was made to find a geologic setting where uranium might be concentrated from solution. The carbonaceous strata in the Cretaceous rocks in the vicinity of La Ventana provide such a setting and for that reason this area was investigated.

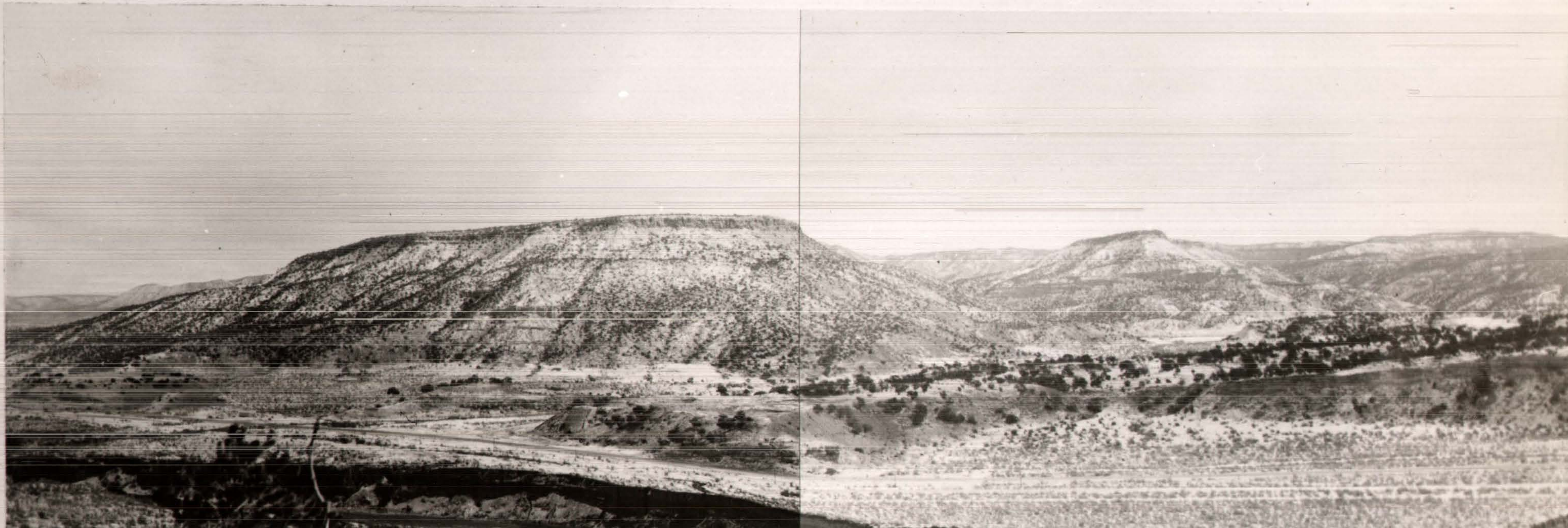


Figure 2. La Ventana Mesa, Sandoval County, New Mexico. View looking east across Rio Puerco showing north butte on left and south butte on right, state highway No. 44 in foreground.

Field work was done during the summer and fall of 1951. One hundred and eight samples for analysis were collected from 70 localities along the outcrop of the mineralized zone around the periphery of the two buttes, and 17 samples were collected from seven localities in the hogback area and west of the mesa. Many of these were collected at natural exposures, whereas others were collected at localities where excavation was necessary. Radiometric reconnaissance was performed with the aid of a Model 2610-A Nuclear Instrument and Chemical Corporation Counter. Geologic mapping was done on aerial photographs at a scale of about 1:36,000 and, where greater detail was needed, on enlargements at a scale of about 1:9,600. The geologic data were transferred to a topographic map at a scale of 1:12,000 that was compiled from aerial photographs with vertical and horizontal control established by plane-table mapping.

Previous investigations

The area described herein has been studied and mapped previously in connection with investigations of the water resources (Renick, 1931); the coal resources (Dane, 1936); and the potential oil and gas resources (Wood and Northrop, 1946). Preliminary announcements of the occurrence of uranium in the La Ventana area were made by Bachman and Read (1951) and by Read (1952).

GENERAL GEOLOGY

Structural setting

The most striking geologic feature in the area is the Nacimiento Mountains, a high mountainous area of pre-Cambrian rocks which is 2 to 3 miles east of La Ventana Mesa. (See fig. 1.) The west flank of the

Nacimiento Mountains is characterized by hogbacks of steeply dipping Paleozoic and Mesozoic strata while still farther west the rocks dip gently under La Ventana Mesa and beyond they pass under the San Juan Basin. The mesa lies along the axis of a broad syncline that plunges gently to the northwest. (See fig. 1.) This structural feature is referred to in this report as the La Ventana syncline.

Stratigraphy

The sequence of sedimentary strata exposed in the area is shown in the following table (Dane, 1936, p. 92-108).

Age	Formation	Member	Thickness (feet)
Cretaceous	Lewis shale		
	Mesaverde fm.	La Ventana sandstone Allison member and Gibson coal member Hosta sandstone	60-80 640 100
	Mancos shale		2,000
	Dakota sandstone		200
Jurassic and older	Morrison and older formations		

Of these, the strata pertinent to this report are those of the Upper Cretaceous Mesaverde formation and the Dakota sandstone. The Mesaverde formation is divisible into three members, here listed from oldest to youngest: the Hosta sandstone, the Allison-Gibson member, and the La Ventana sandstone. The Hosta sandstone member, 100 feet or more in thickness, consists chiefly of pale yellow to brown sandstone interbedded with one or more thin beds of carbonaceous shale or coal. Because of the difficulty in distinguishing the Gibson coal member from the Allison member these units are not differentiated. The Allison-Gibson member undifferentiated consists of about 640 feet of lenticular sandstone, clay, carbonaceous shale and numerous coal beds. On the geologic map of the La Ventana Mesa area, (fig. 3) a contact at the top of a prominent sandstone in the Allison-Gibson member about 250 feet below the base of the La Ventana sandstone is shown. This contact divides the Allison-Gibson member into two parts, which in this report are referred to as the upper and lower parts. The La Ventana sandstone consists of about 60 to 80 feet of light yellow to brown sandstone. This sandstone is of probable marine origin as it contains sharks' teeth. It forms the resistant caprock at the top of La Ventana Mesa (fig. 4).

URANIUM DEPOSITS

Uranium occurs in coal, carbonaceous shale, and carbonaceous sandstone in the Mesaverde formation on La Ventana Mesa. Uranium-bearing coal directly underlies the La Ventana sandstone member at many places on the periphery of both the north and south buttes (fig. 5). Uranium mineralization also occurs in hogbacks east of La Ventana Mesa in carbonaceous shale near the base of the Mesaverde formation (Hosta sandstone member) and in carbonaceous shale in the Dakota sandstone.

South butte

Uranium-bearing strata of possible economic significance are present on the west tip of the south butte where concentrations of as much as 0.51

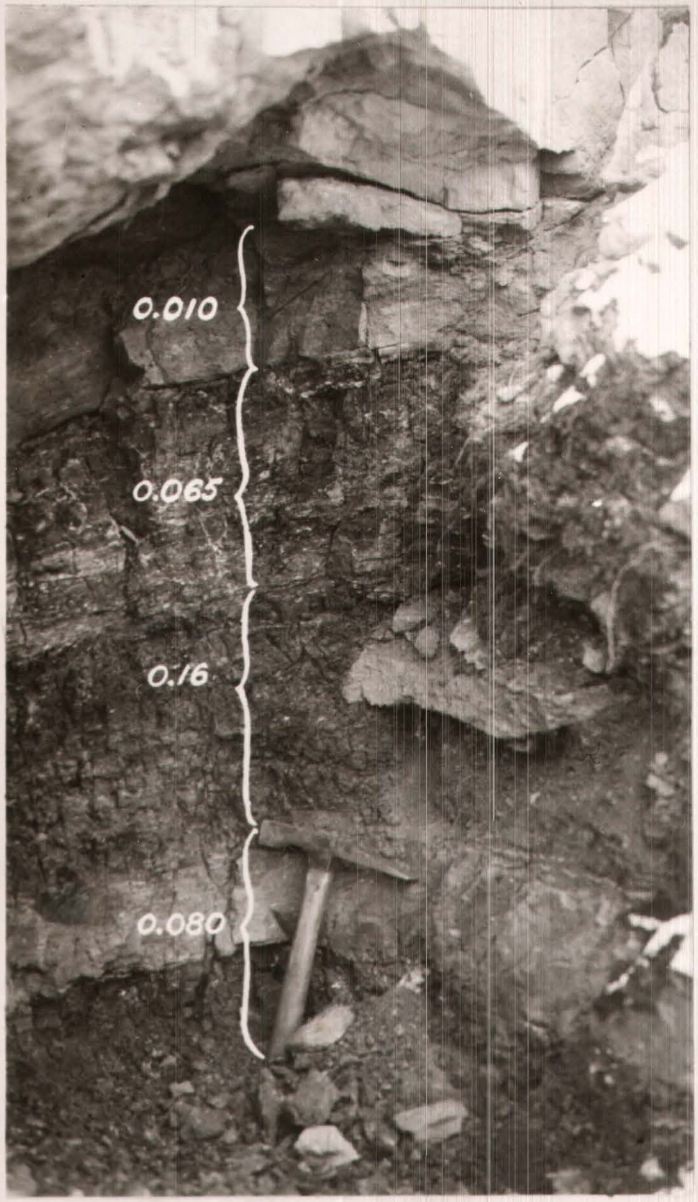


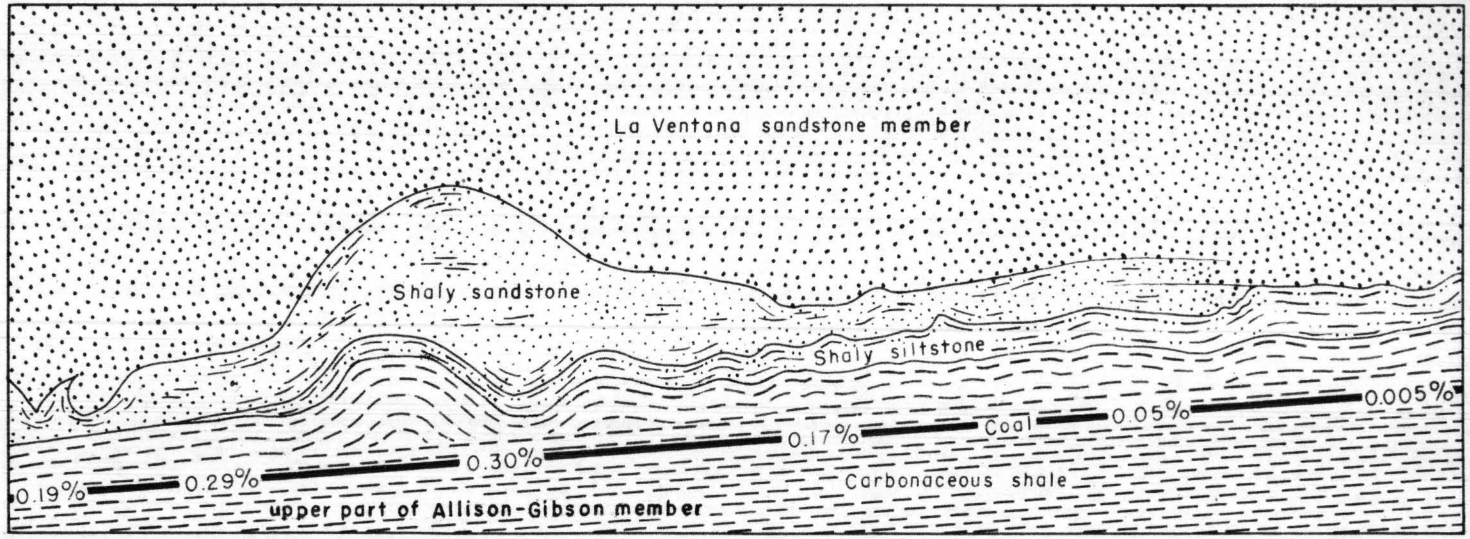
Figure 4. (above) North butte La Ventana Mesa viewed from south butte. The arrow indicates the uranium-bearing coal bed directly below the cliff-forming La Ventana sandstone.

Figure 5. (left) The weathered outcrop of a three foot uranium-bearing coal bed at locality number 4. The uranium content is indicated in percent.

percent uranium in coal occur with 0.84 percent uranium in the ash. The mineralized zone was sampled at closely spaced intervals for about 1,000 feet along the south face of the butte, but only one sample was obtained from the north face. The zone of mineralization is probably continuous, though somewhat variable in thickness and grade at the west tip of the south butte. An area directly east of the west tip is underlain by a low grade (0.002 to 0.021 percent uranium) mineralized zone. Still farther east, though still on the westward extension of the south butte, is another area of possible economic significance (fig. 3, locality 59). The grade of this deposit, however, is quite variable as shown in detail in fig. 6. Analyses range from 0.005 to 0.3 percent uranium.

Uranium occurs in carbonaceous strata in three stratigraphic units that directly underlie the La Ventana sandstone (fig. 7). The uppermost unit consists of 6 to 24 inches of friable sandstone that contains variable amounts of carbonaceous debris, silt, and shale. An irregular erosion surface locally separates the friable sandstone from the more indurated La Ventana sandstone (figs. 6, and 8). As much as 0.058 percent uranium is contained in this unit. Impure coal, 2 to 8 inches thick, underlies the friable sandstone unit. The coal contains as much as 0.51 percent uranium with 0.84 percent in the ash. A bed of carbonaceous shale 10 feet or more in thickness underlies the coal, but only the top 6 to 18 inches contains significant quantities of uranium. The shale contains as much as 0.062 percent uranium.

The largest concentration of uranium is found in the coal--the highest stratigraphic unit on the mesa which contains significant quantities



VERTICAL SECTION

VARIATION OF URANIUM CONTENT IN A COAL BED BELOW A MINOR STRUCTURE

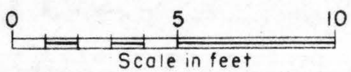


FIGURE 6

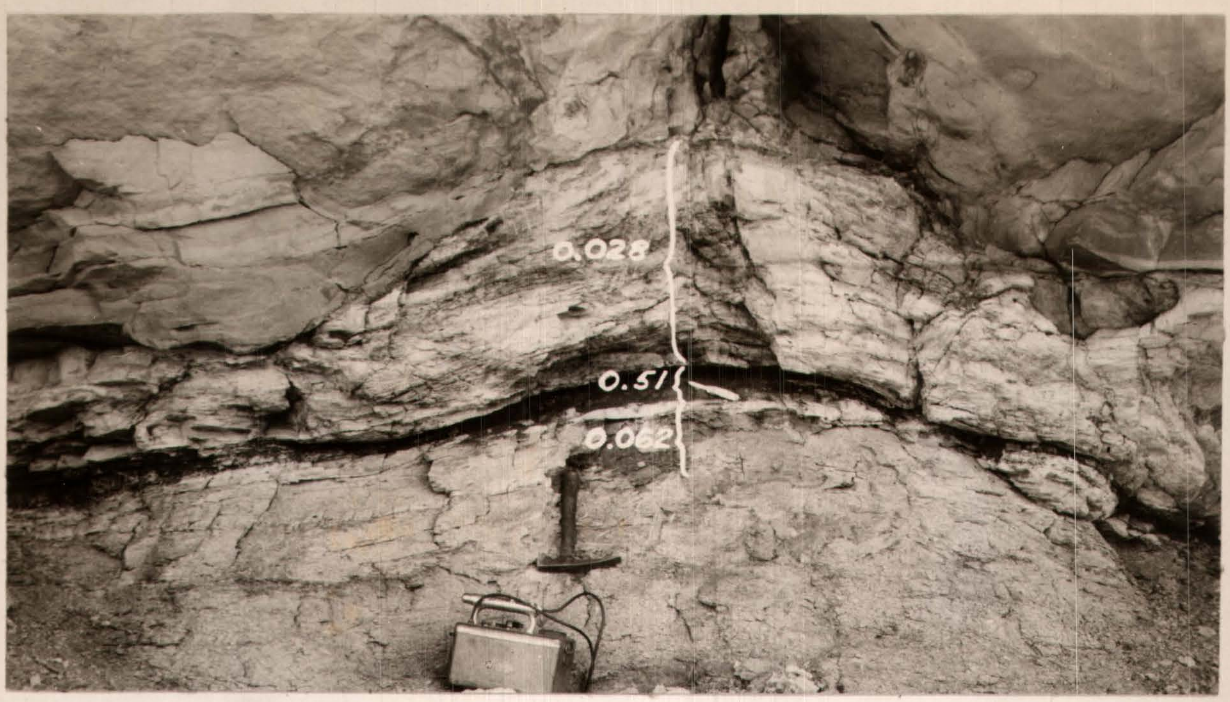


Figure 8. Uranium-bearing strata at locality No. 46 on south butte La Ventana Mesa showing content of uranium in percent.

Figure 9. Effect of a minor structure on uranium content. A minor syncline in the coal below a sandstone body at the base of the La Ventana sandstone shows a variation in the concentration of mineralization. The value of equivalent uranium in percent indicates more intense mineralization in the trough of the syncline than on the flanks.

of carbonaceous material. The amount of uranium decreases abruptly downward from this mineralized zone.

The variably mineralized strata can be traced around the periphery of the south mesa, although the coal thins to the east. Areas of significant radioactivity were not found on the main eastern portion of the mesa.

North butte

Uranium occurs in coal and carbonaceous shale directly below the La Ventana sandstone on the north butte. The sequence of mineralized strata is similar to the units described for the south butte but the coal on the north butte is as much as 4 feet thick. The uranium content in the strata directly below the La Ventana sandstone ranges from less than 0.001 percent at locality 28 on the north tip to 0.62 percent uranium in the coal and 1.34 percent uranium in the ash at locality 5 on the southwest end of the butte. Coal that contains more than 0.1 percent uranium was found at widespread localities on the west and south faces of the butte in beds as much as 3 feet thick (fig. 5).

Hogback area

In the hogback area uranium-bearing shale beds occur in the Dakota sandstone at San Miguel Mine Canyon and Arroyo de dos Gordos. These occurrences have been described by Read (1952). According to Renick (1931, pp. 35-36) the Dakota sandstone at San Miguel Mine Canyon is approximately 188 feet thick and is divisible into three units as follows:

Mancos shale (not measured)

Dakota sandstone

Sandstone, fine- to medium-grained, with carbonaceous material (wood fragments) disseminated throughout and containing streaks of carbonaceous sandstone; massive at base, medium- to thin-bedded at top............	64 ft. 8 in.
Carbonaceous shale, sandy shale and shaly carbonaceous sandstone, mostly concealed..........	67 ft. 6 in.
Sandstone, massive, with thin layers of grit and conglomerate; some carbonaceous sandstone..	56 ft.
	188 ft. 2 in.

Morrison formation (not measured)

Uranium is present in a carbonaceous shale bed in the upper part of the basal unit of the above section at San Miguel Mine Canyon. The carbonaceous shale is about 6 inches thick and contains 0.02 percent uranium. Uranium is present in other less persistent lenses of carbonaceous material in the upper part of the basal unit. One small lens of impure coal is present and contains 0.088 percent uranium with 0.10 percent uranium in the ash. Sandstone that contains fragments of carbon is present in association with the shale beds and contains 0.004 percent uranium.

In the Arroyo de dos Gordos about 5-1/2 miles south of San Miguel Mine Canyon, the Dakota sandstone is similar in character to the section just described. A bed of radioactive carbonaceous shale 18 inches thick occurs near the base of the middle unit. The equivalent uranium content of the carbonaceous shale is 0.007 percent but the uranium content is only 0.002 percent. The Dakota sandstone has been examined in the other water gaps between San Miguel Mine Canyon and Arroyo de dos Gordos, but no radioactivity has been noted. This indicates that the uranium deposits in the Dakota sandstone east of La Ventana Mesa are discontinuous, but this fact should not discourage future prospecting in the Dakota sandstone. The data are, at present, inadequate to appraise the possibilities of this outcrop belt.

Three uranium-bearing zones are present east of La Ventana Mesa in the Hosta sandstone member of the Mesaverde formation. These zones average about 1 foot in thickness and consist of carbonaceous shale and carbonaceous sandstone. Each uranium-bearing bed is in contact with a permeable sandstone. The uranium content ranges from 0.012 to 0.12 percent.

Area west of La Ventana Mesa

West of New Mexico State Highway 44 the La Ventana sandstone forms a prominent escarpment for several miles both north and south of La Ventana. The strata in this escarpment have been examined at numerous localities, but the uranium content is negligible. Several samples were collected from coal and natural ash which occurs at the base of the La Ventana sandstone north and northwest of La Ventana. The location of those samples is shown on fig. 1. The highest uranium content is 0.009 percent which occurs in a natural ash at locality 74 north of La Ventana. The remainder of the samples contained from 0.001 to 0.004 percent uranium.

STRUCTURAL CONTROL OF URANIUM DEPOSITS

The two major deposits of uranium-bearing sediments on La Ventana Mesa are located near the axis of the La Ventana syncline. (See fig. 1.) This relationship suggests that the migration of uranium-bearing solutions was influenced by the geologic structure of the region.

Individual concentrations of uranium indicate that minor structural features also influenced the migration of uranium-bearing solutions. At least three types of structural features on La Ventana Mesa show close relationships with the uranium deposits. They are:

1. Tent-shaped structural features in the upper part of the Allison-Gibson member of the Mesaverde formation which are present directly below the La Ventana sandstone (figs. 6 and 8).
2. Minor synclines in the mineralized coal horizon (fig. 9).
3. Joints in the La Ventana sandstone directly overlying the mineralized zone.

The tent-shaped structural features are best exposed on south butte. Figure 8 shows a typical example of this feature. Apparently the relatively soft, plastic beds in the mineralized zone have been diagenetically deformed by the more competent overlying La Ventana sandstone. At the peak of the structure prominent joints are present in the La Ventana sandstone. The greatest concentrations of uranium on the south butte are usually associated with these structures whereas laterally from the structures the uranium content decreases. A similar structural feature is illustrated in figure 6. This locality was examined in some detail, and it was found that the uranium content ranges from 0.005 percent to 0.3 percent along a 50-foot exposure. The carbonaceous sandstone which directly overlies the coal and is generally about 1 foot thick is about 6 feet thick directly above the highest uranium concentration. The manner by which this structural feature effected a concentration of uranium is not clearly understood, but it is possible that it has controlled the lateral movement of the mineralizing solutions.

A second and distinctly different structural type is the lenticular feature illustrated in figure 9. Here, a lens of indurated sand above the coal has caused the coal horizon to be bowed down in the form of a minor syncline. The concentration of uranium is greatest in the trough of the syncline and decreases toward each flank.

Joints are commonly present in the La Ventana sandstone overlying the mineralized zone. Particularly suggestive of the influence of joints on mineralization is a joint observed at locality number 8 (fig. 3) which contains a deposit of uranium-bearing opal. The uranium content of the coal bed underlying this joint averages 0.3 percent down dip from the intersection of the joint with the coal bed; whereas up dip from the joint the coal averages 0.047 percent uranium. This might be interpreted as indicating that uranium-bearing solutions were introduced along the joint, during the deposition of the siliceous material in the joint, and that the solutions percolated down dip from the point of introduction. On the other hand, the La Ventana sandstone has such a high permeability that joints, although possibly important in localizing mineralization at some places, may be insignificant in others. The configuration of the base of the La Ventana sandstone may be a significant factor in concentrating or localizing mineralization, but at present, data are inadequate to evaluate the importance.

STRATIGRAPHIC CONTROL OF URANIUM DEPOSITS

Certain stratigraphic features are closely involved in the concentration of uranium at La Ventana. For example, all major concentrations of uranium observed in the La Ventana area are in, or closely related to, carbonaceous sediments. Also, porous sandstone beds are closely related to each deposit.

The physical and chemical conditions which account for the concentration of uranium in carbonaceous material are poorly understood. Likewise, little is known of the nature of the uranium compounds that occur in carbonaceous material. However, the association of uranium with fossil wood in carnotite deposits has long been established (Boutwell, 1904, p. 200). The occurrence of uranium in lignite, coal, and similar carbonaceous sediments has been reported in widespread areas: from North and South Dakota (Denson, Bachman, and Zeller, 1950); from the Red Desert, Wyo. (Wyant, Sharp, and Sheridan, 1951); from Churchill County, Nev. (Staatz and Bauer, 1951); from the Fall Creek area, Idaho (Vine and Moore, 1952); from the Goose Creek area, Idaho (Hail, Gill, and Duncan, 1952); and from the Leyden area, Jefferson County, Colo. (McKeown and Gude, 1951). Uranium minerals have not been reported from uranium-bearing coal and lignite except in the Leyden area, Jefferson County, Colo. where carnotite has been identified (McKeown and Gude, 1951, p. 6).

Adsorption of uranium by carbonaceous material is the most plausible explanation known by the writers for the association of uranium with carbon as found in nature. Tolmachev (1943) demonstrated in the laboratory that activated charcoal and carbonaceous shale remove uranium from a uranyl nitrate solution. An experiment performed by T. S. Lovering and G. W. Moore demonstrated that coal also will take up uranium from solution 1/.

Autoradiographs were made by the writers of both polished sections and thin sections of the uranium-bearing coal in an attempt to determine the nature of the mineralization. Autoradiographs of polished sections of the coal demonstrate that the most intense radiation is associated with fractures and joints in the coal. Less intense radiation emanates from certain bands parallel with the bedding planes. These bands, which are faintly visible on the polished sections, are brown and may represent clay or shale partings stained brown by humic colloids. The radiation associated with these bands could be due to greater adsorbency of the material but is probably due to greater permeability along the band. A faint gray fog on the film over the entire area covered by the coal specimen indicates mild radiation uniformly distributed throughout the specimen. Autoradiographs of thin sections of the coal examined under high magnification demonstrate that most of the radiation emanates from opaque constituents in the coal.

These studies indicate that the uranium is in close association with carbonaceous material, that uranium-bearing solutions entered the coal along fractures and joints in the coal, and that certain constituents of the coal are better adsorbents of uranium than others.

1/ A sample of subbituminous coal containing 0.0002 percent uranium was ground and screened until it was between 40 and 80 mesh size and placed in a container in which was circulated a solution of uranyl sulfate containing 196 parts per million of uranium. After two weeks of circulation the coal was analyzed and found to contain 0.2 percent uranium. The solution used showed on analysis only 0.48 parts per million of uranium which indicates that the coal adsorbed nearly 99.8 percent of the uranium that was in solution.

The close association of the uranium deposits in the La Ventana area with beds of permeable sandstone suggests that the sandstone beds have served as aquifers through which uranium-bearing solutions have migrated. This is especially suggested in the mineralized beds in the hogback area where carbonaceous shale and sandstone are in contact with permeable sandstones of Dakota and Hosta age. On La Ventana Mesa the mineralized zone is directly overlain by the La Ventana sandstone whose permeability has been augmented by numerous joints. Only the coal bed which directly underlies the La Ventana sandstone is uranium-bearing though numerous coal beds are present at lower stratigraphic horizons.

ORIGIN OF DEPOSITS

Uranium in the La Ventana area is believed to be of epigenetic origin and to have been carried to the present sites of concentration by meteoric water. This is suggested by the occurrence of uranium in the highest stratigraphic zone containing carbonaceous material on La Ventana Mesa. Uranium in the hogback area is believed to have been carried down the dips through permeable sandstones until a physical and chemical environment favorable for concentrating uranium was reached. Concentrations of uranium in coal may locally be related to major joints in the La Ventana sandstone. Consideration has been given to the possibility that the uranium could have been introduced into the area in hydrothermal or juvenile solutions because slightly radioactive travertine is being deposited at the present time around a well which emits warm water at Warm Springs, 15 miles south of La Ventana. The Quaternary travertine deposits in the SW$\frac{1}{4}$ sec. 32, T. 19 N.,

R. 1 W., in the vicinity of a fault, were checked radiometrically and were found to be non-radioactive. Strata of Cretaceous age in the vicinity of the fault and numerous coal beds throughout the stratigraphic sequence were examined without finding additional radioactivity.

The writers believe that the Bandelier tuff of Pliocene (?) age, which is widespread on the Jemez volcanic plateau to the east of the Nacimiento Mountains, has supplied the uranium for the deposits at La Ventana. The Bandelier tuff may have once covered the area west of the Nacimiento Mountains including the La Ventana Mesa area. If so it has since been eroded away, for a careful search revealed no remnants of the Bandelier in the vicinity of La Ventana Mesa. Analyses of the Bandelier tuff show 0.003 to 0.006 percent equivalent uranium and 0.003 percent uranium. Meteoric water percolating through this thick and porous formation could carry in solution the uranium made available by weathering of the tuff.

RESERVES

A total of 125 samples was collected from the La Ventana area and analyzed in the laboratory for uranium content. A detailed list of the samples is given in the appendix. Local variations in both thickness and uranium content of the mineralized zone have made calculations of reserves difficult. Isopach maps were prepared for rock of 0.1 percent uranium in the mesa area. The thickness at each locality was determined by combining material of greater than 0.1 percent with that of less than 0.1 percent until the average equals 0.1 percent uranium. On the basis of geometric constructions derived from relative spacing of sample stations and geologic inference as to the continuity of the mineralized zone behind the outcrop, the writers infer that two major mineralized areas contain about 132,000 tons of material with 0.1 percent uranium. These reserves are summarized on Table 1.

Table 1.--Summary of inferred reserves of uranium-bearing material 1 foot or more in thickness and containing at least 0.10 percent uranium

Location	Average percent uranium	Range in thickness	Mineralized material (short tons)	Uranium (short tons)
North butte	0.10	1-3 feet	120,000	120
South butte	0.10	1-1.5 feet	12,000	12
		Total	132,000	132

The largest mineralized body is on the southwestern part of the north butte (NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 32; and SE$\frac{1}{4}$ sec. 29, T. 19 N., R. 1 W.). It is estimated to contain about 120,000 tons of uranium-bearing coal, carbonaceous shale, and carbonaceous sandstone which ranges in thickness from 1 to 3 feet and ranges from 0.10 to 0.40 percent in uranium content. The average ash content of the mineralized material is estimated to be about 50 percent. Consequently, by burning, the uranium-bearing material could be concentrated to about 60,000 tons of ash that would contain between 0.20 and 0.80 percent uranium.

The second largest mineralized body is located on the west tip of the south butte (N$\frac{1}{2}$, SE$\frac{1}{4}$, and S$\frac{1}{2}$, NE$\frac{1}{4}$, Sec. 33, T. 19 N., R. 1 W.). It is estimated to contain about 12,000 tons of uranium-bearing coal, carbonaceous shale, and sandstone. The uranium content ranges from 0.10 to 0.17 percent in beds 1 to 1½ feet thick and an average of 0.10 was used in estimating reserves. The average ash content is approximately 88 percent; therefore, burning would be less effective in increasing the uranium content of the ash than burning the material on the north butte. However, burning would concentrate the uranium-bearing material to about 10,000 tons of raw material which would contain between 0.11 and 0.19 percent uranium.

Other small bodies of uranium-bearing material of more than 1 foot in thickness and containing more than 0.10 percent uranium are present on the two buttes. Notable is the small body in the vicinity of locality 15 (fig. 3) on the north butte. More than 1,000 tons of uranium-bearing coal may be present at this locality. The uranium-bearing coal is 1.5 feet thick and contains an average of 0.12 percent uranium with an average of 0.56 percent uranium in the ash. The average ash content of the coal is 20 percent.

Many parts of the La Ventana area appear to contain reserves of lower grade uranium-bearing material (i.e., material that contains between 0.01 and 0.10 percent uranium). In addition to the north and south buttes, these reserves occur in deposits in the Dakota sandstone and the Hosta sandstone member of the Mesaverde formation in the hogback area to the east of La Ventana. A summary of these reserves is given in Table 2.

Table 2.--Summary of low-grade inferred reserves of uranium-bearing material averaging at least 1 foot in thickness and containing between 0.01 and 0.10 percent uranium

Location	Average percent uranium	Range in thickness	Mineralized material (short tons)	Uranium (short tons)
North butte	0.04	1-1.5 feet	336,000	134
South butte	0.02	1-1.5 feet	57,000	11
Hosta sandstone	0.05	1 foot	13,000	6
Dakota sandstone	0.02	1 foot	8,000	1
		Total	414,000	152

RECOMMENDATIONS

Physical exploration of both the north and south buttes will be necessary to determine distribution of uranium in the coal, carbonaceous shale, and sandstone in the buttes. On the basis of present information it seems probable, however, that the buttes contain deposits of uranium-bearing material of such grade and nature that they can be mined commercially. It is understood that the Anaconda Copper Company plans to examine the deposit. If north butte is not drilled by private interest, it is recommended that the Geological Survey do about 1,500 feet of exploratory drilling there to determine approximate grade of the deposit in the area back of the outcrop. The average depth of the holes to be drilled is 100 feet. It would be necessary to construct an access road to the top of the mesa at an estimated cost of about $2,000. If the results of exploration on north butte warrant it, exploration should then be extended to south butte.

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APPENDIX

ANALYSES OF SAMPLES COLLECTED IN LA VENTANA AREA, NEW MEXICO

Samples collected from La Ventana Mesa

Locality number	Sample number	Lab. number	Percent eU	Percent ash	Percent U in ash	Percent U in sample	Description
1	VNM-467	69769	0.028	-	-	0.038	8" carb. shale
1	468	69770	0.060	59.3	0.130	0.077	6" impure coal
1	469	69771	0.11	55.8	0.195	0.11	7" impure coal
2	470	69772	0.11	59.7	0.075	0.045	9" impure coal
3	471	69773	0.027	61.3	0.028	0.017	12" impure coal
3	472	69774	0.040	58.4	0.042	0.025	12" impure coal
4	473	69775	0.012	-	-	0.010	6" friable sandstone
4	474	69776	0.083	58.7	0.110	0.065	12" impure coal
4	475	69777	0.13	38.8	0.42	0.16	12" coal
4	476	69778	0.061	49.7	0.16	0.080	12" coal and bone
5	477	69779	0.17	-	-	0.18	3" carb. shale & jarosite
5	478	69780	0.46	46.0	1.34	0.62	3" coal
5	479	69781	0.34	36.8	1.24	0.46	6" coal
6	480	69782	0.064	53.1	0.19	0.10	6" impure coal
7	481	69783	0.063	-	-	0.065	9" carb. sandstone
7	482	69784	0.20	58.7	0.50	0.30	5" impure coal
7	483	69785	0.13	-	-	0.16	5" impure coal
8	458	71945	0.003	-	-	0.003	Opal vein above coal
9	484	69786	0.051	55.7	0.085	0.047	7" impure coal
10	485	69787	0.070	52.0	0.155	0.081	3" - 6" impure coal
11	486	69788	0.075	54.9	0.177	0.097	12" impure coal
12	487	69789	0.033	28.0	0.154	0.043	12" coal
13	488	69790	0.034	68.3	0.050	0.034	12" impure coal
14	489	69791	0.008	23.0	0.039	0.009	12" coal
15	490	69792	0.19	24.8	1.07	0.27	6" coal
15	491	69793	0.032	16.6	0.305	0.051	12" coal
15	492	69794	0.030	-	-	0.008	3" carb. shale
16	493	69795	0.005	15.5	0.064	0.010	12" coal
17	494	69796	0.006	-	-	0.005	12" coal and carb. shale
18	495	69797	0.041	68.4	0.020	0.014	6" impure coal
19	496	69798	0.031	54.6	0.065	0.035	8" impure coal
20	497	69799	0.014	62.5	0.023	0.014	6" impure coal
21	498	69800	0.010	64.2	0.009	0.006	5" impure coal
22	453	69756	0.014	39.7	0.038	0.015	6" coal
23	452	69755	0.008	28.7	0.042	0.012	15" coal
24	451	69754	0.006	55.8	0.011	0.006	12" impure coal
25	450	69753	0.012	37.0	0.046	0.017	10" coal
26	449	69752	0.005	60.3	0.007	0.004	12" impure coal

Samples collected from La Ventana Mesa (Cont.)

Locality number	Sample number	Lab. number	Percent eU	Percent ash	Percent U in ash	Percent U in sample	Description
27	VNM-454	69757	0.009	45.4	0.028	0.013	10" coal
28	455	69758	a	60.8	-	-	6" coal
29	456	69759	0.002	-	-	-	12" impure coal
30	457	69760	0.009	41.7	0.018	0.008	12" coal
31	459	69761	0.024	49.9	0.058	0.029	3" - 6" coal
32	460	69762	0.025	57.5	0.032	0.018	12" impure coal
33	461	69763	0.021	48.4	0.037	0.018	12"± coal breccia
34	463	69765	0.039	51.6	0.060	0.031	12"± impure coal
35	462	69764	0.051	37.5	0.112	0.042	12"± coal breccia
36	464	69766	0.020	45.0	0.084	0.038	12" coal
37	465	69767	0.031	33.7	0.176	0.059	12" coal
38	466	69768	0.057	59.7	0.152	0.091	12" impure coal
39	BNM-92	67892	0.084	62.9	0.12	0.075	3" - 6" impure coal
40	72	67873	0.012	-	-	0.015	11" friable sandstone
40	73	67874	0.10	64.9	0.12	0.078	5" impure coal
40	74	67875	0.030	-	-	0.033	6" carb. shale
41	68	67869	0.014	-	-	0.006	8" friable sandstone
41	69	67870	0.066	-	-	0.040	7" impure coal
41	70	67871	0.019	-	-	0.013	5" carb. shale
41	71	67872	0.019	-	-	0.022	5" carb. shale
42	75	67876	0.036	-	-	0.030	19" friable sandstone
42	76	67877	0.087	-	-	0.088	8" coal and carb. shale
42	77	67878	0.046	-	-	0.060	14" carb. shale
43	78	67879	0.057	-	-	0.058	11" carb. sandstone
43	79	67880	0.14	77.7	0.27	0.21	7" impure coal
43	80	67881	0.016	-	-	0.019	21" carb. shale
43A	81	67882	0.17	71.2	0.34	0.24	4" impure coal
44	84	67884	0.039	-	-	0.046	9.5" carb. sandstone
44	82	67883	0.30	56.3	0.74	0.42	3.5" impure coal
45	85	67885	0.018	-	-	0.021	12" carb. sandstone
45	86	67886	0.24	48.0	0.70	0.34	3.5" coal
45	87	67887	0.014	-	-	0.013	6" carb. shale
46	88	67888	0.032	-	-	0.028	20" carb. sandstone
46	89	67889	0.32	61.1	0.84	0.51	2.5" impure coal
46	90	67890	0.046	-	-	0.062	7" carb. shale
47	91	67891	0.017	-	-	0.019	13" carb. sandstone

Samples collected from La Ventana Mesa (Cont.)

Locality number	Sample number	Lab. number	Percent eU	Percent ash	Percent U in ash	Percent U in sample	Description
48	VNM-499	71946	0.006	81.0	0.004	0.003	1" impure coal
49	500	71947	0.029	76.4	0.028	0.021	2.5" impure coal
50	501	71948	0.011	80.4	0.009	0.007	2.5" impure coal
51	502	71949	0.006	82.4	0.005	0.004	2.5" impure coal
52	503	71950	0.004	76.4	0.002	0.002	1" impure coal
53	424	67963	0.015	-	-	0.010	2.5" impure coal
54	425	67964	0.074	60.5	0.136	0.082	3" impure coal
55	426	67965	0.028	89.3	0.025	0.022	10" carb. shale
55	427	67966	0.11	73.9	0.060	0.044	3" impure coal
55	428	67967	0.013	87.3	0.010	0.009	12" carb. shale
56	429	67968	0.017	-	-	0.011	6" impure coal
57	430	67969	0.061	59.7	0.17	0.10	3.5" impure coal
58	431	67970	0.029	-	-	0.028	3.5" impure coal
59A	432	67971	0.18	62.3	0.30	0.19	2" impure coal
59B	433	67972	0.18	60.7	0.48	0.29	2" impure coal
59C	438	67977	0.014	-	-	0.013	12" carb. sandstone
59C	434	67973	0.21	61.1	0.48	0.30	2" impure coal
59C	439	67978	0.027	-	-	0.036	12" carb. shale
59D	435	67974	0.096	56.3	0.30	0.17	2" impure coal
59E	436	67975	0.034	45.2	0.11	0.05	2" coal
59F	437	67976	0.013	38.9	0.014	0.005	2" coal
60	442	67981	0.004	-	-	-	12" carb. shale
61	443	67982	0.005	-	-	0.003	12" carb. shale
62	444	67983	0.006	-	-	0.002	12" carb. shale
63	445	67984	0.004	-	-	-	12" carb. shale
64	446	67985	0.002	-	-	-	18" carb. shale
65	447	67986	0.003	-	-	-	6" carb. shale
66	448	69751	0.003	-	-	-	4" carb. shale
67	423	67962	0.003	-	-	-	6" carb. shale
68	422	67961	0.001	-	-	-	4" carb. shale
69	441	67980	0.007	-	-	0.003	6" carb. shale
70	440	67979	0.007	-	-	0.005	6" carb. shale
71	504	71951	0.002	27.7	0.003	0.002	12" coal

Samples collected west of La Ventana Mesa

72	BNM-43	63896	0.001	15.5	0.013	0.002	0.3' coal, bony
73	45	63898	0.001	13.8	0.012	0.002	2' coal, some bone
74	44	63897	0.006	-	-	0.009	0.4' natural ash and clinker
75	47	63900	0.003	22.2	0.019	0.004	Upper 1' of 2' of coal
75	46	63899	<0.001	12.2	0.005	0.001	Lower 1' of 2' of coal

Samples collected from the hogback area

Locality number	Sample number	Lab. number	Percent eU	Percent ash	Percent U in ash	Percent U in sample	Description and locality
76	BNM-60	66368	0.028, 0.029	-	-	0.028	San Miguel Canyon, Upper 2" of 6" carb. sh. in Dakota
76	61	66369	0.028, 0.027, 0.023	-	-	0.016, 0.014	Same as above but middle 2"
76	62	66370	0.025, 0.027, 0.027, 0.029	-	-	0.012, 0.014	Same as above but bottom 2"
76	63	66371	0.030, 0.030, 0.030, 0.034	-	-	0.018, 0.020	Same locality as BNM 60, 6"
76	64	66372	0.009, 0.009, 0.012	-	-	0.004, 0.004	Same locality, roof rock, carb. sandstone in Dakota sandstone
76	65	66373	0.074, 0.071	87.8	0.10	0.088	Same locality, pocket bony coal, sandy streamers
77	97		0.013	-	-	0.012	Sandy carb. sh., Hosta sandstone
77	98		0.021	-	-	0.031, 0.036	Carb. shale, coaly, Hosta sandstone
77	99		0.021	-	-	0.019	Sandy carb. sh., Hosta sandstone
77	100		0.065	-	-	0.120, 0.120	Carb. sh., coaly, Hosta sandstone
77	101		0.054	-	-	0.066, 0.066, 0.060	Carb. sh., Hosta sandstone
78	66	66374	0.006, 0.007, 0.006	-	-	0.002	Arroyo de dos Gordos, carb. sh. in the Dakota