

**THE GEOLOGY, LEASING, AND
PRODUCTION HISTORY OF THE
URANIUM-VANADIUM MINES ON NORTH
STAR MESA, APACHE COUNTY, ARIZONA
AND SAN JUAN COUNTY, NEW MEXICO**

by

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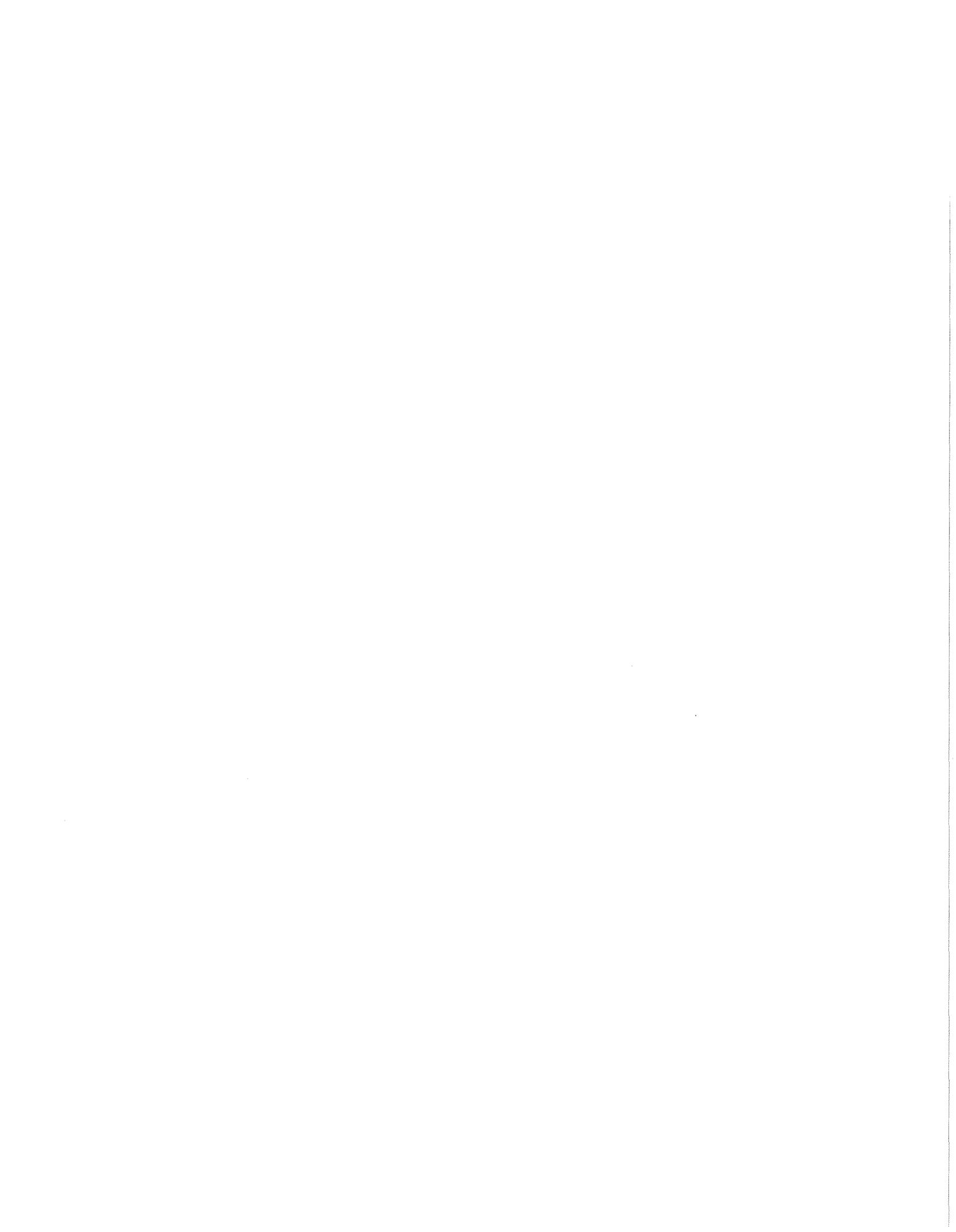
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INTRODUCTION

The exposures of the uranium-vanadium minerals on the rim of North Star Mesa were some of the first to be discovered in the Carrizo Mountains of northeastern Arizona and northwestern New Mexico. The host rock for the ore deposits is the Salt Wash Member of the Morrison Formation of Late Jurassic age.

The area was first leased for radium ore in the 1920s. A small amount of ore was mined and later sold for its vanadium content. In the early 1940s, the area was again leased for vanadium mining and a few hundred tons were produced. Under the U.S. Atomic Energy Commission (AEC) ore procurement program, mining resumed in 1949 and continued intermittently through 1957 with final shipments made in 1962. Under the AEC program approximately 800 tons of uranium-vanadium ore was produced.

LOCATION

North Star Mesa is a small mesa astride the Arizona-New Mexico State line. AEC geologists informally named it in the early 1950's, due to the existence of the North Star mine on the north rim of the mesa. The plots (claims) on the mesa were tied to a brass cap, Milepost 16 Witness Corner, near the center of the mesa (Figure 1). This monument is not shown on the Beclabito 7 ½ minute quadrangle [U.S. Geological Survey, 1982]. It is located on the Arizona-New Mexico state line at latitude 36° 46' 03" N and longitude 109° 02' 40" W. According to a Vanadium Corporation of America (VCA) surveyor [oral communication, 1962] Milepost 16 would be approximately 480 ft north of the Witness Corner in an arroyo, tributary to Cottonwood Wash [ed. note--the location given for WC MP-16 is approximately 480 feet south of the arroyo on the north side of North Star Mesa, but is some 1600 feet north of the intersection of New Mexico T30N Township boundary with the state line, which is in the arroyo south of North Star Mesa].

The canyons of tributaries of Cottonwood Wash bound the mesa on the north and south. A small arroyo separates North Star Mesa from Syracuse Knoll to the west. On the Beclabito 7 ½ minute quadrangle, a jeep trail marked 5J is in this arroyo. The highest point on North Star Mesa is marked 6181T on the quadrangle map. The Syracuse mine, located on Syracuse Knoll, is described in Chenoweth [1997].

The mines that have been developed on North Star Mesa are, west to east, White Cap (Plot 11), Hazel, North Star later known as Syracuse (Plot 12), and Lone Star (Plot 9). The mines are accessible from the Oak Springs-Beclabito Road (Figure 1). The White Cap and Hazel are accessed by the jeep trail marked 5J on the quadrangle map, and the Syracuse and Lone Star mines are accessed by a jeep trail along the north base of the mesa.

LAND AND STATUS

The mines on North Star Mesa are 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 Af-

fairs, 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. Only individual Navajos could obtain mining permits only. Permit holders could assign the mining rights to another individual or a company, but the Tribal Council and the BIA had to approve these assignments. 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. 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.

PREVIOUS STUDIES

Chenoweth [1989] has described leasing and mining of the uranium deposits in the Carrizo Mountains for radium extraction. Chenoweth [1991] reports details of the vanadium production in the Carrizo Mountains. An earlier report by Chenoweth [1984] summarizes the uranium-vanadium production in the eastern Carrizo Mountains.

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. Ore production royalty records prepared by the U.S. Geological Survey, Conservation Division, for the Bureau of Indian Affairs, were reviewed to obtain the names of the contract miners, the mines and the months they were operating. Information on the early vanadium ore production that 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 have been donated to the Arizona Geological Survey's Library. The author traced the maps of the mine workings (Figures 2,3,4,6) in 1985 from the files of the Foote Mineral Company, successor to VCA, and the area was last examined in May 1983.

GEOLOGIC SETTING

The uranium-vanadium ore bodies on North Star Mesa occur in the Salt Wash Member of the Upper Jurassic Morrison Formation. In the Oak Springs – King Tutt Mesa area, the Salt Wash Member is approximately 220 feet thick. It is composed of light gray, fine – to very fine-grained, well rounded, quartz sandstone with interbedded lenses in beds of reddish-brown and greenish-gray mudstone and siltstone. The mudstone and siltstone beds make up between 5 to 45 percent of the total thickness of the member. Huffman and others [1980] have subdivided the Salt Wash Member in the Oak Springs – King Tutt Mesa area into three stratigraphic units based on depositional environments. Recent investigations of the Morrison Formation by Anderson and Lucas [1998] have determined that the lower unit of Huffman and others [1980] should be included with the underlying Bluff Sandstone and not with the Morrison Formation. The stratigraphic divisions of Huffman and others [1980] are used in this report. The lower unit is an average of 30 feet thick and was considered by Huffman and others [1980] to be predominantly overbank deposits of alternating thin mudstone and sandstone. The present author notes that this unit is lithologically distinct from the overlying ore-bearing unit. It reportedly contains a few channel sandstones, and does not host any uranium-vanadium ore deposits.

The middle stratigraphic unit of Huffman and others [1980] is an average of 70 feet thick and is composed of channel-sandstone deposits, partially and completely abandoned channel-fill deposits, and overbank deposits. Its base is a sharp erosional contact on the underlying unit. Approximately 80 percent of the sandstone in this unit is active channel fill deposited in a generally east-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. Huffman and others [1980] interpreted their Salt Wash Member of the Morrison to represent a prograding, wet, alluvial fan.

The channel sandstones that contain the ore bodies at North Star Mesa are approximately 30 feet above the base of the Salt Wash Member of Huffman and others [1980], within the middle unit. The outcrop of these sandstones was mapped as the “ore rim” by VCA (Figures 2,3,4,6). Detrital organic plant material, including leaves, branches, limbs and trunks, is common in the ore-bearing channel. Most of this material is carbonized.

The uranium-vanadium ore bodies were formed by the selective impregnation of the sandstone and adsorption by the mudstone and fossil plant material. Ore bodies were commonly associated with detrital plant fragments in the sandstone. They were up to several feet wide, up to nearly one hundred feet in length and up to three feet thick.

The ore deposits in the Carrizo Mountains were originally called carnotite, because of their yellow color. Carnotite is a bright yellow, potassium uranium vanadate. Work by Corey [1958] and S.R. Austin [written communication, 1967] found tyuyamunite, a calcium uranium vanadate, and meta-tyuyamunite as the only uranium minerals in the Carrizo deposits. The mineralogy of the nearby Nelson Point mine was studied by

Corey [1958]. In this mine, vanadium clay and montrosite were present. These minerals have been oxidized to form a number of secondary vanadium minerals, including sherwoodite, duttoniite (?), hewettite, methahewettite, rossite, metarossite, and hendersonite [Corey, 1958]. Calcite is a common cement in ore. Pyrite, iron oxides, and gypsum may also be present.

North Star Mesa is located on the south flank of the east – plunging Syracuse Nose in the eastern Carrizo Mountains. This nose is probably due to an unexposed igneous sill of the Carrizo laccolith. Beds of the Salt Wash on North Star Mesa dip eight degrees to the southeast.

EARLY LEASING AND VANADIUM PRODUCTION

RADIUM: THE NEW ELEMENT

The discovery of radium by Marie and Pierre Curie in 1898 led to the realization that all uranium ores contained this new element. Radium was found to be a radioactive decay product of the element uranium. Experiments showing that radium inhibited the growth of certain cancers created an incentive to mine uranium-bearing ores. Shortly before 1910, metallurgical processes for relatively large-scale recovery of radium from carnotite ores were perfected. The improved processes resulted in greatly increased demands for carnotite and in accelerated prospecting in southern Colorado. About one gram of radium is present in every 200 to 300 tons of ore containing 2.0 percent U_{308} . 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 led to prospecting and the discovery of similar deposits in the Carrizo Mountains.

EARLY PROSPECTING

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 [personal 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 and mining, John F. Wade, d.b.a. the Carriso Uranium Company, located 41 claims astride the Arizona – New Mexico state line in the vicinity of Milepost 16 [oral communication, 1955]. The GSA [1981] could not locate the details of the Carriso Uranium Company's lease, except for the first year's rental \$44.36, on 177.45 acres was paid on May 19, 1922, and noted that no production was reported. This amount acreage would indicate that the Carriso Uranium Company intended to retain only eight claims, probably some of the North Star group.

In April 1921 W.H. Staver, a consulting mining engineer, examined the area. Staver [1921] noted that the company's holding consisted of the South Butte, Bluebell, North Star, and Hilltop claim groups. The North Star Group was located astride the state line, with five claims in New Mexico and six claims in Arizona, and contained the only development. Thirty-seven sacks of high-grade ore from these claims were stored at Beclabito Trading Post (Figure 1). In the radium industry, the standard shipping containers were 75 pound canvas bags [Kithil and Moore, 1917, p. 41]. Thus, there would have been approximately 1.4 tons of ore ready to be shipped. Staver estimated that a total of 2,900 tons of probable ore could be developed on the property. Butler and Allen [1921] mention that 500 feet of benching and 100 feet underground development had been done on the claims. Hess [1924] also visited the area of the Carriso Uranium Company's activities in 1921 and reported that no shipments had been made, and that the ore was richer in vanadium than in uranium.

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. The disposition of the stored ore at Beclabito was never mentioned in any of the early reports. However in 1926, Hess [1929] reported that the Utah Vanadium Company obtained some ore from the Carrizo Mountains and the ore was shipped to Denver for the production of fused vanadium oxide used by eastern ferroalloy manufacturers. Although there are no details on the size of this shipment, it represents the first vanadium production from the Carrizo Mountains. The shipment no doubt included the 1.4 tons of sacked ore observed by Staver at Beclabito, five years earlier.

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

Executive Committee rejected the resolution, evidently because the committee did not want prospecting or mining on the Reservation at that time.

LEASING FOR VANADIUM

By the mid-1930s, the mines in the carnotite region of southwestern Colorado and southeastern Utah were being reopened for their vanadium content to be used as a steel alloy, and the Secretary of Interior was asked to open the Navajo Indian Reservation for prospecting and mining. A Congressional Act of May 11, 1938 opened the Navajo Indian Reservation for prospecting and mining 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 regulations 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.

On April 9, 1941, the Navajo Tribal Council requested the Secretary of the Interior to lease lands for mining purposed 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 the specified 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.

THE EAST RESERVATION LEASE

When the United States entered World War II, the demand for vanadium by the steel industry greatly increased. Due to the uncertainty of foreign supplies and the need for strategic materials, the Federal government 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 stimulus to renew interest in the carnotite deposits in the Carrizo Mountains. Metals Reserve's vanadium program was to acquire five million pounds V_2O_5 for the nation's strategic stockpile.

On May 29, 1942, in response to requests by several mining companies, the Office of Indian Affairs advertised an exploration lease sale for carnotite and related minerals in the eastern Carrizo Mountains. The area offered was described as follows:

“beginning at a point on the New Mexico-Arizona State Line which is approximately 8 1/3 miles south of the corner common to the state of Colorado, Utah, New Mexico, and Arizona; thence east 6 miles, thence south 12 miles; thence west 6 miles to the Arizona-New Mexico state line; thence west 3 1/2 miles; thence north 2 miles; thence east one mile; thence north 10 miles; thence east 2 1/2 miles to the Arizona-New Mexico state line and in the point of beginning”

The area contained approximately 104 square miles. This was the second carnotite lease sale for Navajo lands held under the bidding procedures.

Bids were opened on June 15, 1942, at which time Vanadium Corporation of America (VCA) bid \$7,600, and John F. Wade and Thomas F.V. Curran, partner, bid \$7,550. [GSA, 1981, exhibit 31]. As the bids were nearly equal, and since Wade and Curran offered to pay \$2,000 over and above the highest bid received, the General Superintendent of the Navajo Service requested that the Commissioner of Indian Affairs make the decision to award the lease. VCA was awarded the lease I-149-IND-5705, which was executed on July 14, 1942, effective July 23, 1942, for a period of 10 years.

On September 2, 1943, the lease was reduced to a permanent operating lease and 12 plots totaling 436.79 acres were selected to be retained. Six of the plots (1-6) were on King Tutt Mesa, two of the plots (7,10) were along the north side of the canyon of Oak Springs Wash and the remaining four plots (8,9,11, and 12) were in the vicinity of Milepost 16 on the New Mexico-Arizona State Line. Each of the plots was named by VCA (Table 1). Lease I-149-IND-5705 was renamed as the "East Reservation Lease" by VCA. The mines on this lease were originally known as the Eastside mines, a name still used today in U.S. Geological Survey (USGS) reports. For Lease I-149-IND-5905, the Tribe received a royalty of 10 percent of the mine mouth value of the ore.

VANADIUM MINING

Mining on the East Reservation Lease commenced in August 1942 on King Tutt Mesa. When the operations were examined by the USGS in November 1942, approximately 1,800 tons of ore with an average grade of 2.30 percent V_2O_5 had been produced mainly from Plot 3 [Duncan and Stokes, 1942, p. 26].

Mining continued through August 1944. Single shipments were recorded in February 1945 and in July 1947. Total vanadium production from Lease I-149-IND-5705 was 10,294.74 tons of ore containing 504,822.27 pounds V_2O_5 and averaging 2.47 percent V_2O_5 [Chenoweth, 1991]. With the exception of the 1947 shipment, which was made to its mill at Naturita, Colorado, VCA shipped ore from this lease to the Monticello, Utah mill operated by VCA for the Metals Reserve Co. The Metals Reserve vanadium program ended in February 1944 when the strategic stockpile had been filled. At that time, mining all but ceased in the Four Corners area including the Carrizo Mountains. Plot 12, the former North Star mine, renamed Syracuse by VCA, appears to be the only mine on North Star Mesa that produced vanadium ore in the early 1940s.

URANIUM MINING: THE AEC PROGRAM

During 1947, the U.S. Atomic Energy Commission (AEC) began a procurement program on the Colorado Plateau to obtain uranium. The first domestic contract was signed with VCA on August 29, 1947, retroactive to May 20, 1947, to purchase uranium concentrates from the company's mill in Naturita, Colorado. The

AEC also contracted with VCA, effective October 8, 1948, to buy concentrates from the AEC-owned mill at Durango, Colorado, which VCA had leased with an option to buy [Albrethsen and McGinley, 1982].

Since a market had developed, VCA began prospecting and mining on their East Reservation Lease. In March 1948, shipments began from the lease, mainly from Plot 3 [Page Edwards, 1955, personal communication]. Production in 1948 amounted to 1,302.62 tons averaging 0.29% U_3O_8 and 2.59% V_2O_5 (Table 2).

The reopening of the Durango mill in March 1949 resulted in a shorter haulage for the mines in the Carrizo Mountains and production from the East Reservation Lease increased to 4,331.62 tons (Table 2). It was not until early 1950 that VCA began to separate the shipments from the East Reservation Lease by the individual plots on mill receipts to the AEC.

During the spring and summer of 1953, the AEC drilled a number of holes on North Star Mesa. Wagon drilling was done on 100 ft centers behind the mines on Plots 11 and 12 in expectation of locating additional ore bodies [Blagbrough and Brown, 1955]. No ore bodies were located by this drilling. Unfortunately, the large mine on Plot 12 was identified as the Lone Star, instead of the North Star, and the mesa was called Lone Star Mesa [Blagbrough and Brown, 1955, p. 16].

The AEC ore procurement program ended at midnight, December 31, 1970. After that date all uranium produced in the United States was purchased by electric utilities for use in nuclear power plants.

DESCRIPTION OF INDIVIDUAL MINES

WHITE CAP, PLOT 11

Plot 11, White Cap, is a 20.66-acre tract located on the western end of North Star Mesa. The mined area consists of two short adits and a rim stripped area approximately 200 ft by 50 ft. All of the workings are in the northwest corner of the plot (Figure 2). The underground mines are approximately 2,000 ft southwest of the Milepost 16 Witness Corner (Figure 2). The stripped area and the southern adit are shown on the Beclabito quadrangle [U.S. Geological Survey, 1982]. When Coleman, of Union Mines Development Corporation, examined the area during the summer of 1944, he noted two unmined mineralized outcrops in the area where the mines would later be developed. Coleman [1944, p. 15] described the outcrop as follows: "S-W 25, Outcrop is 10 ft long, 0.17 to 0.4 ft in thickness. Not sampled. Estimated grade is 1.50% V_2O_5 , 0.10 SOQ" (% U_3O_8) and "S-W 26, Outcrop is 57 ft. in length, 0.5 to 1.0 ft. in thickness for 44 ft.; 0.1 to 0.2 ft. for 13 ft. Not sampled." From this information, it would appear that Plot 11 was not mined during the pre-AEC period. In the AEC records, there are no shipments identified as Plot 11 or White Cap mine. It is estimated that a few hundred tons of ore were mined by VCA in the 1949-1950 period and shipped as the East Reservation Lease.

HAZEL

In the summer of 1955, Leroy Pettigrew, an experienced Navajo miner, applied to the Navajo Tribal Council for a mining permit for the area between VCA's Plots 11 and 12. Pettigrew had determined that an unmined mineralized exposure, on the north rim of North Star Mesa, was not covered by VCA's East Reservation Lease. In 1944, Coleman [1944, p. 12] had described the S-W 27 outcrop as "Outcrop in 48 ft. long, 1 to 3 ft. in thickness. Office sample No. 1393: 2.5 ft. 0.32 (%U₃O₈) – 3.55 (%V₂O₅)".

On August 25, 1955, Mr. Pettigrew was issued Navajo Tribal Mining Permit No. 337. The mine he developed on this permit was named Hazel for his wife. The small mine was located approximately 650 ft north-east of the workings on Plot 11 (Figure 2). The mine's portal is shown on the Beclabito quadrangle [U.S. Geological Survey, 1982] northeast of the trail marked 5J. Late in 1955, Mr. Pettigrew shipped 29.72 tons of ore averaging 0.16 percent U₃O₈ and 1.81 percent V₂O₅ to the mill at Shiprock, New Mexico, operated by Kerr-McGee Oil Industries, Inc. (Table 3). The mine was idle until early 1957, when Pettigrew shipped an additional 6.62 tons of ore with an average grade of 0.13 percent U₃O₈ and 2.12 percent V₂O₅ (Table 3). After having such disappointing results, Mr. Pettigrew canceled his mining permit on February 11, 1958. Total production from the Hazel mine was only 36.35 tons of ore averaging 0.15 percent U₃O₈ and 1.88 percent V₂O₅ (Table 3).

SYRACUSE, PLOT 12

The Syracuse, Plot 12, is a 4.13-acre tract on the north rim of North Star Mesa. The east line of this small tract is the Arizona-New Mexico State Line (Figure 3). It is unfortunate that VCA named this tract Syracuse, because that was the name of a mine just west of North Star Mesa, operated by Wade, Curran and Company mined for vanadium in 1942 and 1943; this earlier Syracuse mine was renamed the R F and R mine in the 1950s [Chenoweth, 1997]. The mine workings on Plot 12 consist of three mines and two short adits, which are located along the rim of the mesa 130 ft to 370 ft west of the State Line (Figure 4). The easternmost mine is the North Star, which was the source of some of the ore that the Carriso Uranium Company mined in the 1920s. It was located on one of the eleven North Star claims of Carriso Uranium [Staver, 1921].

When Duncan and Stokes, of the U.S. Geological Survey examined vanadium mining operations in the Carrizo Mountains in November, 1942, they noted that VCA had worked some of the small ore bodies exposed northeast of the Syracuse (R F and R) mine, but the deposits were too small to be economic [Duncan and Stokes, 1942, p. 26]. The ore bodies they described would be on the north rim of North Star Mesa and would have been mined by Carriso Uranium Company, not VCA, and would have been the source of the 1.4 tons of ore Staver [1921] observed at Beclabito. Coleman examined the area in the summer of 1944, and mapped the North Star mine (Figure 5). The only other mining he observed along the north rim of North Star Mesa were two short adits east of the mine [Coleman, 1944, p. 16]. VCA no doubt worked the mine in the early 1940s and probably produced less than 200 tons of vanadium ore [Chenoweth, 1991, p. 30].

Under the AEC program, VCA may have mined on Plot 12 in 1949 and in early 1950, but no shipments identified as Plot 12 or Syracuse are in the AEC records for those years. In October 1950, Leroy Pettigrew obtained a contract from VCA to mine on Plot 12. During the last three months of 1950, he shipped 145.12 tons of ore averaging 0.29 percent U_3O_8 and 3.05 percent V_2O_5 to the VCA mill at Durango, Colorado. (Table 4). Pettigrew also made a 56.64-ton shipment in April 1951 and a 28.85-ton shipment in May 1952. When Mr. Pettigrew canceled his contract in the summer of 1952, he had produced 225.61 tons of ore with an average grade of 0.27 U_3O_8 and 2.96 percent V_2O_5 (Table 4).

VCA's contract with the AEC to produce uranium concentrates (yellowcake) was due to expire March 31, 1962. On May 22, 1961, effective April 1, 1961, VCA and the AEC entered a new contract for the Durango mill which ran through December 31, 1966 [Albrethsen and McGinley, 1982, p. A-10]. In the new contract, VCA was required to list mining units where the company planned to mine company controlled ore. Plots 9 and 12 were listed as Mining Unit 69 of Contract No. AT (05-1)-900. During May through July 1962, VCA company miners shipped 75.57 tons of ore with an average grade of 0.18 percent U_3O_8 and 1.69 percent V_2O_5 from Mining Unit No. 62 (Table 4). Field investigations by the author indicated the ore came from Plot 12, although one of the Navajo miners told the author the ore came from the Lone Star (North Star) mine. These shipments would be the last from the North Star Mesa area. Total ore production, identified as Syracuse and/or Plot 12, was 300.18 tons, averaging 0.25 percent U_3O_8 and 2.65 percent V_2O_5 (Table 4).

LONE STAR, PLOT 9

This plot is a 6.20-acre tract located on the rim of North Star Mesa in San Juan County, New Mexico. The west line of this tract is the Arizona-New Mexico State Line (Figure 3). The mine workings are located approximately 600 ft northeast of the Milepost 16, Witness Corner, and consist of a small stope 15 ft wide and 30 ft deep. The outcrop was also mined for 20 ft east from the mine's portal (Figure 6).

When the area was examined by Coleman in the summer of 1944, he noted only a mineralized exposure where the mine was later developed. Coleman [1944, p. 16] described the outcrop as follows: "S-W 31, Outcrop is 40 ft. in length, 0.17 to 0.33 ft. in thickness. Not sampled. Estimated grade V_2O_5 , 0.20 SOQ" (U_3O_8). This would indicate that Plot 9 was not mined during the 1940s vanadium era.

Although some mining for uranium and vanadium could have occurred in 1949, the only ore production credited to Plot 9 began in late 1950. In the fall of 1950, Raymond Marshall, a Navajo miner, was given a contract, by VCA, to mine on Plot 9. In October 1950 he shipped 5.59 tons of ore averaging 0.28 percent U_3O_8 and 2.70 percent V_2O_5 to Durango, Colorado and then canceled his contract (Table 5). Harry Russell, an experienced Navajo miner took over mining on Plot 9 after Marshall. During the period December 1950 through July 1951, Russell produced 149.17 tons of ore averaging 0.45 percent U_3O_8 and 3.99 percent V_2O_5 (Table 5). A

24.58-ton lot shipped in December, 1950 averaged 0.61 percent U_3O_8 and 4.20 percent V_2O_5 , one of the highest-grade uranium shipments ever made from the mines in the Carrizo Mountains.

In April 1952, Leroy Pettigrew who was mining adjacent Plot 12, shipped 32.86 tons with an average grade of 0.17 percent U_3O_8 and 2.45 percent V_2O_5 (Table 5). VCA Company miners, in February 1962, made a final shipment of 12.72 tons averaging 0.17 percent U_3O_8 and 1.87 percent V_2O_5 from Plot 9, (Table 5). Total ore production, identified as coming from Plot 9, was 200.34 tons averaging 0.34 percent U_3O_8 and 3.57 percent V_2O_5 (Table 5).

SUMMARY

The "carnotite" deposits in the Salt Wash Member of the Morrison Formation on North Star Mesa were some of the first to be discovered in the Carrizo Mountains of northeastern Arizona and northwestern New Mexico. However, from the time the first claims were staked in 1919 until the last shipment in 1962, less than 1,000 tons of ore were mined. Slightly over one ton of high-grade ore, mined for its radium content about 1920, was later sold for its vanadium content. During the vanadium boom of the early 1940s, less than 200 tons of ore was mined for its vanadium content. During the AEC procurement program, approximately 800 tons of ore was mined for uranium with vanadium as a co-product. All of the uranium recovered at the Naturita, Durango, and Shiprock mills was sold to the AEC. At Naturita and Durango, the vanadium that was produced was purchased by the steel industry. Excess vanadium concentrate was purchased by the AEC. At Shiprock, vanadium was paid for, but not all of it was recovered [Albrethsen and McGinley, 1982, p. A-67].

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REFERENCES

- Albrethsen, Holger, 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.
- Anderson, O.J., and Lucas, S.G., 1998, Redefinition of Morrison Formation (Upper Jurassic) and related San Rafael Group strata, southwestern U.S.: *Modern Geology*, vol. 22, p. 39-69.
- Blagbrough, J.W. and Brown, J.F., 1955, Diamond and wagon drilling in the east Carrizo area, Apache County, Arizona and San Juan County, New Mexico, Contracts No. AT (30-1)-1364 and AT(05-1)-231: U.S. Atomic Energy Commission Raw Materials Exploration Report RME-83, 33p.
- Butler, G.M., and Allen, M.A., 1921, Uranium and radium: *Arizona Bureau of Mines Bulletin* 117, 26 p.
- Chenoweth, W.L., 1984, Historical review of uranium-vanadium production in the eastern Carrizo Mountains, San Juan County, New Mexico, and Apache County, Arizona, with production statistics compiled by E.A. Learned: *New Mexico Bureau of Mines and Mineral Resources Open-File Report* 193, 22 p.
- Chenoweth, W.L., 1989, Leasing and mining of carnotite deposits in the 1920s, Carrizo Mountains, Apache County, Arizona, and San Juan County, New Mexico: *Arizona Geological Survey Contributed Report* CR-89-F, 48 p.
- Chenoweth, W.L., 1991, Vanadium mining in the Carrizo Mountains, 1942-1947, San Juan County, New Mexico and Apache County, Arizona: *New Mexico Bureau of Mines and Mineral Resources Open-File Report* 378, 33 p.
- Chenoweth, W.L., 1997, The geology and production history of the Syracuse (RF and R) uranium-vanadium mine, Apache County, Arizona: *Arizona Geological Survey Contributed Report* CR-97-D, 14 p.

- Coleman, A.H., 1944, A report on the geology and ore deposits of the B'Cla B'Tah (Beclabito) district Carrizo uplift area, Arizona: U.S. Army, Manhattan Engineer District Raw Materials Operations Report RMO-469, 21 p. (Open-filed 1957).
- Corey, A.S., 1958, Petrology of the uranium-vanadium ores of the Nelson Point No. 1 Mine, San Juan County, New Mexico: U.S. Atomic Energy Commission Raw Materials Exploration Report RME-122, 30 p. (Open-filed 1970)
- Craig, L.C., and others, 1955, Stratigraphy of the Morrison and related formations, Colorado Plateau region, a preliminary report: U.S. Geological Survey Bulletin 1009-E, p. 125-168.
- 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).
- Duncan, D.C., and Stokes, W.L., 1942, Vanadium deposits in the Carrizo Mountains district, Navajo Indian Reservation, northeastern Arizona and northwestern New Mexico: U.S. Geological Survey Raw Materials Operations Report RMO-28, 32 p. (Open-filed by DOE 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.
- Hess, F.L., 1924, Radium, uranium, and vanadium, in Mineral resources of the United States, 1921, part I--metals: U.S. Geological Survey, p. 225-233.
- Hess, F.L., 1929, Rare metals in Mineral resources of the United States, 1924, part I--metals: U.S. Bureau of Mines p. 249-274.
- Huffman, A.C., Jr., Kirk, A.R., and Corken, R.J., 1980, Depositional environments as ore controls in the Salt Wash Member, Morrison Formation (Upper Jurassic), Carrizo Mountains area, Arizona and New Mexico; in Rautman, C.A., compiler, Geology and mineral technology of the Grants uranium region 1979: New Mexico Bureau of Mines and Mineral Resources Memoir 38, p. 121-130.
- Kithil, K.L., and Davis, J.A., 1917, Mining and concentration of carnotite ores: U.S. Bureau of Mines Bulletin 103, Mineral Technology 11, 89 p.
- Staver, W.H., 1921, Report in the Carriso Uranium Company's claims in the San Juan Indian Reservation: unpublished consulting mining engineers report, 25 p. (copy on file at the Arizona Geological Survey).

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Table 1. Name, size and location of Plots

Number	Plot Name	Acres	Location
1	Red Wash Point	3.53	S.E. King Tutt Mesa
2	King Tutt Point	9.14	S.W. King Tutt Mesa
3	Shadyside	145.13	W. Central King Tutt Mesa
4	Williams Point	8.62	N. Central King Tutt Mesa
5	Fissure	1.57	N. Central King Tutt Mesa
6	Franks Point	6.23	N.W. King Tutt Mesa
7	Lower Oak Creek	205.39	Oak Creek Canyon
8	Cottonwood Butte	20.66	N.E. of MP-16
9	Lone Star	6.20	E. of MP-16
10	Oak Springs	5.53	S.E. of Oak Springs
11	White Cap	20.66	S.W. of MP-16
12	Syracuse	4.13	W. of MP-16
Total		436.79	

All were located in San Juan County, New Mexico except numbers 10, 11, and 12 in Apache County, Arizona.

Source: Unpublished data, U.S. Atomic Energy Commission, Grand Junction, Colorado office.

Table 2. Uranium - vanadium ore production only identified as being shipped from the East Reservation Lease, New Mexico - Arizona

YEAR	SHIPPER	TONS OF ORE	POUNDS U ₃ O ₈	% U ₃ O ₈	POUNDS V ₂ O ₅	% V ₂ O ₅
1948	VCA	1,302.62	7,613.87	0.29	67,396.00	2.59
1949	VCA	4,331.62	15,090.72	0.17	174,222.00	2.01
1950	VCA	1,123.44	7,081.30	0.31	69,895.00	3.11
TOTALS		6,757.68	29,785.89	0.22	311,503.00	2.30

Source: Unpublished AEC ore production records.
 Majority of ore shipped from Plot 3, also includes minor production from Plots 1,2,4,6,7,11, and 12.

Table 3. Uranium-vanadium ore produced from the Hazel mine, Apache County Arizona

YEAR	QTR	SHIPPER	TONS OF ORE	POUNDS OF U ₃ O ₈	% U ₃ O ₈	POUNDS OF V ₂ O ₅	%V ₂ O ₅
1955	4th	Leroy Pettigrew	29.73	95.15	0.16	1,076.35	1.81
1957	1st	Leroy Pettigrew	6.62	17.22	0.13	281.00	2.12
TOTALS			36.35	112.37	0.15	1,357.35	1.88

Source: Unpublished AEC ore production records.

Table 4. Uranium-vanadium ore identified as being produced from Plot 12, Syracuse, Apache County Arizona

YEAR	QTR	SHIPPER	TONS OF ORE	POUNDS OF U ₃ O ₈	% U ₃ O ₈	POUNDS OF V ₂ O ₅	% V ₂ O ₅
1950	4th	Leroy Pettigrew	145.12	847.59	0.29	8,853.00	3.05
1951	2nd	Leroy Pettigrew	56.64	212.97	0.14	3,006.00	2.65
1952	2nd	Leroy Pettigrew	22.85	142.51	0.31	1,463.00	3.20
1962	2nd	VCA*	48.95	179.94	0.18	1,619.00	1.65
1962	3rd	VCA*	26.62	98.79	0.14	942.00	1.77
TOTALS			300.18	1,481.80	0.25	15,883.00	2.65

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Source: Unpublished AEC ore production records.

*Shipped as Mining Unit No. 62, Lease I-149-IND-5705

Table 5. Uranium-vanadium ore identified as being produced from Plot 9, Lone Star, San Juan County, New Mexico

YEAR	QTR	SHIPPER	TONS OF ORE	POUNDS OF U ₃ O ₈	% U ₃ O ₈	POUNDS OF V ₂ O ₅	%V ₂ O ₅
1950	4th	Raymond Marshall	5.59	31.31	0.28	302.00	2.70
1950	4th	Harry Russell	38.05	366.67	0.48	2,950.00	3.88
1951	1st	Harry Russell	59.36	581.17	0.49	4,522.00	3.81
1951	2nd	Harry Russell	51.76	402.16	0.39	4,434.00	4.28
1952	2nd	Leroy Pettigrew	32.86	111.50	0.17	1,610.00	2.45
1962	1st	VCA	12.72	42.24	0.17	473.00	1.86
TOTALS			200.34	1,535.05	0.38	14,291.00	3.57

Source: Unpublished AEC ore production records.

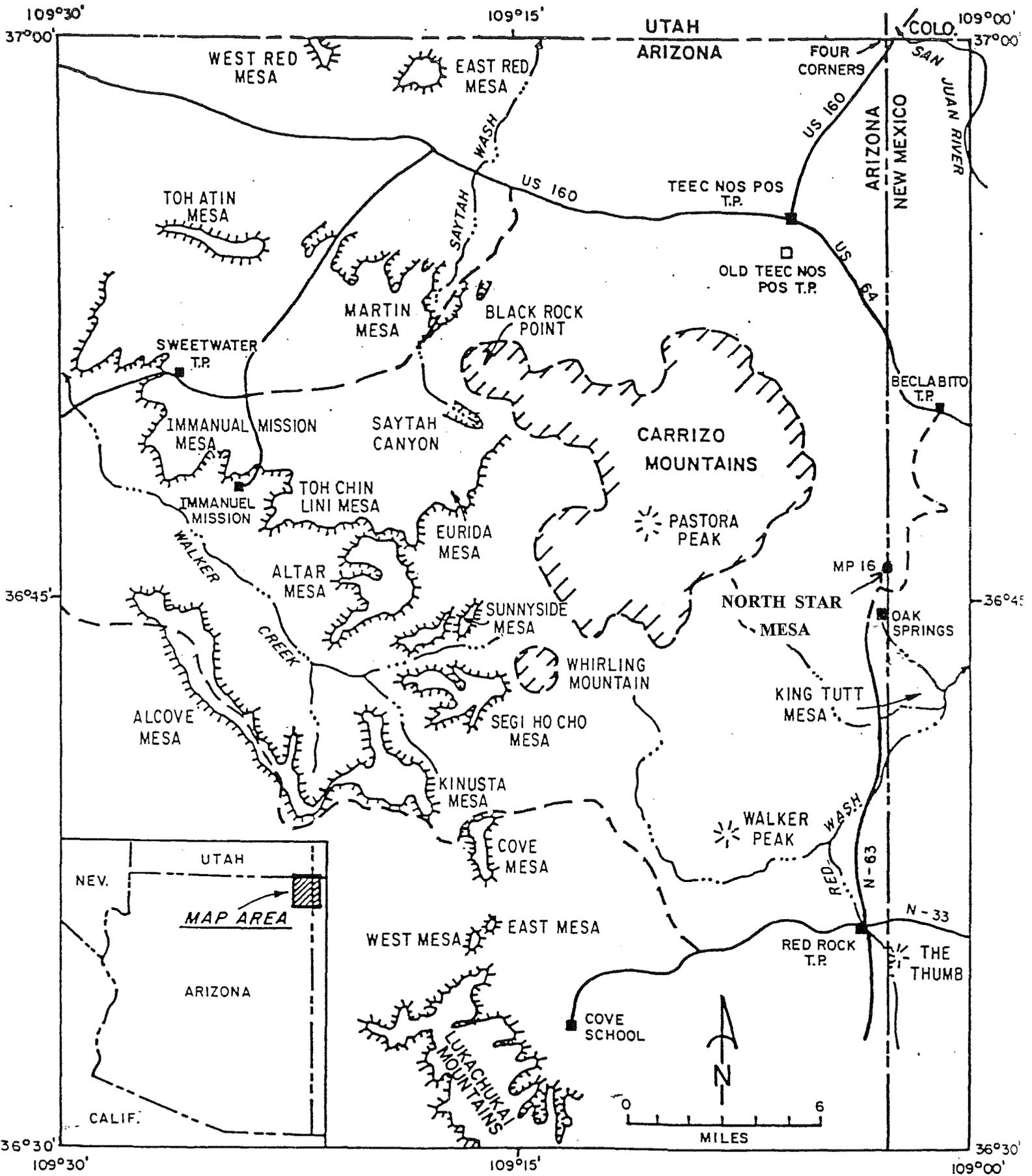


Figure 1. Index map of the Carrizo Mountains, Arizona-New Mexico, showing the location of the North Star Mesa.

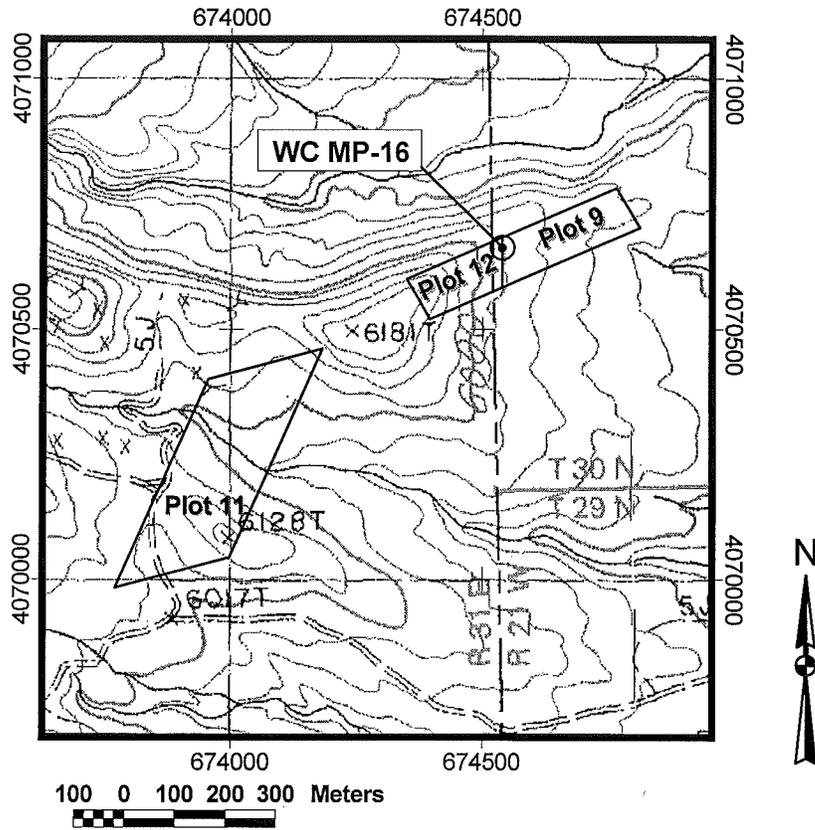


Figure 1a. Map showing locations of Plots 9, 11, and 12, based on location of WC MP-16 given in text and survey information in Figures 2 and 3. Base map is Beclabito, N. Mex-Az. USGS 1:24,000 Quadrangle

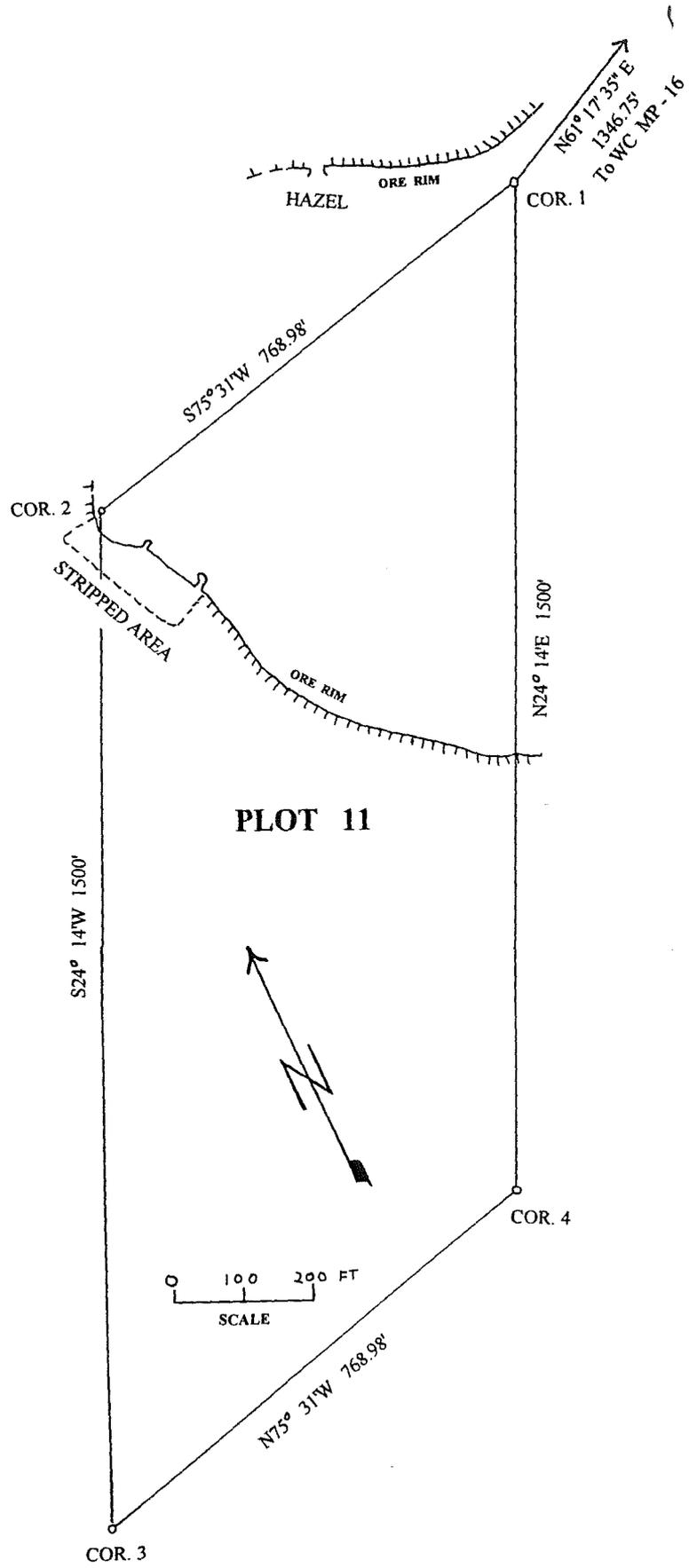


Figure 2. Plan map of Plot 11. East Reservation Lease, Apache County, Arizona.

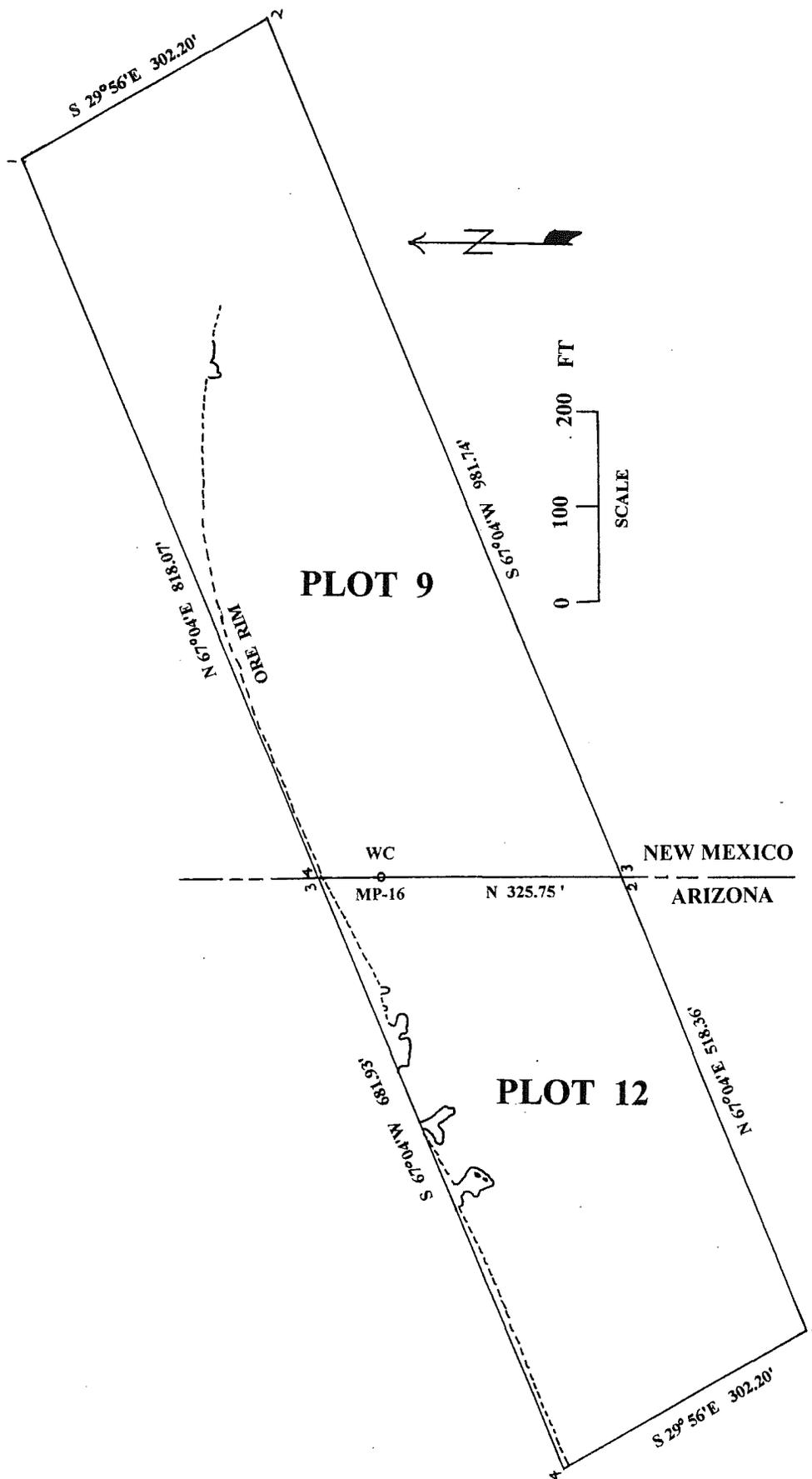


Figure 3. Plan map of Plots 12 and 9, East Reservation Lease. Apache County Arizona and San Juan County, New Mexico.

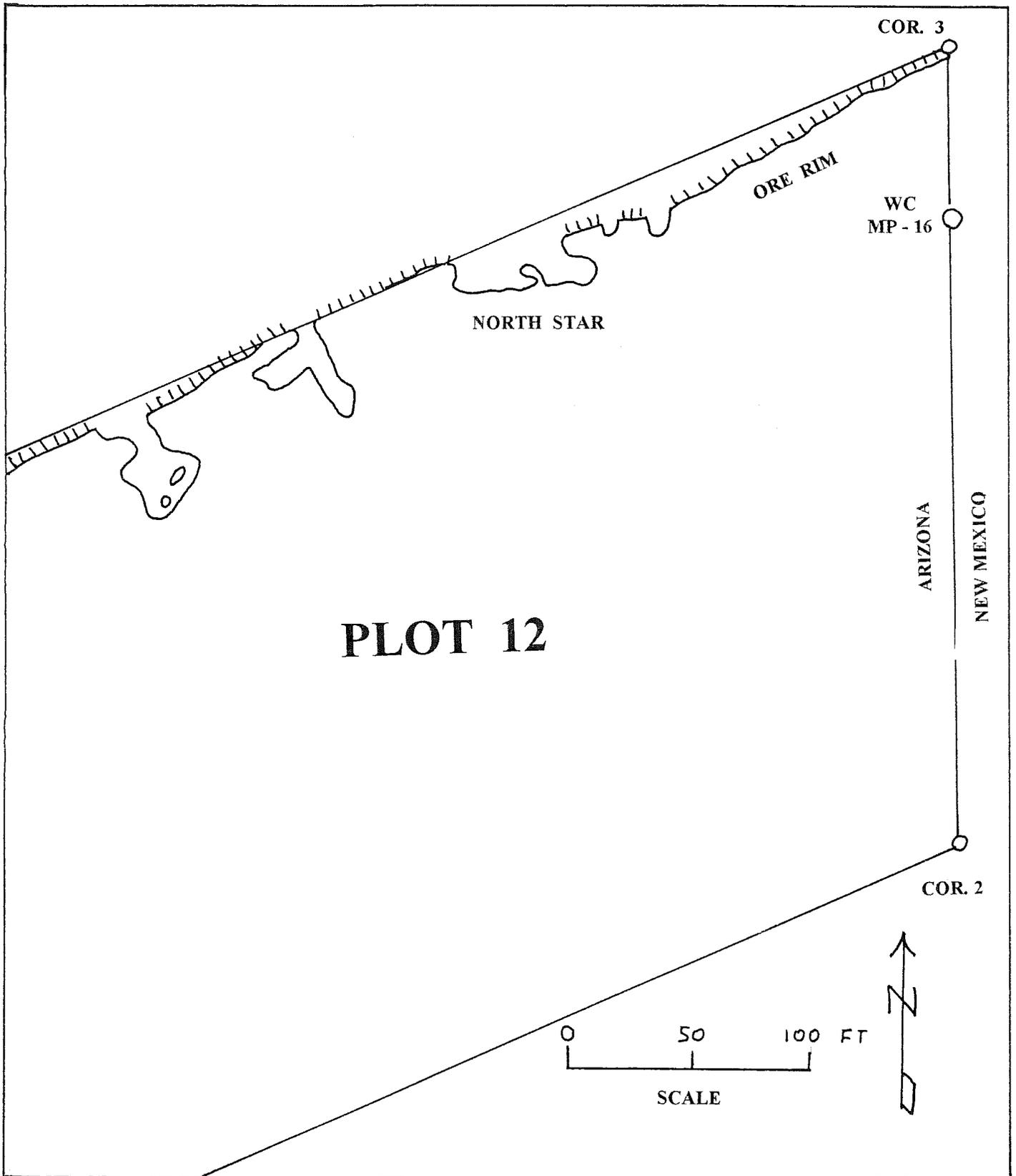


Figure 4. Plan map of the mines, Plot 12. East Reservation Lease, Apache County, Arizona.

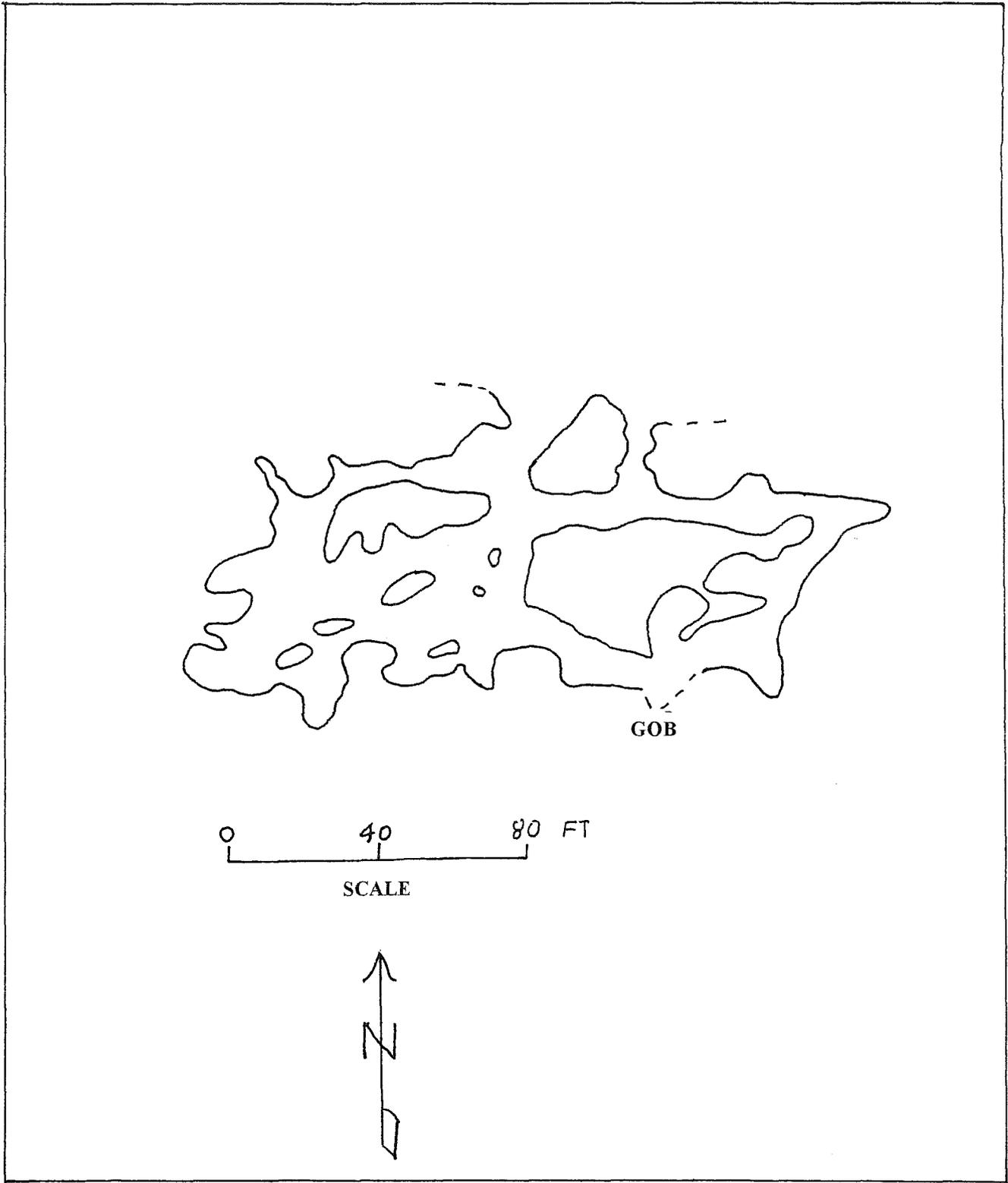


Figure 5. Plan map of the North Star Mine, 1944.
From Coleman [1944].

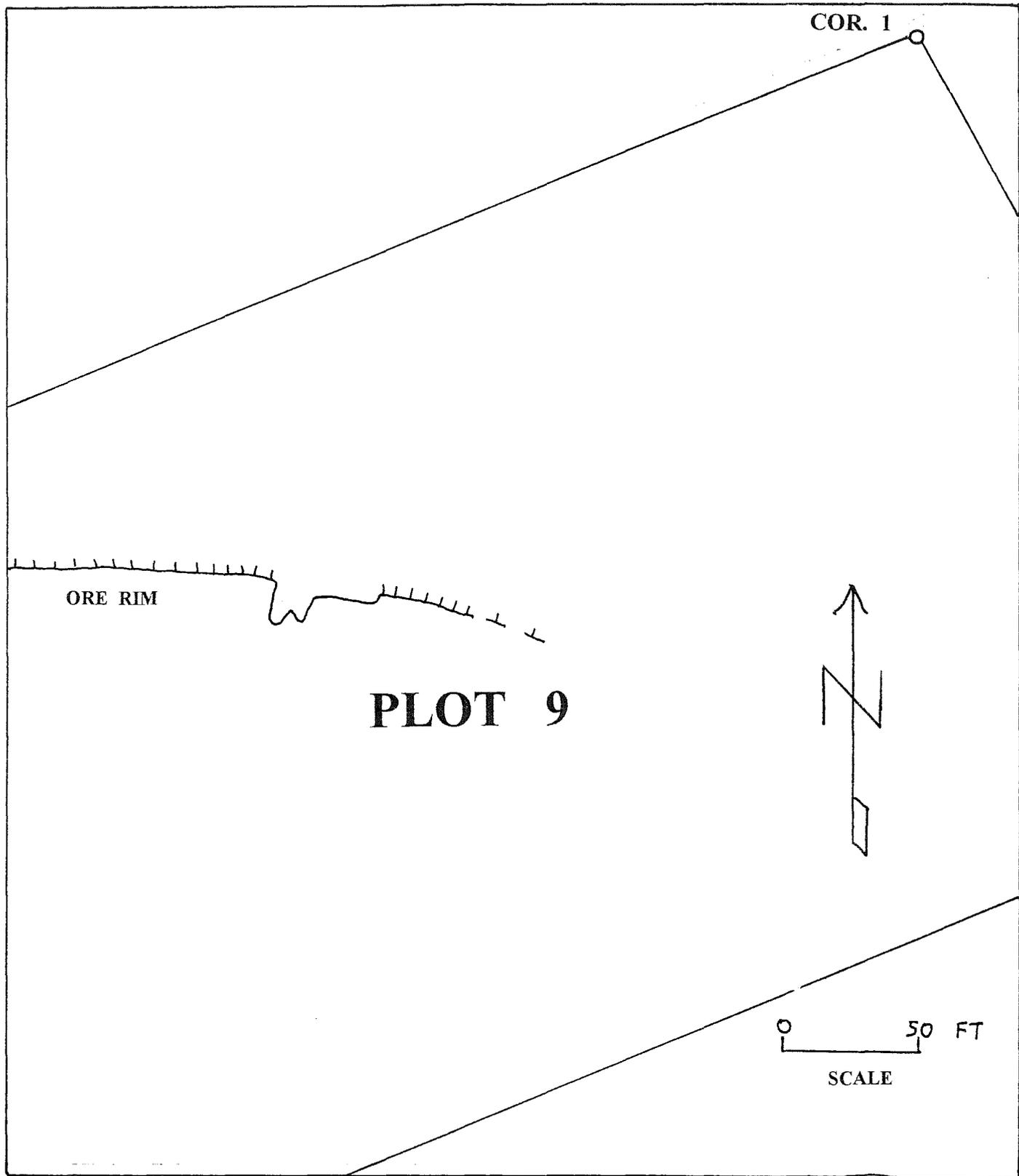


Figure 6. Plan map of the mine, Plot 9, East Reservation Lease, San Juan County, New Mexico.