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RESULTS OF EXPLORATION AT THE OLD LEYDEN COAL MINE, JEFFERSON COUNTY, COLORADO*

By

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Part I

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ABSTRACT

Six diamond-core holes totaling 2,201 feet were drilled by the U. S. Bureau of Mines under contract to the U. S. Atomic Energy Commission at the Old Leyden coal mine, Jefferson County, Colo. The holes were spotted on the basis of geologic mapping by the U. S. Geological survey and were drilled to explore the lateral and downward extent of a uranium-bearing coal and the associated carnotite deposits in the adjacent sandstone. The data obtained from the diamond-core holes helped to explain the geology and structural control of the deposit. The uranium is most abundant in a coal bed that in places has been brecciated by shearing, and then altered to a hard, dense, and silicified rock. The uraniferous coal is in the nearly vertical beds of the Laramie formation of Upper Cretaceous age.

Small lenticular bodies of uraniferous material, 50 feet long, 25 to 30 feet wide, and 2 to 4 feet thick, occur at intervals in the coal and silicified coal over a strike length of about 800 feet. These bodies contain 0.10 to 0.50 percent uranium. Data obtained from the drilling indicate a discontinuous radioactive zone between these higher-grade bodies; assays of samples from the cores range from 0.001 to 0.10 percent uranium. All drill holes were probed by Survey and A. E. C. logging equipment and showed anomalies where the core assayed more than 0.005 percent uranium.

Material of ore grade--0.10 percent uranium--was found in one core; the rock in the other five holes was of lower grade. The presence of the radioactive zone in all holes suggests, however, that uranium is distributed irregularly in a southerly plunging deposit which is exposed in the adit, on the outcrop, and in other diamond-drill holes that were put down by the lessee.

INTRODUCTION

Captain E. L. Berthoud (Berthoud, 1875) discovered uranium minerals in the Old Leyden coal mine, sec. 28, T. 2S., R. 70 W., Jefferson County, Colo. (fig. 1) in 1874. No uranium ore was mined, however, until 1950 when Ray A. Bennett of the Moreno-Cripple Creek Corporation, Denver, Colo., leased the property from the owner, George W. Lindsay of Denver, Colo. Mr. Bennett reopened the old adit and recovered a few tons of silicified coal that assayed about 0.15 percent uranium. Geologic studies of this occurrence by the U. S. Geological Survey (McKeown and Gude, 1951) lead to a diamond-drilling exploration project by the U. S. Bureau of Mines on the property on behalf of the U. S. Atomic Energy Commission. Six drill holes were spotted on the basis of previous geologic mapping and the cores were logged by the Survey. The holes were cored to explore the uraniferous deposit in and adjacent to the mine, and to obtain the geologic, structural, and mineralogic setting of this unique deposit.

The holes were radiometrically logged with portable gamma-ray, long-cable probes and recording equipment of the Geological Survey and the Atomic Energy Commission. The Survey truck-mounted unit ("Barnaby"), under the supervision of K. G. Bell, U. S. Geological Survey, was used in holes LE-1, LE-2, and LE-6. Holes LE-2, LE-3, LE-4, and LE-5 were probed with the A. E. C. long-cable field counter operated by Kenneth Baker of the Atomic Energy Commission. In addition to radiometric logging of the holes, all the core was scanned with portable field counters before sampling.

Samples of the cores selected on the basis of the field radiometric tests were split and analyzed radiometrically, chemically, and spectrographically in the Geological Survey Trace Elements Section Denver Laboratory, under the supervision of L. F. Rader, Chief. Core from 19 coal-bearing intervals in holes LE-1 through LE-4 was sent to the Survey's Coal Geology Laboratory, Columbus, Ohio, where the samples were examined petrographically and paleobotanically by J. M. Schopf, Geologist-in-charge. He sent splits of the coal to the U. S. Bureau of Mines laboratory in Pittsburgh, Pa., for proximate analyses.

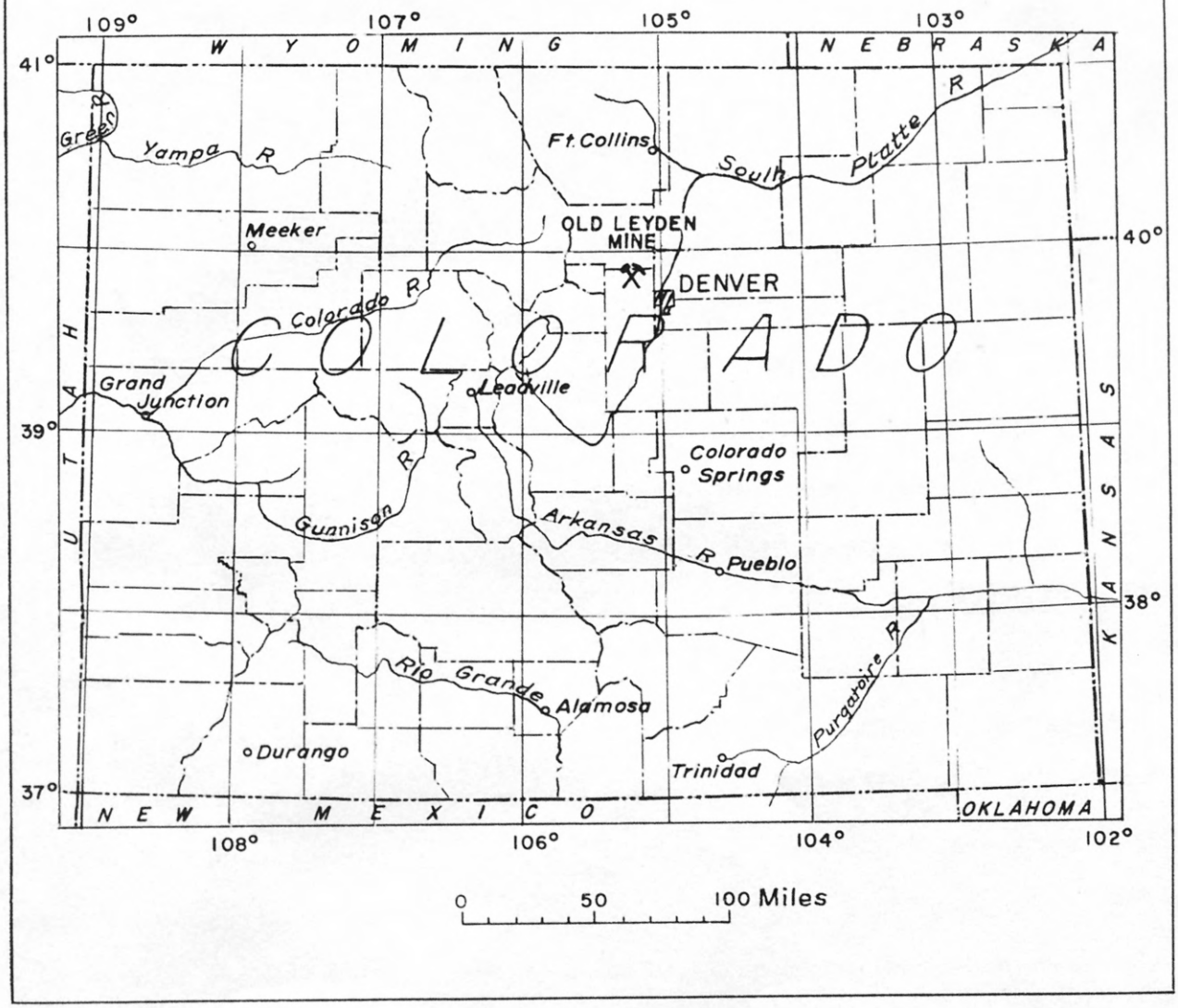

FIGURE 1.-- INDEX MAP SHOWING THE OLD LEYDEN COAL MINE, SEC. 28, T. 2 S., R. 70 W., JEFFERSON COUNTY, COLORADO.

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Particular acknowledgment is made of the cooperation given the writers by Ray A. Bennett of the Moreno-Cripple Creek Corporation who gave us the cores and analyses of the three AX diamond core holes MC-1, MC-2, and MC-3 (fig. 2), drilled for him in the adit. Lewis Harmon of Denver and Christopher Bennetts of Leyden supplied valuable information about the Independence mine, which is adjacent to the Old Leyden coal mine and is now caved and inaccessible.

GEOLOGY

Uranium in the Old Leyden coal mine occurs in a brecciated, silicified coal bed and an overlying silicified sandstone in the Laramie formation of Upper Cretaceous age. The sandstone forms Leyden Ridge hogback; prominent cliffs characterize the eastern and western side of the ridge. These rocks are part of a monoclinal fold on the western flank of the Denver basin (Van Tuyl, et al., 1938, p. 22). The beds strike N. 4° E. and range in dip from about 60° SE. though vertical to 75° NW. Bedding-plane and low-angle reverse faults have sheared and brecciated the rocks in the vicinity of the Old Leyden coal mine.

The strata in the Laramie formation are typically discontinuous within distances of several hundred to a thousand feet. The silicified sandstone unit, which forms the crest of Leyden Ridge, provides the best and most distinctive stratigraphic marker horizons. The top and bottom of this unit can be determined with little difficulty and are the only horizons that could be determined with certainty in the cores.

A generalized vertical section through holes LE-1 and LE-2 (fig. 3) shows the irregularity and discontinuity of the beds in the Laramie formation.

The low-angle reverse fault (fig. 3) was inferred from the offset of the silicified sandstone unit to the east from its expected position, as projected downward from the cliff outcrop. It is further confirmed by the described location of the underground workings of the Independence mine (personal communication, Lewis Harmon, Denver) which is about 800 feet south of the Old Leyden mine. The underground workings of the Independence mine are shown projected into the plane of the section 100 feet north of their approximate location. Both of the reverse faults shown on figure 3 are diagrammatic. These faults actually

consist of zones of many small closely-spaced offsets, the sum total of which is a displacement of many feet.

Figure 4 is an east-west vertical section showing hole LE-3, the Old Leyden mine adit, and hole MC-2, projected into the plane of the section. Hole MC-2 is an AX diamond core hole drilled by the mine operator. The inferred faults shown on this drawing are assumed to be the same as, or related to, the steeply dipping reverse fault shown in figure 3.

The uranium is localized where the zone of coal or carbonaceous clay that underlies the silicified sandstone unit is in or adjacent to the shear zones associated with the faulting shown in figures 2-5. The only identified uranium mineral found at this locality is carnotite (Wilson, 1925). Uranium and vanadium analyses of the uraniferous coal, silicified coal, and silicified sandstone, however, show that there is more uranium present than can be accounted for in carnotite alone. The excess uranium present may be an unidentified oxide. Field studies indicate that the carnotite is probably a secondary mineral. It usually occurs in openings in the brecciated, silicified coal or as coatings around sand grains and along fractures in the overlying silicified sandstone.

The unidentified uraniferous material is associated with coal, silicified coal, and carbonaceous clay. Autoradiographs of specimens from the cores and from the exposure in the Old Leyden adit show that the radioactivity, other than that associated with the carnotite, is higher in intensity where the coal has been crushed and is adjacent to silicified coal. This is also borne out by the gamma-ray logs of holes LE-1, LE-2, and LE-6.

RESULTS OF DIAMOND DRILLING

At the start of the drilling program, the inferred size of the known ore body was described as follows (McKeown and Gude, 1951): "The known deposit is a nearly vertical, tongue-shaped body approximately 280 feet long, 110 feet wide, and 4 feet in average thickness." The objectives of the drilling were not limited to exploration of this inferred body because the coal bed, 2 to 12 feet thick, immediately under the silicified sandstone appeared to be the locus for other uranium deposits. It was expected that the more uraniferous parts of the coal would be small-- on the order of lenses not over 50 feet in their

longest dimension, 25 to 30 feet wide and 2 to 4 feet thick.

Four holes--LE-3, LE-4, LE-5, and LE-6 were drilled to explore the coal bed along strike and down dip from the deposit exposed in the mine, on the outcrop above the mine, and in the lessee's core holes (figs. 2, 4). Specimens of silicified uraniferous coal found in dump rock from the Independence mine indicated that similar deposits had been exposed in this mine. Because no reliable descriptions of the workings were available, holes LE-1 and LE-2 were placed so as to penetrate the uraniferous coal bed below the lowest known level of the mine.

The six NX-BX core holes were drilled from sites on opposite sides of Leyden Ridge. The first two holes--LE-1 and LE-2--and the last--LE-6--penetrated the rocks from the west side of the ridge; and holes LE-3, LE-4, and LE-5 from the east side. A total length of 2,201 feet was drilled, of which 1,846.4 feet was cored. General drilling data for each hole are given below and detailed descriptive logs of the holes and graphic sections are shown in figures 5-10.

Hole number	Bearing	Inclination	Elevation (feet)		Length (feet)	
			Collar	Bottom	Drilled	Cored
LE-1	N. 89° E.	-45°	5905	5688	305.0	275.0
LE-2	N. 89° E.	-55°	5905	5535	451.3	421.3
LE-3	S. 74° W.	-53°	5959	5651	387.0	332.2
LE-4	S. 55° W.	-45°	5959	5674	402.7	312.9
LE-5	N. 63° W.	-62°	5959	5605	401.0	281.0
LE-6	N. 78° E.	-45°	5888	5709	254.0	224.0
				Totals:	2,201.0	1,846.4

Only one of these six drill holes--LE-1--penetrated uraniferous material of ore grade. The presence of abnormal radioactivity ("highs") in all holes except LE-5, showed that uranium, although not of ore grade, is disseminated along the coal seam beyond the limits of the exposed deposit. Holes MC-1 and MC-2, drilled from the mine, cut ore in the coal and silicified coal directly below the adit that assayed as much as 0.70 percent uranium.

The distribution of rock units in the cores, obtained from both Government and private drilling, indicates the presence of the three interconnected, north-trending faults and the N. 23° E. reverse fault

zone which is also recognized on the surface (fig. 2). Uraniferous rocks in the cores are either on or near these faults, and rock of ore grade (0.10 percent or more) is most abundant in brecciated and silicified parts of the coal bed that are adjacent to faults. In the unbrecciated coal, only one sample--FK-89--contained 0.10 percent uranium over a core length of 0.2 feet. This sample came from the east (upper) contact of the uraniferous coal bed in drill hole LE-1 and is separated from the main north-trending fault by 15 feet of porous sandstone. All samples containing smaller, but appreciable, amounts of uranium are either near this same contact or at the contact of minor coal and claystone lenses within this same faulted sandstone bed.

This relationship of uranium concentrations to stratigraphic and structural controls was not apparent until after drilling was completed. It was impossible, therefore, to outline closely by drilling the most favorable area for ore deposits, namely, the area where coal is adjacent to the north-trending faults. The drilling, however, is sufficiently closely spaced to show: (1) that the coal is not continuously uraniferous and (2) that, in general, the most favorable zone for deposits of ore grade is the coal bed above and to the north of the government drill holes.

The nonuraniferous coal seams and carbonaceous clay beds can be distinguished from sandstone and claystone beds by the intensity of gamma radiation shown on the Barnaby logs. In general, the coal and carbonaceous clay are distinctively less radioactive than sandstone or claystone. Sandstone and claystone can not be distinguished on the logs.

Holes LE-1 and LE-2

Holes LE-1 and LE-2 were drilled from the same site (figs. 2 and 3) on the west side of Leyden Ridge, about 1,300 feet south of the Old Leyden mine portal. Both were collared within a foot of each other and drilled along the same bearing--N. 89° E. Approximately 30 feet of surficial debris was drilled in each hole before starting the coring.

Hole LE-1 (fig. 6), inclined at -45°, penetrated twelve recognizable coal beds. These beds were

readily distinguished from the very dark carbonaceous claystone facies of the coal. The hole was bottomed in massive silicified sandstone at 305 feet. Two anomalous radioactivity highs were recorded near the bottom of this hole with Barnaby, but no uranium minerals were observed in the core. The coal from the core in the lower seven seams was shipped to the Coal Geology Laboratory at Columbus for study, but no differences in composition in the various beds were found that could explain the selective deposition of uranium in one coal and not in the others. Assays of core through the radioactive intervals ranged from 0.001 up to 0.10 percent uranium. The most radioactive core segment, sample FK-89 (fig. 3), was a 0.2-foot segment of coal that contained 0.10 percent uranium and 0.074 percent equivalent uranium.

Hole LE-2 (fig. 7), inclined at -55°, was also bottomed in silicified sandstone at 451.3 feet. This hole cut 19 coal beds. One radioactivity high--at 407.0 feet--was found and a second high was found at 414.0 feet. Samples from the two anomalous intervals contained as much as 0.028 percent uranium, the highest being a 1-foot sample of silicified sandstone, number FK-72 (fig. 3) containing 0.028 percent uranium and 0.042 percent equivalent uranium. Six coal beds between 225 and 390 feet were sampled for the Columbus laboratory, but as in hole LE-1 there were no significant results.

Holes LE-3, LE-4, and LE-5

Holes LE-3, LE-4, and LE-5 (figs. 8, 9, and 10) were drilled from the same site on the east flank of the hogback, nearly opposite the portal of the Old Leyden mine. These holes were drilled at different inclinations and bearings to fan out under the deposit in the mine. Barnaby was not available to survey any of these holes; all were logged with the A. E. C. equipment. Very weak radioactivity anomalies were detected in the lower 150 feet of holes LE-3 and LE-4, but no anomalies were found in hole LE-5. All the assays of samples are correspondingly low, ranging up to 0.014 percent uranium. The intensity of the radioactivity in these holes is low compared to that in holes LE-1 and LE-2.

Nine coal beds were cored in hole LE-3 of which three, between 230 feet and the bottom at 387 feet, were sampled for the Coal Geology Laboratory. As in holes LE-1 and LE-2 the coal from holes LE-3

and LE-4 did not show any variations in composition. The coal bed, 40 feet stratigraphically above the massive silicified sandstone, is weakly radioactive, and assayed 0.001 percent equivalent uranium. A second radioactivity high is present in the sandstone near the lower contact of the main uraniferous coal and clay.

Holes LE-4 and LE-5 cut five coal beds. Three of these, between 270 and 380 feet, were sampled in hole LE-4. The radioactivity in hole LE-4 was similar in intensity and distribution to that in hole LE-3. Hole LE-5, however, showed no abnormal radioactivity either by logging or by the assaying of samples from an interval where a field counter showed a very weak anomaly.

Hole LE-6

Hole LE-6 (fig. 11) was drilled to core the main uraniferous coal bed midway between the other two drill sites. It was drilled at an inclination of -45° on the west side of the ridge, about 400 feet south of the Old Leyden adit (fig. 2). This hole was bottomed in silicified sandstone about 80 feet beyond the lower sandstone-claystone contact. Ten coal seams were penetrated; they correlate roughly with those in hole LE-1, although these correlations are poor at best. The hole was radiometrically probed with Barnaby and two weak anomalies were measured. The geologic location of these anomalies agrees closely with the radioactivity highs in the other holes. Assays of samples from the radioactive intervals are less than 0.005 percent uranium.

CONCLUSIONS

Data obtained from the six diamond-core holes drilled at the Old Leyden mine area helped to explain the geology and structural control of the deposit. Although ore-grade material was found in only one hole, 0.10 percent uranium in LE-1, the indications of radioactivity show that the uranium deposit is more extensive than previously known (McKeown and Gude, 1951). The principal bedding-plane and cross faults (figs. 2, 3, 4, and 5) caused brecciation where the coal and silicified sandstone were sheared. These areas in the main uraniferous coal bed are the favorable ore loci. Holes LE-1 and LE-2 showed the highest

uranium assays although they were drilled farthest from the mine. This fact seems to indicate that the uranium is concentrated in a body that rakes downward and to the south from the exposures near the mine.

A complete and representative section through the lower 420 feet of the Laramie formation is exposed in the composite drill-core records. The irregularity and discontinuity of the individual lithologic units is immediately apparent upon examination of the logs. This heterogeneity is characteristic of near-shore, continental sediments such as the Laramie formation. Faulting, such as found in this area, is common to sedimentary rocks that have been folded during mountain-building processes. It is not surprising, therefore, that the occurrences of uranium deposits are also heterogeneous, and spottily and weakly exposed in the drill core. The six holes sampled only a very small portion of the structure, but the indications are that more extensive exploration by mining should find uraniferous coal or silicified coal above holes LE-3, LE-4, LE-5, and LE-6 and to the north of holes LE-1 and LE-2 in the zone within or immediately underlying the massive silicified sandstone, that is, where the beds have been sheared and brecciated by the north-trending faults.

Because of the erratic distribution of the uranium in the sheared and irregularly bedded Laramie formation, diamond drilling should not be used to block out deposits of ore-grade material. Diamond drilling should only be used in conjunction with exploratory mining.

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