Section 1

MINING HISTORY AND MINE SITE INFORMATION

MINING HISTORY

An extensive review of records and literature was conducted in an effort to identify the locations of uranium mining activities within the Navajo Nation and to reconstruct production histories for these mines. Significant assistance in determining the locations of abandoned uranium mines (AUMs) was provided by the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and Mr. William Chenoweth, who previously worked with the Atomic Energy Commission and the U. S. Department of Energy's Grand Junction Office. This section presents information about the history of uranium mining within the United States, and focuses on the mining areas, leasing and permitting history, and location and production statistics of AUMs on the Navajo Nation.

URANIUM MINING HISTORY IN THE UNITED STATES

To understand uranium mining on the Navajo Nation it is useful to review the history of uranium mining and the interrelation between uranium, radium, and vanadium. The discovery of radium by Marie and Pierre Curie in 1898 resulted in the realization that all uranium ores contained this new element. Carnotite is a uranium-vanadium mineral with colorful red and yellow ores that had been used as body paint by early Navajo and Ute Indians. Carnotite was found on the Colorado Plateau to contain uranium, vanadium, and trace amounts of radium (Utah History Encyclopedia, 2005 - S09190504). This co-product relationship allowed many mines to survive even after the radium content of their ores was no longer economic (Hahne, 1989 - S09190503).

The history of uranium mining in the U.S. can be divided into four periods, as shown in Table 1. After 1905, interest in mining uranium ore for radium recovery led to an expansion of mining on the Colorado Plateau. The U.S. dominated the world radium market from 1912 to 1922, until high grade ore from the Belgian Congo entered the market, which by 1925 ended the radium period in the U.S. On the Navajo Nation, John F. Wade, working with local Navajos, located carnotite-bearing outcrops in the Carrizo Mountains. From 1920 to 1923, three leases were issued in the Carrizo Mountains to mine carnotite ore for its radium content (Chenoweth, 1991 - S02020701). In 1920, twenty (20) tons of radium ore was mined from a lease in the northeastern Carrizo Mountains (Chenoweth, 2007 - S07110701).

Table 1. U.S. General Uranium Mining Periods.

1905 - 1925	Radium
1925 - 1947	Vanadium
1947 - 1970	Uranium (Government)
1970 - present	Uranium (Commercial)

From 1925 to 1947, vanadium was extracted from the tailings of the radium mines. When added to molten steel vanadium greatly increases its tensile strength and elasticity. This, and the armaments industry of World War II, made the vanadium industry flourish. During this period, prospecting and mining increased and expanded geographically as the demand for vanadium increased (Hahne, 1989 - S09190503).

As a result of the atomic age and subsequent arms race of the Cold War, uranium that was previously considered a waste product of vanadium mines, came into demand as a key element for nuclear weaponry. Beginning in World War II, almost 90 percent of the uranium supply for the U.S. was imported from the Belgian Congo and Canada. The Manhattan Project, tasked with development of an atom bomb, instituted a program to extract uranium from the radium and vanadium mill tailings on the Colorado Plateau and sent geologists to explore the region in search of new uranium sources.

With the end of World War II, the Atomic Energy Commission (AEC) was established by the Atomic Energy Act of August 1, 1946. The AEC was a civilian agency created to ensure continued development of atomic energy. The AEC constructed roads into the back country, promised $10,000 bonuses for new lodes of high-grade ore, guaranteed minimum prices, constructed mills, and helped with haulage expenses. The AEC also provided geologic data for promising areas found by federal geologists using airborne scintillometers and other radiation detection instruments (Utah History Encyclopedia, 2005 - S09190504).

As a result of federal inducements, the Four Corners area was filled with prospectors. They concentrated on exposed outcroppings along canyon rims, where they searched primarily for the Salt Wash Member of the Morrison Formation. When a likely claim was located, they used diamond drills to core test holes to determine if mineable ore was present. By 1955 there were approximately 800 mines producing high-grade ore on the Colorado Plateau. By 1967, however, the uranium mining industry almost came to a standstill. The AEC, holding ample reserves, announced an eight-year limited program and finally stopped buying uranium in 1970. Private industry triggered a brief second boom when nuclear power plants came on line in the mid-70s; but foreign competition, federal regulations, and nuclear fears virtually put an end to domestic uranium mining (Utah History Encyclopedia, 2005 - S09190504). In New Mexico the extensive high grade uranium ores in the Grants Uranium District on and near the Navajo Nation were mined until at least 1989 (McLemore and Chenoweth, 1989 - S08200608).

New interest in uranium is occurring as prices are increasing and demand is exceeding supply worldwide. The New Mexico Bureau of Geology and Mineral Resources (NMBGMR, 2007 - S05200701) reports that in 2006 four mining companies submitted exploration permit applications to the State Mining and Minerals Division for the Grants Uranium District. The Navajo Nation Diné Natural Resources Protection Act of 2005 forbids uranium mining on the Navajo Nation (Navajo Nation, 2005 - S09300605).

URANIUM MINING AREAS ON THE NAVAJO NATION

Uranium mining occurred across the Navajo Nation in six (6) AUM Regions (shown on Figure 2). On the Western AUM Region the major mining area is Cameron, although mining ranged from Bitter Springs in the north to Grand Falls in the south and as far east as the Ward Terrace. The Morale Mine among the Hopi Buttes was the only productive mine in the Southern AUM Region. The Central AUM Region was dominated by the mines on the east side of Black Mesa, with a few mines located at the foot of Black Mesa near Rough Rock. Mining in Monument Valley straddled the Arizona-Utah border in the North Central AUM Region. The Whirlwind mine was a significant outlier on the San Juan River. In the Northern AUM Region mining areas encircled the Carrizo Mountains in Arizona. The eastern Carrizo Mountains mines straddled the Arizona-New Mexico border. To their south was Cove Mesa and further south were the Lukachukai Mountains.[1] The mines of the Sanostee area were solely in New Mexico. The Eastern AUM Region is where much of the productive Grants Uranium District is located, stretching from the Church Rock area in the west, through Smith Lake to Ambrosia Lake on the east.

[1] The cover photo is the Kerr-McGee Mesa II, P-21 mine in the Lukachukai Mountains taken in 1956. Photo courtesy of William Chenoweth.

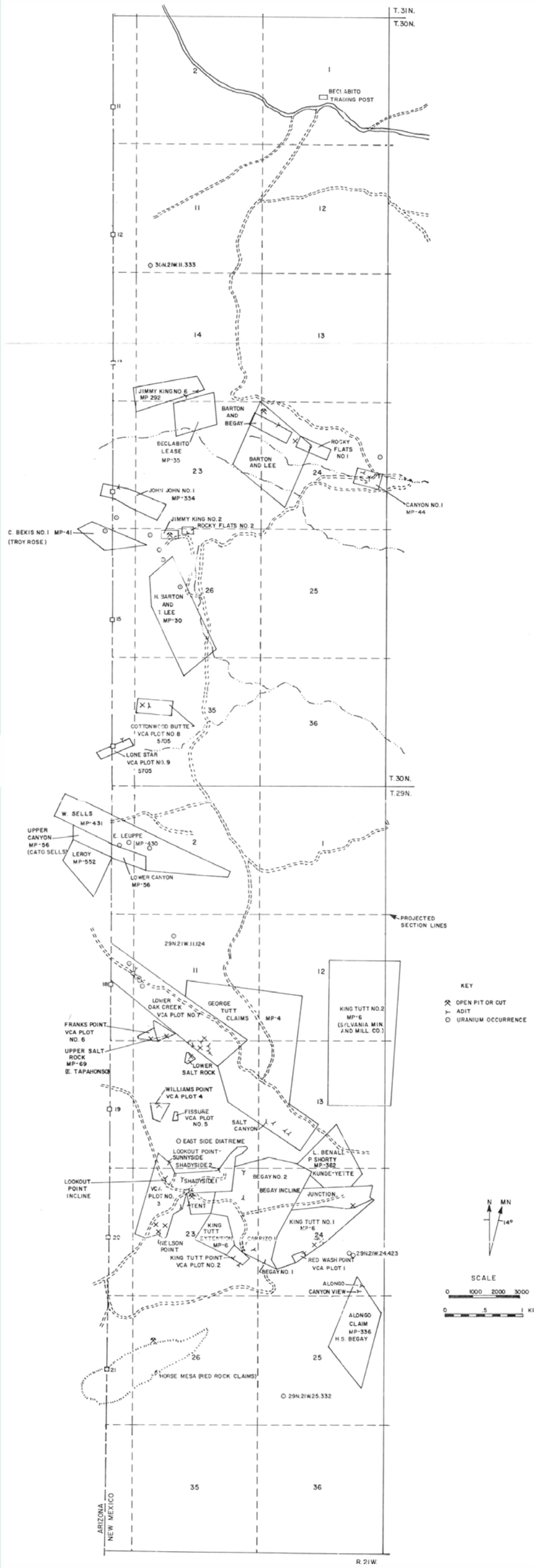


Figure 1. Map of Uranium Mines and Claims in the Eastern Carrizo Mountains. McLemore (1983 - S12110202).

LEASES AND MINING PERMIT HISTORY

In order to locate and identify uranium mines on the Navajo Nation, it was necessary to understand that the mining lease and permit process was complex and evolved over time. The following provides a chronology of significant events that impacted the Navajo Nation lease and mining permit process.

The U.S. Congressional Act of June 30, 1919 opened the Navajo Reservation to mining and prospecting in the same manner as prescribed in the U.S. Mining Law of 1872. If a discovery was made, land could then be leased from the Office of Indian Affairs. Due to the lack of mining activity when the radium market collapsed, the Navajo Reservation was closed to prospecting and mining by the Secretary of Interior on March 25, 1936, thereby canceling any existing leases (Chenoweth, 1997 - S03310301).

Due to the demand for vanadium, the Secretary of Interior was asked to open the Navajo Reservation for prospecting and mining. The Congressional Act of May 11, 1938 reopened the Navajo Reservation to mining under new procedures; prospectors could no longer enter the Navajo Reservation and stake a mining claim under regulations similar to those of the U.S. Mining Law. With the approval of the Secretary of the Interior, the Navajo Tribal Council could now enter into leases with mining companies. Leases were limited to a period of 10 years, which could be extended by production. The new regulations provided for a base 10% royalty with escalating annual rentals and bonding requirements (Chenoweth, 1991 - S02020701).

On April 9, 1941 the Navajo Tribal Council requested the Secretary of the Interior to lease lands for mining purposes to the highest bidder. Mining leases were written for large areas and were subsequently reduced in acreage at the end of a specified time period. The net effect of this type of lease was that a prospecting permit was issued to the highest bidder, who then had the right to lease up to 960 acres within the permit area (Chenoweth, 1991 - S02020701).

After World War II, the AEC was established to ensure the continued development of atomic energy. In 1949 the Secretary of Interior and the Navajo Tribal Council developed new regulations that permitted individual Navajos to prospect and hold unnumbered Tribal Mining Permits upon discovery of a resource. On September 19, 1951, additional regulations permitted non-Navajos to prospect, but still required that only Navajos could hold unnumbered mining permits for a renewable two year period. Permits could be assigned to non-Navajo individuals or companies to explore and mine. Permits and assignments were subject to approval by the Navajo Tribal Council and the U.S. Bureau of Indian Affairs (BIA). Both the Navajo Nation and the permittee received royalties (Chenoweth, 1997 - S03310301). The Navajo Nation and the permittee also received royalties on the vanadium in the ores, as well as copper, and any AEC bonuses received for new discoveries (Chenoweth, 2007 - S07110701).

Drilling and exploration permits were also issued for a non-renewable period of 120 days. The number of Navajos applying for permits was so large that in April 1952, the Navajo Tribal Mining Department began to issue numbered mining permits (Chenoweth, 1995 - S10100231). The BIA encouraged permitted mine operators to convert assignments to 10-year leases upon development of large amounts of ore (Chenoweth, 1993 - S10100239).

Figure 1 is an example of a claim map for the east Carrizo Mountains covering an area from Horse Mesa in the south, to the Beclabito Trading Post to the north (McLemore, 1983 - S12110202). This is one of many maps that were reviewed, scanned, and georeferenced to assist with identifying uranium mines, leases, and mining permits. Most maps were schematic and were based largely on older, less accurate surveys of the Public Land Survey System, as shown by dashed section lines in Figure 1.

ABANDONED URANIUM MINES (AUM)

URANIUM MINING

The excavation of uranium ore bodies is associated with hazards due to both physical conditions and radiation exposure. Although outcrops of radioactive minerals exist throughout much of the Navajo Nation, the areas where ore was extracted and deposited in mine waste piles exhibits higher radiation levels than most undisturbed natural areas. Radiation is particularly hazardous because it cannot be seen or detected without the aid of specialized equipment. The result is that radiation exposure or contamination is not readily apparent. Hazards associated with AUMs include open portals, adits, vertical openings, inclines and declines, pits, radioactive waste piles, radioactive dust, rim cuts, high walls, and embankments (OSM, 1999 - S05070313). Figure 2 shows the locations of AUMs that were mapped on or within one (1) mile of the Navajo Nation. These AUMs are discussed in the following text by AUM Region:

North Central AUM Region: Uranium and vanadium was mined in this region from the Monument Valley mining area, which is located in the southern portion of the Monument Upwarp in the west-central part of the Colorado Plateau. The uranium host rock crops out around the perimeter of the Monument Upwarp and also caps the many mesas and buttes within Monument Valley (Chenoweth, 1991 - S03100502). Uranium mines throughout this region were primarily located in ore bodies formed in channel deposits of the Shinarump Member of the Chinle Formation. These paleochannels range from 5 to 200 feet deep and from 10 to 2,000 feet wide (Black and others, 1962 - S04220602). However, not all paleochannels in the area were mineralized by uranium-bearing fluids. In a few mines, (e.g., Moonlight) ore extended downward as much as 15 feet into underlying beds of the Moenkopi Formation. The deposits also contain variable amounts of vanadium and copper. Shallow deposits at or near an outcrop were mined by adit or open pit, depending on the size of the deposit. Deeper deposits were developed and mined by shafts or inclines. Forty-one (41) separate properties produced uranium or uranium-vanadium ores from 1942 through 1969. However, the location of the productive Harvey Lee Sampson No.s 1 and 9 mine is unknown (Chenoweth, 1991 - S03100502). The Mexican Hat Stockpile was located within one (1) mile of the Navajo Nation.

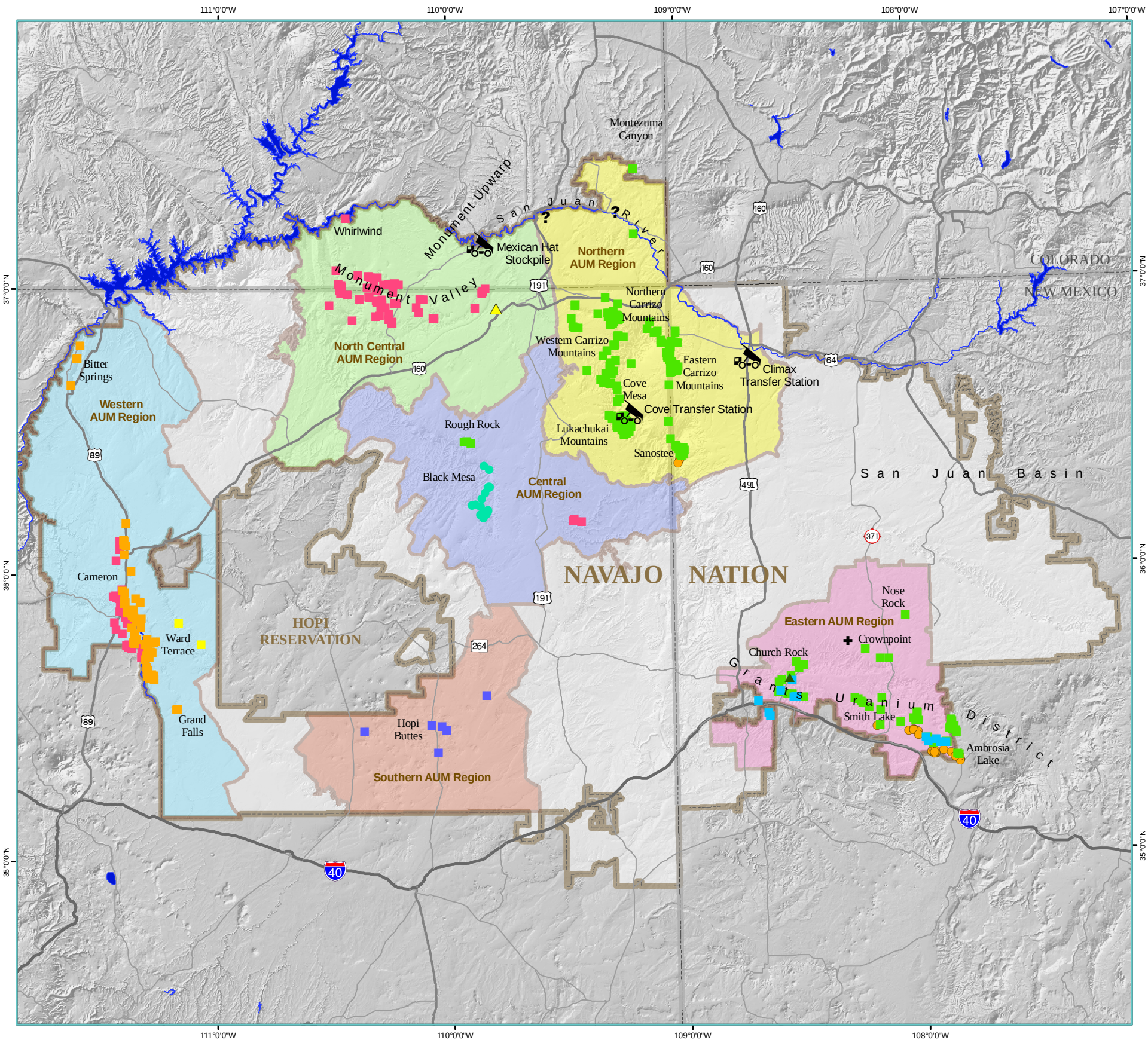
Northern AUM Region: From the late-1940s through 1967 uranium ore in the Northern AUM Region was mined mostly from mesa tops, rims, and from canyon walls. The Enos Johnson 3 mine in the Sanostee area was the one mine that produced until 1982 into the post-AEC period (Chenoweth, 1985 - S08250504). Ore bodies at or near the surface of mesa tops were excavated from relatively shallow pits or trenches. Often the pits were less than 10 feet deep, with unexcavated lower grade ore (protore) at the base and a protore debris pile on the surface. Buried ore bodies and ore bodies exposed on canyon walls were mined by digging down to the ore, or into the face of a hillside or canyon wall, creating mine entrances (e.g., shafts, inclines, declines, and/or adits). The debris pile/talus slope of protore emits gamma radiation at the surface where none may have been emitted before mining (EPA, 1999 - S12120285). Higher grade ores were transported to buying stations and processing mills and the waste rock consisting of overburden and protore was left behind in debris piles. For example, ore was transported from the Lukachukai mines by loading the ore onto dump trucks and driving down steep, winding dirt roads to the Cove Transfer Station, where the ore was dumped and stockpiled. The ore was then reloaded onto larger trucks to haul the ore to the Shiprock mill (Dare, 1961 - S10280202). Two transfer stations were mapped, Cove Transfer Station at the northern base of the Lukachukai Mountains, and the Climax Transfer Station just south of the town of Shiprock, New Mexico. Uranium was produced from 174 properties and 55 properties were not productive.

Western AUM Region: Uranium mining in this region was active from 1951 through 1963. Most of the mining was from open pits, which ranged in size from a shallow trench containing a single fossil log to pits as deep as 130 feet. Uranium ore was produced from 98 properties. The bulk of the ore (98%) was mined from the Petrified Forest Member of the Chinle Formation, about 2% of the uranium was mined in the Shinarump Member of the Chinle Formation, and the Kayenta Formation produced a minor amount (approximately 550 pounds) of uranium (Chenoweth, 1993 - S10100239).

Central AUM Region: Uranium in this region was mined on Black Mesa, a southwest dipping cuesta capped by the Upper Cretaceous Mesaverde Group. The uranium deposits occur on the east side of Black Mesa in the Toreva Formation. Ore was mined from shallow open pits, rim cuts, and underground (Chenoweth, 1990 - S10100236). A small amount of uranium was mined from the Salt Wash Member at the foot of Black Mesa near the Rough Rock Trading Post. Mining at this location was by rim stripping and shallow bulldozer cuts (Chenoweth, 1989 - S10100212). Uranium was produced from 1954 through 1968 from 15 properties in the Toreva Formation and two in the Morrison Formation. Uranium occurrences were prospected in the Chinle Formation near the village of Chinle in Apache County, Arizona. The workings in this area consisted of rim stripping, bulldozer cuts, prospect pits, and small open pits (Chenoweth, 1990 - S10020207).

Southern AUM Region: Uranium was discovered in the Southern AUM Region within the Hopi Buttes volcanic field in the early 1950's. The Hopi Buttes volcanic field is characterized by eroded dikes, necks, diatremes, flows, and tuff of Pliocene and Miocene age (8-4 million years ago). More than 300 diatremes have been located in the Hopi Buttes volcanic field. Many of the diatremes are expressed on the surface as maars that were often filled by localized lakes believed fed by rising thermal solutions. Anomalous concentrations of uranium are located only in those diatremes containing maar lakes with ephemeral lake deposits (Wenrich-Verbeek and Mascarenas , 1982 - S06280601). The Morale mine was the only productive AUM, and was mined between 1954 and 1959 (Chenoweth, 1990 - S10020205). Five non-productive AUMs were also mapped in the Southern AUM Region.

Eastern AUM Region: Uranium was mined in the Eastern AUM Region from the Grants Uranium District from 1951 to at least 1989. The Grants Uranium District is located in the southern San Juan Basin in northwestern New Mexico. The district spans the area from Gallup in the west to Laguna in the east, mostly north of Interstate 40 in the south and to north of Crownpoint. It produced more than 240,600,000 pounds of uranium (McLemore and Chenoweth, 2003 - S03030608), and for three decades was the largest uranium district in the world (NMBGMR, 2007 - S05200701). This region covers the western half of the Grants Uranium District. The 1950 discovery of uranium near Haystack Butte initiated the development of the Grants Uranium District. Uranium was produced from the Todilto Limestone in the Haystack Chapter (Chenoweth, 1985 - S08020601). Most uranium in the Grants Uranium District was produced from underground mines in the Westwater Canyon and Brushy Basin Members, or Poison Canyon Sandstone of the Jurassic Morrison Formation (McLemore and Chenoweth, 2003 - S03030608). Grace In Situ Leach near Church Rock was the one mine that produced using In Situ methods. Leaching solution was injected underground via injection wells, the uranium was dissolved and pumped to the surface via production wells and then extracted by an ion exchange process. Another method was to pump a leaching solution into old underground mines, then pump the water out to surface settling and holding ponds, and finally process via ion exchange. The Church Rock and Mariano Lake mines used this method, as did many mines in the Ambrosia Lake area (Holen and Hatchell, 1986 - S08200601). The Cretaceous Dakota Sandstone was another significant uranium host rock for uranium mines in the southern part of the Eastern AUM Region. Most of the mines were developed at the surface, but the largest production was from underground workings (Chenoweth, 1989 - S08020602).



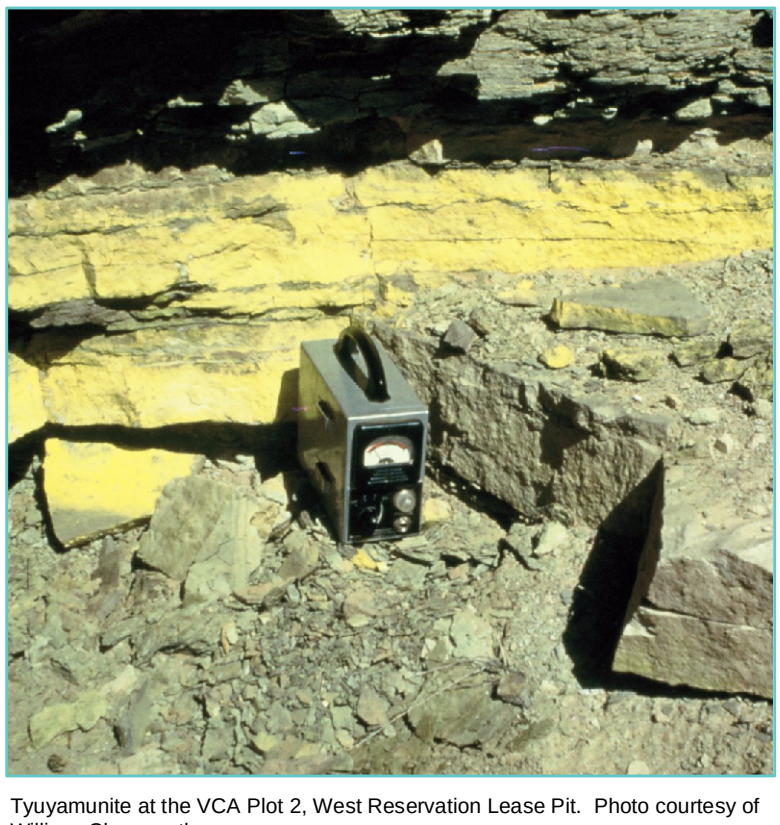
ABANDONED URANIUM MINES AND THE NAVAJO NATION

ABANDONED URANIUM MINES

N W E S

0 50 Miles

Map Scale 1:1,750,000



Tyuyamunite at the VCA Plot 2, West Reservation Lease Pit. Photo courtesy of William Chenoweth.

Legend

Abandoned Uranium Mine Host Rock

- Tertiary Bidahochi Formation
- Cretaceous Dakota Sandstone
- Cretaceous Toreva Formation
- Cretaceous Point Lookout Sandstone
- Cretaceous Dakota Sandstone and Jurassic Morrison Formation
- Jurassic Morrison Formation
- Jurassic Kayenta
- Jurassic Navajo
- Jurassic Todilto Limestone
- Triassic Petrified Forest Member, Chinle Formation
- Triassic Shinarump Member, Chinle Formation
- Transfer Station
- ? Unknown

Source

Abandoned Uranium Mine locations and host rock types were produced from Navajo Abandoned Mine Lands Reclamation Program maps, and sources by William L. Chenoweth, Virginia McLemore, US Atomic Energy Commission/US Department of Energy Documents, and other sources.

Filenames: DB/AUM/NN_AUM_Production_Pts.shp

Figure 2. Abandoned Uranium Mines Shown by Geologic Host Rock Formation.

ABANDONED URANIUM MINES (continued)

METHOD FOR DETERMINING POINT MINE FEATURE LOCATIONS

Since May 1990, the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) has worked to reclaim eligible AUMs on the Navajo Nation. Their initial efforts involved compiling information about each reported occurrence of past uranium activity on the Navajo Nation. NAMLRP then conducted field inventories and investigations to develop a more comprehensive inventory of the AUM sites.

Initially, the NAUM Project concentrated on the AUMs located in the Red Valley Chapter within the Northern AUM Region. NAMLRP prepared a set of USGS topographic maps with mapped AUM feature locations for the Red Valley Chapter. These mine features were automated into a GIS point dataset and compared to those developed from georeferenced mine sketch maps from William Chenoweth's multiple publications covering the East Carrizo Mountains area of Arizona and New Mexico. NAMLRP mine features were also compared with USGS digital orthophoto quarter quadrangles (DOQQ) and USGS 7.5 minute topographic maps. In consultation with Chenoweth (2003 - S07100301) and using a GIS overlay process, it was determined that most NAMLRP mine features were accurately positioned at the 1:24,000 scale and would be used as the primary source for mine feature locations.

For the remainder of the Navajo Nation, NAMLRP prepared multiple sets of USGS topographic maps, covering their inventory areas in the North Central, Northern, Western, Central, and Southern AUM Regions. These maps located all inventoried mine features and coded them by mine feature type (e.g., portal, shaft, prospect, rim strip, and pit). For each AUM region these maps were georeferenced and a GIS point dataset was developed. There are 1,265 mine features mapped on or within one (1) mile of the Navajo Nation. These mine features are provided on the GIS Data DVD (DB/AUM/NN_AUM_Pt_Features.shp). The number of mine feature types by AUM Region is shown in Table 2.

Table 2. Mine features by AUM Region.

Mine Site Feature/AUM Region	Central	Eastern	North Central	Northern	Southern	Western	Total
Drillhole	0	0	0	1	0	0	**1**
Portal	4	53	55	417	1	3	**533**
Prospect	5	4	1	135	1	11	**157**
Rim Strip / Pit	44	44	29	302	0	84	**503**
Vertical	0	36	12	9	0	2	**59**
Waste Pile	1	6	1	4	0	0	**12**
Total	**54**	**143**	**98**	**868**	**2**	**100**	**1265**

Most of the mine features (1,126) were mapped from sources provided by NAMLRP. The remaining 139 mine features were mapped from other sources, and 122 of these were mapped in the Eastern AUM Region. NAMLRP only mapped twenty-one (21) mine features in the Eastern AUM Region, which were associated with the Christensen, Foutz No. 1, Foutz No. 2, Foutz No. 3, and Rats Nest mines north of the town of Church Rock, New Mexico. This was primarily due to NAMLRP's authorization to reclaim only those AUMs that fall within Tribal Trust Lands. Land ownership in the Eastern AUM Region is significantly mixed (see Section 3, page 3-4). The other mine features were mapped in the Eastern AUM Region using reports and maps from multiple literature sources in conjunction with USGS 7.5 minute topographic maps and DOQQ imagery.

There were seventeen (17) mine features added to the other AUM Regions that were not mapped by NAMLRP. These were mapped from other literature sources, USGS 7.5 minute topographic maps, and DOQQ imagery. These additional mine features included: four (4) in the Central AUM Region, six (6) in the North Central AUM Region, and seven (7) in the Northern AUM Region. Eleven (11) of these additional mine features were portals or vertical shafts that were added based upon mine entrances shown on underground mine sketches.

Some NAMLRP mine feature positions were adjusted. These are documented in the "COMMENTS" attribute of the GIS dataset (NN_AUM_Pt_Features.shp). The location source attribute "LCTN_SRC" provides a reference for mine features that were added from sources other than NAMLRP, or for NAMLRP mine feature positions that were adjusted.

Seventy four (74) AUM sites do not have mapped mine features. Sixty three (63) of these AUM sites were not mapped by NAMLRP, and no specific mine feature was present on available maps, interpreted from imagery, or found in the literature. Eleven (11) AUM sites were originally mapped by NAMLRP as single NAMLRP Project sites that were subsequently split into multiple named AUM sites. The splits did not result in mapping any additional mine features.

The "SITE_ID" attribute provides identifiers for the mine features. The NAMLRP mine features use a three character abbreviation for the NAMLRP Problem Area in which they are located[1], followed by a three integer number that was arbitrarily assigned during field inventories. Sometimes there is a character following the three integers. For the mine features added from non-NAMLRP sources, the identifier provided by the source was used for the SITE-ID. In cases where a source identifier was not available for added mine features, a two character abbreviation designating the Chapter was used. For mine features that were located off the Navajo Nation, two XX's were used. These two characters were followed by a two integer sequential number.

Figure 3 provides an example of mine features in an area of the Lukachukai Mountains, Apache County, Arizona. Mine features are shown in red and they have been symbolized by the type of feature. The inset location map shows the distribution of mine features (shown in black) in an overview of the Navajo Nation.

[1] For the NAMLRP mine features at the Christensen, Foutz No. 1, Foutz No. 2, Foutz No. 3, and Rats Nest mines, the identifiers used by McLemore and others (2002 - S12160205) were adopted.

109°15'0"W

36°32'30"N

36°32'30"N

COVE

ROUND ROCK

109°15'0"W

ABANDONED URANIUM MINES AND THE NAVAJO NATION

MINE FEATURES OF THE LUKACHUKAI MOUNTAINS

N
W E
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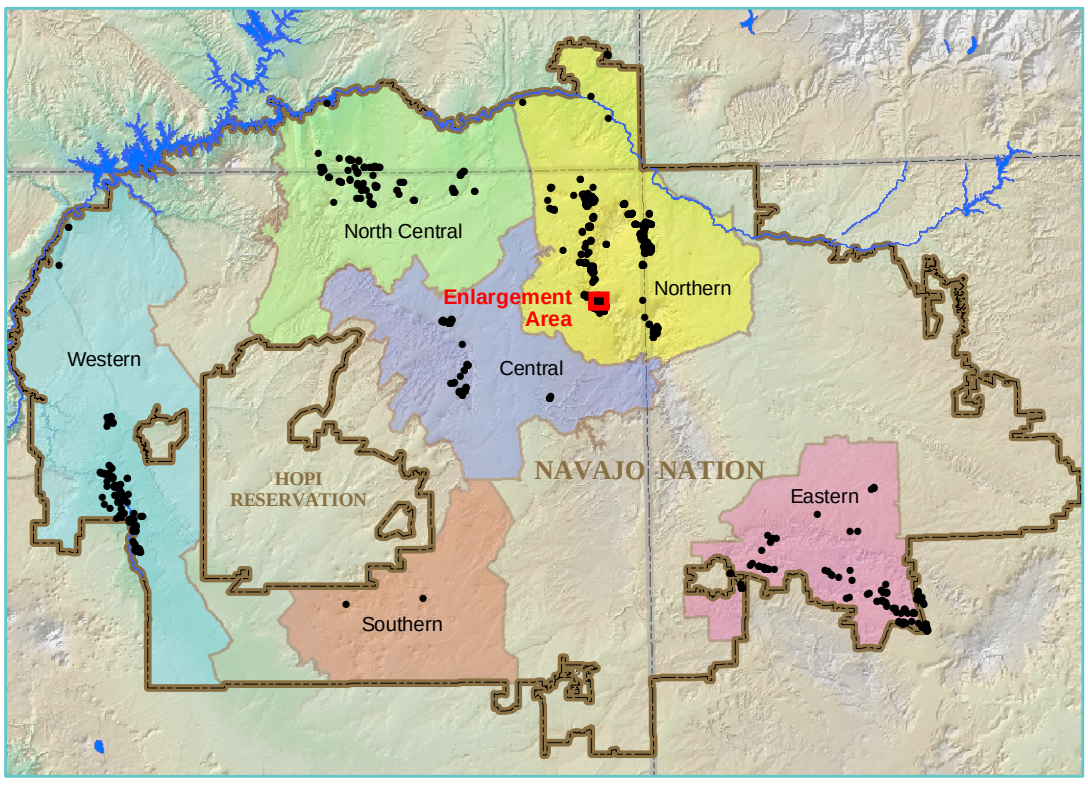
0 1 Miles

Map Scale 1:24,000



Overview of Mine Feature Locations Across the Navajo Nation.

Legend

Mine Features

- Portal
- Prospect
- Rim Strip / Pit
- Vertical

Source

Abandoned Uranium Mine feature locations are from Navajo Abandoned Mine Lands Reclamation Program maps, and sources by William L. Chenoweth, Virginia McLemore, USGS 7.5 minute topographic maps, Digital Orthophoto Quarter Quads (DOQQs), and other sources.

Filename: DB/AUM/NN_AUM_Pt_Features.shp

Figure 3. Mine Features on the Lukachukai Mountains.

ABANDONED URANIUM MINES (continued)

ABANDONED URANIUM MINE POLYGON DELINEATION

NAMLRP provided maps showing the location of NAMLRP Reclamation Project Areas for the North Central, Northern, Western, Central, and Southern AUM Regions. NAMLRP provided coordinates from Global Positioning System (GPS) measurements for the location of AUM project areas in the North Central and Western AUM Regions. Seven (7) of 51 NAMLRP AUM reclamation project areas in the North Central AUM Region were mapped using GPS and 83 of 86 NAMLRP AUM reclamation project areas in the Western AUM Region were mapped using GPS. NAMLRP inventories were conducted on Navajo Nation Trust Lands; therefore, maps were not provided in the Eastern AUM Region outside the area of the Christensen, Foutz No. 1, Foutz No. 2, Foutz No. 3, and Rats Nest mines. NAMLRP project areas generally included groups of mine features that were associated with one or more mining operations. They encompass the mapped mine features, smaller unmapped features of a mining operation, and a buffer around the mining operations by about 50 feet. These NAMLRP AUM reclamation project polygons provide excellent mine operation locations and extents and are provided on the GIS Data DVD (DB/AUM/NN_AUM_Project_Sites.shp).

AUM polygons were also generated for mine features and unreclaimed mine waste piles that were not reclaimed by NAMLRP. These AUM polygons were generated by creating a 200 foot buffer around the feature. In some cases, it was possible to further refine the AUM boundaries by including NAMLRP unreclaimed mine waste piles, airborne radiological anomalies, and/or photo-interpreted mine-related surface disturbances. Many AUMs across the Navajo Nation occur in areas of high relief, characterized by flat-topped mesas with vertical or near vertical cliffs. Mine waste was often pushed down these cliffs forming potentially radioactive mine waste talus slopes. These mine waste piles were not individually mapped; however, they were identified by NAMLRP and coded into the mine features GIS dataset. In these areas, the boundaries of NAMLRP project polygons were extended down-slope 200 feet.

Some NAMLRP project boundaries were modified based on aerial radiation data collected by the U.S. Department of Energy's Aerial Measuring System (Hendricks, 2001 - S03310309). NAMLRP project boundaries were enlarged where the excess Bismuth-214 7.4 µR/hr contour levels extended beyond these boundaries. This contour level was chosen because it represents about twice the background excess Bismuth-214 expected across the Navajo Nation. DOQQ imagery was inspected around NAMLRP projects. Boundaries were extended where distinct AUM related disturbances could be photo-interpreted and mapped contiguous with NAMLRP projects. Some NAMLRP projects encompassed more than one mine. In these cases the project polygons were split or merged to enable the separate representation of AUMs. All of the modifications to the NAMLRP project boundaries were documented in the metadata, and resulted in a new GIS dataset of AUM boundaries.

For the Eastern AUM Region, NAMLRP AUM Reclamation Project Areas and field inventories were used to develop six (6) AUM polygons. Eighty five (85) AUMs were identified from McLemore's database of point locations for uranium and thorium occurrences in New Mexico (McLemore et al., 2002 – S12160205). Locations for eight (8) AUM polygons were added from other reports and documents (Chenoweth, 2007 - S01150706; DOE, Unpublished - S08020610; Holen and Hatchell, 1986 - S08200601; and McLemore and Chenoweth, 1991 - S03030608). Most AUM polygons were developed using point locations and/or mine claim or permit boundaries from these and other supporting literature. They were further developed using USGS 1997 black and white and 2005 color DOQQs and USGS 7.5 minute topographic maps. The aerial radiation survey did not cover the Eastern AUM Region.

Mine names were identified for most AUMs. Some AUM polygons have the same mine name because a mine may have more than one associated area of disturbance. The final boundaries for the AUMs are provided on the GIS Data DVD (DB/AUM/NN_AUM_Poly_Surf.shp), and represent the AUM surface extents. These were used as the basis for generating buffers for the Soil, Air and Surface Water Pathway analyses.

<u>Underground AUM Workings</u>

North Central AUM Region: Thirty-seven (37) of the AUMs in the North Central AUM Region had documented underground workings, although most uranium mines in this region were mined underground. Many historical reports contained sketches of the underground workings of the mines, which were used to develop polygon boundaries representing the extents of the underground workings.

Northern AUM Region: A significant number of the AUMs had extensive underground workings, particularly those in the Lukachukai and Cove Mesa area.

Central AUM Region: Four (4) AUMs in the Black Mesa area of the Central AUM Region used underground methods (Claim 7, Dan Taylor No. 1, Etsitty No. 1 and Rough Rock Slope No. 9) (Chenoweth, 1990 – S10100236). With the exception of Claim 7, historical reports did not contain sketches of the underground workings of the mines. The sketch for Claim 7 could not be georeferenced, so no polygon boundaries representing the extents of the underground workings were developed.

Southern AUM Region: The Morale mine was the only productive mine in the Southern AUM Region, and it used underground methods (Chenoweth, 1990 – S10020205). However, no map for the underground workings was located.

Western AUM Region: There was no significant underground mining in the Western AUM Region. However, it is known that at the base of some large pits (e.g., Ramco 20 and 21) adits were dug into pit walls in order to follow minor ore trends (Chenoweth, 1993 – S10100239). These minor underground workings were not mapped or entered into the GIS database.

Eastern AUM Region: Most mines in the Eastern AUM Region were underground mines. Seven (7) underground mine maps were automated. Eighty-five (85) ore body extent polygons were automated. These represent areas of ore bodies known to have been mined; however, precise underground mine workings are unknown. Many AUMs with underground mines are unmapped due to the lack of literature sources.

A GIS dataset with the polygons for these compiled underground AUM mine workings is provided on the GIS Data DVD (DB/AUM/NN_AUM_Poly_Undrgnd.shp). The combined area of the surface and underground AUM boundaries were used to generate the buffers used for the ground water pathway analyses.

Figure 4 shows the spatial distribution of surface and underground AUMs for an area of the Lukachukai Mountains, Apache County, Arizona. For a comparison, the original NAMLRP reclamation project sites are shown as dashed polygons.

109°15'0"W

36°32'30"N

36°32'30"N

COVE

ROUND ROCK

109°15'0"W

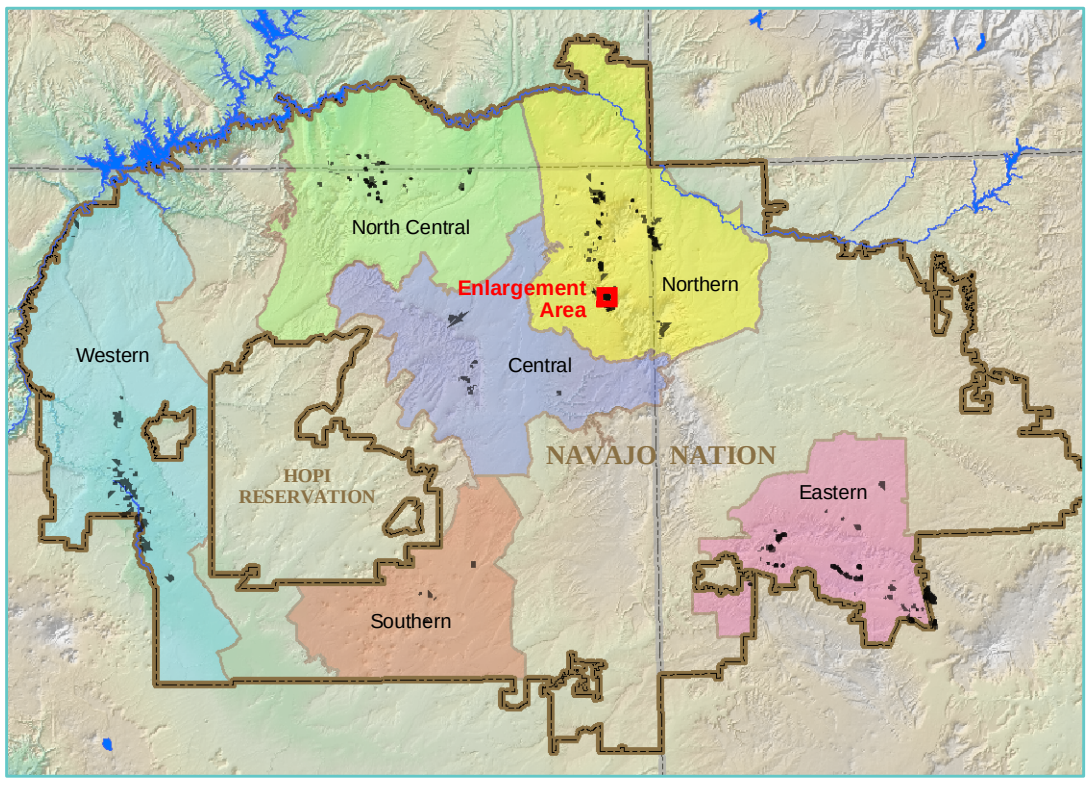
ABANDONED URANIUM MINES AND THE NAVAJO NATION

SURFACE AND UNDERGROUND AUMS OF THE LUKACHUKAI MOUNTAINS

N
W E
S

0 1.2 Miles

Map Scale 1:24,000



Overview of AUM Locations Across the Navajo Nation.

Legend

NAMLRP Reclamation Project Sites

Underground AUMs

Surface AUMs

Sources

Reclamation Project Sites are from Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) maps. Abandoned Uranium Mine site locations are from NAMLRP maps, and sources by William L. Chenoweth, Virginia McLemore, USGS 7.5 minute topographic maps, Digital Orthophoto Quarter Quads (DOQQs), and other sources. Mapped underground AUM extents are from various sources.

Filenames:
DB/AUM/NN_AUM_Pt_Features.shp
DB/AUM/NN_AUM_Project_Sites.shp
DB/AUM/NN_AUM_Poly_Surf.shp
DB/AUM/NN_AUM_Poly_Undrgnd.shp

Figure 4. Surface and Underground AUMs of the Lukachukai Mountains.

ABANDONED URANIUM MINES (continued)

PRODUCTION

Production Data Development

William Chenoweth reported that the documentation of ore production records is indebted to the AEC's requirement for monthly reports from the uranium ore processing mills (DeVoto and Huber, 1982 – S10020206). These monthly ore receipts were compiled on a quarterly basis and included the following information: name of property and shipper, mining district, state and county, AEC license number, and usually the number of miles from the mine to the mill or ore buying station. They also contained the following production data: dry tons of ore; contained pounds and the calculated percents of uranium oxide (U_3O_8), vanadium oxide (V_2O_5), and calcium carbonate ($CaCO_3$). These records were subsequently compiled for the 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 through March 4, 1983 by the General Services Administration (GSA, 1981 – S03210322). Chenoweth has continued to publish uranium mine and production history for uranium-vanadium mines across the Navajo Nation to the present. Chenoweth has maintained a comprehensive library on the uranium history of the Four Corners states, as well as an extensive personal experience and memory of the uranium history of the region from the 1950s to the present. This report's documentation of uranium and vanadium production has benefited from numerous personal communications with William Chenoweth that permitted the compilation of production data from various unpublished records. A major source of archived unpublished uranium and vanadium production records were the Atomic Energy Commission and the Department of Energy records held at the U.S. National Archives and Records Administration (NARA), National Record Group 434-00-287, Rocky Mountain Region at the Denver Federal Center, Colorado.

Working with William Chenoweth to build this extensive set of publication data also improved development of the AUM datasets. The work led to the discovery of additional documents, or Chenoweth's recollections of mine site visits, which resulted in the development of a few new AUMs or refinement of existing AUMs. This facilitated separating production estimates for individual mines in cases where the records reported production statistics as a combined total for an entire lease. In the Northern AUM Region, the Vanadium Corporation of America's (VCA) East and West Reservation Lease production records were not recorded by Plot (claim) where individual mines were located, but by total production for each lease. Chenoweth was also invaluable in documenting post-AEC production for the Grants Uranium District in the Eastern AUM Region. McLemore and Chenoweth (1991 - S03030608) and McLemore et al., (2002 - S12160205) previously reported post-AEC (after 1970) production statistics as large ranges, due to company confidential records. Since that time, Chenoweth has been able to access now public NARA records up to about 1983. These production statistics are documented in this report. A few mines in the Ambrosia Lake area likely produced after 1983, but any production after 1983 is not included in this report.

In some cases, production for multiple mines on a lease was reported as a single combined production value for all those mines. During the period 1942-1947 production for the 12 Plots (or claims) of VCA's East Reservation Lease (I-149-IND-5705), the 16 Plots of VCA's West Reservation Lease (I-149-IND-5456), the 12 Plots of the AEC Lease (I-149-IND-6197, also known as the Curran Brothers and Wade Lease), the 3 Plots of the Wade, Curran, and Co. Lease I-149-IND-3798, and the 2 Plots of the Wade, Curran, and Company Lease I-149-IND-4225, all had production recorded by Lease and not by individual Plot (Chenoweth, 1991 – S02020701). Further, the East Reservation Lease had combined production reported for the period 1948-1950 (Chenoweth, 1985 – S03130303), as did the West Reservation Lease for the period 1948-1952 (Chenoweth, 1984 – S10020203). This happened during the period 1942-1947 when these mines were operated as vanadium mines, and when the shipper or operator of all the mines on a lease were the same company. Separate production values for these mines was estimated based upon ore tonnage and grade estimates for vanadium in various Chenoweth reports and personal communications (Chenoweth, 2007 – S01150701). Unlike the other Plots of the East Reservation Lease, a further separation of production was performed for Plot 3, because at this time it had four producing mines: Shadyside No. 1, Shadyside No. 2, Lookout Point and Nelson Point. Actual production for each of these four mines was used to estimate the relative ratio of production. This ratio was applied to the estimated Plot 3 production for the period 1942-1945 and 1948-1950 to produce estimated production of tons of ore and pounds of vanadium oxide.

During World War II, production from these Northern AUM Region vanadium mines was used to extract uranium for the atom bomb. Uranium oxide production (U_3O_8) was estimated based upon the uranium to vanadium ratio for each lease (Chenoweth, 1991 – S02020701).

In 1962, production at the C-3 and Taylor Reid No. 1 mines was reported as combined production under the same mine operator, Dumont Development (Chenoweth, 1991 – S03100502). Also, during 1956 and the period 1964-1965, production for the Shadyside No. 1 and Shadyside Incline mines was reported as combined production by VCA under the name Shadyside Mines (Chenoweth, 1996 – S03240304). Separate mine production was estimated based on the ratio of actual production of the two mines during the years that production was reported separately.

The estimated values for tons of ore and pounds of uranium and vanadium oxide discussed above are included in the final total production reported in the GIS datasets provided on the GIS Data DVD (DB/AUM/NN_AUM_Production_Pts.shp and DB/AUM/NN_AUM_Production.shp). Notes about actual versus estimated ore production values will be found in the "COMMENT" field of the two production GIS datasets.

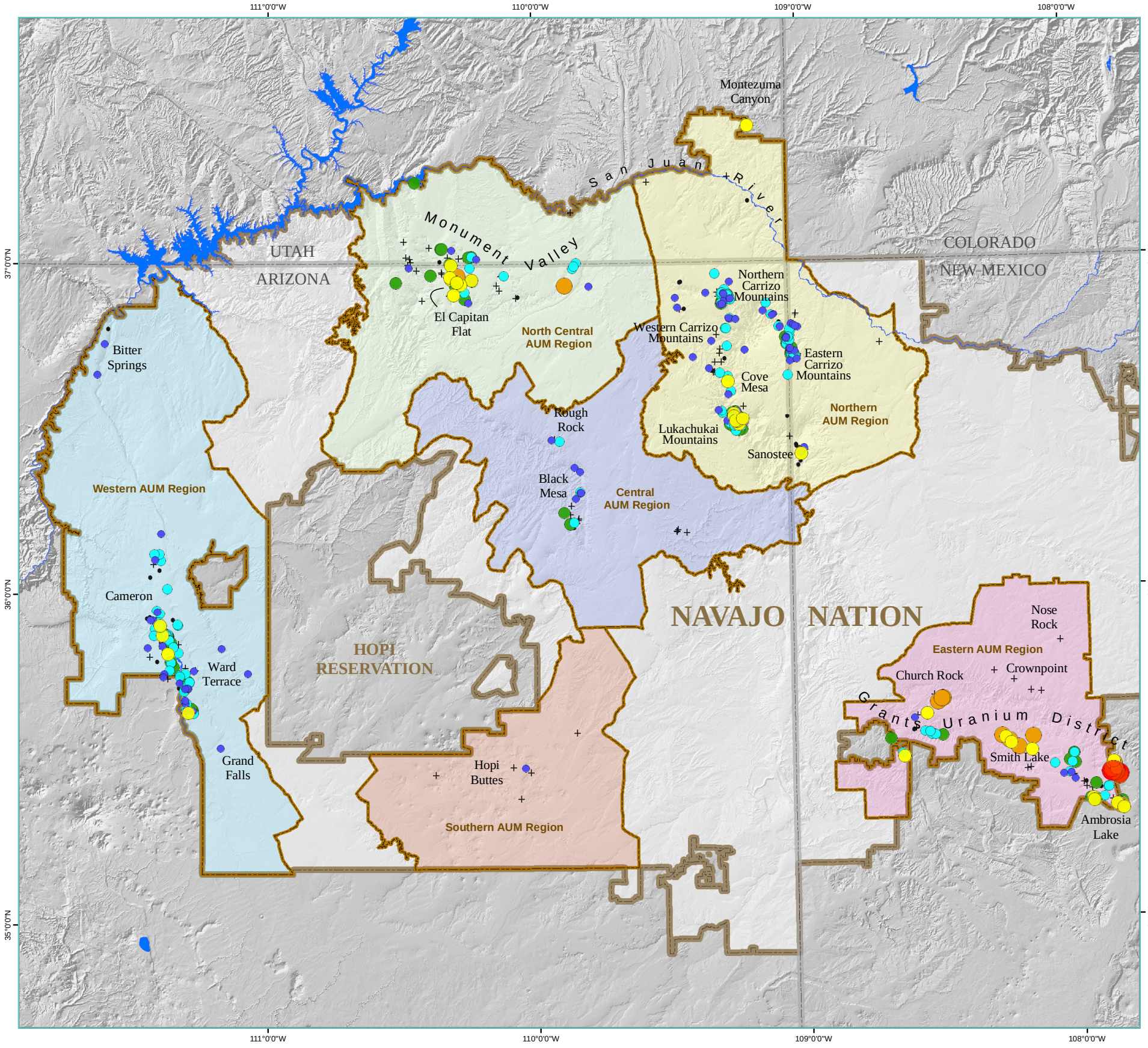
Figure 5 presents the results of the compiled and estimated uranium oxide (U_3O_8) production on and within one (1) mile of the Navajo Nation. The ranges of uranium production are symbolized on a base ten logarithmic scale where each higher production range is a magnitude larger than the previous production range. The largest producing mines are shown as red circles (>10,000,000 pounds of U_3O_8) and orange circles (1,000,001 to 10,000,000 pounds U_3O_8). Fourteen (14) of these sixteen (16) large mines are located mostly in the Grants Uranium District of the Eastern AUM Region, with the largest AUM located in the Ambrosia Lake area. Outside the Eastern AUM Region there are two (2) mines that produced more than 1,000,000 pounds U_3O_8: the Monument No. 1 and Moonlight mines, both located in Monument Valley within the North Central AUM Region.

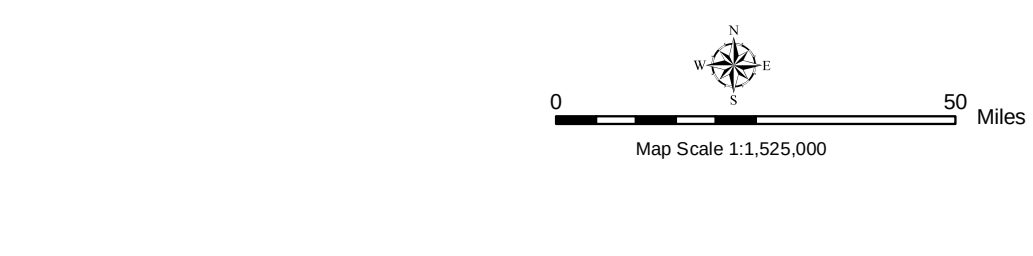
Mines that produced in the range of 100,001 to 1,000,000 pounds of U_3O_8 are shown as yellow circles. These include: thirteen (13) mines across the Eastern AUM Region; eight (8) mines in the El Capitan Flat area of Monument Valley in the North Central AUM Region; six (6) mines in the Lukachukai Mountains, three (3) mines on Cove Mesa, at the south end of Montezuma Canyon, and in Sanostee in the Northern AUM Region; and four (4) mines within the Western AUM Region.

The largest producer in the Central AUM Region is Claim 28 (17,327 pounds U_3O_8). The only producing mine in the Southern AUM Region was the Morale mine (580 pounds U_3O_8).

ABANDONED URANIUM MINES AND THE NAVAJO NATION

ABANDONED URANIUM MINE PRODUCTION





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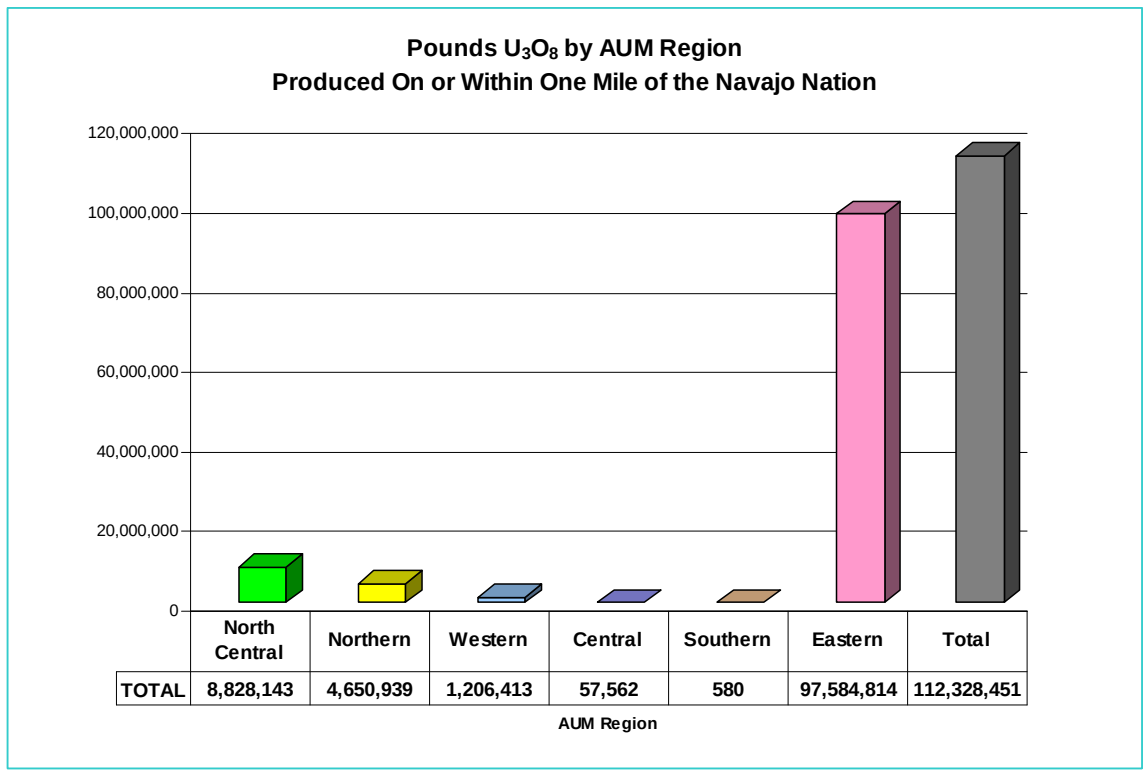


	North Central	Northern	Western	Central	Southern	Eastern	Total
TOTAL	8,828,143	4,650,939	1,206,413	57,562	580	97,584,814	112,328,451

Legend

Abandoned Uranium Mine Production
Pounds U_3O_8

- 10,000,001 - 17,520,976
- 1,000,001 - 10,000,000
- 100,001 - 1,000,000
- 10,001 - 100,000
- 1,001 - 10,000
- 101 - 1,000
- 1 - 100
- \+ No Production

Source

Uranium production was compiled primarily from published reports and personal communications by William L. Chenoweth.

Filename: DB/AUM/NN_AUM_Production_Pts.shp

Figure 5. Uranium (U_3O_8) Production on the Navajo Nation.

ABANDONED URANIUM MINES (continued)

PRODUCTION (continued)

Production Polygon GIS Dataset Development

AUM polygons with total production were developed and are provided as a GIS dataset on the GIS Data DVD (DB/AUM/NN_AUM_Production.shp). Figure 6 shows the AUM polygons for an area of the Lukachukai Mountains, Apache County, Arizona. These mine polygons are symbolized using the same color scheme and production ranges as shown on Figure 5 for AUM points. They were developed by merging and dissolving the surface (NN_AUM_Poly_Surf.shp) and underground (NN_AUM_Poly_Undrgnd.shp) AUMs by all Mine-IDs that comprised a single productive mine. The polygon includes the full known productive extent of a mine.

Frank No. 1 Mine (yellow polygon) and the Frank No. 2 Mine (white polygon) are shown in the top map of Figure 6 at the center of the red outlined box. The Frank No. 1 Mine and Frank No. 2 Mine can also be seen in the inset map enlargement on Figure 6. In the inset map there are three blue surface polygons for the Frank No. 1 Mine (i.e., North, East, and South Portals), and three yellow polygons that represent the underground workings from each portal. These polygons are all associated with the same mine, which was operated by Frank Natcheenbetah and Climax Uranium (Chenoweth, 1988 - S10280203). These six (6) surface and underground polygons comprise the single yellow mine polygon for the Frank No. 1 shown on the top map of Figure 6.

Production Point GIS Dataset Development

The point production GIS dataset was developed from centroids of the production polygons GIS dataset. These centroid points are located at the center weighted average for all polygons that comprise a single AUM. Most AUMs are single polygons and the centroids fall within them. An example is shown in the Figure 6 inset map with the blue point representing the centroid of the Frank No. 2 Mine. In cases where there are multiple polygons comprising a single AUM site, the centroid point will not necessarily fall within the center of one of the polygons. An example is shown in the Figure 6 inset map where the centroid (red dot) is located at the center weighted location between all of the surface and underground polygons comprising the Frank No. 1 Mine. The production points GIS dataset is provided on the GIS Data DVD (DB/AUM/NN_AUM_Production_Pts.shp).

Production Tabulation

The production data attributes collected for each AUM are listed in Table 3 below. This is an example from the production point GIS dataset for the Frank No. 1 Mine. Note that the single Frank No. 1 Mine has three AUM polygons (e.g., three IDs under "AllMineIDs"). This is also represented in the "COMMENTS" field where it is stated that the Frank No. 1 Mine is comprised of three portals. These attributes are included in the two production GIS datasets (DB/AUM/NN_AUM_Production.shp and DB/AUM/NN_AUM_Production_Pts.shp). The grades presented are actual grades for periods of production.

Table 3. Example Production Record for Frank No. 1 Mine.

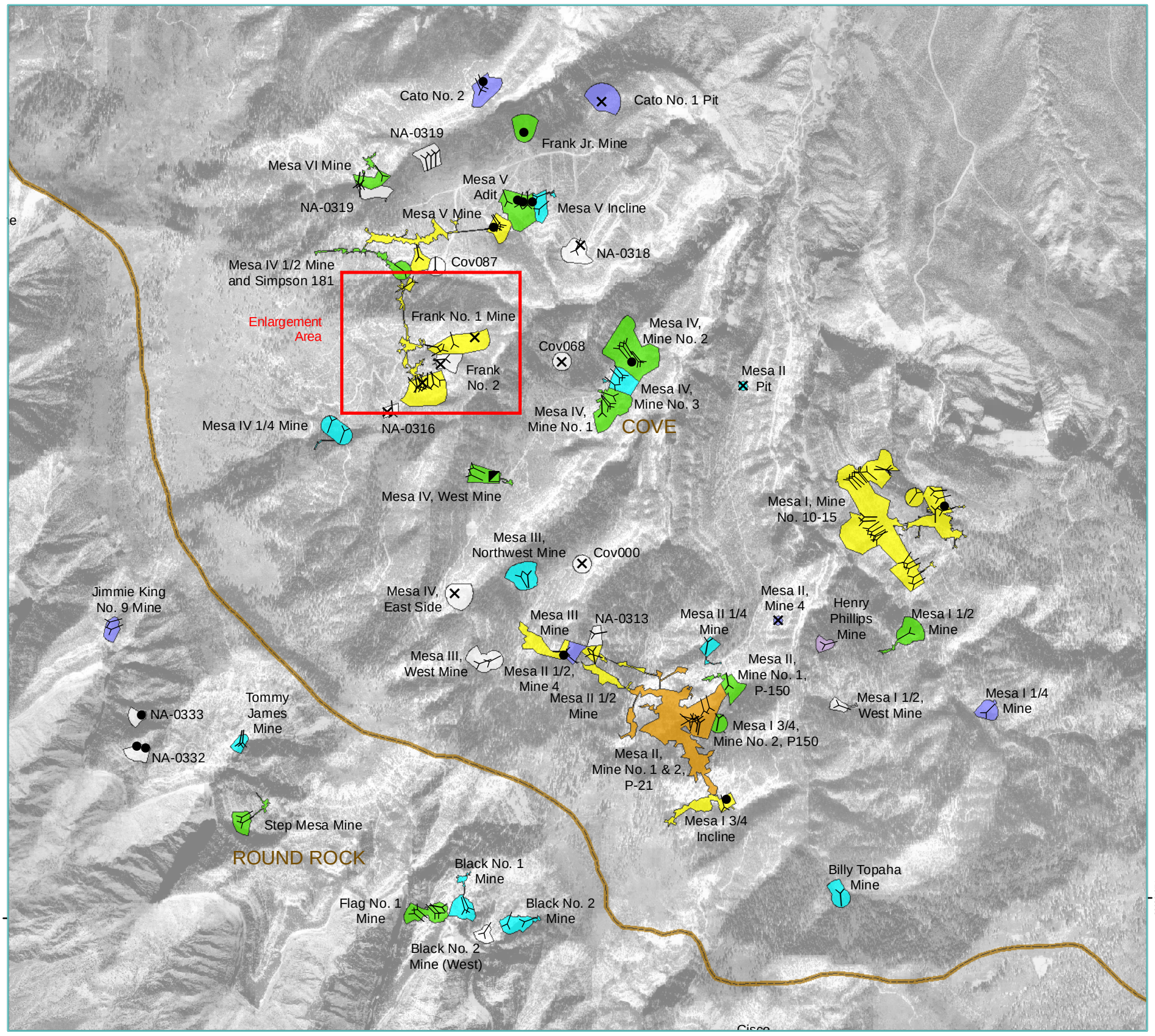
NN_AUM_Production_Pts
Frank No. 1 Mine

Location: (-109.251112 36.529669)

Field	Value
FID	81
Shape	Point
Mine_ID	106
AllMineIDs	106, 505, 509
Mine_Name	Frank No. 1 Mine
Aliases	South Portal, 4B Mine; North Portal, 1207 Mine; East Portal, 709 Mine
Stratum	Surface and Underground
PRODUCER	Yes
TONS	75739
U3O8_LBS	373141
U3O8_PRCNT	0.25
V2O5_LBS	1738347
V2O5_PRCNT	1.15
START_YEAR	1951
END_YEAR	1967
PROD_SRC	S10280203
COMMENT	Includes the South Portal (4B Mine), East Portal (709 Mine), and North Portal (1207 Mine).
HOST_ROCK	Jmsw
HOST_SRC	S10280203
SURF_UNDER	S & U
S_U_SRC	S06220502
WTR_TABLE	Above
WTRTBL_SRC	S03190701
REGION	Northern

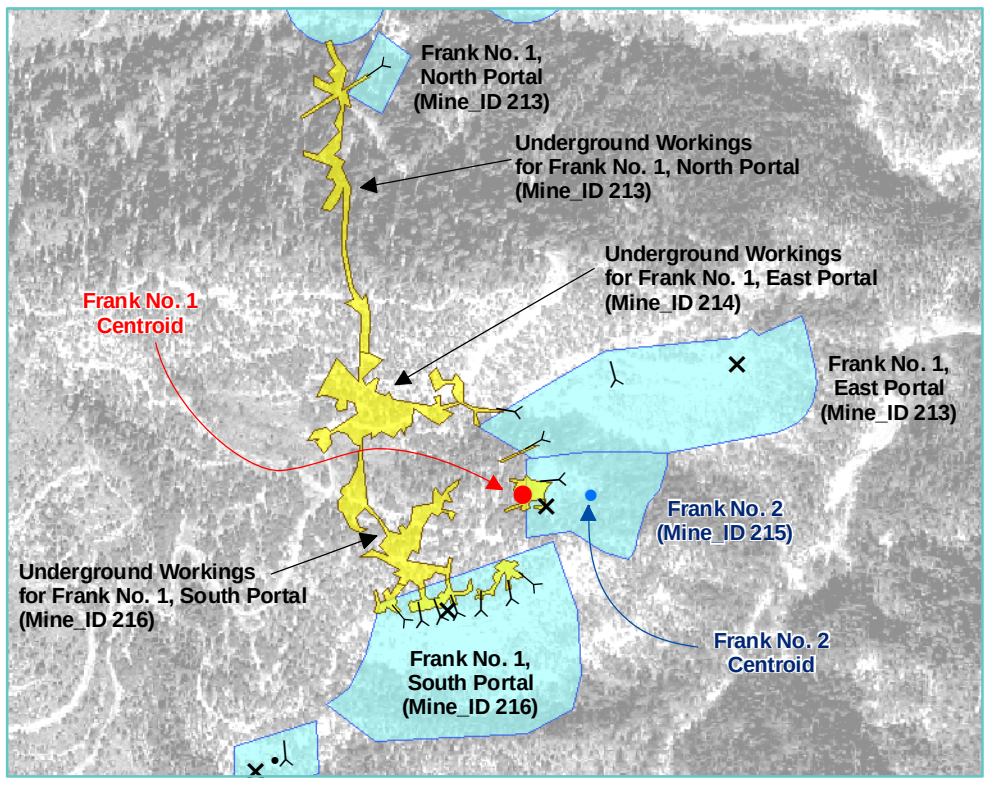
ABANDONED URANIUM MINES AND THE NAVAJO NATION

MINE PRODUCTION FOR THE LUKACHUKAI MOUNTAINS



0 1 Miles

Map Scale 1:30,000



Map of surface (cyan) and underground (yellow) workings for the Frank No. 1 and Frank No. 2 Mines. The red dot is the centroid for the combined surface and underground workings for Frank No. 1 mine. The smaller blue dot is the centroid for Frank No. 2. Production from these mines is designated by color-coding in the map above this enlargement (red box outline).

Legend

Abandoned Uranium Mine Production

Pounds U3O8

- 1,000,001 - 17,520,976
- 100,001 - 1,000,000
- 10,001 - 100,000
- 1,001 - 10,000
- 101 - 1,000
- 0 - 100
- No Production

Mine Features

- Portal
- Prospect
- Rim Strip / Pit
- Vertical

Source

Uranium production was compiled from published reports and personal communications by William L. Chenoweth.

Filename: DB/AUM/NN_AUM_Production.shp

Figure 6. Uranium (U_3O_8) Production for the Lukachukai Mountains.

URANIUM MILLS ON THE NAVAJO NATION

Some AUM Regions had uranium mills sited on or near the Navajo Nation (shown on Figure 7). The Tuba City Mill is in the Western AUM Region. The Mexican Hat Mill along the San Juan River, and the Monument Valley Upgrader Site that serviced only the Monument No. 2 mine, was in the North Central AUM Region. In the Northern AUM Region was the Shiprock Mill. The Church Rock Mill is the only mill in the Eastern AUM Region on the Navajo Nation. Nearby, however, were also the Ambrosia Lake, Rio Algom, Blue-water, and Homestake Mining Company Mills. There were no mills near the mines within the Central and Southern AUM Regions.

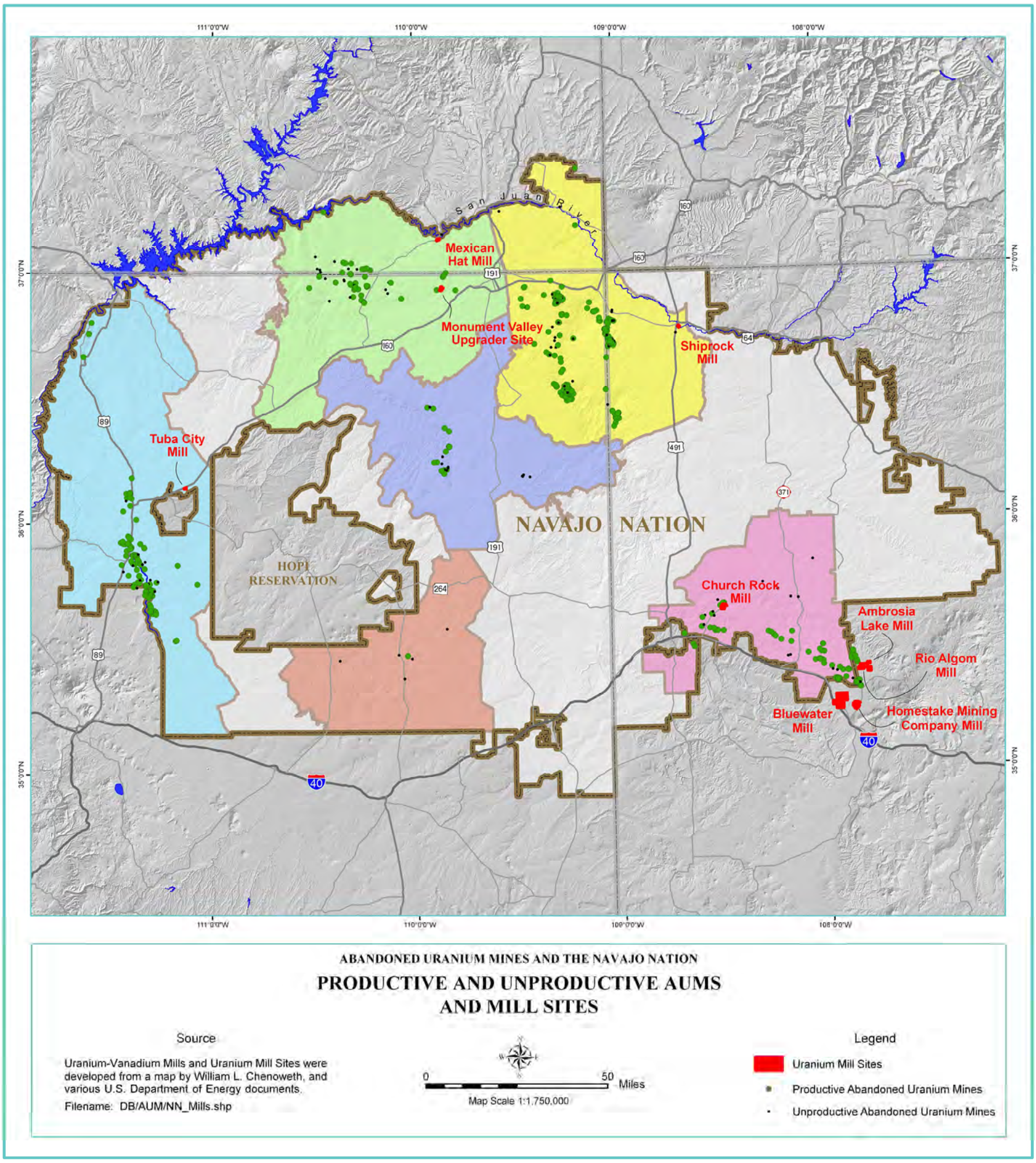


Figure 7. Mill Sites on or Near the Navajo Nation.