THE GEOLOGY, EXPLORATION AND PRODUCTION HISTORY OF THE BLOCK K (MIKE BRODIE NO.6) URANIUM-VANADIUM MINE, APACHE COUNTY, ARIZONA

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William L. Chenoweth
Consulting Geologist, Grand Junction, Colorado
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INTRODUCTION

The Block K uranium-vanadium mine, also known as the Mike Brodie No. 6 mine, was located in the northwestern Carrizo Mountains, Apache County, Arizona. The mine was developed as the result of gamma-ray logging of a seismic shot hole drilled for an oil company survey. Drilling by the U.S. Atomic Energy Commission (AEC) adjacent to the mineralized shot hole located four single hole ore bodies. Drilling by a private company adjacent to one of the AEC ore holes located additional ore, which became the mine.

LOCATION

The Block K uranium-vanadium mine was located approximately 11 miles west of Teec Nos Pos, Arizona (Figure 1). It was in the northwest Carrizo mining area. In this area, the majority of the mines are located on the Toh Atin Anticline. This structure extends from Black Rock Point of the Carrizo Mountains, northwesterly across Marin Mesa to Toh Atin Mesa before it loses its identity. The Block K mine is on the northeast flank of the anticline in the sand covered plain that extends from the anticline to East and West Red Mesas (Figure 1).

When the mine was being operated it could be reached by traveling west from Teec Nos Pos and Navajo Route 1 (now U.S. 160) for 9.6 miles passed the turnoff on the left to the main mining area. Continue one mile and turn left on to a sandy, bulldozer road. The mine is located 2.4 miles southwesterly down this road.

The location of the mine is not shown on the Toh Atin Mesa East quadrangle [U.S. Geological Survey, 1982]. The portal of the inclined shaft is 2,450 ft north and 500 ft west of the brass cap marking the southeast corner of Section 36, T.41 N., R.28 E., Gila Baseline and Meridian.

LAND STATUS

The northwest Carrizo area is located within the Navajo Indian Reservation. On the Reservation all prospecting, leasing, and mining are controlled by the Navajo Tribal Council and the Bureau of Indian Affairs, U.S. Department of the Interior. During the 1920s and 1940s mining companies obtained leases from the Secretary of the Interior to mine on the Navajo Reservation. Due to the uranium boom on the Colorado Plateau, the Tribal Council adopted Resolution CM-3-51 on March 22, 1951 authorizing the Advisory Committee to draft new mining regulations. New regulations pertaining to prospecting and mining were adopted on April 27, 1951 and were approved on September 19, 1951. The new regulations stated that all prospectors must have a permit. Mining permits and leases were to be issued by the Navajo Tribal Council and approved by the Bureau of Indian Affairs (BIA), U.S. Department of Interior. Mining permits could be obtained by individual Navajos only. Permit holders could assign the mining rights to another individual or a company; like the permits, these assignments had to be approved by the Tribal Council and the BIA. Leases would be issued directly by the BIA, and approved by the Secretary of the Interior. Permits were issued for a 2-year period and could be renewed for an additional 2 years. Leases were issued for a period up to 10 years. No more than
960 acres of tribal land could be held by any one company or individual. Both the permittee and the tribe would receive royalties from ore production.

In addition to mining permits, the tribe issued drilling and exploration permits. These permits were good for 120 days and were not renewable.

**SOURCES OF INFORMATION**

Most of the information presented in this report was obtained while the author was employed by the U.S. Atomic Energy Commission (AEC) and succeeding agencies the U.S. Energy Research and Development Administration and the U.S. Department of Energy (DOE). The author worked on the AEC drilling projects in the northwestern Carrizo Mountains from September 1953 until March 1955 and last examined the mine in March 1962. Information on the development of the mine was taken from the author’s field notes. A copy of the map of the mine workings was located in the AEC files at the Grand Junction DOE facility.

**GEOLOGIC SETTING**

The uranium-vanadium deposits in the Carrizo Mountains occur in the Salt Wash Member of the Morrison Formation of Late Jurassic age. In the northwest Carrizo area, the Salt Wash is approximately 200 feet thick. It is composed pale gray to greenish-gray, fine-grained, well sorted sandstone with rounded to subrounded grains of predominately quartz. The sandstone forms lenses that are rarely up to 20 ft thick. Interbedded with sandstone lenses are thin beds of reddish-brown and greenish-gray mudstone and siltstone that form only five to eight percent of the total Salt Wash.

Huffman and others [1980] have subdivided the Salt Wash Member in the Carrizo Mountains into three stratigraphic units based on depositional environments. The lowermost unit is an average of 30 feet thick and was considered by those authors to be predominantly overbank deposits of alternating thin mudstone and sandstone. It reportedly contains a few channel sandstones, however, the present author notes that his unit is lithologically distinct from the overlying ore-bearing unit. It, also, does not host any uranium-vanadium ore deposits. Investigations of the Morrison Formation by Anderson and Lucas [1998] have determined that this lower unit should be included with the underlying Bluff Sandstone and not with the Morrison Formation. The subdivisions of Huffman and others are used in the report.

The middle stratigraphic unit is an average of 70 feet thick and is composed of channel-sandstone deposits, partially and completely abandoned channel-fill deposits, and overbank deposits. It rests with sharp erosional contact on the lower unit. Approximately 80 percent of the sandstone in this unit is active channel fill in a generally eastward flowing fluvial system [Craig and others, 1955].

The upper unit is 120 feet thick. Most of the unit is composed of braided-stream deposits, and thin overbank deposits. Active channel-fill sandstone and conglomerates are also present. The sequence of stratigraphic units probably represent a prograding wet, alluvial fan [Huffman and others, 1980].
The channel sandstone that contains the orebodies at the Block K mine, within the middle unit of the Salt Wash Member, is approximately 20 feet above the base of the member.

The uranium-vanadium orebodies were formed by the selected impregnation of the sandstone and adsorption by the mudstone and fossil plant material. Detrital organic plant material, such as leaves, branches; limbs and small trunks are common in the ore-bearing sandstone. Most all of this material is carbonized. The larger orebodies were commonly associated with the plant material and range from several feet in width to over fifty feet in length. Orebodies are at the Block K mine ranged from a feather-edge up to 5 ft thick, with an average thickness of 2.5 ft

The ore deposits in the Carrizo Mountains were originally called carnotite after the bright yellow mineral carnotite, a potassium uranium vanadate. After studying dozens of samples, including work by Corey [1956, 1958], S. Ralph Austin, AEC petrologist, identified only tyuyamunite, a calcium uranium vanadate, and metatyuyamunite as the only uranium minerals in the Carrizo deposits [written communication, 1967].

In a study of the mineralogy and petrology of the nearby Martin mine (Figure 1), Corey [1956] found tyuyamunite to be the only uranium mineral present. Vanadium was present in the tyuyamunite and in the mineral montosite, an iron, and vanadium oxide. Vanadium minerals pascolite and volborthaite were found as stains on surface outcrops at the Martin mine. Calcite was the major cementing agent of the ore. The large amounts of calcite, greater than six percent $\text{CaCO}_3$, resulted in the ore being classified by the AEC as “high lime”, which created problems in the acid leach circuits of processing mills. Pyrite, limonite, hematite and gypsum were also present in the ore at the Martin mine [Corey, 1956].

The Toh Atin anticline is the dominant structure in the northwest Carrizo area. Somewhat asymmetrical, the northern flank dips an average of seven degrees to the northeast while the opposite limb dips one half to one degree to the southeast. The entire structure in capped with the Salt Wash Member. The mines were developed along the rim of Saytah Wash and on the rims of the canyons on the northeast flank.

The Rattlesnake group of mines was developed on the northeast flank at the edge of the sand covered plain. Across the sand covered plain, about six miles north of the anticline are the East and West Red Mesas (Figure 1). These mesas are capped with Salt Wash and are located near the crest of the east plunging East Boundary Butte anticline. Drilling in the area between the two structures has shown that a broad, shallow syncline exists under the sand covered plain [Bollin and other, 1956, Chenoweth, 1956]. Where the Salt Wash is covered by alluvium on the north flank of Toh Atin anticline, there is an abrupt flattening of the beds, and the dip of the Salt Wash beneath the sand cover is about one and a half degrees to the northeast. A reversal of about four degrees has been indicated across the valley just north of Navajo Route 1 where the Salt Wash is absent beneath the alluvium. Overlying the Salt Wash in the syncline is up to 80 ft of pediment pebbles and cobbles of diorite, alluvium and blow sand. At the Block K mine, the overburden above the Salt Wash averaged 40 ft in thickness.
GOVERNMENT EXPLORATION

Early in 1952 the Shell Oil Company began a seismic survey of the northern and western Carrizo Mountains. Since many of the holes would penetrate the Salt Wash Member of the Morrison Formation, the AEC requested the U.S. Geological Survey (USGS) probe these holes with gamma-ray detection equipment. The USGS probed holes from February 18, 1952 until September 11, 1952 [Bell, 1953]. In September the probing was taken by the AEC and continued for the four remaining months of the project. Appreciable radioactivity was found in six holes that had been drilled in the syncline [Hatfield and Maise, 1953].

Starting on March 8, 1953, the AEC commenced a series of five drilling projects in the northwestern Carrizo area. The initial drilling was behind existing vanadium mines and as offsets to mineralized seismic shot holes. The drilling was expanded to include drilling in a grid pattern in the sand covered syncline between the Toh Atin Anticline and Navajo Route 1 (now U.S. 160) where six of the mineralized shot holes were located. The Rattlesnake No. 1-4 projects have been summarized by Bollin and other [1956] and the Rattlesnake No. 5 project was reported on by Chenoweth [1956].

In the Rattlesnake No. 1 project, core hole J-46 was drilled as an offset to mineralized shot hole number 8097 (Table 1). As part of Phase 3 of the Rattlesnake No. 3 project, an area around hole J-46 was drilled on 65 ft centers. When drilling was completed in March 1955, an area 600 ft by 600 ft had been explored with 91 holes (Figure 2). This area was known as the geochemical area [Bollin and other, 1956]. Cuttings from each foot of the ore zone were sampled for chemical determination of copper, lead and zinc by the dithizone method [Huff, 1951]. No criterion of favorability was found as anomalous amounts of the heavy metals were found not only in uranium, but also in mudstone and in zones of abundant carbon associated with limonite [Bollin and others, 1956].

Using a cutoff of 4 ft of 0.15 percent U₃O₈, an ore reserve of 1,760 tons averaging 0.29 percent U₃O₈ and 1.41 percent V₂O₅ was calculated around drill holes J-354, 589, 600 and 678 (Figure 2) [Chenoweth, unpublished field notes, 1962].

PRIVATE EXPLORATION AND MINING

Anticipating that the AEC would do some exploration drilling in the sand covered plain, north of the mines on the Toh Atin Anticline, Mike Brodie, in 1952, was issued Navajo Tribal Mining Permit No. 81. This permit covered a large area down dip from the Rattlesnake mines (Figure 1). The mining rights to the permit were later assigned to Saint Anthony Oil Company of Grand Junction, Colorado. Shortly after the AEC finished drilling in March 1955, St. Anthony drilled 37 holes as 25 ft offsets to the AEC ore holes, J-589, 600, 654 and 678, in the geochemical area. This drilling indicated the ore was not continuous between the holes on 65 ft centers. St. Anthony cancelled their assignment in 1956.

There was no activity in the geochemical area until the fall and winter of 1961 when Kerr-McGee Corporation took out a drilling permit covering the area. Drilling by Kerr-McGee located some small orebodies adjacent to AEC drill holes J-46, 602, 607, 611, 667, 670, 674,
675, 676 and 678 (Figure 2). On March 14, 1962, Mike Brodie was issued Navajo Tribal Mining Permit No. 567. This permit covered 192 acres of the geochemical area and was referred to a Mike Brodie No.6. The assignment to Kerr-McGee was approved by the Bureau of Indian Affairs on March 21, 1962.

During a conference held on March 6, 1962, between AEC and Kerr-McGee officials, the company stated that the drilling had located a minimum of 2,700 tons averaging 0.22 percent U₃O₈ and 1.35 percent V₂O₅ to a maximum of 5,000 tons averaging 0.21 percent U₃O₈ and 1.30 percent V₂O₅. The ore ranged from 1 to 5 ft in thickness with an average thickness of 2.5 ft. The average depth of the deposits was 110 ft [Chenoweth, unpublished notes, 1962].

On April 25, 1962, A and B Mining Company of Moab, Utah, began a 300 ft long, 25 degree decline into the easternmost orebody. Once the decline was completed, a contractor, Jeff Brumbley, began mining. Shipments of ore began to mill at Shiprock, New Mexico, operated by Kerr-McGee, in July 1962. These shipments were identified as the Block K mine. An inspection by the Arizona State mine inspector in late 1962 noted two men underground and one on the surface.

In March 1963, Vanadium Corporation of America (VCA) acquired Kerr-McGee’s mill at Shiprock and all their mines in the Lukachukai Mountains as well as the Block K mine in the Carrizo Mountains. When VCA took over Block K, Kerr-McGee had produced 731.88 tons averaging 0.20 percent U₃O₈ and 1.48 percent V₂O₅ (Table 2).

VCA continued mining in 1963. The Arizona State mine inspector noted three men underground and one on the surface in 1963. VCA ceased mining in March 1964. At that time the company had produced 1,284.49 tons of ore averaging 0.16 percent U₃O₈ and 1.20 percent V₂O₅ (Table 2).

**SUMMARY**

During the 20 months the mine was in operations it produced 2,016.37 tons of ore averaging 0.17 percent U₃O₈ and 1.30 percent V₂O₅ (Table 2). All of the uranium concentrate recovered from this ore at the Shiprock mill was sold to the AEC. Although the operators of the mill paid for vanadium not all of it was recovered [Albrethsen and McGinley, 1982].

**Acknowledgement:**

Stephen M. Richard’s review of an earlier version of this report, for the Arizona Geological Survey, is gratefully acknowledged.
REFERENCES


Table 1. Chemical assays of drill hole cuttings from selective drill holes, geochemical area, northwest Carrizo Mountains, Apache County, Arizona.

<table>
<thead>
<tr>
<th>DRILL HOLE NO.</th>
<th>DEPTH</th>
<th>THICKNESS</th>
<th>% U₃O₈</th>
<th>% V₂O₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>J-46</td>
<td>103-106</td>
<td>3</td>
<td>0.28</td>
<td>1.87</td>
</tr>
<tr>
<td>J-354</td>
<td>106-110</td>
<td>4</td>
<td>0.32</td>
<td>1.68</td>
</tr>
<tr>
<td>J-578</td>
<td>99-102</td>
<td>3</td>
<td>0.14</td>
<td>0.90</td>
</tr>
<tr>
<td>J-584</td>
<td>111-113</td>
<td>2</td>
<td>0.20</td>
<td>0.95</td>
</tr>
<tr>
<td>J-600</td>
<td>111-114</td>
<td>3</td>
<td>0.18</td>
<td>1.26</td>
</tr>
<tr>
<td>J-611</td>
<td>110-112</td>
<td>2</td>
<td>0.09</td>
<td>0.74</td>
</tr>
<tr>
<td>J-629</td>
<td>106-108</td>
<td>2</td>
<td>0.14</td>
<td>1.84</td>
</tr>
<tr>
<td>J-656</td>
<td>97-99</td>
<td>2</td>
<td>0.13</td>
<td>1.28</td>
</tr>
<tr>
<td>J-663*</td>
<td>104-106</td>
<td>2</td>
<td>0.02</td>
<td>0.59</td>
</tr>
<tr>
<td>J-667</td>
<td>99-100</td>
<td>1</td>
<td>0.01</td>
<td>1.19</td>
</tr>
<tr>
<td>J-667</td>
<td>102-103</td>
<td>1</td>
<td>0.02</td>
<td>2.25</td>
</tr>
<tr>
<td>J-670</td>
<td>98-99</td>
<td>1</td>
<td>0.02</td>
<td>1.22</td>
</tr>
<tr>
<td>J-674</td>
<td>104.5-106.5</td>
<td>2</td>
<td>0.11</td>
<td>1.22</td>
</tr>
<tr>
<td>J-678</td>
<td>109-112</td>
<td>3</td>
<td>0.43</td>
<td>1.53</td>
</tr>
<tr>
<td>J-679</td>
<td>105-106</td>
<td>1</td>
<td>0.12</td>
<td>0.04</td>
</tr>
</tbody>
</table>

*5 ft offset to J-46

Source: Author’s field notes dated June 7, 1962

Table 2. Uranium-vanadium ore production, Block K mine Apache County, Arizona.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>QUARTER</th>
<th>OPERATOR</th>
<th>TONS OF ORE</th>
<th>POUNDS U₃O₈</th>
<th>% U₃O₈</th>
<th>POUNDS V₂O₅</th>
<th>% V₂O₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>1962</td>
<td>3</td>
<td>Kerr-McGee</td>
<td>298.80</td>
<td>1,375.25</td>
<td>0.23</td>
<td>8,848.51</td>
<td>1.48</td>
</tr>
<tr>
<td>1962</td>
<td>4</td>
<td>Kerr-McGee</td>
<td>188.28</td>
<td>709.13</td>
<td>0.19</td>
<td>5,968.82</td>
<td>1.59</td>
</tr>
<tr>
<td>1963</td>
<td>1</td>
<td>Kerr-McGee</td>
<td>244.80</td>
<td>877.68</td>
<td>0.18</td>
<td>6,804.97</td>
<td>1.39</td>
</tr>
<tr>
<td>1963</td>
<td>1</td>
<td>VCA</td>
<td>120.83</td>
<td>302.00</td>
<td>0.12</td>
<td>2,880.00</td>
<td>1.19</td>
</tr>
<tr>
<td>1963</td>
<td>2</td>
<td>VCA</td>
<td>264.50</td>
<td>924.33</td>
<td>0.17</td>
<td>7,172.00</td>
<td>1.36</td>
</tr>
<tr>
<td>1963</td>
<td>3</td>
<td>VCA</td>
<td>300.53</td>
<td>996.08</td>
<td>0.17</td>
<td>7,050.00</td>
<td>1.18</td>
</tr>
<tr>
<td>1963</td>
<td>4</td>
<td>VCA</td>
<td>224.78</td>
<td>692.06</td>
<td>0.15</td>
<td>5,141.00</td>
<td>1.14</td>
</tr>
<tr>
<td>1964</td>
<td>1</td>
<td>VCA</td>
<td>373.85</td>
<td>1,167.63</td>
<td>0.16</td>
<td>8,462.00</td>
<td>1.13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>2,016.37</td>
<td>7,044.16</td>
<td>0.17</td>
<td>52,342.30</td>
<td>1.30</td>
</tr>
</tbody>
</table>

Figure 1. Index map of the Carrizo Mountains, Apache County, Arizona and San Juan County, New Mexico showing the location of the Block K uranium-vanadium mine.
Figure 2. Drill hole location map of the geochemical area showing the location of the Block K orebodies. Modified from Bollin and others [1956]
Figure 3: Plan map of the Block K mine.