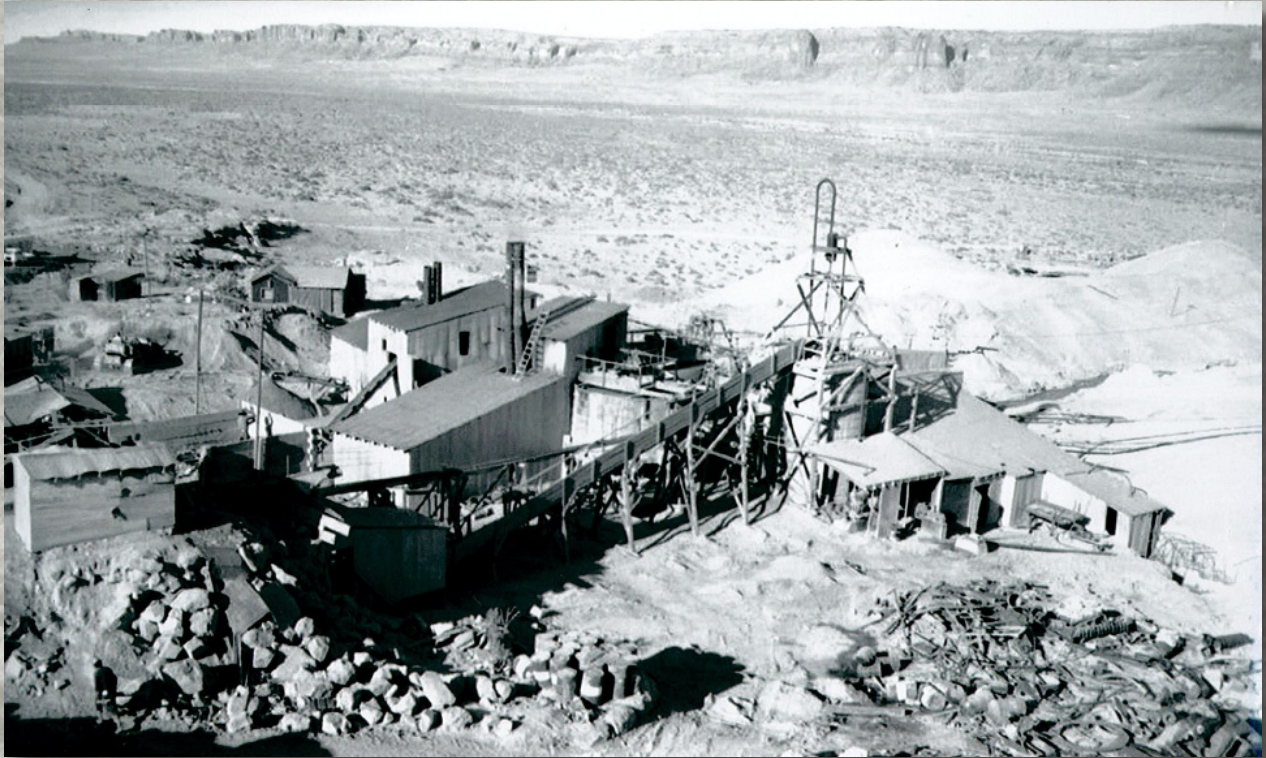


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Upgrader Plant at Monument No. 2 Site, Apache County, Arizona

**THE URANIUM-VANADIUM PRODUCTION HISTORY
OF THE MONUMENT NO. 2 SITE
MONUMENT VALLEY, APACHE COUNTY, ARIZONA**

October 2011

William L. Chenoweth

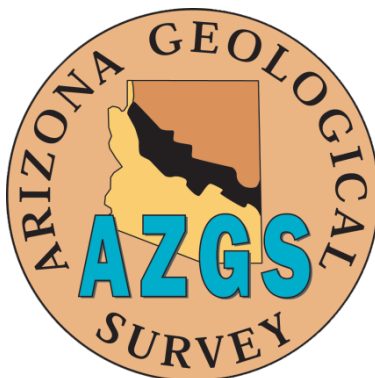
ARIZONA GEOLOGICAL SURVEY

Arizona Geological Survey Contributed Report CR-11-P

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INTRODUCTION

The Monument No. 2 site consisted of a large open-pit mine, an upgrader, a concentrator and a heap leaching operation. Ore from the mine as well as products from other operations were shipped to mills for further processing and are included in the production totals.

Unpublished records of the U.S. Atomic Energy Commission (AEC) indicate the Monument No. 2 site produced more uranium during its procurement program (1947-1970) than any other mine in the State of Arizona. Production tonnage in published records ranged from 773,132 tons in Gregg and Evensen (1989) to 766,998 tons in Scarborough (1981). The purpose of this report is to give a summary of the production history of the site and to present what is believed to be the correct total as the result of researching existing records.

Location

The Monument No. 2 area is located in the extreme northwestern corner of Apache County, Arizona (Figure 1). The site is in Cane Valley on the eastern flank of the Monument Uplift. The original access to the mine was via a 19-mile dirt road that headed south from the Mexican Hat–Kayenta Indian Service road (now U.S. Highway 163) one mile southwest of Mexican Hat, Utah. Another access road went from the mine, over Comb Ridge and connected with the Shiprock–Kayenta Indian Service road (now U.S. Highway 160) near Mexican Water, Arizona. Both these access roads were improved with AEC funding beginning in 1952 (Chenoweth, 1989).

The Monument No. 2 open pit is shown at the center of the right margin of the Rooster Rock topographic quadrangle (USGS, 1988a). The tailings pile from the upgrader is shown on the adjacent Garnet Ridge quadrangle (USGS, 1988b).

Land Status

The Monument No. 2 site is located on the Navajo Indian Reservation. It was acquired as the result of a lease sale held by the Office of Indian Affairs, U.S. Department of the Interior. The lease was for 10 years and could be extended by having ore production. The Navajo Tribe received a 10 percent royalty on the value of the ore.

About 1950, the Tribal Council issued a series of new regulations that would allow individual Navajos to stake claims (Mining Permits). Only Navajos could be issued Mining Permits. Navajos could assign a permit to an individual or company to explore and mine on the permit. Permits and assignments had to be approved by the Tribal Council and the Bureau of Indian Affairs. Both the permittees and the Tribe received a royalty from ore production.

As the result of these new regulations, several individual Navajos were issued Mining Permits contiguous with or adjacent to the Monument No. 2 lease (Figure 2). The author has prepared three reports on the exploration and production history of the mines on these Mining Permits (Chenoweth, 2011, a,b,c).

Previous Studies

The geology and mineralogy of the Monument No. 2 area have been described by Witkind and Thaden (1963). The mining and upgrading of the ore at the Monument No. 2 mine is given in a guidebook on uranium deposits of the western United States (AEC, 1959). Gregg and Evensen (1989) mapped the underground workings of the Monument No. 2 and described the early mining history of the area.

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 uranium and vanadium production given in Table 2 was compiled from three sources: 1) DOE (1997) report in the National Archives, Rocky Mountain Region, Denver, Colorado; 2) AEC (1953) report; and 3) U.S. Geological Survey document (Allport, 1948) in the author's personal files.

GEOLOGIC SETTING

The Monument No. 2 ore deposit is in the basal Shinarump Member of the Triassic Chinle Formation. The Shinarump here is unusually thick, filling a large and deep erosional depression in the underlying Moenkopi Formation and, at the deepest point, extending down through the Moenkopi to the Permian De Chelly Sandstone. The "paleochannel" or "scour", apparently with closed ends, extends at least 2 miles along the axis of a wider depression. The wider depression is about 3 miles wide and 50 feet deep; the narrower, inner scour is about 30 feet deeper and about 700 feet wide.

The host rock is "trashy", cross-bedded, conglomeratic sandstone, containing considerable clay and fossil wood. The wood is partly carbonized, but much has been replaced by silica, tyuyamunite, limonite or uraninite.

Generally the ore minerals fill interstices in the sandstone, and coat pebbles and fractures, but the richest concentrations are in elongate, horizontal, flattened cylindrical "rods", up to 8 feet in diameter and in places more than 100 feet long. Rims of the rods are cemented with limonite around an inner rim of sandstone impregnated with tyuyamunite; the sandstone core generally appears structureless, or much less distinctly cross-bedded than the enclosing sandstone. The rods are aligned approximately parallel to the N18°W trend of the scour.

Ore occurs at various horizons in the Shinarump, and also extends as much as 7 feet down into the De Chelly Sandstone where this unit is in contact with the Shinarump. The original exposures on both the north and south sides of the Main Ridge gave but slight indication of the large amount of uranium-vanadium ore contained in the channel.

The principal ore minerals are tyuyamunite and carnotite; others include the oxides montroseite, uraninite, navajoite and the hydrous oxides becquerelite and fourmarieite; the vanadates rauvite, volborthite, steigerite, hewettite and corvusite; the silicate uranophane; the phosphate torbernite;

and the arsenate metazeunerite. For additional details on the ore occurrences and mineralogy the reader is referred to a report by Witkind and Thaden (1963).

THE VANADIUM MARKET

Due to the uncertainty of foreign supplies and the need for vanadium for war armaments, the federal government formed the Metals Reserve Company in 1942. The company began an ore-purchasing program and increased the base price paid for vanadium ore. At Monticello, Utah, the Defense Plant Corporation, a government agency, funded the construction of a vanadium plant to be operated by the Vanadium Corporation of America (VCA). Actual construction started in February, and on August 24, 1942, the first vanadium was produced. In April 1942, while construction was under way, the Metals Reserve Company (MRC) established an ore-buying station at Monticello and appointed the United States Vanadium Corporation (USV) as its buying agent. The purchased ores were processed at the mill, operated by VCA for the MRC.

The Metals Reserve's program was the stimulus to commence vanadium mining in the Four Corners area. However, the Metals Reserve program was short-lived as the Monticello plant closed in February 1944.

In 1945, VCA leased the Monticello mill from the Defense Plant Corporation and purchased the remaining ore stockpiles from Metals Reserve. VCA processed the stockpiled ore, plus ore from other sources, until the mill closed again in 1946. At the Monticello mill, uranium was secretly recovered from the carnotite ore for the Manhattan Engineer District (Chenoweth, 1997).

VCA'S MONUMENT NO. 2 LEASE

Lease Sale

Luke Yazzie discovered carnotite mineralization southeast of Yazzie Mesa in the eastern part of Monument Valley in 1942. He told Harry Goulding, a local trader of this discovery, and he in turn contacted VCA. As news of this discovery spread, other firms and individuals examined the area (Witkind and Thaden, 1963, p. 68-69).

As the result of interest in the area, the Office of Indian Affairs advertised an exploration lease sale for carnotite and related minerals on July 21, 1943. The area in Apache County, Arizona, was described as follows: "beginning at a point south 32°28' east, 28,949.78 feet from mile post 227 on the Utah-Arizona line and running thence north 25°00' east one mile; thence east one and one quarter miles; thence south 25°00' west one mile; thence south one and one quarter miles; then west one and one quarter miles; thence north one and one quarter miles to the point of beginning, containing approximately 1,845 acres."

Bids were opened on August 3, 1943 with the only bidder being VCA, with a bonus bid of \$3,000.00 (GSA, 1981, exhibit 43). At the same time as the Monument Valley lease sale, another sale was being held for some 168 square miles in the northern and western Carrizo Mountains. Vanadium companies such as Wade, Curran and Company and U.S. Vanadium Corporation

(USV) apparently were more interested in the carnotite deposits in the Morrison Formation of the Carrizo Mountains than in the deposits in the Shinarump Conglomerate in Monument Valley.

Lease I-149-IND-6204 with VCA was executed on August 6, 1943, effective September 23, 1943, for a period of 10 years. The lease was named Monument No. 2 by VCA.

On March 6, 1944, the exploration lease was reduced to a permanent operating lease with two plots (claims) totaling 42.09 acres selected to be retained. Plot 1, about 39 acres, covered the mineralized Shinarump channel across the Main Ridge, and Plot 2, about 3 acres, covered the projection of the channel on South Ridge (Figure 2).

Vanadium Mining

Ore shipments to Metal Reserve at Monticello, Utah, began in October 1943 and continued until April 1944. Later shipments were recorded in February and December 1945 and in January 1946, at which time VCA operated the Monticello mill. Details of the vanadium production are given in Table 1.

During the interval of the 28 months the mine was active, a total of 489.17 tons of ore containing 13,736.83 pounds V_2O_5 was mined from mineralized outcrops on the lease. The value of the ore was listed at \$6,574.85, of which the Navajo Tribe received \$646.83 in royalties (GSA, 1981, p. 49).

Uranium-Vanadium Mining

Mining at the Monument No. 2 lease resumed in October 1947 under the AEC's uranium procurement program. The ore was originally trucked to the company's mill at Naturita, Colorado, a distance of about 175 miles. Some shipments were made to the AEC ore-buying mill at Monticello, Utah only 87 miles away. Some shipments in 1949 and 1950 were made to the company's mill in Durango, Colorado, a distance of 185 miles.

Prior to 1952, all uranium-vanadium ores mined in Monument Valley were hauled northward, crossing the San Juan River at Mexican Hat, Utah. The small, narrow suspension bridge across the San Juan River could not support large trucks. Ores were hauled from mines in Cane Valley and in central Monument Valley in five-ton trucks to a stockpiling area about a mile north of Mexican Hat. When an individual mine's stockpile reached a few dozen tons, 21-ton semitrailer trucks were used to haul the ores to the AEC ore-buying station at Monticello, Utah or to mills in Colorado.

These stockpiles, especially the large Monument No. 2 one, are believed by Chenoweth (1994) to have been the source of 94.76 tons of ore averaging 0.23 percent U_3O_8 and 1.99 percent V_2O_5 shipped to the Durango mill in November 1950 through October 1951 by Capitan and Thomas Benally as coming from their Black Mustache mine. By late 1951, all Monument No. 2 ores were shipped to the mill at Durango, Colorado via the Comb Ridge-Shiprock route, a distance of 170 miles.

It is interesting to note that a U.S. Geological Survey examination of the Monument No. 2 mine in April, 1948, reported that low-grade ore from the mine was being mechanically upgraded at a small plant on the bank of the San Juan River at the Mexican Hat bridge (GSA, 1981, exhibit 52). This upgrader no doubt was a prototype for the plant that began operating in 1955 at the mine site. A 1949 shipment of 676.35 tons of ore averaging 0.11 percent U_3O_8 and 0.71 percent V_2O_5 reported to the AEC as the Mexican Hat Stockpile may have been from the cleanup of this plant.

The early underground mining at Monument No. 2 was very selective and VCA was able to maintain a shipping grade of 0.41 percent U_3O_8 and 1.34 percent V_2O_5 through 1953 (Table 2). Eleven separate underground mines were developed on the Main Ridge and a single mine operated on South Ridge (Figure 3).

In late 1953, VCA began stripping the area of the North Workings (Figure 4) and by 1957 the entire Main Ridge was converted to an open-pit mine and, except for a few truckloads per week of shipping grade ore, the mine production ranged in grade from 0.04 to 0.09 percent U_3O_8 and 0.4 to 0.8 percent V_2O_5 . This mine production was too low grade to ship to the Durango mill. Hence, in 1954, VCA constructed a mechanical upgrader at the mine site. Figure 5 is a photograph of the upgrader plant. Details of the operation of the upgrader are given in the Appendix. The upgrader product (ore slimes) was shipped to the Durango mill until it shut down in March, 1963 and then to the Shiprock mill which VCA purchased from Kerr-McGee Oil Industries, Inc.

During a field conference of the Four Corners Geological Society, VCA allowed participants to examine the open pit and collect samples on June 17, 1955. Figure 6 is a photograph taken at this stop on the field conference.

All underground mining ceased in 1957 when the stripping of the open pit was completed (Table 3). Mining in the open pit would continue until June 1964.

In the pit, the sandstone overburden was drilled and blasted, using wagon drill holes 10 feet deep and 4½ feet apart, together with jack hammer holes 4 to 6 feet deep and 3 feet apart. The deeper holes were loaded with 12½ pounds of bag powder per hole, and the shallower ones with 5 to 6 sticks of dynamite; all were exploded simultaneously with black fuse and No. 6 caps. Broken rock was bulldozed into waste piles, and loaded by power shovel or frontend loaders into diesel or gasoline powered trucks which hauled it to waste dumps within or outside the pit or to backfill into mined out parts of the pit.

Ore was drilled, broken and hauled in the same way. Faces of various height were worked at different places, due to the erratic ore occurrence. Ore of 0.20 percent U_3O_8 or better was mixed with selected high grade to maintain a grade of 0.30 percent U_3O_8 for hauling by truck about 170 miles to the company mill at Durango, Colorado via the Comb Ridge road. Low grade ore is stockpiled for processing through the upgrader.

When the author last examined the operating mine on July 17, 1959, there were 59 men employed on the site: 24 drillers, 11 muckers, 5 truck drivers, 1 shovel operator, 5 laborers and 1

foreman. The upgrader was operating with two shifts of a foreman and 5 operators. This number is smaller than what the Arizona mine inspector reported for 1959 (Table 3).

With the approval of the Navajo Tribal Council and the Bureau of Indian Affairs, VCA modified their original lease on July 20, 1959. The lease was amended to include the Mining Permits of adjacent Navajos. Listed below are these Mining Permits (Figure 7).

Yazzie Mesa

Amended Plot A

Chee Nez MP-189

John Yazzie and Thomas Clani MP-288

Main Ridge

Amended Plot B-1

Cato Sells MP-55 Tract No. 2

Amended Plot B-2

Cato Sells MP-55 Tract No. 1 North

Jessie Black and Harvey Blackwater MP-47

South Ridge

Amendment Plot C

Willie Waters MP-188

(formerly Cato Sells MP-55 Tract No. 1 South)

With the addition of these four plots to the lease, the new amended lease totaled 229.69 acres. Any ore mined on the former Mining Permits would be credited to VCA's Monument No. 2 lease. The amended lease would be known as VCA's Mining Unit No. 66 for the AEC's allocation program that began in 1962. Reports in the AEC files indicated that VCA planned to investigate the mines on the four new plots for a source of low grade material for the upgrader.

In March 1963, VCA acquired from Kerr-McGee Oil Industries, Inc. the mill at Shiprock, New Mexico, uranium-vanadium mines in the Lukachukai Mountains and a mine in the Carrizo Mountains, both in Apache County, Arizona. At the same time VCA closed its Durango mill. This reduced the hauling from Monument No. 2 from 170 miles to 98 miles from Monument No. 2.

Prior to the shutdown of the upgrader in July 1964, VCA determined that the upgrader sand tailings still contained sufficient values to warrant retreatment. Hence a second plant or concentrator, termed by VCA the "Upflow Batch Leach Plant", was constructed and commenced operation in October, 1964. It operated for three years and was shut down in November, 1967. The uranium and vanadium product from the concentrator was shipped to the Shiprock mill. Details of the operation of the concentrator are given in the Appendix.

In 1966, VCA began heap leaching low grade ore at its Monument Valley operations. The uranium-vanadium precipitate from heap leaching was also processed in the Shiprock mill. Details of this operation are also given in the Appendix. In the AEC records (Table 2) a separate

shipment in 1967 of 236.13 tons averaging 2.09 percent U_3O_8 and 7.08 percent V_2O_5 was listed as a heap leaching product.

VCA was merged into the Foote Mineral Company in August, 1967 and milling at Monument No. 2 continued until early 1968. The Shiprock mill was closed in April, 1968 as were all Foote mining operations on the Colorado Plateau, including Monument No. 2. In 1969, A.K. Skalla, made a clean-up shipment from the upgrader site to the Western Nuclear, Inc. mill at Jeffery City, Wyoming. It consisted of 83.35 tons that averaged 0.29 percent U_3O_8 and 1.83 percent V_2O_5 (Table 2).

Comparison of Ore Production Totals

Since two different numbers have been published for the uranium produced from the Monument No. 2 site, the objective of this report is to document the correct number. DOE (1997, p. 563-564) lists the year-by-year production by VCA and A.F. Skalla from the Monument No. 2 site. However, the pre 1954 production is shown as a single number. AEC (1953, p. 209-210) gives the annual production for 1948 through June 30, 1953. The small amount of production in 1947 is included with 1948. Allport (1948) tabulated the month-by-month ore production from October 1947 through March 1948. The author believes that Table 2 is the most accurate tabulation possible.

Comparison of Ore Production Numbers					
<u>Source</u>	<u>Tons of Ore</u>	<u>Pounds</u> <u>U_3O_8</u>	<u>% U_3O_8</u>	<u>Pounds</u> <u>V_2O_5</u>	<u>%V_2O_5</u>
Scarborough (1981)	766,998	---	0.34	---	1.42
Gregg & Evenson (1989)	773,132	5,276,093	0.34	21,915,125	1.42
This Report (2011)	748,786	5,139,949	0.34	21,383,178	1.43

It appears that the number Scarborough (1981, p. 122) used came from DOE (1997, p. 564) which included some of Cato Sells and Black and Blackwater's production added to VCA and Skalla's production. The number used by the author in Gregg and Evensen (1989, p. 5) came from an unpublished AEC resource report and was labeled "amended lease". No doubt it included production from the adjacent mining permits.

SUMMARY

The early uranium ore shipments to the AEC ore-buying station at Monticello, Utah were later processed at the Monticello mill operated by an AEC contractor. The uranium recovered at the Monticello, Naturita, Durango and Shiprock mills was purchased by the AEC. During 1967 and 1968 the VCA mill at Shiprock sold 1,390 pounds of uranium oxide to an electric utility (Albrethsen and McGinley, 1982).

Vanadium recovered at the Naturita, Durango and Shiprock mills by VCA was sold to the steel industry. Excess vanadium at the Naturita and Durango mills was purchased by the AEC. The AEC sold some vanadium at auctions and the remainder was transferred to the General Services Administration (Albrethsen and McGinley, 1982).

EPILOGUE

The DOE began remedial action on the ore processing sites in May 1986 under its Uranium Mill Tailings Radiation Control Act of 1978. A total of 1.3 million tons of tailings, structural debris and contaminated soils were transported to a disposal site 17 miles to the north and near Mexican Hat, Utah. The remediation was completed in March 1994.

The open pit and the mines on the amended lease were remediated by the Navajo Abandoned Mine Lands Reclamation Project.

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APPENDIX

Summary of the upgrader, concentrator and heap leaching operations at the Monument No. 2 Site.

During the period of operation of the upgrader, from mid-1955 until June 1964, an estimated 1,100,000 tons of low grade mine production were fed to process. Feed grade ranged from 0.04 to 0.09% U_3O_8 and 0.40 to 0.80% V_2O_5 . The upgrader operated at a feed rate of about 500 tons per day (tpd), although it is reported that at times the total feed rate exceeded 700 tpd. The product, a slime concentrate, contained approximately 10 percent moisture, and assayed 0.25 to 0.30% U_3O_8 and 1.5 to 3.0% V_2O_5 , depending on the millfeed grade. Production was 40 to 50 tons per day and an estimated total of 100,000 tons for the life of the upgrader. Recovery was estimated at about 60 percent of both uranium and vanadium. Truck haulage distance to the Durango mill was 170 to 185 miles depending on the route taken. The Shiprock mill was somewhat closer.

The upgrader consisted of two nearly identical parallel circuits, each operating at a feed rate of about 250 tpd. The flowsheet for the operation was very simple. The run of mine ore was crushed to about one inch and then ground in rod mills to about 10-mesh. The ground pulp was classified in spiral classifiers and the slime fraction was thickened and the sands were pumped to the tailings area. The thickener underflow was further classified with cyclones to reject additional barren sand which was discarded to tailings. The slimes from cyclone treatment were filtered on disc filters and the wet cake was dried in two steps in oil-fired rotary driers. The slime concentrate represented 10 percent of the original feed weight. No chemicals, other than flocculants, were used in the upgrader operation.

The concentrator retreated the accumulated sand tailings from the upgrader operation. It operated from October 1964 until November 1967, and processed approximately one million tons of sand tailings at an average feed rate of about 1,000 tpd. The plant consisted of large lined steel tanks in which sand tailings were placed for leaching by an upward flow of a sulfuric acid solution. When essentially all the values have been extracted, the tank was emptied to tailings. When solutions had been recycled sufficiently to reach the desired uranium and vanadium contents, ammonia was added to neutralize the acid and precipitate the uranium and vanadium. The precipitate was filtered, partially dried, and trucked to the Shiprock mill. No data are available on the tonnage of precipitate nor the U_3O_8 and V_2O_5 contents. One could assume that about 200,000 lbs. U_3O_8 and two million lbs. V_2O_5 were recovered, if the sand tailings feed contained an average of 0.02% U_3O_8 and 0.20% V_2O_5 and that 50 percent of the values were extracted and recovered. The quantity (tonnage) of sand tailings from the concentrator would have been essentially equal to the feed tonnage because so little weight of uranium and vanadium was removed.

The heap leaching started on an experimental basis in 1966 and proved attractive for treating low grade mine dumps. The material was crushed to one inch and placed on polyethylene sheeting with orangeburg pipes for solution collection. Sulfuric acid solution was percolated through the heaps until a concentration of about 1.5 g. U_3O_8 per liter and 7.0 g. V_2O_5 per liter was obtained,

then ammonia was added to precipitate the values. The precipitate was handled in the same manner as that from the concentrator. Heap leaching continued intermittently (winter shutdowns were sometimes required) until late 1967 when all activities ceased. The total quantity of low grade material that was heap leached is not known but has been estimated to be as much as 100,000 tons.

The Monument Valley operations generated an estimated 1,100,000 tons of sand tailings and heap leach residues. The tailings are in two piles about 500 feet apart. One pile covers an area of about 10 acres and is located east of the concentrator or upgrader. It is estimated to contain 165,000 tons with an average depth of 2 to 3 feet. The second pile, covering 20 acres, is 500 feet to the east of the other pile, and is cone shaped and approximately 55 feet high. This pile is estimated to contain 935,000 tons. The heap leach residues are thought to be contained in the smaller pile.

Source: Albrethsen and McGinley (1982 p. A-123-A124).

Table 1. Early vanadium production, Monument No. 2 Lease.

Year	Tons of Ore	Pounds V ₂ O ₅	Percent V ₂ O ₅
1943	94.35	2,662.76	1.41
1944	185.44	5,242.07	1.41
1945	48.93	336.00	0.37
1946	<u>159.45</u>	<u>5,496.00</u>	1.72
Totals	489.17	13,736.83	1.40

Source: GSA (1981, p. 55-60 of Appendix)

Table 2. Uranium production, Monument No. 2 site, Apache County, Arizona.

Year	Tons	Pounds U ₃ O ₈	% U ₃ O ₈	Pounds V ₂ O ₅	% V ₂ O ₅
1947	85.34	1,586.00	0.95	8,528.00	5.12
1948	8,191.41	63,971.00	0.39	252,334.00	1.54
1949	23,998.74	149,533.00	0.31	398,338.00	0.84
1950	22,877.51	196,120.31	0.43	896,539.33	1.96
1951	28,511.40	353,784.00	0.62	1,104,911.00	1.94
1952	53,720.58	485,026.39	0.49	1,687,425.00	1.60
1953	96,196.90	649,800.01	0.34	2,826,937.61	1.47
1954	98,741.21	785,967.65	0.40	2,429,901.00	1.23
1955	110,675.84	545,475.11	0.25	2,574,473.00	1.16
1956	91,357.48	392,710.04	0.21	1,996,422.00	1.09
1957	72,712.40	322,087.26	0.22	1,528,346.00	1.05
1958	33,392.48	274,579.50	0.42	1,202,007.00	1.80
1959	20,369.73	128,851.36	0.32	940,840.00	2.31
1960	18,220.43	124,924.39	0.34	620,521.00	1.70
1961	15,148.79	129,046.67	0.43	535,068.00	1.77
1962	17,291.01	125,770.88	0.36	735,267.00	2.13
1963	18,577.82	116,805.80	0.31	699,164.25	1.88
1964	11,324.06	72,660.76	0.32	451,199.00	1.99
1965	2,909.55	98,089.27	1.51	148,135.00	2.55
1966	3,673.21	100,433.84	1.37	241,124.00	3.28
1967	1,462.67	22,098.10	0.76	67,752.00	2.32
1967*	236.13	9,872.26	2.09	33,431.00	7.08
1968	29.04	274.46	0.47	1,398.00	2.41
1969	<u>83.35</u>	<u>481.33</u>	<u>0.29</u>	<u>3,056.47</u>	<u>1.83</u>
TOTAL	748,785.68	5,139,949.39	0.34	21,383,177.66	1.43

*This shipment listed as a heap leaching product.

Note: Tons include ore as well as products from upgrader, heap leaching and from the concentrator.

Source: DOE (1997, p. 563-564), AEC (1953, p. 209-210) Allport (1948).

Table 3. Employment at the Monument No. 2 Site

Year	No. of Inspections	First Inspection		Last Inspection	
		No. of Men Underground	No. of Men Surface	No. of Men Underground	No. of Men Surface
1949	0				
1950	1	57	4		
1951	2	73	0	51	32
1952	2	74	0	81	2
1953	2	46	42	79	9
1954	2	69	29	93	7
1955	3	92	7	33	8
1956	1	0	102		
1957	1	5	134		
1958	3	0	115	0	97
1959	4	0	99	0	71
1960	4	0	32	0	64
1961	5	0	28	0	25
1962	4	0	24	0	20
1963	4	0	20	0	24
1964	4	0	24	0	23
1965	4	0	26	0	19
1966	3	0	24	0	25
1967	2	0	19	0	19
1968	0				
1969	0				

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

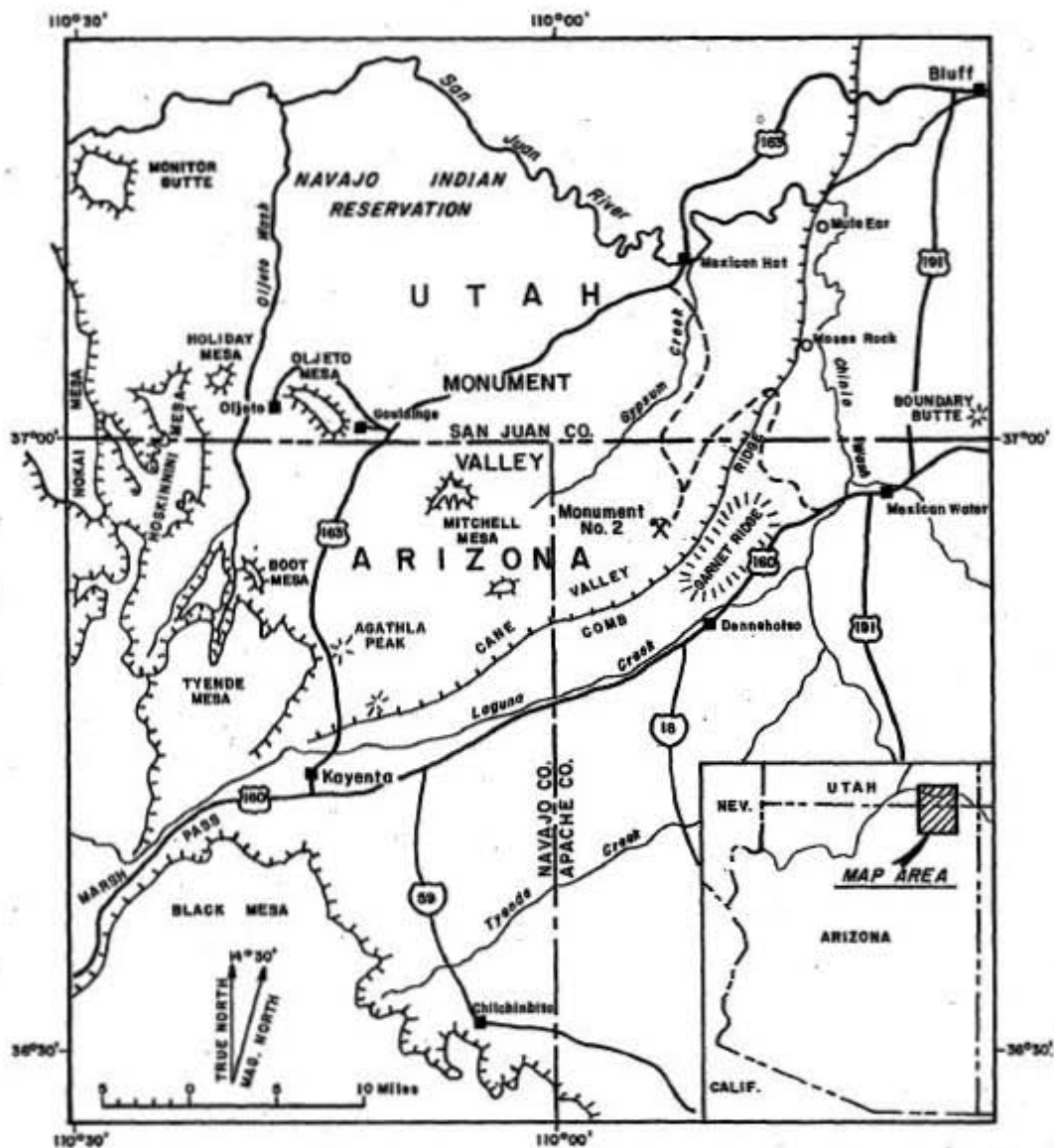


Figure 1. Index map of the Monument Valley area showing the location of the Monument No. 2 mine.

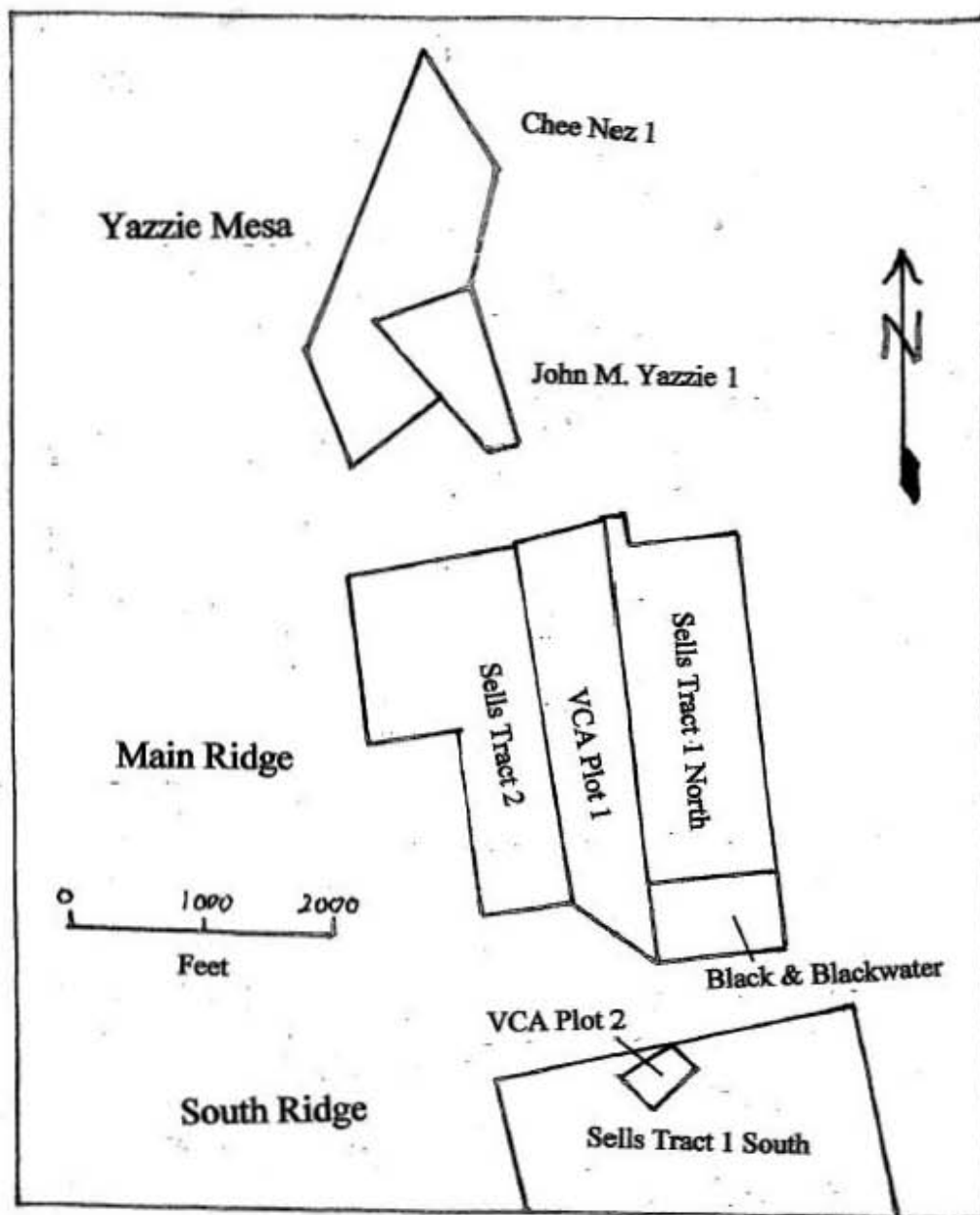


Figure 2. Map of VCA's Lease and the adjacent Mining Permits. From AEC files.

Figure 3. Geologic map of the Monument No. 2 mine showing the early underground workings and the adjacent mines on Navajo Mining Permits. Modified from Scarborough (1981, p. 36).

Explanation

Qd	Dune sand
Tcs	Shinarump Member, Chinle Formation
Tm	Moenkopi Formation
Tmh	Hoskinnini Tongue, Moenkopi Formation
Pd	DeChelly Sandstone
	Structure contours on base of the Monument No. 2 channel.
	Blackened areas, upper level workings
	Clear areas, lower level workings
	Later open pit outline

Mine Names

1. John M. Yazzie mine	11. Black and Blackwater mines
2. North workings	12. Incline No. 1
3. North drifts	13. Incline No. 2
4. West red oxide workings	13a. Incline No. 2 lower workings
5. East red oxide workings	14. Bobcat workings
6. South red oxide workings	15. South workings
7. Incline No. 3	16. South extension
8. Central workings	17. Willie Waters mine
9. Cato Sells Tract 2	18. Cato Sells Tract 1 South
10. Cato Sells Tract 1 North	19. Chee Nez mine

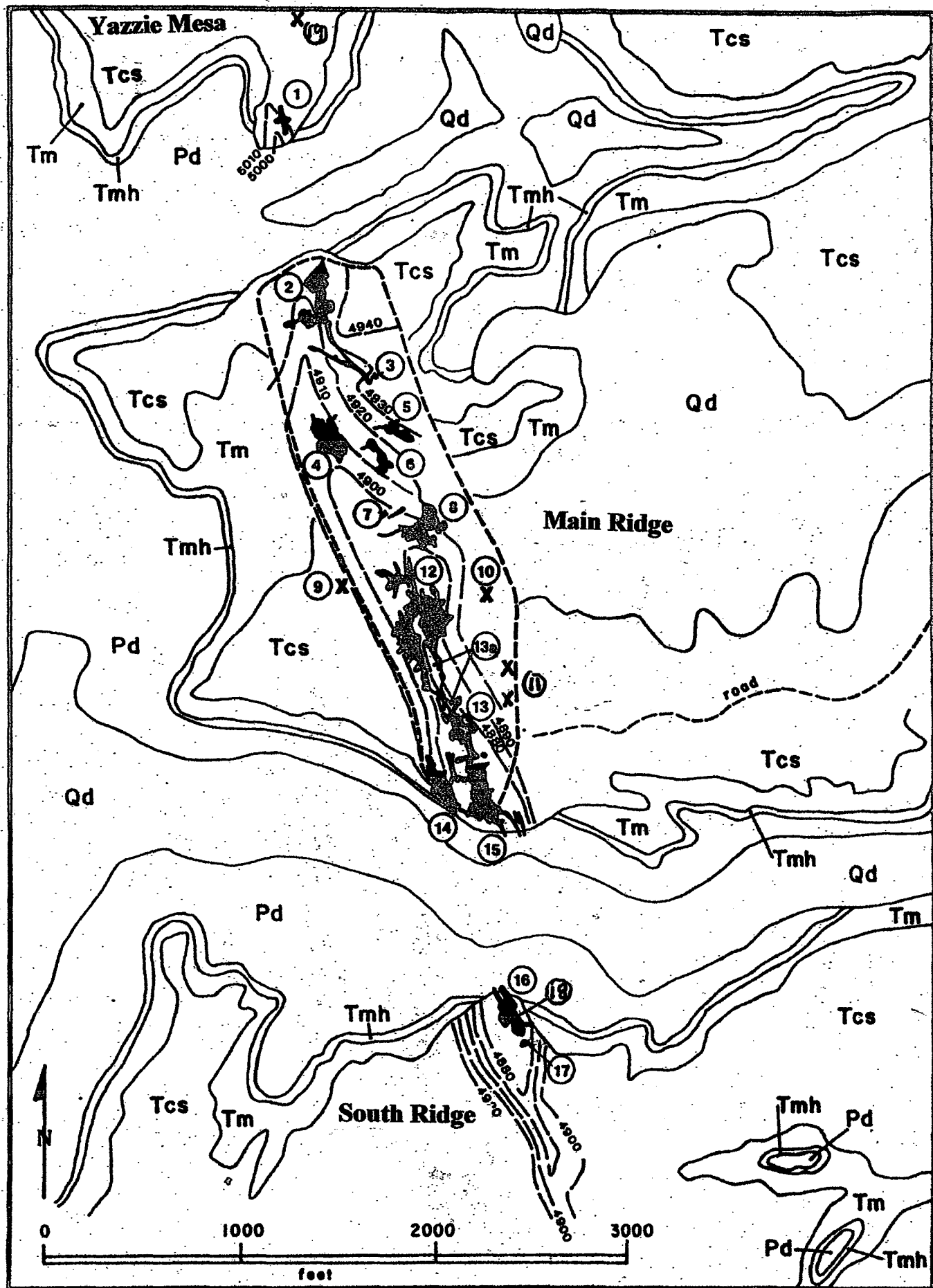


Figure 3



Figure 4. Aerial view of the area of the North Workings after stripping, circa 1954.
From AEC files



Figure 5. Upgrader plant at the Monument No. 2 site, circa 1959. Note. Comb Ridge on the skyline. From AEC files.



Figure 6. Geologists on a geological field conference examining the Monument No. 2 pit on June 16, 1955. Note the brightly colored oxidized uranium and vanadium minerals. Courtesy Exxon Mobil Corporation.

