THE GEOLOGY, LEASING AND PRODUCTION HISTORY OF THE MARTIN URANIUM-VANADIUM MINE, APACHE COUNTY, ARIZONA

by

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INTRODUCTION

The Martin mine was developed on one of the initial discoveries of uranium-vanadium minerals in the Carrizo Mountains of northwestern Arizona and northeastern New Mexico. The host rock for these ore deposits is the Salt Wash Member of the Morrison Formation of Late Jurassic age. The mineralized exposures on the original Martin claim were some of those mined for their radium content in 1920. In 1942-1943, the Martin mine was developed behind these outcrops and at least 1,500 tons of vanadium ore was produced for the federal government’s Metals Reserve program. In 1944, the Martin mine was one of several areas in the Carrizo Mountains acquired by the federal government for its uranium resources.

In 1948, the U.S. Atomic Energy Commission (AEC) contracted with Vanadium Corporation of America (VCA) to mine the Martin mine. Using Navajo contractors, 1,481 tons of uranium-vanadium ore was produced by clean up mining and mining of an orebody discovered by drilling. Exploration drilling behind the Martin mine, on George Simpson’s mining permit found additional orebodies, which produced 1,697 tons of uranium-vanadium ore. This ore was accessed through the Martin mine.

Included with this report are some unpublished field notes on geologic mapping in the Martin mine, which were made by AEC geologists in 1956. These notes and drawings were located in the files of the U.S. Department of Energy, Grand Junction, Colorado and are being donated to the Arizona Geological Survey.

LOCATION

The Martin mine is located on the west rim of the canyon of Saytah (Tisitah) Wash where that drainage cuts through the Toh Atin anticline in northeastern Apache County, Arizona. The area west of the canyon is known as Martin Mesa (Figure 1). The mine can be reached by traveling west on U.S. Highway 160 some seven miles from Teec Nos Pas, Arizona and then traveling five miles to the southwest on an unimproved dirt road. The mine is shown on the Toh Atin Mesa East quadrangle [U.S. Geological Survey, 1982a] at 36° 52'33"N latitude and 109° 17'35"W longitude, but is not labeled. The Carson mine on the Toh Chin Lini Mesa quadrangle [U.S. Geological Survey, 1982b] at 36° 52' 22" N latitude and 109° 17' 17"W longitude is incorrectly labeled as the Martin mine. The writer has been unable to determine the origin of the name Martin for the claims, mine and mesa.

LAND STATUS

The Martin mine 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 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.

**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. 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. A copy of the vanadium and uranium section was obtained by the Grand Junction Area Office of the U.S. Department of Energy. 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 have been donated to the Arizona Geological Survey Library.

**GEOLOGICAL SETTING**

The uranium-vanadium deposits at the Martin mine occur in the Salt Wash Member of the Morrison Formation of Late Jurassic age. In the Saytah Wash 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 rarely up to 20 ft. thick. Interbedded with the 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 Member.
Huffman and others [1981] 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 this unit is lithologically distinct from the overlying ore-bearing unit. It does not host any uranium-vanadium ore deposits. Recent 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 this 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 sandstones that contain the orebodies at the Martin mine are within the middle unit of the Salt Wash member, approximately 30 feet above the base of the member. Stokes [1953] measured a paleo stream direction of N 83°E for the ore-bearing sandstones at the Martin mine.

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 one hundred feet in length. Orebodies at the Martin mine ranged from a feather-edge up to five feet thick. The thickest ore the author observed was in the older part of the mine [Figure 2].

During March 1956, AEC geologists, V.A. Means and R.K. Labrecque, mapped the newer workings of the Martin mine and the connecting George Simpson No. 1 mine. Their mapping and associated field notes are in Appendix A.

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].

-3-
In a study of the mineralogy and petrology of the Martin mine, Corey [1956] found tyuyamunite to be the only uranium mineral present. Vanadium was present in the tyuyamunite and in the mineral montrosite, an iron-vanadium oxide. Vanadium minerals pasc01ite and volborthaite were found as stains on surface outcrops at the Martin mine. Calcite was the major cementing agent of the ore. The large amount of calcite, greater than six percent CaC\textsubscript{3}, resulted in the ore being classified by the AEC as “high lime”, which created problems in the acid leach circuits of processing mills, a fact noted earlier by Handley [1946] of Union Mines Development Corporation. Pyrite, limonite, hematite and gypsum were also present in the ore at the Martin mine [Corey, 1956]. A summary of Corey’s petrographic work on samples from the Martin mine is in Appendix B.

The Martin mine is located on the southwestern flank of the Toh Atin anticline. This structure extends from Black Rock Point of the Carrizo Mountains, northwesterly across Martin Mesa to Toh Atin Mesa [Figure 1]. The beds of the Salt Wash at the Martin mine dips one degree to the south, southwest.

**EARLY LEASING**

The discovery of radium by Marie and Pierre Curie in 1898 led to the realization that all uranium ores contained this new element. Radium is a radioactive decay product of uranium. Experiments which showed that radium inhibited the growth of certain cancers so astonished the medical profession that an incentive to mine the uranium-bearing ores was created.

Shortly before 1910, metallurgical processes for relatively large-scale recoveries of radium from carnotite ores were perfected. The improved processes resulted in greatly increased demands for carnotite and in accelerated prospecting in western Colorado. About one gram of radium is present in every 200 to 300 tons of ore containing 2.0 percent U\textsubscript{3}O\textsubscript{8}.

Shortly after 1910, the carnotite deposits in southwestern Colorado and southeastern Utah became one of the principal world sources of radium [Tyler, 1930]. For about 12 years, these deposits were mined for radium and yielded some byproduct uranium and vanadium. This activity lead to prospecting and the discovery of similar deposits in the Carrizo Mountains.

Outcrops containing uranium and vanadium minerals in the Carrizo Mountains were discovered by John F. Wade in about 1918 with the assistance of local Navajos [oral communication, 1955]. Wade came from Farmington, New Mexico and operated the Sweetwater Trading Post in the western Carrizo Mountains (Figure 1). Through business contacts and field trips he had determined that the same rocks that contained the carnotite deposits of southwestern Colorado were present in the Carrizo Mountains. The newly discovered deposits could not be mined because the Navajo Indian Reservation was then closed to prospecting and mining. A Congressional Act of June 30, 1919, opened the Navajo Reservation to prospecting and locating mining claims in the same manner as prescribed by the United States Mining Law of 1872. This Act allowed prospectors to enter the Reservation and stake a mining claim if their prospecting located promising mineral deposits. The
locator of the claim then obtained a lease on this land under terms that included escalating advance royalties and rentals, and annual work commitments.

During the 1920s the Office of Indian Affairs (later changed to Bureau of Indian Affairs), U.S. Department of the Interior, issued four leases for metal mining in the Carrizo Mountains [GSA, 1981]. Three of these were for carnotite mining. A fourth lease, located in the northeastern Carrizo Mountains is believed to have been for copper.

After the Navajo Indian Reservation was opened to prospecting, Radium Ores Company, John F. Wade, president, located 28 claims in the northern and western Carrizo Mountains (Figure 1). Details of the location and size of the claims are given in Table 1. Another of Wade's companies, Carrizo Uranium Company located 41 claims in the vicinity of the Arizona-New Mexico state line Milepost 16, in the eastern Carrizo Mountains (Figure 1).

In November, 1920 Radium Ores Company produced 40,000 pounds of ore valued at $1,600. A transportation charge of $1,200 left the value at only $400 [GSA, 1981]. It is possible that this material was shipped to the Standard Chemical Company's ore-buying station near Naturita, Colorado, which was buying carnotite ores for their radium content in the 1910s and 1920s. The November, 1920 shipment represented the first production of carnotite ore from the Carrizo Mountains. According to Wade [oral communication, 1955] this shipment came from mineralized exposures along Saytah Wash. This shipment was apparently made in trespass, as Radium Ore Company’s lease did not become effective until December 23, 1922 [GSA, 1981]. At that time, Radium Ores paid their first year’s rental of $142.50 for the 570.016 acres held under lease [GSA, 1981]. When the area of the leases were first examined by a U.S. Geological Survey engineer in October 1929, Dyer, [1929], noted numerous open pits had been dug into mineralized outcrops, especially on the Saytah and Martin claims.

Radium Ores apparently never canceled their lease and by 1931, some $3,990.00 in back rent was due [DeVoto and Huber, 1982]. The Federal government apparently settled with the bonding company in 1932 for $500.00 [DeVoto and Huber, 1982].

By 1922 the radium industry in southwestern Colorado was beginning to decline as the carnotite ores were no longer competitive with the newly developed high-grade pitchblende ore in the Belgian Congo (now Congo). A vanadium market never developed, as there was little demand for domestic vanadium because of imports from Peru.

On March 25, 1936, the Secretary of the Interior closed the Navajo Indian Reservation to claim location and prospecting for minerals until further authorization. In July 1936, an application to prospect was made to the Executive Committee of the Navajo Tribal Council. The application asked the council to pass a resolution requesting the Secretary of the Interior to open the Navajo Indian Reservation for mining to the applicant. The resolution was rejected by the Executive Committee, which evidently did not want prospecting or mining on the Reservation at that time.
VANADIUM LEASING AND MINING

By the mid-1930s the mines in the carnitite 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.

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, buying stations, etc., was the stimuli to renew interest in the carnitite deposits in the Carrizo Mountains. At Monticello, Utah and Durango, Colorado, Metals Reserve had mills to process vanadium ore.

On December 4, 1939, effective January 19, 1940, John F. Wade, Thomas F. V. Curran, and H.R. Redington (d.b.a. Wade, Curran and Co.) leased 65.02 acres in the Carrizo Mountains. Their lease, I-149-IND-3798, covered the Martin Claim, Say-Tah Claim, and the Eurida No. 2 Claim as described in U.S. Mineral Survey Nos. 3701 and 3703. The lease was for a period of five years.

These were three of the properties formerly held by Wade’s Radium Ores Company. Shipments from Lease I-149-IND-3798 were recorded from August 1942 through November 1943 [GSA, 1981].

Although the production is not separated by claim, Wade [oral communication, 1955] stated the ore-bearing outcrops along Saytah Wash were the first to be mined. Ore mined by Wade, Curran and Company was shipped by truck to Farmington, New Mexico and then by rail to the mill at Durango, Colorado. Lease I-149-IND-3798 was due to expire on January 19, 1945 but was apparently canceled earlier.

As part of the U.S. Geological Survey’s (USGS) investigations of critical war materials, the vanadium deposits of the Carrizo Mountains were examined during October and November, 1942. The USGS geologists examined and mapped the existing mines, and acquired production history and statistics from the mine operators.

The detailed results of the October-November 1942 investigations are in a report by Duncan and Stokes [1942] which was submitted to the U.S. Army’s Manhattan Engineer District. The general
geology and the description of the ore deposits was later published by Stokes [1951]. Duncan and Stokes [1942, Figure 3] mapped the Martin mine and stated that approximately 500 tons of ore averaging 2.50 percent \( V_2O_5 \) had been mined to date. At that time the mine workings consisted of four short adits and some rim stripping. When shipments from Lease I-149-IND-3798 ceased in November 1943, a total of 2,198.05 tons of ore averaging 2.91 percent \( V_2O_5 \) had been produced (Table 2). The value of the ore was reported as $54,380.69 from which the Navajo Tribe received $8,157.09 in royalties [GSA, 1981].

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).

Shipments commenced in December 1943 and continued through February 1944. Total production from the lease was 388.35 tons with an average grade of 1.94 percent \( V_2O_5 \) (Table 3). The ore was mined from the Saytah Canyon mine and the CB & W Main Claim mine in Saytah Canyon and from the North Martin mine in Saytah Wash. A small amount may have been mined from the west side of Cove Mesa [Harshbarger, 1946, Figure 3]. The ore was shipped by truck and rail to the mill at Durango, Colorado. The value of ore was reported as $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 4. Plot 1 was a 20.2 acre, rectangular tract on the west side of Saytah Wash. It measured 500 ft. wide and 1,760 ft. long with the long dimension parallel to the rim of the canyon. The workings of the Martin mine were in the northeast corner of the plot.

**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.
A contract, No. W-7405, effective May 11, 1943, was made with Union Mines Development Corporation (UMDC), a subsidiary of Union Carbide and Carbon Corporation, for carrying out the work.

On the Colorado Plateau, UMDC's geologic investigations were limited to the Salt Wash Member of the Morrison Formation, and the Entrada Sandstone in the area of the roscoelite deposits.

Geologic studies and resource estimates for the northwestern Carrizo Mountains are contained in reports by Eakland and Wardwell [1943] and Harshbarger [1946]. All of the known outcrops of uranium/vanadium minerals, prospects, and mines were mapped and described by UMDC geologists. The geologists also proposed an exploration program for developing additional ore reserves. Activities of the Manhattan Engineer District in Arizona have been summarized by Chenoweth [1998].

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 USV 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].

The workings of the abandoned Martin mine were mapped by Sam K. Smyth and John W. Harshbarger of UMDC on April 14, 1944 [Harshbarger, 1946, Figure 39]. Judging from the size of the workings of the Martin mine (Figure 2) in comparison to the other mines worked by Wade, Curran and Co. on lease I-149-IND-3798, I would estimate that the Martin mine produced at least 1,500 tons of vanadium ore during 1942-1943. Uranium values in the ore were secretly recovered at the Durango, Colorado mill by U.S. Vanadium Corporation, a contractor to the Manhattan Engineer District [Chenoweth, 1988].

**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. On February 17, 1949, effective October 8, 1948, VCA entered into contract AT (49-1)-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 AEC, effective February 28, 1949 [unpublished document in the AEC files].

Using a Navajo contract miner, Leo Redhouse, VCA began pulling pillars and clean up mining in the old Martin mine. During the spring of 1951, Redhouse shipped 218.05 tons of ore averaging 0.40 percent U\textsubscript{3}O\textsubscript{8} and 3.39 percent V\textsubscript{2}O\textsubscript{5} to the VCA mill at Durango (Table 5).

Due to VCA’s activity at the Martin mine, George R. Simpson, a Navajo prospector, became interested in the area west of the mine. On August 6, 1952, Navajo Tribal Mining Permit No. 48 was issued to Simpson. The ground covered by MP-48 was contiguous with the west and south boundaries of Plot 1.

The corner monuments of Plot 1, established in 1944, were not well marked nine years later. During May 1953, Climax Uranium Company of Grand Junction, Colorado drilled 37 holes behind the workings of the Martin mine, believing they were on Mining Permit 48. Gamma-ray logging of some of these holes by the AEC indicated that some ore grade mineralization had been encountered [Chenoweth, 1955]. Subsequent drilling by Capital Uranium Company of Farmington, New Mexico confirmed ore in the vicinity of the Climax drilling and also discovered ore to the west on George Simpson’s Mining Permit 48.

During the fall of 1953 and continuing into the early part of 1954, Jimmie King, a local Navajo, reworked the old Martin mine dump and shipped 218.05 tons of ore, averaging 0.15 percent U\textsubscript{3}O\textsubscript{8} and 0.78 percent V\textsubscript{2}O\textsubscript{5} to the AEC ore-buying station at Shiprock, New Mexico and to the VCA mill at Durango (Table 5). This was material which had been discarded during the 1943-44 vanadium mining by Wade, Curran and Company. The shipments by King were identified as Saytah. A
resurvey of the boundaries of Plot 1 by the AEC in March 1954 established that the Martin dump was on Plot 1, and King was ordered to cease his trespass.

George Simpson signed an operating agreement with Capital Uranium Company to mine the ore discovered on his mining permit. Simpson also signed an agreement with VCA to use the Martin mine for access to his mining permit. In order to mine the ore discovered between the Martin mine and his mining permit, George Simpson was issued a mining contract by VCA. In his agreement with VCA, it specified all ore mined on Mining Permit No. 48 would be shipped to the VCA mill at Durango, Colorado.

During the spring of 1954, Capital began drifting toward the orebodies on Mining Permit 48. The first ore was shipped in June 1954 (Table 6). Once the Simpson ore was intercepted, mining of the ore on Plot 1 commenced. Capital Uranium also did the mining for George Simpson on Plot 1. Mining on Plot 1 was completed in April 1955, and mining on MP-48 continued until May 1956. A total of 1,697.24 tons of ore averaging 0.25 percent \( \text{U}_3\text{O}_8 \) at 1.87 percent \( \text{V}_2\text{O}_5 \) was produced from MP-48 and 976.47 tons averaging 0.26 percent \( \text{U}_3\text{O}_8 \) and 1.99 percent \( \text{V}_2\text{O}_5 \) was mined from the new orebodies on Plot 1 (Figure 3, Tables 5,6). By using Navajo contractors, Leo Redhouse and George Simpson, on this AEC lease, VCA did not have to pay the AEC a royalty on ore production [unpublished AEC document, 1962].

VCA’s contract with the AEC to operate Lease No. 1-149-IND-6197 expired on June 30, 1958. Up to that time VCA has produced ore from Plots 1, 4, 7 and E (Table 4). On July 1, 1958, a new contract, AT (05-1)-756, went into affect, but this contract covered only Plot 7 on Cove Mesa (Figure 1). The other 11 plots were dropped from the lease for lack of recent production, and control of the land reverted to the Navajo Tribe [unpublished AEC document, 1962].

There has been no mining at the Martin mine, including the Simpson portion since 1956, although the area of Plot 1 has been controlled by at least one mining permit. On August 25, 1961, Gloria Emerson was issued Navajo Tribal Mining Permit 535 covering some 80 acres of the former Plot 1 and Mining Permit No. 48.

When the Martin mine was last examined by the writer in May 1985, the portals had been blasted shut by the Navajo Abandoned Mined Lands program.

**SUMMARY**

The 1920 shipment of 20 tons of high-grade “carnotite” ore from exposures along Saytah Wash in the Carrizo Mountains, Apache County, Arizona, represents the first production of uranium-vanadium ore from the Navajo Indian Reservation. All of the vanadium concentrate produced in 1942-1943, from the Martin mine, at Durango, Colorado went into the nation’s strategic stockpile, a program operated by the Metals Reserve Company. Uranium in the ore was secretly recovered at Durango for use in the atomic bombs of the Manhattan Project.
The uranium concentrate produced from the Martin mine and the George Simpson No. 1 ores, at Durango, was purchased by the AEC. The vanadium concentrate was sold to the steel industry with any excess purchased by the AEC [Albrethsen and McGinley, 1982, p. A-15].

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

REFERENCES
Stokes, W.L., 1951, Carnotite deposits in the Carrizo Mountains area, Navajo Indian Reservation, Apache County, Arizona and San Juan County, New Mexico: U.S. Geological Survey Circular 111, 5p.
U.S. Geological Survey, 1982a, Toh Atin Mesa East quadrangle, Arizona-Utah, 7 ½ minute series (topographic), provisional, scale 1:24,000.
Table 1. Claims included in Radium Ores Company carnitite lease

<table>
<thead>
<tr>
<th>Name</th>
<th>Acres</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunnyside</td>
<td>20.661</td>
<td>Sunnyside Mesa</td>
</tr>
<tr>
<td>Eurida Nos., 1,2,3,5</td>
<td>103.305</td>
<td>Eurida Mesa</td>
</tr>
<tr>
<td>Eurida No. 4</td>
<td>20.661</td>
<td>Eurida Mesa</td>
</tr>
<tr>
<td>Preston, Preston No. 1, Stormy Day</td>
<td>61.983</td>
<td>Saytah Wash</td>
</tr>
<tr>
<td>Preston Nos. 2,3,4,5</td>
<td>82.644</td>
<td>Saytah Wash</td>
</tr>
<tr>
<td>Say Tah, Martin</td>
<td>41.322</td>
<td>Saytah Wash</td>
</tr>
<tr>
<td>Martin Nos. 2-13</td>
<td>230.440</td>
<td>Saytah Wash</td>
</tr>
<tr>
<td><strong>Total Acres</strong></td>
<td><strong>570.016</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: GSA [1981].

See Figure 1 for locations.

Table 2. Vanadium ore production, Lease I-149-IND-3798, Apache County, Arizona

<table>
<thead>
<tr>
<th>YEAR</th>
<th>MONTH(S)</th>
<th>TONS OF ORE</th>
<th>POUNDS V₂O₅</th>
<th>% V₂O₅</th>
</tr>
</thead>
<tbody>
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<td>1942</td>
<td>Aug. - Dec.</td>
<td>301.56</td>
<td>44,948.28</td>
<td>7.45</td>
</tr>
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<td>1943</td>
<td>Jan. - Nov.</td>
<td>1,896.49</td>
<td>82,960.75</td>
<td>2.19</td>
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<td><strong>Total</strong></td>
<td></td>
<td><strong>2,198.05</strong></td>
<td><strong>127,909.03</strong></td>
<td><strong>2.91</strong></td>
</tr>
</tbody>
</table>

Shipped by Wade, Curran and Co. from the Martin, Say-Tah and Eurida No. 2 Claims.

Source: GSA [1981].
Table 3. Vanadium ore production, Lease I-149-IND-6197, Apache County, Arizona

<table>
<thead>
<tr>
<th>YEAR</th>
<th>MONTH(S)</th>
<th>TONS OF ORE</th>
<th>POUNDS V₂O₅</th>
<th>% V₂O₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>1942</td>
<td>Dec</td>
<td>170.65</td>
<td>7,390.63</td>
<td>2.17</td>
</tr>
<tr>
<td>1943</td>
<td>Jan, Feb.</td>
<td>217.70</td>
<td>7,669.65</td>
<td>1.76</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total</strong></td>
<td><strong>15,060.28</strong></td>
<td><strong>1.94</strong></td>
</tr>
</tbody>
</table>

Shipped by Curran Brothers and Wade - U.S. Vanadium Company before the 12 plots of the lease were selected.

Source: GSA [1981].

Table 4. Location, mine name, and size of Plots, Lease No. I-149-IND-6197

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>MINE NAME</th>
<th>ACRES</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Martin</td>
<td>20.2</td>
<td>Saytah Wash, west rim</td>
</tr>
<tr>
<td>2</td>
<td>North Martin</td>
<td>14.4</td>
<td>Saytah Wash, west rim</td>
</tr>
<tr>
<td>3</td>
<td>--</td>
<td>2.2</td>
<td>Saytah Wash, east rim</td>
</tr>
<tr>
<td>4</td>
<td>Saytah Canyon</td>
<td>10.4</td>
<td>Saytah Canyon, north rim</td>
</tr>
<tr>
<td>5</td>
<td>CB &amp; W Main Claim</td>
<td>5.7</td>
<td>Saytah Canyon, south rim</td>
</tr>
<tr>
<td>6</td>
<td>Eurida</td>
<td>20.6</td>
<td>Eurida Mesa</td>
</tr>
<tr>
<td>7</td>
<td>Cove Mesa</td>
<td>246.2</td>
<td>Cove Mesa, southern 3/4 ths</td>
</tr>
<tr>
<td>A</td>
<td>--</td>
<td>16.0</td>
<td>Saytah Canyon, north rim</td>
</tr>
<tr>
<td>B</td>
<td>--</td>
<td>17.3</td>
<td>Segi Ho Cho Mesa, north point</td>
</tr>
<tr>
<td>C</td>
<td>--</td>
<td>39.9</td>
<td>Segi Ho Cho Mesa, southwest point</td>
</tr>
<tr>
<td>D</td>
<td>--</td>
<td>37.8</td>
<td>Segi Ho Cho Mesa, southwest point</td>
</tr>
<tr>
<td>E</td>
<td>Tree Mesa</td>
<td>529.0</td>
<td>Kinusta Mesa, eastern end</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>959.7</strong></td>
<td></td>
</tr>
</tbody>
</table>

No mines were developed on Plots 3, A, B, C, D
Table 5.  Uranium-vanadium ore production, Plot 1, Lease I-149-IND-6197, Martin 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>1951</td>
<td>2nd</td>
<td>Leo Redhouse</td>
<td>218.05</td>
<td>1,731.77</td>
<td>0.40</td>
<td>14,791.20</td>
<td>3.39</td>
</tr>
<tr>
<td>1953</td>
<td>3rd</td>
<td>Jimmie King *</td>
<td>141.62</td>
<td>461.12</td>
<td>0.15</td>
<td>1,819.63</td>
<td>0.64</td>
</tr>
<tr>
<td>1953</td>
<td>4th</td>
<td>Jimmie King *</td>
<td>85.63</td>
<td>290.47</td>
<td>0.17</td>
<td>1,329.17</td>
<td>0.78</td>
</tr>
<tr>
<td>1954</td>
<td>1st</td>
<td>Jimmie King *</td>
<td>59.61</td>
<td>173.72</td>
<td>0.15</td>
<td>1,357.00</td>
<td>1.14</td>
</tr>
<tr>
<td>1954</td>
<td>3rd</td>
<td>George R. Simpson</td>
<td>12.05</td>
<td>122.66</td>
<td>0.51</td>
<td>177.00</td>
<td>2.63</td>
</tr>
<tr>
<td>1954</td>
<td>4th</td>
<td>George R. Simpson</td>
<td>507.70</td>
<td>2,419.91</td>
<td>0.24</td>
<td>19,495.00</td>
<td>1.92</td>
</tr>
<tr>
<td>1955</td>
<td>1st</td>
<td>George R. Simpson</td>
<td>438.89</td>
<td>2,436.37</td>
<td>0.28</td>
<td>17,258.00</td>
<td>1.97</td>
</tr>
<tr>
<td>1955</td>
<td>2nd</td>
<td>George R. Simpson</td>
<td>17.84</td>
<td>114.49</td>
<td>0.32</td>
<td>940.00</td>
<td>2.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1,481.20</td>
<td>7,705.51</td>
<td>0.26</td>
<td>57,167.00</td>
<td>1.93</td>
</tr>
</tbody>
</table>

* Mined in trespass from the Martin mine dump.


Table 6.  Uranium-vanadium ore production, George Simpson No. 1 mine (Access though the Martin 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>1954</td>
<td>2nd</td>
<td>George R. Simpson</td>
<td>14.01</td>
<td>72.87</td>
<td>0.26</td>
<td>210.20</td>
<td>0.75</td>
</tr>
<tr>
<td>1954</td>
<td>3rd</td>
<td>George R. Simpson</td>
<td>17.93</td>
<td>39.45</td>
<td>0.11</td>
<td>329.99</td>
<td>0.92</td>
</tr>
<tr>
<td>1954</td>
<td>4th</td>
<td>George R. Simpson</td>
<td>62.58</td>
<td>360.37</td>
<td>0.29</td>
<td>2,524.26</td>
<td>2.02</td>
</tr>
<tr>
<td>1955</td>
<td>1st</td>
<td>George R. Simpson</td>
<td>543.90</td>
<td>2,749.43</td>
<td>0.25</td>
<td>22,391.69</td>
<td>2.06</td>
</tr>
<tr>
<td>1955</td>
<td>2nd</td>
<td>George R. Simpson</td>
<td>432.09</td>
<td>1,934.10</td>
<td>0.22</td>
<td>16,535.61</td>
<td>1.91</td>
</tr>
<tr>
<td>1955</td>
<td>3rd</td>
<td>George R. Simpson</td>
<td>403.72</td>
<td>1,817.70</td>
<td>0.23</td>
<td>13,376.34</td>
<td>1.66</td>
</tr>
<tr>
<td>1956</td>
<td>1st</td>
<td>George R. Simpson</td>
<td>67.86</td>
<td>558.65</td>
<td>0.41</td>
<td>3,121.67</td>
<td>2.30</td>
</tr>
<tr>
<td>1956</td>
<td>2nd</td>
<td>George R. Simpson</td>
<td>156.15</td>
<td>839.70</td>
<td>0.27</td>
<td>4,970.70</td>
<td>1.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1,697.24</td>
<td>8,372.27</td>
<td>0.25</td>
<td>63,460.46</td>
<td>1.87</td>
</tr>
</tbody>
</table>

Figure 1: Index map of the Carrizo Mountains, Arizona-New Mexico showing the location of the Martin mine.
Figure 2. Map of the Martin mine, April 1, 1944. From Harshbarger [1946, fig. 39].
APPENDIX A. GEOLOGIC MAPPING IN THE MARTIN MINE

Victor A. Means and Ronald K. Labrecque

During March 1956, nine longwall sections in the Martin mine were mapped geologically. The sections, A-A' - J-J', follow this summary and the locations of the sections are shown on Figure 3.

In the Martin mine the upper parts of the drifts are mostly in crossbedded sandstone, whereas the lower parts of the drifts are largely in nearly flat-lying sediments (see sections D-D', F-F' and G-G'). In both the crossbedded and essentially horizontally - bedded portions these are considerable amounts of intercalated mudstones and siltstones. These units are usually thicker and more numerous in the nearly flat-lying beds, although a few thick irregular mudstones and mud-gall conglomerates are seen in the crossbedded zones (see section G-G').

Most of the ore in the Martin mine, montrosite and tyuyamunite, is in the upper, crossbedded zone, although a considerable amount of both occur just below the crossbedded zone, and some well below it (see sections C-C', F-F'). The ore minerals are found most frequently in or adjacent to the zones of finer material marking the contacts of the sand lenses. In the Martin mine the mineralized and ore zones frequently extend through several sandstone lenses and the argillaceous contact zones between them (see sections F-F' and G-G'). Also, many of the large, irregular mud gall zones in the crossbedded portion of the host rock have been strongly mineralized (see sections G-G').

Zones of dark gray to black montrosite - bearing material coincide, for the most part, with radioactive zones containing the disseminated oxidized uranium mineral tyuyamunite. There are exceptions to this general rule, however, and there are places where either montrosite or tyuyamunite occur without the other (see sections E-E', F-F' and J-J').

There is a large amount of carbon trash in the Martin mine, and it is likely that there is some genetic relationship between the mineralization and the carbonaceous material. However, many of the carbonaceous zones are not mineralized (see sections H-H' and J-J'). For uranium mineralization without visible carbonaceous material, see sections C-C' and F-F'.

In general, the most strongly mineralized zones contain the highest content of limonite, although there are exceptions (see sections D-D' and F-F'). The upper, crossbedded portion of the mine, for example, has on the average, a stronger brownish tinge than the lower more horizontally - bedded portion. In a few places in the mine, small, 1/4 inch, oval masses of tyuyamunite with limonite centers were observed.

Interstitial carbonate in abundant in the mine. Most of the carbonate is unstained, although there are considerable amounts of limonite stained carbonate. Where the ore is abundant, carbonate is also abundant, whereas in barren connecting drifts, carbonate is sparse and the sandstone is much more friable, due to the absence of cementing material (see sections C-C' and H-H').
Gypsum is common in the Martin mine, and is concentrated chiefly in logs and in other carbonaceous fragments.

Some of the smooth joint surfaces in the sandstone of high carbonate content have coatings of tyuyamunite. Obviously there has been redistribution of uraniferous material since time of jointing.
Figure 3. Plan map of Martin Mine showing location of longwall sections
This ore-bearing mud-pellet cgl also contains much CO₂ (both stained and unstained) and some scattered limonite.
EXPLANATION OF SYMBOLS

SANDSTONE, unstained, or only slightly stained, without concentration of carbonate. Color chiefly light yellow. Chiefly fine- to med fine-grained. Chiefly laminated, non-massive, parallel lines indicate direction of lamination in plane of section.

SANDSTONE, same as above, with zone of dark gray to black ss., due to vanadium mineralization (chiefly montroseite).

MUDSTONE & SILTSTONE in beds, thin "stringers"; irreg masses, and "galls", in ss. Mudstone except where labelled Sts. Color green or gray except where labelled otherwise.

Concentration of SECONDARY CaCO₃ in ss. Chiefly unstained or only slightly stained. Where strongly stained, labelled St.

CARBONACEOUS MATERIAL

OXIDIZED URANIUM ORE AND MINERALIZATION — chiefly tyuyamunite.

ABBREVIATIONS:

Lim — Strong limonite staining
Hem.— Strong hematite staining in ss
m — Mottling in mudstone and siltstone; brown or red spots or zones in otherwise gray or green ms and sts. Cause of staining indicated in parenthesis, as m(lim) and m(hem).
Sts — Siltstone
Sty — Silty
St — Strong ankeritic staining in secondary carbonate zones.
APPENDIX B. SUMMARY OF THE PETROLOGY AND MINERALOGY OF THE MARTIN MINE

Alice S. Corey

INTRODUCTION

Two days were spent collecting samples in the Martin mine during April, 1956. Twenty-nine thin sections were prepared and studied by means of petrographic and binocular microscopes. Chronographic contact prints, using 1:7 HNO3 and K4Fe(CN)6 solution were made of these rock sections to show the distribution of the uranium. Several minerals were identified by x-ray diffraction in the laboratory of the U.S. Geological Survey in Denver.

Megascopically the uranium mineral, tyuyamunite, is disseminated in friable dark gray layers, limonitic clay-bearing layers, or is concentrated on fracture surfaces in the more-massive calcite-rich zones. Scattered logs have been partly replaced by tyuyamunite and gypsum. Secondary vanadium minerals, pascoite and volborthite, appear only as very thin coatings on the cliff near the mine adits.

LITHOLOGY

The grain size of the detrital minerals varies considerably and changes quite abruptly. In general, the grains are .05 to .50 millimeter in diameter with occasional large fragments as large as 5 or 6 millimeters. Quartz and feldspar grains are about the same size in any one section and average .05 to .50 millimeter across. Most fragments of tourmaline and zircon are finer grained, rarely more than .10 millimeter. Many pebbles of mudstone, siltstone, and limestone, and wood fragments, are much coarser than the average grain-size, giving a knotty appearance to the rock in both hand specimen and thin section.

Most of the pebbles of quartz, chalcedony, and limestone are subrounded to rounded although each section contains many angular fragments. Feldspars are also mostly subrounded to rounded but some are angular. Tourmaline and zircon occur as small oval grains. The mudstone and siltstone fragments vary widely in shape and may be rounded or considerably elongated. The wood and carbonaceous material usually form long stringers.

The matrix-spacing is quite variable, from 0 to .50 millimeter, but averaging about .01 to .10 millimeter.

TEXTURE

The rock is typically banded, both megascopically and microscopically. The banding is due to several causes including:
1. different grain size in different layers.
2. concentration of woody stringers in some beds.
3. changes in iron concentration from one layer to another.
4. concentration of heavy minerals, mainly tourmaline, in some beds.
5. variation in thickness of montroseite coating on detrital grains.

Spotted texture is due to:
1. scattered large pieces of mudstone, siltstone, and limestone.
2. hematite segregations surrounded by tyuyamunite.

MINERALOGY

Detrital Minerals:

Various forms of silica form the major portion of the detrital grains. Quartz is the main detrital constituent, making up 75 to 85 percent. Much of the quartz contains minute bubbles, and inclusions of other minerals such as tourmaline. About 5 percent of the silica is in quartzite pebbles, with sutured texture and undulating extinction, indicating strain. Grains of brownish chalcedony, and fragments of yellowish chert constitute about 10 percent of the silica.

Approximately 10 to 15 percent of the grains are feldspar. Orthoclase and microcline are essential constituents while plagioclase is present only in accessory amounts. Many feldspar grains have been partly replaced by calcite which tends to invade the feldspar along cleavage planes, and also replaces it in irregular patches from the grain boundary inward.

Woody fragments and carbonaceous material are plentiful locally. They appear to be wrapped around the quartz and feldspar grains due to compaction of the sediments. Much of the original cell structure remains in some of the wood.

Pebbles of ferruginous mudstone and siltstone, many of which contain angular fragments of quartz and feldspar, are scattered though the sections, being abundant in some places and absent in others. Grains of aphanitic limestone are also erratically distributed. Other accessory minerals include brown, green, and bluish tourmaline, specular and red hematite, and rare zircon.

Cementing minerals:

Calcite is the major cementing agent. It typically is in anhedral crystals up to 5 millimeters in diameter, each of which encloses many detrital grains. It is present in all thin sections observed, but only as a minor constituent in some.

Rock flour, made up of clay and other finely crushed minerals, and stained gray or brown by iron oxides, is next in abundance to calcite as a cement. In some sections it predominates and, in others, is completely absent. No vanadium clay was observed. Carbonaceous material, probably pulverized wood, occupies the pores in places.

B-32
Hematite and/or limonite is locally concentrated. The hematite occurs as opaque metallic and deep red translucent masses, as staining in the calcite, and as cement in the clay. Limonite coats grains of quartz and feldspar and colors the cements. Casts of pyrite cues are present in some of the hematite-stained claystone pebbles. All of the iron in the sections observed appears to be in the ferric oxidation state.

Overgrowths of quartz partly or completely fill the space between many of the original quartz grains. The authigenic quartz has the same optical orientation as the original detrital quartz on which it is deposited in all cases observed.

An unidentified fibrous clay-like mineral appears in one section where it is closely associated with stringers of wood. The fibers have been bent around quartz grains as was the wood. In one place the mineral has replaced the cell centers in the wood, leaving the black carbonaceous cell walls.

The only uranium mineral observed is tyuyamunite, which was precipitated in the interstices of the sandstone. Tyuyamunite occurs closely associated with woody and carbonaceous fragments, and with the fibrous clay-like mineral, much of it being enclosed by the latter. The cell structure of the wood has been destroyed in the sections containing tyuyamunite. In these areas the tyuyamunite is either finely granular or more coarsely bladed. In some locations the fine-grained cementing tyuyamunite is concentrated around limonite and hematite centers. In the more massive sections tyuyamunite coats fracture surfaces.

Vanadium occurs with uranium in tyuyamunite, and rarely, in pasocite and volborthite staining the cliff outside the mine, and in montroseite. The montroseite seems to be localized in one section of the mine (Sections G-G', Fig. 3). It occurs as masses of very fine needles averaging .01 to .03 millimeter in length, rimming quartz and feldspar grains, and less often, disseminated in the calcite cement. The thickness of the montroseite coating varies in different sections, ranging from .01 to .10 millimeters. The passage of the vanadium-bearing solutions seems to have been controlled to some extent by the presence of relatively impermeable layers which acted as barriers.

Gypsum was observed replacing logs in the mine, but did not appear in any thin sections.

PARAGENSIS

The sequence of events in the Martin mine is interpreted to be:

1. Deposition and burial of the original detrital minerals, including fine-grained clay and rock-flour which filled some of the voids.

2. Introduction of solutions carrying vanadium, uranium, and iron, and deposition of primary minerals, montroseite, uraninite?, and pyrite.

3. Oxidation of the uranium, iron, and some of the vanadium.

4. Introduction and precipitation of calcite and/or recrystallization of calcite already present, some replacing the feldspar grains.
The ore minerals were introduced some time after the deposition of the original sediments, as evidenced by the euhedral montroseite needles surrounding the detrital grains, and by the bladed tyuyamunite filling pore spaces between grains.

There appears to be a definite association between the location of uranium and the calcite cement. There is always some calcite present in those sections that contain uranium. The explanation offered for this is simply that the clay cement filled the pore spaces during deposition of the original detrital grains, making the rock impermeable in these places, whereas the calcite followed the tyuyamunite and filled up most of the voids that remained.