



EXPLORATION AND PRODUCTION HISTORY OF THE URANIUM-VANADIUM MINES ON COVE MESA, APACHE COUNTY, ARIZONA

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Arizona Bureau of Geology & Mineral Technology's Bob Scarborough in uranium-vandium mine portal at Cove Mesa, 1980.

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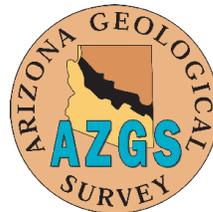
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The Geology, Exploration and Production History Of the Uranium-Vanadium Mines on Cove Mesa, Apache County, Arizona

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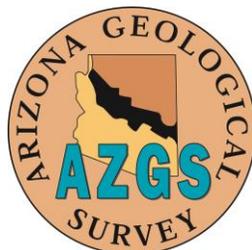
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INTRODUCTION

Cove Mesa is a small mesa in the southern Carrizo Mountains, Apache County, Arizona. The mesa is capped by beds of the Salt Wash Member of the Jurassic Morrison Formation. This member is the host rock for the uranium-vanadium deposits on the mesa. A small shipment of vanadium ore was made in early 1944. Later that year, a 959.7 acre lease in the western and southern Carrizo Mountains was acquired by a civilian contractor for the Manhattan Engineer District. Included in this lease was a 246.2 acre tract on Cove Mesa. The lease was transferred to the United States of America; i.e., the U.S. Atomic Energy Commission (AEC), in 1949. Drilling projects by the AEC discovered a considerable amount of uranium-vanadium ore on Cove Mesa, which was mined during 1948-1965.

Location

Cove Mesa is a small mesa on the Navajo Indian Reservation, located between the Carrizo and Lukachukai Mountains (Figure 1). It is about 1.5 miles long and has a maximum width of 0.5 miles. It has a total area of about 0.70 square miles. Cove Mesa is shown in the southeastern corner of the Kinusta Mesa topographic quadrangle (USGS, 1982).

When the mines were active, Cove Mesa could be reached by turning west off of U.S. Highway 666 (now U.S. 491) six miles south of Shiprock, New Mexico. The road goes to the Red Rock Trading Post and to Cove, Arizona. Seven miles past Red Rock, a truck road to Cove Mesa goes to the northwest. About two miles of this road goes up a dry wash and some switchbacks are present on the east side of the mesa.

Land Status

Cove Mesa is located within the Navajo Indian Reservation. On the Reservation all prospecting, leasing, and mining was controlled by the Navajo Tribal Council and the Bureau of Indian Affairs (BIA), 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 were to be issued by the Navajo Tribal Council and approved by the BIA. 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. Leases were issued for a period up to 10 years. Any one company or individual could hold no more than 960 acres of tribal land. Both the permittee and the Tribe would receive royalties from ore production.

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 and the U.S. Energy Research and Development Administration and the U.S. Department of Energy (DOE). Information on the early vanadium ore production is contained in a detailed report prepared by the General Services Administration (GSA), Indian Trust Accounting Division for the Navajo Tribe. This document (GSA, 1981) was admitted as evidence in U.S. Claims Court, Navajo Tribe vs. United States, Docket Nos. 69 and 299 (copper, vanadium, uranium, sand, rock and gravel claims) held in Albuquerque, New Mexico, February 24-March 4, 1983. The Grand Junction Area Office of the U.S. Department of Energy obtained a copy of the vanadium and uranium section. Details of the mineral leasing regulations, applicable to the Navajo Indian Reservation, were taken from a report prepared by DeVoto and Huber (1982) for the U.S. Department of Justice, which was also admitted as evidence in the above case. Copies of both the GSA report and the DeVoto and Huber report are now in the National Archives, Rocky Mountain Region, Denver, Colorado, Record Group 434-99-200.

The ore production figures presented in this report are from unpublished documents in the AEC files. The ore production report available to the public (DOE, 1997) has the totals for all three properties described in this report. However, their totals are in error. This is due to the fact that Vanadium Corporation of America (VCA) mined the two Navajo Tribal Mining Permits at the same time and that VCA also had a Plot 7 in its East Reservation Lease in San Juan County, New Mexico. Pre 1954 production was taken from reports by Allport (1951, 1952, 1953).

The author worked on the AEC's Cove Mesa No. 4 drilling project in 1953. He last examined the active mines in September 1961.

GEOLOGIC SETTING

The uranium-vanadium deposits on Cove Mesa occur in the Salt Wash Member of the Jurassic Morrison Formation. Cove Mesa is capped by the lower 115 feet of the member. The Salt Wash sandstones form steep irregular cliffs on the rim of the mesa. The upper one-half of the member has been removed by erosion.

The Salt Wash is a sandstone with minor amounts of mudstone and siltstone. The sandstone is light red to pale gray, fine- to very fine-grained, well-sorted, with rounded to subrounded quartz grains. It consists chiefly of imbricated lenses whose maximum thicknesses range up to 25 ft. These lenses are usually moderately cross-bedded and obscurely interfingering with flat, even-bedded, flaggy layers, some of which are ripple-marked. Locally it is well-cemented with secondary calcite. Red and green mudstone galls are common throughout the sandstone lenses.

The mudstone and siltstone lenses separating the sandstones range in thickness from a few inches up to 3 ft. They are gray, greenish-gray, or reddish-brown and commonly are

somewhat mottled. Lenses are seldom longer than 200 to 300 ft and commonly pinch, swell, split, and coalesce along the bedding.

Fossil logs and carbonaceous materials are common throughout the Salt Wash on Cove Mesa. Fragmented particles and flakes of carbon form seams along the bedding. Finer particles of carbonaceous matter disseminated through the sandstone impart its typical bluish gray color. Abundant imprints of organic material are found on thin clay partings.

AEC drilling located ore in at least three horizons in a zone 20 to 100 ft above the base of the Salt Wash. The ore minerals are metatyuyamunite, montroseite, vanadium clays, and partly to completely oxidized vanadium materials. They occur as fillings of interstices, sand-grain coatings, and replacement of clay particles and carbonaceous material. Some logs are mineralized and run higher in uranium and vanadium than the surrounding rock. Calcite cement varies throughout the ore but is commonly present in such amounts that the ore is classed as "high-lime ore".

The deposits are generally tabular and conform to the sandstone beds; however, a few "rolls" occur that cut the bedding planes at low angles. Lateral terminations of ore vary from gradual thinning to abrupt termination. Ore bodies on Cove Mesa range in size from individual small pods to clusters of pods almost completely covering an area 600 by 150 ft. The average diameter of the ore bodies is about 150 ft, and the average thickness is about 2 ft. The grade averages about 0.19 percent U_3O_8 and 1.40 percent V_2O_5 . The small size of the ore bodies in this area makes closely spaced drilling necessary for blocking out ore.

The ore-bearing sands are gray, with associated greenish-gray mudstone and siltstone lenses and galls. Limonite flecks are common in the ore-bearing rock, and limonite is considered to be an ore guide in this area.

Stokes (1953) studied the direction of the flow of the Salt Wash streams on Cove Mesa for the AEC. His measurements were summarized by Scarborough in Figures 4 and 5. Stokes concluded that areas where streams changed directions were favorable locations for ore deposits.

Cove Mesa is a broad syncline between the Carrizo and Lukachukai Mountains. The beds on the mesa dip 2 to 3 degrees to the northwest.

VANADIUM LEASING AND MINING

By the mid-1930s, the mines in the carnotite region of southwestern Colorado and southeastern Utah were being reopened for their vanadium content. At the same time the Secretary of Interior was asked to open the Navajo Indian Reservation for prospecting and mining.

The Navajo Indian Reservation was subsequently opened by a Congressional Act of May 11, 1938, but with new procedures. This Act gave the Tribal Council the authority to enter into leases for the Reservation land with approval of the Secretary of Interior. Prospectors no longer

could enter the Reservation and stake a mining claim under regulation similar to those of the United States Mining Law. The new mining regulation contained escalating annual rentals, a base royalty of 10 percent (mine mouth value), bond requirements, acreage limitations, and a term of 10 years which could be extended by production (DeVoto and Huber, 1982).

On April 19, 1941, the Navajo Tribal Council requested the Secretary of the Interior to lease lands for mining purposes to the highest bidder. In order to take care of this situation, the mining leases were written for large areas and subsequently reduced in acreage at the end of a specified time period. The net effect of this type of lease was that a prospecting permit was issued to the highest bidder, who then had the right to lease land within the permit area up to a maximum acreage. The maximum acreage a company could lease on the Reservation was 960 acres (DeVoto and Huber, 1982).

When the United States entered World War II, the demand for vanadium by the steel industry increased significantly. Due to the uncertainty of foreign supplies and the need for vanadium, and other strategic materials, the Federal government had formed Metals Reserve Company in December 1941. This agency was part of the Reconstruction Finance Corporation. The Metals Reserve vanadium program with increased ore prices, ore-buying stations, etc., was the stimuli to renew interest in the carnotite deposits in the Carrizo Mountains. At Monticello, Utah and Durango, Colorado, Metals Reserve had mills to process vanadium ore.

On July 21, 1943, in response to requests from mining companies, the Office of Indian Affairs advertised an exploration mining lease sale for carnotite and related minerals in the northern and western Carrizo Mountains. The area offered consisted of 168 square miles in a tract 7 miles wide east-west, and 24 miles long, north-south, with the southeast corner located near Cove School (Figure 1). Excluded were all lands subject to prior approved mineral leases.

Bids were opened on August 3, 1943 at which time the only bid received was \$5,085.00 from Thomas F.V. Curran, Charles, F. Curran, and John F. Wade, d.b.a. Curran Brothers and Wade (GSA, 1981). Lease I-149-IND-6107 was executed on August 6, 1943, effective October 27, 1943 for a period of ten years. On the date the lease became effective, a two-thirds interest was assigned to U.S. Vanadium Corporation (USVC).

During the period December 1943 through February 1944, Curran Brothers and Wade mined 388.35 tons of ore averaging 1.94 percent V_2O_5 (GSA, 1981). This ore came from outcrops in Saytah Wash, South Saytah Canyon and on the west side of Cove Mesa. The majority of the ore was mined from the CB&W Main Claim mine in South Saytah Canyon (Chenoweth, 2011). The ore was hauled by truck to the Metals Reserve ore-buying station in Farmington, New Mexico. There it was put on cars of the Denver and Rio Grande Western Railroad's narrow gage to be shipped to the Metals Reserve mill in Durango, Colorado, operated by USVC. At Durango, USVC also operated a plant secretly recovering uranium from the vanadium mill tailings for the Manhattan Engineer District (Chenoweth, 1988). The value of the ore was reported at \$6,605.69 from which the Navajo Tribe received \$660.57 in royalties (GSA, 1981).

On March 22, 1944, the lease was reduced to a permanent operating lease with 12 plots, totaling 959.7 acres, selected to be retained. The location and size of the plots is given in Table 1. Plot 7 comprised 246.2 acres on the southern two-thirds of Cove Mesa (Figures 4 and 5).

MANHATTAN PROJECT ACTIVITIES

During World War II, the Army Corps of Engineers formed the Manhattan Engineer District (MED) for the development of atomic weapons and acquisition of raw materials for the production of weapons. The Murray Hill Area of MED was established on June 15, 1943 for the major purpose of the exploration and development of raw materials on which the entire Manhattan Project was dependent. Determination and evaluation of the uranium resources of the world was first undertaken, and the program was later expanded to include thorium ores.

Union Mines Development Corporation (UMDC), a subsidiary of Union Carbide and Carbon Corporation, was contracted to carry out the work (contract, No. W-7405, effective May 11, 1943). On the Colorado Plateau, UMDC's geologic investigations were limited to the Salt Wash Member of the Morrison Formation, and the Entrada and Glen Canyon Sandstones in the areas of roscoelite deposits.

UMDC geologists began work on the Navajo Indian Reservation on July 28, 1943 (Chenoweth, 1988). They were to make a reconnaissance of the Salt Wash Member of the Morrison Formation in the area of the Curran Brothers and Wade lease. All known outcrops of uranium-vanadium minerals were described and plotted on maps. Geologic studies and resource estimates on Cove Mesa were done by Alfred H. Coleman and John W. Harshbarger.

Party No. 1 under Coleman worked on Cove Mesa in August and September 1943. He recorded 59 outcrops of uranium-vanadium minerals on the rim of Cove Mesa (Coleman, 1943). Figure 2 is a map of Cove Mesa showing the location of these outcrops.

Party No. 3 under Harshbarger returned to the southern and western Carrizos in July and August 1945 to reexamine and resample many of the mineralized occurrences. A sketch of the area where Curran Brothers and Wade mined ore is shown in Figure 3.

On Cove Mesa, UMDC geologists proposed a 336 hole drilling project, totaling 13, 440 ft to develop uranium resources (Harshbarger, 1946). MED did not approve this project.

As part of their investigations, UMDC geologists recommended areas that should be acquired by the Federal government for the development of uranium resources. In the northern and western Carrizo Mountains, UMDC took action to acquire the lease of Curran Brothers and Wade-U.S. Vanadium, which consisted of 12 plots, UMDC had helped to select. On April 17, 1944, the one-third interest in Lease I-149-IND-6197 held by Curran Brothers and Wade, was reassigned to Union Mines. The two-thirds interest held by USVC was reassigned to UMDC on April 24, 1944. Both reassignments were approved by the Office of Indian Affairs on October 31, 1944. The cost of acquiring the lease was reported at \$16,000 or about \$16.50 per acre

(Manhattan District Engineers, 1948). There was no more mining on the lease once it was acquired by UMDC.

URANIUM-VANADIUM MINING

The U.S. Atomic Energy Commission was established by the Atomic Energy Act of August 1, 1946, in recognition of a need to provide for a civilian Government agency which could assure the continued development of atomic energy for military purposes and also promote the research and development necessary to the utilization of atomic energy for peaceful applications.

During World War II, the Manhattan Engineer District, under the Army Corps of Engineers, had been charged with the development of atomic weapons. Its activities included research and development, engineering and design, the operation of production facilities for weapons materials and components, and the acquisition of uranium for the production of nuclear weapons.

All of these MED functions, and the numerous Government-owned facilities in which many of them were being performed, were transferred to the AEC by Executive Order 9816, effective at midnight, December 31, 1946. An Office of New York Directed Operations was established by the AEC on June 9, 1947, and that office supervised the procuring and processing of uranium until the AEC's Division of Raw Materials was formed in October 1947 to direct those activities from the AEC's Headquarters office in Washington, D.C.

On the Colorado Plateau, the AEC began a procurement program for uranium concentrate. The first domestic contract was signed with VCA on August 28, 1947, effective May 20, 1947, to purchase uranium concentrates from the company's Naturita, Colorado mill. The AEC also contracted with VCA, effective October 8, 1948, to buy concentrates from the AEC owned mill at Durango, which VCA had leased with an option to buy (Albrethsen and McGinley, 1982).

Since a market had developed, VCA began reopening their inactive mines in the Carrizo Mountains which had previously been mined for vanadium. Since VCA was mining in the area, the AEC asked VCA if they were interested in exploring and mining on the 12 plots of the Curran Brothers and Wade lease. On February 17, 1949, effective October 8, 1948, VCA entered into contract AT (49-I)-305 with the AEC to mine the plots covered by lease I-149-IND-6197. This lease was officially transferred from Union Mines Development Corp. to the "United States of America", effective February 28, 1949 (unpublished document in the AEC files).

VCA began mining of Plot 7 in December 1948 with the ore being shipped to the company's mill in Durango, Colorado. Beginning in 1950, VCA began to use Navajo contractors to mine on Cove Mesa (Table 2). In their contract with the AEC ores mined by Navajo contractors were not subject to an AEC royalty. Leroy Pettigrew mined the longest time, shipping ore in 1951-1957 (Table 2). Plate 2 in Garcia (1952) shows that by September 1951, VCA had 27 mine openings on the rim of Plot 7.

Since there were mineralized exposures on both the west and east rims of Core Mesa (Figure 2), the AEC decided to drill on the mesa. Between March 1951 and November 1953, the AEC carried out four drilling projects on the mesa. Considerable ore was found on Plot 7 which VCA would later mine. A summary of the drilling projects is given in the appendix.

VCA continued to mine and ship ore to Durango up to July 1958, when their contract to operate on Lease No. I-149-IND-6197 expired on June 30, 1958.

Besides a large amount of ore from Plot 7, VCA also produced from Plots 1, 4 and E.

Plot	Tons of Ore	% U ₃ O ₈	% V ₂ O ₃
1	1,481	0.26	1.93
4	112	0.18	1.71
E	753	0.08	1.78

(Unpublished AEC document)

On July 1, 1958, a new contract, AT (05-1) 756, went into affect, but covered only Plot 7 on Cove Mesa. Due to lack of recent production, the other 11 plots were returned to the Navajo Tribe.

VCA continued to mine on Plot 7 until June 30, 1961 when the AEC cancelled its lease with the Navajo Tribe. Total ore production from Plot 7 was 30,732.20 tons of ore that averaged 0.23 percent U₃O₈ and 1.62 percent V₂O₅ (Table 2).

William George's Navajo Tribal Mining Permit

After the AEC cancelled their lease, VCA had William George, a mine foreman, apply for a Navajo Tribal Mining Permit covering the former Plot 7. Mining Permit No. 558 was issued to Mr. George on July 31, 1961. The assignment to VCA was approved on August 21, 1961. The permit was for the same 246.2 acres as Plot 7.

VCA continued to mine on the former Plot 7 until early 1965. In March 1963, VCA acquired the mill in Shiprock, New Mexico from Kerr-McGee Oil Industries, Inc. This made the haulage distance to a mill much shorter. Total production from Mining Permit No. 558 was 3,085.23 tons of ore averaging 0.16 percent V₃O₈ and 1.47 percent V₂O₅ (Table 3).

Cato Sells' Navajo Tribal Mining Permit

On August 15, 1949, Cato Sells, a Navajo businessman from Farmington, New Mexico, was issued an unnumbered Navajo Tribal Mining Permit covering 647.20 acres. This permit included two claims near Oak Springs, a claim each on Mesa 5 and Mesa 6 in the Lukachukai

Mountains, two claims in the Saytah Wash area and a single claim covering the northern one-third of Cove Mesa (Figure 1).

During 1950, Sells shipped 159.55 tons of ore averaging 0.24 percent U_3O_8 and 4.44 percent V_2O_5 from Cove Mesa to the VCA mill in Durango, Colorado. Plate 2 in Garcia (1952) shows that this ore came from the area of UMDC's outcrop S-58 (Figure 2). On August 6, 1952, Sells' mining permit was reissued as No. 56.

In the spring of 1953, Sells resumed mining on his Cove Mesa property (Table 4). This ore was shipped to the AEC ore-buying station at Shiprock, New Mexico.

Mining did not resume until the spring of 1956 and continued until the spring of 1958 (Table 4). Shipments were made to the mill at Shiprock operated by Kerr-McGee Oil Industries, Inc., a mill at Grand Junction, Colorado operated by Climax Uranium Company and the VCA mill at Durango, Colorado. On August 24, 1959, Cato Sells cancelled his mining permit.

On September 26, 1960, Sells was issued Navajo Tribal Mining Permit No. 547. It included 135.27 acres: 62.47 acres of two claims in the Oak Springs area and 72.80 acres of the northern one-third of Cove Mesa. The Cove Mesa acres were assigned to VCA on March 16, 1961. A map in the AEC files indicates that in 1962 Mining Permit 547 was converted to Lease No. 14-20-0603-8249.

VCA commended mining in the summer of 1962 and continued until early 1964 (Table 4). A small shipment in 1962 went to the VCA upgrader at Naturita, Colorado. Shipments in 1963 and 1965 went to the mill in Shiprock, New Mexico now operated by VCA.

Scarborough's map of Cove Mesa (Figure 3) shows that Sells had one large mine and one small mine on the west rim of Cove Mesa and a large and a small mine on the east rim of the mesa. Total production from the Sells portion of Cove Mesa was 2,690.67 tons of ore that averaged 0.15 percent U_3O_8 and 1.69 percent V_2O_5 (Table 4).

Table 5 gives the employment on Cove Mesa during the last years of mining there.

SUMMARY

During the period 1948 through 1965, the mines on Cove Mesa produced 36,508.20 tons of uranium-vanadium ore that averaged 0.22 percent U_3O_8 and 1.61 percent V_2O_5 (Table 6). Considering the size of the mesa, this was the most productive area in the Carrizo Mountains.

Ore delivered to the AEC ore buying station at Shiprock, New Mexico was later processed at the adjacent mill. Material from the Naturita upgrader was processed at the mill in Durango, Colorado. All of the uranium produced at the mills in Durango, Shiprock and at Grand Junction was sold to the AEC. Vanadium was recovered at the mills at Durango and Grand Junction. Vanadium was recovered at Shiprock only after VCA operated the mill (Albrethsen and McGinley, 1982). Vanadium was sold to the steel industry. Excess vanadium at Durango and

Grand Junction was sold to the AEC. The AEC sold vanadium at auctions and later transferred the remainder to the General Services Administration (Albrethsen and McGinley, 1982).

All of the mines on Cove Mesa have been reclaimed by the Navajo Abandoned Mine Lands Reclamation Project.

REFERENCES

- Albrethsen, H., Jr. and McGinley, F.E., 1982. Summary history of domestic uranium procurement under U.S. Atomic Energy Commission contracts, final report: U.S. Department of Energy Report GJBX-220 (82), 162 p.
- Allport, R.H., 1951, 1952, 1953, Report on royalties from vanadium leases and permits, Navajo Indian Reservation: U.S. Geological Survey unpublished report to the Area Director, Navajo Indian Service, Window Rock, Arizona, 11 p., Copies of Cove Mesa pages in Chenoweth's personal files.
- Chenoweth, W.L., 1988, Uranium procurement and geologic investigations of the Manhattan Project in Arizona: Arizona Bureau of Geology and Mineral Technology Open-File Report 88-1, 23 p.
- Chenoweth, W.L., 2011, The geology, leasing and production history of the CB&W-MC and adjacent uranium-vanadium mines, Apache County, Arizona: Arizona Geological Society Contributed Report CR-11-M, 19 p.
- Coleman, A.H., 1943, Description of ore outcrops on Cove Mesa, Apache County, Arizona in Webber, B.N., Field survey of Navajo Indian Reservation, Carrizo Uplift and Chuska Mountains area, Arizona: U.S. Army Manhattan Engineer District Raw Materials Operation Report RMO-480 6 p. (Open-filed by AEC, 1960).
- Blagbrough, J.W., Chenoweth, W.L. and Clinton, N.J., 1959, Diamond and wagon drilling on Cove and East Mesas, Apache County, Arizona: U.S. Atomic Energy Commission Raw Materials Exploration Report RME-127, 21 p. (Open-filed, 1973).
- Brown, J. F., 1956, Final drilling report, Cove Mesa area, Apache County, Arizona, Contract Nos. AT(05-1)-120, AT(30-1)-1364, AT(05-1)-231: U.S. Atomic Energy Commission Technical Memorandum TM-109, 11 p. (Open-filed, 1979).
- DeVoto, R.H., and Huber, G.C., 1982, Geology and mineral leasing and mining of the Navajo Indian Reservation 1920-1946: Canyon Resources Corporation, 188 p., (prepared for U.S. Department of Justice). National Archives Record Group 434-99-200.
- Garcia, R. J., 1952, Non-core dig hole drilling at Cove Mesa, Arizona: U.S. Atomic Energy Commission Raw Materials Operation Report RMO-819, Technical Information Service, Oak Ridge, TN, 22 p. 2 plates, (Declassified, 1982).
- General Services Administration, 1981, Navajo vanadium narrative, in, Accounting report on Navajo property, copper, missions, National Monuments, rights of way, sand, rock, gravel, and vanadium, Dockets 69,299,353, volume 1: General Services Administration, Indian Trust Accounting Division Report, p. 45-65, appendix 67 p., exhibits 19-54, National Archives Record Group 434-99-200.

Harshbarger, J.W., 1946, Supplemental and summary report on the western Carrizo uplift and Chuska Mountains areas of the northern Navajo Indian Reservation, northeastern Arizona: U.S. Army Manhattan Engineer District Raw Materials Operations Report RMO-441, 108p., 49 figs., 10 maps, (Open-filed by AEC 1960).

Manhattan District Engineers, 1948, Manhattan District history, book VII, volume 2, geographic exploration: U.S. Army Corps of Engineers Report, 43 p., (Declassified by the AEC 1961).

Scarborough, R.B., 1981, Radioactive occurrences and uranium production in Arizona: Arizona Bureau of Geology and Mineral Technology Open-File Report 81-1, 297 p.

Stokes, W.L., 1953, Primary sedimentary trend indicators as applied to ore finding in the Carrizo Mountains, Arizona and New Mexico: U.S. Atomic Energy Commission Raw Materials Exploration Report RME-3043 (pt. 1), Technical Information Service, Oak Ridge, TN, 48 p.

U.S. Department of Energy, 1997, Tabulation of uranium ore production under AEC program, 1948-1970, 781 p., National Archives Record Group 434-00-287.

U.S. Geological Survey, 1982, Kinusta Mesa quadrangle, Arizona, 7½ minute series (topographic), provisional, scale 1:24,000.

APPENDIX

Summary of AEC Drilling Projects on Cove Mesa

Cove Mesa No. 1

Contract No.: AT(05-1)-155
Contractor: Minerals Engineering Co.
Dates: March 8-August 1, 1951
Type of Drilling: Percussion air drills
Total Footage: 40,974
No. of Holes: 586
Spacing: 256 holes on a 250 ft grid over the entire mesa
370 holes in offsets to ore and mineralized holes
Results: 42 ore holes, 159 mineralized holes, 390 barren holes

Cove Mesa No. 2

Contract No.: AT(05-1)-120
Contractor: Minerals Engineering Co.
Dates: March 30-May 11, 1952
Types of Drilling: Diamond core drill
Total Footage: 2,596
No. of Holes: 23
Spacing: Wide spaced holes for structural data
Results: All barren

Cove Mesa No. 3

Contract No.: AT(30-1)-1364
Contractor: Minerals Engineering Co.
Dates: October 20-December 7, 1952
Type of Drilling: Diamond core drills
Total Footage: 12,712 ft cores
No of Holes: 198
Spacing: Some for stratigraphic information. Others as offsets to ore and mineralized holes of Projects 1 and 2.
Results: 30 ore holes, 13 mineralized holes, 155 barren holes

Cover Mesa No. 4

Contract No.: AT(05-1)-231
Contractor: Oliver Brothers Drilling Co.
Dates: May 12-November 4, 1953
Type of Drilling: Percussion air drill
Total Footage: 39,209
No. of Holes: 626

Spacing: Offsets on 100 and 50 ft centers to areas of ore and mineralized holes of Project 3. Favorable areas from sedimentary trends and 50 ft offsets to ore holes.

Results: 155 ore holes, 81 mineralized holes, 390 barren holes

An ore hole equals 1 ft of 0.10% U_3O_8 or better.

Source: Garcia (1952), Brown (1956), Blagbrough and others (1959).

Table 1. Location, mine name, and size of Plots, Lease I-149-IND-6197.

Number	Mine Name*	Acres	Location
1	Martin	20.2	Saytah Wash, west rim
2	North Martin	14.4	Saytah Wash, west rim
3		2.2	Saytah Wash, east rim
4	Saytah Canyon	10.4	South Saytah Canyon, north rim
5	CB & W Main Claim	5.7	South Saytah Canyon, south rim
6	Eurida	20.6	Eurida Mesa
7	Cove Mesa	246.2	Cove Mesa, southern 3/4ths
A		16.0	South Saytah Canyon, north rim
B		17.3	Segi Ho Cho Mesa, north point
C		39.9	Segi Ho Cho Mesa, southwest point
D		37.8	Segi Ho Cho Mesa, southwest point
E	Tree Mesa	<u>529.0</u>	Kinusta Mesa, eastern end
TOTAL		959.7	

* No mines were developed on Plots 3, A,B,C,D. Plot 6 was mined on an earlier lease.

Source: Unpublished document, AEC files, Grand Junction, Colorado office

Table 2. Uranium-vanadium ore production, Plot 7, Lease I-149-IND-6197, Cove Mesa, Apache County, Arizona.

Year	Operator	Tons of Ore	Pounds U ₃ O ₈	% U ₃ O ₈	Pounds V ₂ O ₅	% V ₂ O ₅
1948	VCA	10.34	37.00	0.18	341.00	1.65
1949	VCA	3,069.80	9,141.00	0.15	109,201.00	1.78
1950	VCA	549.12	2,581.00	0.24	26,545.00	2.42
1950	John Woodrow	93.57	406.19	0.22	1,222.00	0.65
1951	Harvey Young	73.78	485.07	0.33	3,042.00	2.06
1951	Leroy Pettigrew	96.36	434.71	0.23	3,383.00	1.76
1952	Leroy Pettigrew	296.23	1,593.56	0.27	10,032.00	1.69
1952	John Woodrow	59.21	217.93	0.18	2,969.00	2.51
1952	Harvey Young	174.64	785.35	0.22	6,350.00	1.82
1953	Leroy Pettigrew	1,242.25	7,906.32	0.32	45,382.00	1.83
1954	VCA	955.06	4,296.12	0.22	35,565.00	1.86
1954	Leroy Pettigrew	1,782.77	12,851.00	0.36	57,892.00	1.62
1955	VCA	1,369.33	8,330.94	0.30	59,788.00	2.18
1955	Leroy Pettigrew	536.96	3,286.99	0.29	18,946.00	1.68
1956	VCA	5,399.80	22,774.65	0.21	189,807.00	1.76
1956	Leroy Pettigrew	521.67	2,141.36	0.21	15,244.00	1.46
1957	VCA	4,174.91	16,245.96	0.19	116,514.00	1.40
1957	Leroy Pettigrew	49.19	232.67	0.24	2,077.00	2.11
1958	VCA	3,492.47	15,031.76	0.22	90,286.00	1.29
1959	VCA	3,308.45	16,910.63	0.26	90,124.00	1.36
1959	Wm. Wittmeyer	323.72	1,606.85	0.25	10,719.00	1.66
1960	Wm. Wittmeyer	622.96	3,115.54	0.23	21,742.00	1.64
1960	C.H. Covey, Jr.	1,767.26	7,614.07	0.22	59,464.00	1.68
1961	C.H. Covey, Jr.	641.27	2,654.25	0.21	19,248.00	1.50
1961	W.E. Gripe	<u>54.08</u>	<u>204.93</u>	<u>0.19</u>	<u>1,581.00</u>	<u>1.46</u>
TOTAL		30,732.20	140,885.85	0.23	997,464.00	1.62

Source: Unpublished ore production records, AEC files, Grand Junction, Colorado office.

**Table 3.
Permit.**

Uranium-vanadium ore production from William George's Mining

Year	Tons of Ore	Pounds U ₃ O ₈	% U ₃ O ₈	Pounds V ₂ O ₅	% V ₂ O ₅
1961	234.03	970.73	0.21	5,460.00	1.17
1962	431.11	1,384.31	0.16	15,728.00	1.82
1963	1,128.52	3,960.37	0.18	37,139.00	1.65
1964	1,275.05	3,742.89	0.15	32,247.00	1.26
1965	<u>16.52</u>	<u>24.13</u>	<u>0.07</u>	<u>400.00</u>	<u>1.21</u>
TOTAL	3,085.23	10,082.43	0.16	90,974.00	1.47

Operator: VCA

Source: Unpublished ore production records, AEC files, Grand Junction, Colorado office.

Table 4. Uranium-vanadium ore production from Cato Sells' Mining Permit.

Year	Tons of Ore	Pounds U ₃ O ₈	% U ₃ O ₈	Pounds V ₂ O ₅	% V ₂ O ₅
1950	159.55	918.38	0.29	14,179.00	4.44
1953	68.88	231.03	0.17	2,281.90	1.66
1956	305.27	933.57	0.15	8,430.68	1.38
1957	1,652.36	4,501.98	0.14	52,803.61	1.60
1958	94.33	273.29	0.14	2,008.27	1.06
1962	49.59	149.05	0.15	1,606.00	1.62
1963	110.07	226.55	0.10	3,048.00	1.38
1964	<u>250.62</u>	<u>838.20</u>	<u>0.17</u>	<u>6,385.00</u>	<u>1.27</u>
TOTAL	2,690.67	8,072.05	0.25	90,742.46	1.69

Operators: 1950-1958 Cato Sells
 1962-1964 VCA

Source: Unpublished ore production records, AEC files, Grand Junction, Colorado office.

Table 5. Employment on Cove Mesa 1958-1964.

Year	No. of Inspections	First Inspection		Last Inspection	
		No. of Men Surface	No. of Men Underground	No. of Men Surface	No. of Men Underground
1955	2	3	7	3	7
1956	2	3	7	3	8
1957	0				
1958	3	6	6	3	10
1959	2	1	4	1	6
1960	2	2	6	2	9
1961	3	1	6	1	3
1962	2	1	4	1	3
1963	2	2	8	1	5
1963*	1	0	2		
1964	3	5	1	1	4
1965	0				

All on AEC Lease/William George's Mining Permit except as noted.

*Cato Sells Mining Permit.

Source: Compiled from the annual reports of the Arizona Mine Inspector.

Table 6. Uranium-vanadium ore production from Cove Mesa.

Area	Tons of Ore	Pounds U ₃ O ₈	% U ₃ O ₈	Pounds V ₂ O ₅	% V ₂ O ₅
AEC Lease	30,732.20	140,885.85	0.23	997,464.00	1.62
Wm. George MP	3,085.23	10,082.42	0.16	90,974.00	1.47
Cato Sells MP	<u>2,690.77</u>	<u>8,072.05</u>	<u>0.15</u>	<u>90,742.46</u>	<u>1.69</u>
TOTAL	36,508.20	159,040.32	0.22	1,179,180.46	1.61

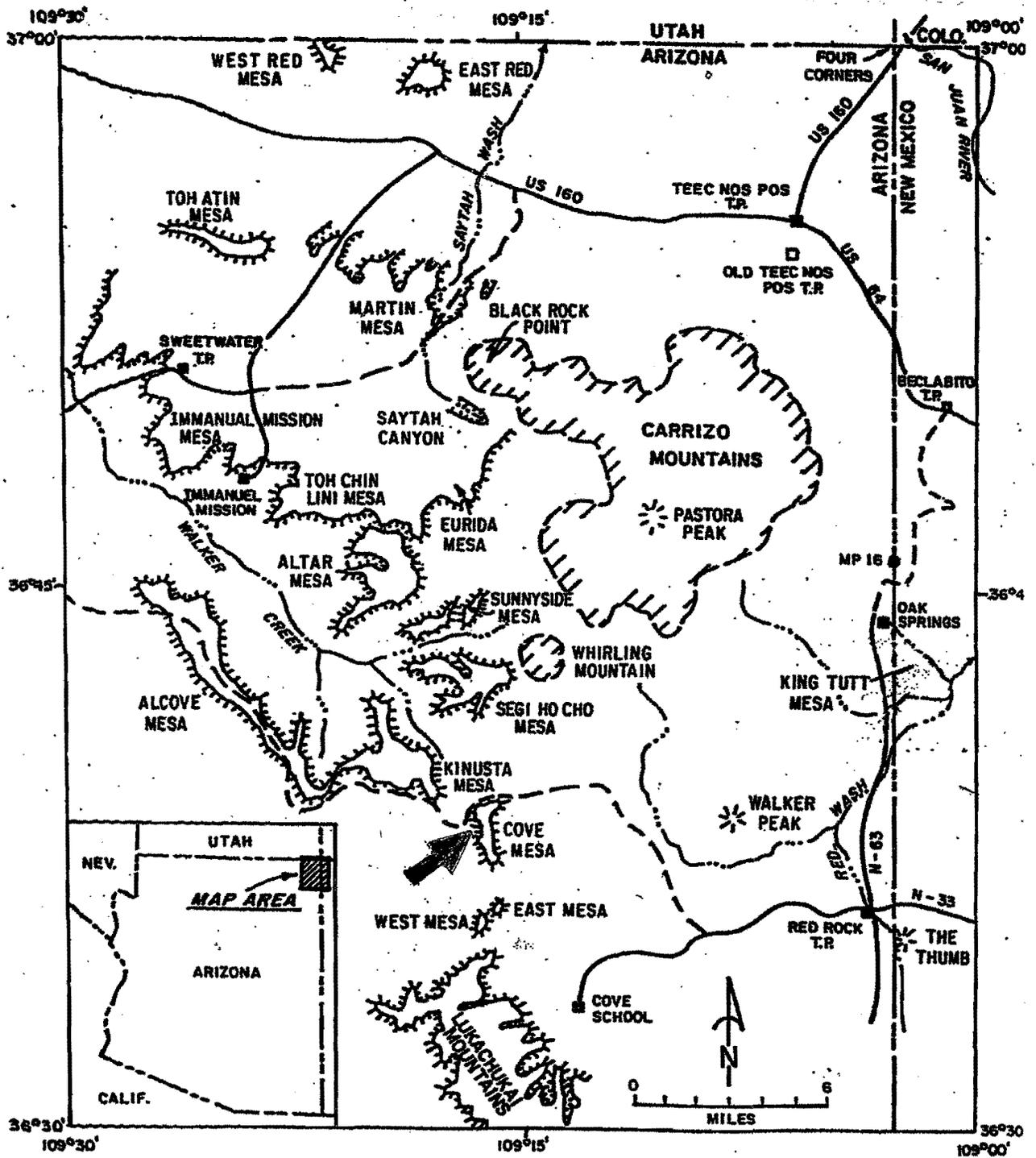


Figure 1. Index map of the Carrizo Mountains, Apache County, Arizona and San Juan County, New Mexico showing the location of Cove Mesa.

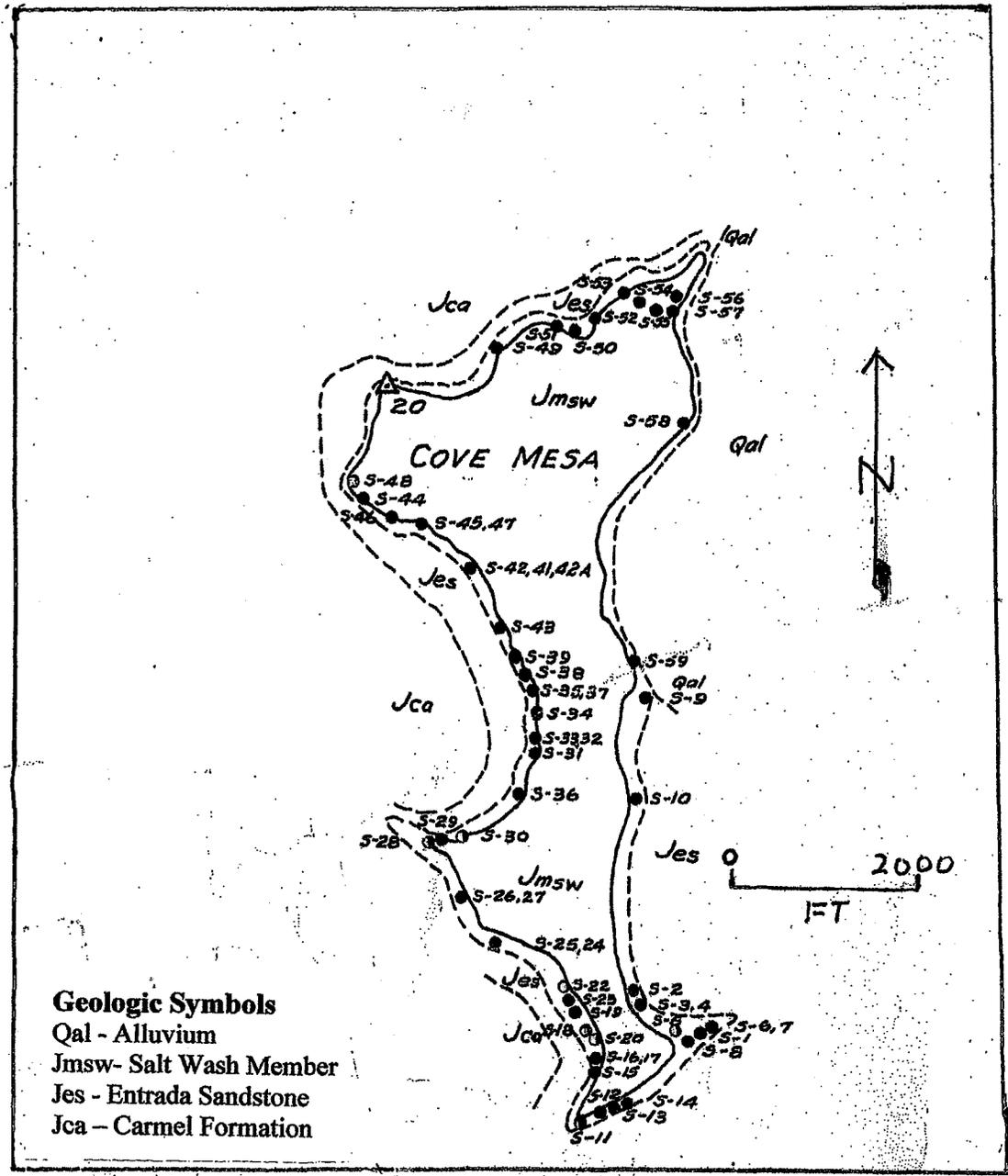


Figure 2. Map of Cove Mesa showing the mineralized outcrops located and described by Coleman (1943). From Harshbarger (1946, map CM-23). Note: Union Mines Entrada Sandstone includes the Bluff Ss., Wanakah Fm. And Entrada Ss. of the current nomenclature.

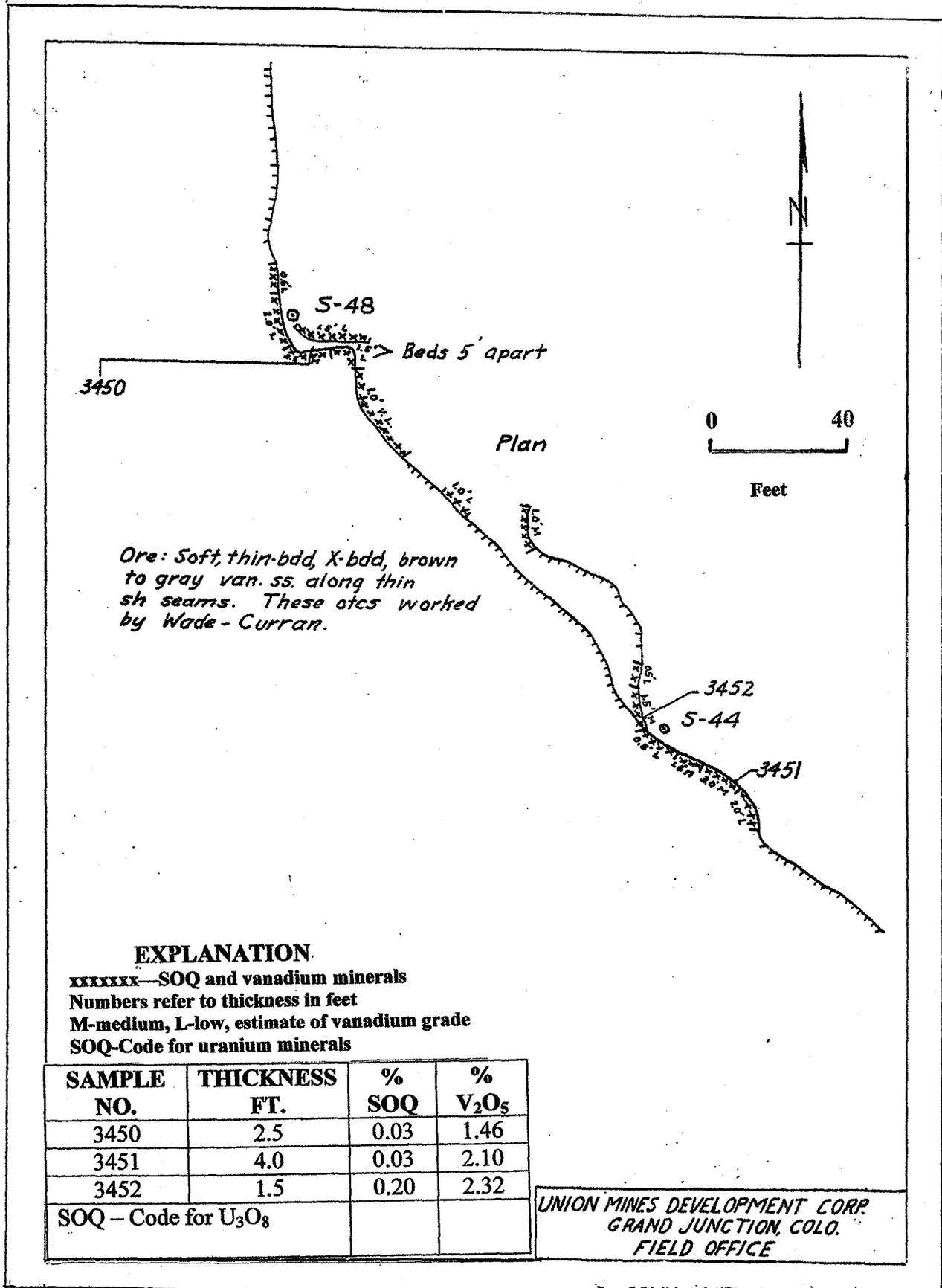


Figure 3. Union Mines map of mineralized outcrops nos. S-44 and S-48. From Harshbarger (1946, figure 4)

Explanation for Figures 4 and 5

Both figures are from Scarborough (1981)

The outlines of the mine workings are from a map the Foote Mineral Company, successor to VCA, gave the Arizona Bureau of Geology and Mineral Technology. The sedimentary trends are from Stokes (1953) and the structural contours are from Blagbrough and others (1959).

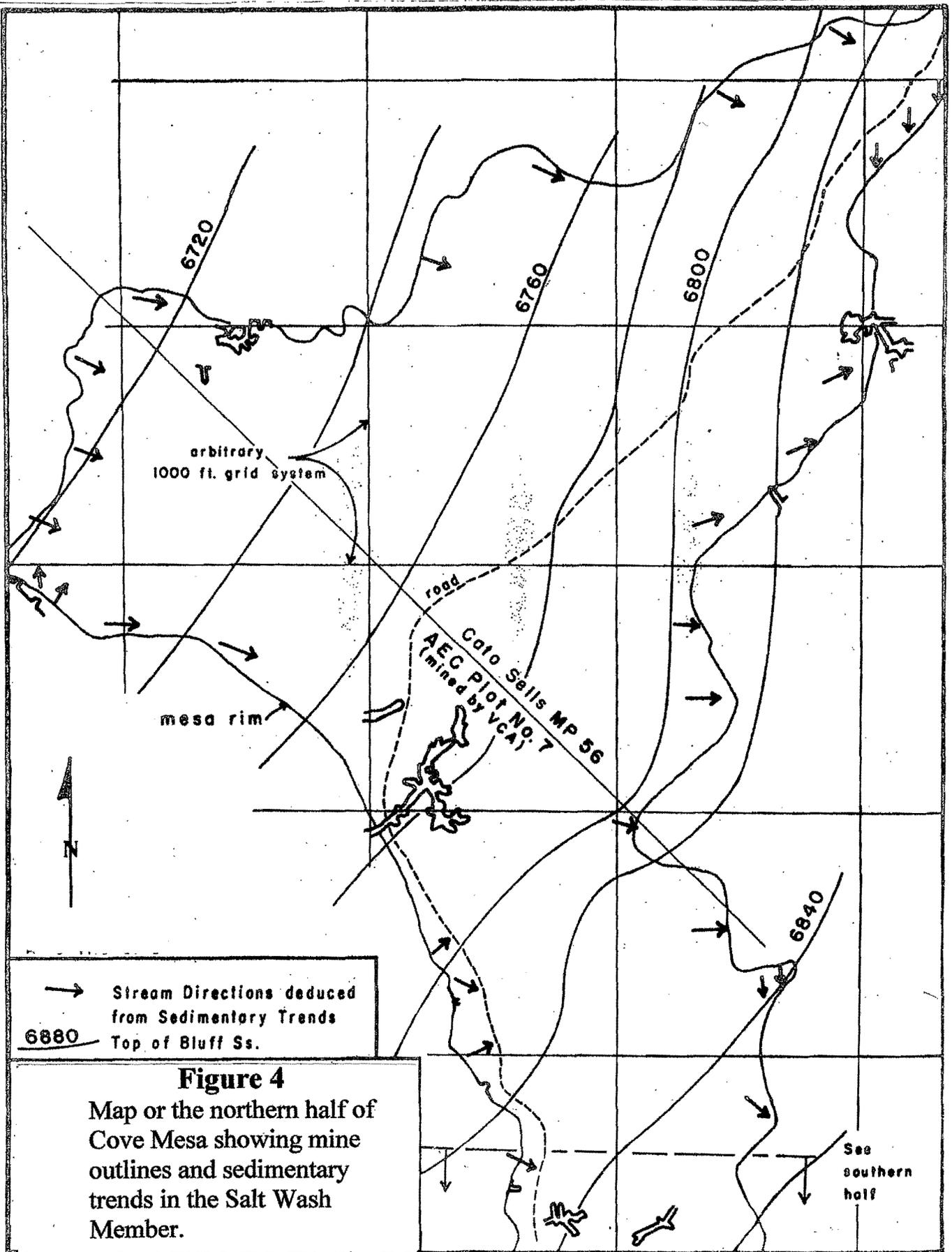


Figure 4
 Map of the northern half of
 Cove Mesa showing mine
 outlines and sedimentary
 trends in the Salt Wash
 Member.

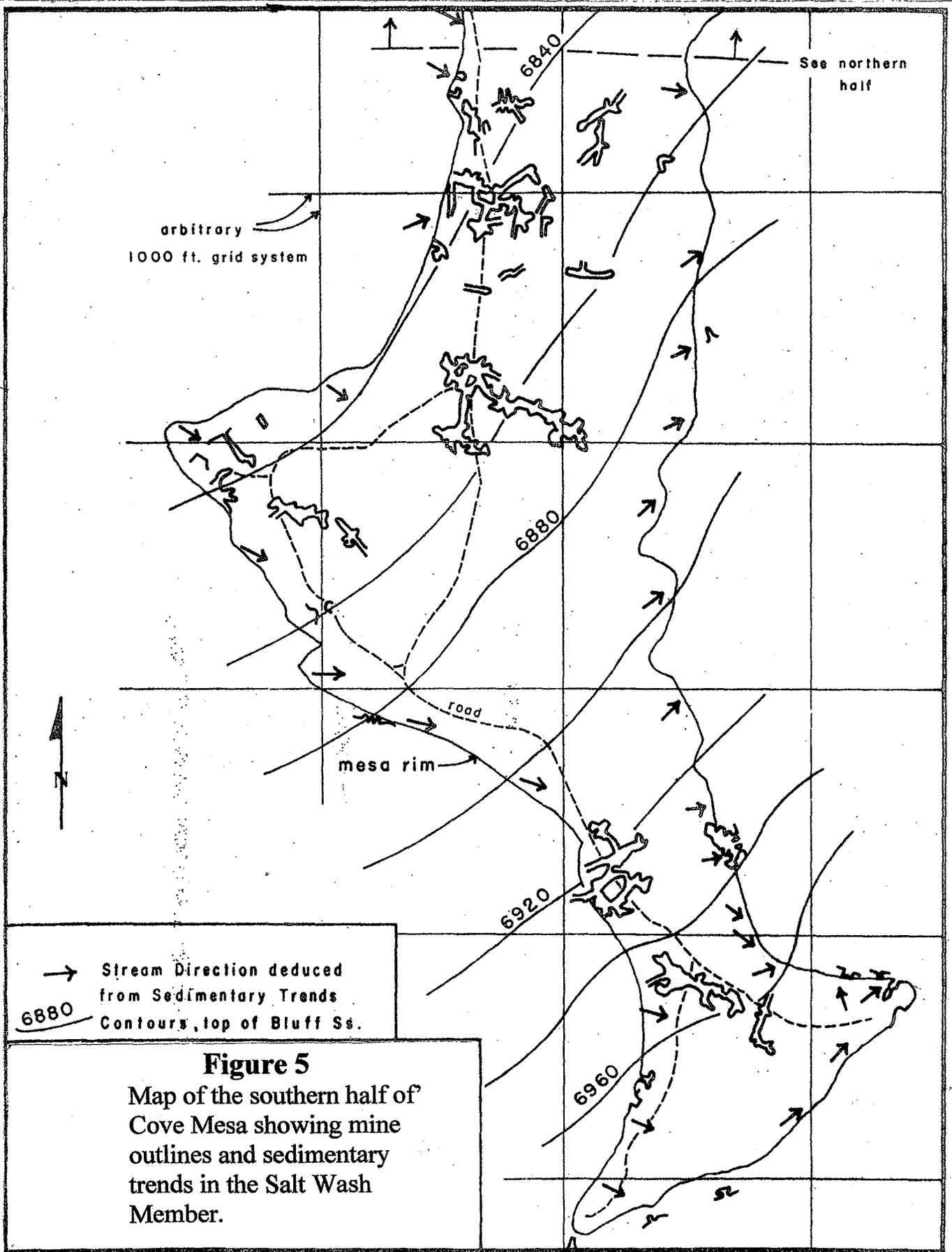




Figure 6. Photograph of rim cut at Union Mines outcrop S-58, northeast Cove Mesa, circa 1952. Note vanadium minerals in left center. From AEC files.

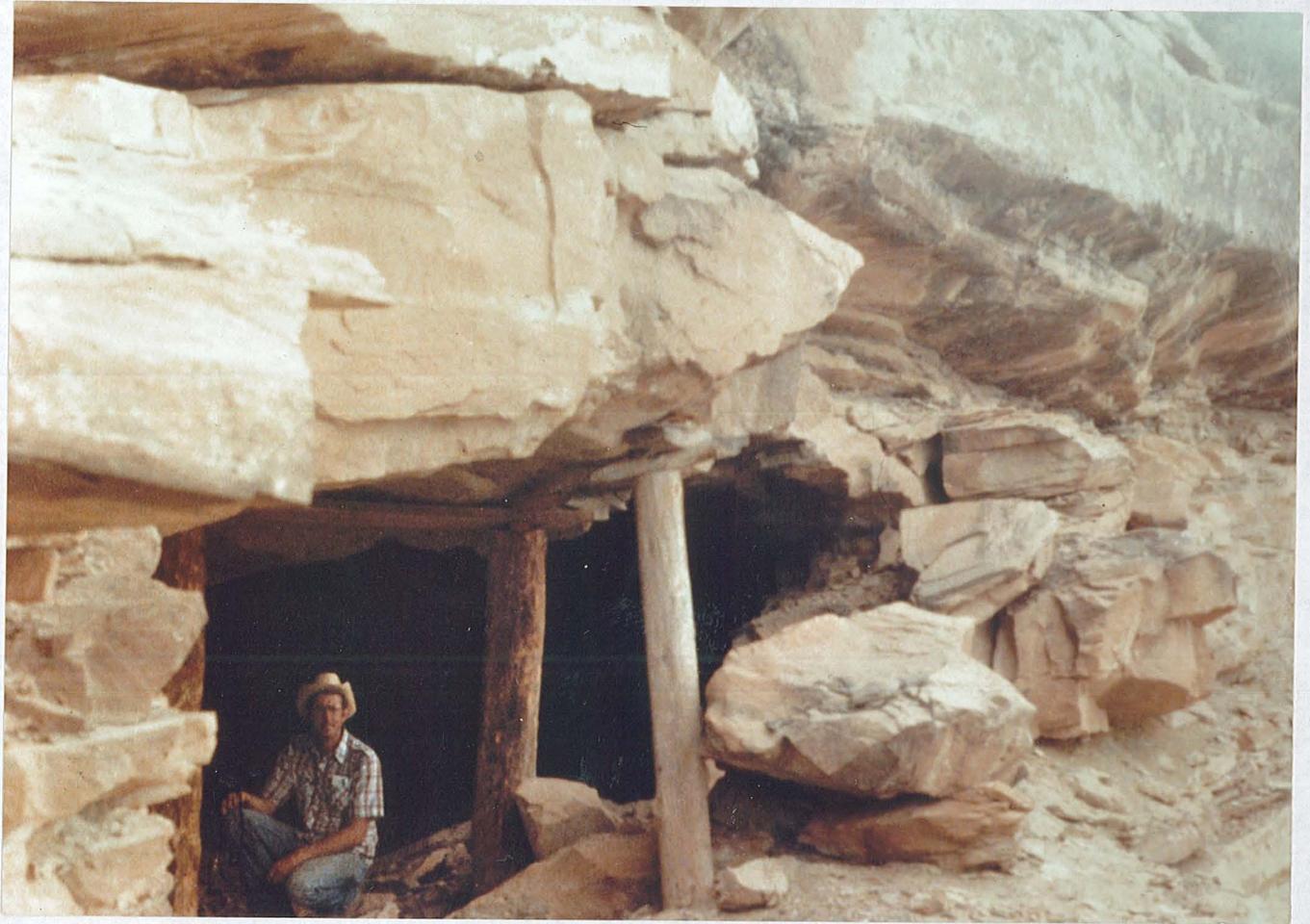


Figure 7. Bob Scarborough, Bureau of Geology and Mineral Technology geologist at the portal of an abandoned uranium-vanadium Cove Mesa, Arizona. Photo by Chenoweth, June 1980.