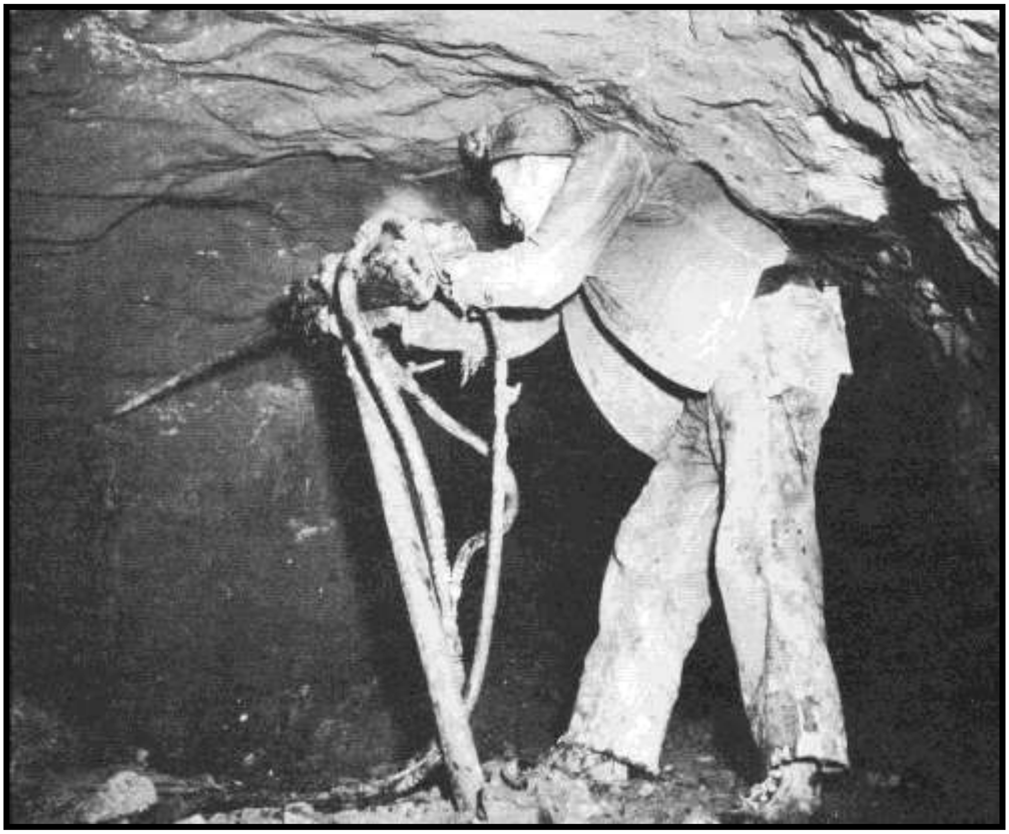
GUIDE TO ASSESSING HISTORIC



RADIUM, URANIUM AND VANADIUM

MINING RESOURCES

IN

MONTROSE AND SAN MIGUEL COUNTIES

COLORADO

MULTIPLE PROPERTY LISTING

Table of Contents for Written Narrative

Provide the following information on continuation sheets. Cite the letter and title before each section of the narrative. Assign page numbers according to the instructions for continuation sheet in *How to Complete the Multiple Property Documentation Form* (National Register Bulletin 16B). Fill in page numbers for each section in the space below.

United States Department of the Interior
National Park Service
National Register of Historic Places
Multiple Property Documentation Form

This form is used for documenting multiple property groups relating to one or several historic contexts. See instructions in *How to Complete the Multiple Property Documentation Form* (National Register Bulletin 10-900-a). Use a typewriter, word processor, or computer to complete all items.

_XX__ New Submission __ Amended Submission

SECTION A: NAME OF MULTIPLE PROPERTY LISTING

Guide to Assessing Historic Radium, Uranium, and Vanadium Mining Resources in Montrose and San Miguel Counties, Colorado

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SECTION B: ASSOCIATED HISTORIC CONTEXTS

(name each associated historic context, identifying theme, geographical area, and chronological period)

None

SECTION C: FORM PREPARED BY

name/title_____Eric Twitty, historian, M.A.
organization___Mountain States Historical (303)499-4334__ date____July 15, 2008______
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city or town___Boulder____________ state_CO________zip code__80305_____________

SECTION D: CERTIFICATION

As the designated authority under the National Historic Preservation Act of 1966, I hereby certify that this documentation form meets the National Register documentation standards and sets forth requirements for listing of related properties consistent with the National Register criteria. This submission meets the procedural and professional requirements set forth in CFR Part 60 and the Secretary of the Interior's Standards and Guidelines for Archaeology and Historic Preservation.
(see continuation sheet for additional comments [ ])

______________________________State Historic Preservation Officer__________________
Signature and title of certifying official date

State Historic Preservation Office, Colorado Historical Society______________________
State or Federal agency and bureau

I hereby certify that this multiple property documentation form has been approved as a basis for evaluating related properties for listing in the National Register.

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Signature of the Keeper date of action

Section E: Statement of Historic Contexts

E.1: INTRODUCTION

In terms of mining history, western Montrose and San Miguel counties rank among the most important regions in the United States and the world. In 1898, Montrose County hosted one of the world's first radioactive metals discoveries in the form of carnotite ore. During the late 1890s, the Curries and other leading scientists in Europe were only beginning their experiments with radioactivity and prized carnotite for its metals content. Limited only to the Colorado Plateau, carnotite had never been recognized or classified prior to the late 1890s and was, in essence, a new mineral. European scientists found that carnotite carried uranium, radium, and vanadium, all of which would figure prominently in national and world history.

Between 1899 and around 1910, Montrose and San Miguel counties were center to the world's most important radium mining industry. Radium was the first of several radioactive metals in carnotite to come under measurable demand. European scientists wanted the metal for research, and the medical industry used it for health applications. Because carnotite had the highest radium content of known ores, the world turned to Montrose and San Miguel counties for its radium. In association with this, the first radium mines and mills in the United States operated in Montrose County.

Between 1910 and 1922, vanadium came under heavy demand as an alloy for steel. San Miguel County offered the richest deposits in the form of roscoelite ore, with carnotite a close second. As with radium, Montrose and San Miguel counties were among the world's most important sources of vanadium. The alloy metal factored heavily into the domestic steel industry, as well as for weapons production among European nations embroiled in World War I.

While the above historical trends are obviously important, it was uranium mining that left the greatest impact on Montrose and San Miguel counties. The Federal Government relied heavily on carnotite for the Manhattan Project during World War II. Carnotite, principally from the two counties, was the only significant domestic source of uranium for nuclear weapons through the 1940s. Uranium was fundamental to the Cold War, and during the early 1950s, the two counties remained among the most important centers of mining and milling. By the latter half of the decade, other regions in the Southwest became as significant, but the counties maintained their prominence.

From the late 1960s through the end of mining around 1980, Montrose and San Miguel counties generated uranium for the nuclear power industry. Their production was substantial and contributed to the viability of this alternative energy source. When uranium prices collapsed around 1980, most of the mines closed and the region lost its economic foundation.

The importance of radioactive metals mining in Montrose and San Miguel counties should not be underestimated. These two counties were the centers of radioactive metals mining on the Colorado Plateau, which is an elevated landform of sedimentary geology in the Four Corners region. By 1964, the Colorado Plateau yielded 70 percent of the uranium, 98 percent of the vanadium, and nearly all of the radium produced within the United States, valued at $2 billion. On a broader scale, the region also generated 44 percent of the world's vanadium.[1] A considerable proportion of these figures came from Montrose and San Miguel counties.

Currently, a legacy of historic resources represents the fascinating and important mining industry of the two counties. After abandonment, many of the mines, mills, and settlements were impacted by scavenging, environmental remediation projects, and natural decay, leaving a number of resources in various states of preservation. Those resources that still retain historical integrity are endangered and now face the additional pressures of mine closures, more environmental cleanup, and especially the resumption of uranium mining.

A consortium of organizations and government agencies local to Montrose and San Miguel counties grew concerned over the gathering threats to the region's historic mining resources. The Bureau of Land Management (BLM) is one of the most active agencies, in large part because it controls nearly all the land in the counties. Some BLM cultural resource administrators forecasted that a wave of uranium mining activity could outpace the objective inventory and eligibility assessments of historic mining resources. The Division of Reclamation, Mining, and Safety (DRMS) is another principal agency and has an interest in seeing uranium mining resources objectively recorded and assessed. The agency cooperates with the BLM and the Environmental Protection Agency (EPA) on the closure and remediation of uranium mine sites. Because the agency has a pro-preservation policy regarding mine closures, it tailors its closure projects to minimize the impacts to historically important sites. The Rimrockers Historical Society, based in Naturita, is a highly active organization in the region. Rimrockers has a strong interest in preserving the region's mining resources because it perceives the resources as a foundation for heritage tourism. Many of the active members are also retired uranium miners and wish to see their legacy preserved.

In 2006, these interests and private individuals came together and contributed to a project that would address some of the pressures that the region's uranium mining resources now and will face in the future. With the financial and administrative backing of the BLM and DRMS, the Western Colorado Interpretive Association (WCIA) applied to and was generously awarded a grant by the State Historical Fund (SHF) with a match by the BLM for the project (2006-02-032). WCIA then contracted with Mountain States Historical (MSH) to complete the work because that firm has experience with both uranium mining resources and producing historic mining contexts.

The project includes three products. The first is an inventory and significance assessment of 65 radioactive metals mining resources. The second is a guide for assessing the significance of these resources, and the third is a sister Multiple Property Documentation Form (MPDF). The inventory of sites was designed to provide qualitative information for the guide and the MPDF.

[1] Fischer, 1968:736; Metal Mining, 1961:5.

E.1.1: Previous Radioactive Metals Mining Context Work

Little context work exists as of 2008 regarding radioactive metals mining in western Colorado. Umetco Minerals Corporation published the only comprehensive work to date, which John S. Hamrick, Diane E. Kocis, and Sue E. Shepard wrote in 2002. *Uravan, Colorado: One Hundred Years of History* provides a well-researched history of uranium mining and milling as related to the company town of Uravan. Umetco funded the context as part of its environmental cleanup of Uravan and the Shamrock Group of mines above and south on Club Mesa. The context, however, lacks reference to cultural resources and their evaluation.

For reference to cultural resources, we must turn to a handful of projects involving uranium mine and mill sites. The firms of Andrews and Anderson, and Cultural Resource Historians, completed one of the earliest qualitative projects in 1984. These two organizations conducted Historic American Engineering Record (HAER) documentation of the Vanadium Corporation of America's Vancorum Mill site prior to environmental cleanup.[2] As such documentation requires, the firms produced a brief and accurate overview of radioactive metals mining in the region.

In 2001, Kurt P. Schweigert with Associated Cultural Resources Experts documented the Department of Energy's Grand Junction Office according to HAER standards.[3] The Department of Energy transferred the office to private ownership and was therefore obligated to document the facility. Schweigert wrote a narrative history of the office in relationship to historical trends of the uranium mining industry.

Jonathan C. Horn of Alpine Archaeological Consultants completed several qualitative projects that included historic uranium mining resources. In 2002, Horn and associates conducted a preservation assessment of Calamity Camp on Calamity Mesa near the town of Gateway, in Mesa County. Horn wrote a very detailed narrative site history, which he tied to general trends of radioactive metals mining.[4] In 2003, Horn also inventoried and evaluated five uranium mines on La Sal Creek in both Montrose County and San Juan County, Utah. In his report, Horn wrote another narrative of radioactive metals mining and detailed site histories.[5]

In 2005, Eric Twitty with Mountain States Historical recorded and evaluated 23 mining resources on the northern portion of Long Park Mesa, Montrose County, in conjunction with a closure and waste rock remediation project. Twitty produced an interpretive report that featured a detailed account of mining in the region, as well as site histories.[6]

A few additional cultural resource projects involving historic uranium mining resources have been carried out in Montrose and San Miguel counties. Most of this work, however, was of a very general nature and lacked full narrative histories, in part because little information on uranium mining history is readily available.

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[2] HAER CO-81.
[3] HAER CO-87.
[4] Firor and Horn, 2002.
[5] Horn and Archimede, 2003.
[6] Twitty, 2006.

E 2: THE PHYSICAL ENVIRONMENT OF WESTERN MONTROSE AND SAN MIGUEL COUNTIES

Few areas in Colorado are as rugged, arid, and desolate as the skirt of mesas and canyon lands extending west from the Rocky Mountains to the Utah border. The canyon lands and mesas are the northeastern portion of a landmass popularly known as the Colorado Plateau, and the physical environment there presented great challenges to settlement and industry. One of those industries, uranium and vanadium mining, thrived on the Colorado Plateau, and primarily in western Montrose and San Miguel counties. While the region offered few resources for agriculture and other traditional forms of economy, its canyon lands and mesas were, into the 1960s, one of the most important sources of uranium and vanadium in the United States.

Carnotite ore was the object of uranium and vanadium, and this important material occurred in geological conditions specific to the Western Slope. Out of thousands of vertical feet of sedimentary rock layers, only several closely spaced and well-defined beds of shale and sandstone offered the right conditions. Further, these beds were exposed almost exclusively within a narrow strip of territory along the Colorado-Utah border. The strip began in Mesa County near the town of Gateway and extended south through Montrose, San Miguel, and Dolores counties. Overall, the strip was as wide as 30 miles and as long as 80 miles and overlapped west into Utah. Carnotite ore could be found anywhere within the strip, although the richest and largest deposits were concentrated in an ovoid tract approximately 20 by 60 miles in area. In 1943, the U.S. Geological Survey identified this concentration during intensive studies of the region and termed it the Uravan Mineral Belt.[7] The U.S. Geological Survey chose the name because Uravan, Montrose County, was center to the most important and highest density of carnotite formations within the mineral belt. In addition to the area around Uravan, western Montrose and San Miguel counties claimed the mineral belt's other significant concentrations of carnotite ore bodies. In general, uranium mines and aspects of the uranium industry were scattered throughout the western 25 miles of the counties, from Naturita to the state line.

The topography of the region featured a number of valleys elongated northwest-southeast, and clusters of mesas and plateaus in between. From south to north, the principal valleys included Disappointment Valley, Big Gypsum Valley, Dry Creek Basin, and the dramatic Paradox Valley. The Dolores River wound its way north through the region regardless of the topography and cut across instead of flowing along the valleys. This puzzled the region's early settlers, who were unaware that the Dolores existed prior to the valleys and incised its way downward into its historic channel as tectonic activity slowly lifted the region. Expressing this, the settlers named Paradox Valley after the river's paradoxical course across instead of along the landform. Like the Dolores River, the San Miguel River incised downward into its historic channel as tectonic activity gently lifted the region. The San Miguel began in the San Juan Mountains in eastern San Miguel County, flowed northwest, and joined the Dolores near Uravan.

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[7] Del Rio, 1960:335; Fischer, 1950:1; Fischer and Hilpert, 1952:3.

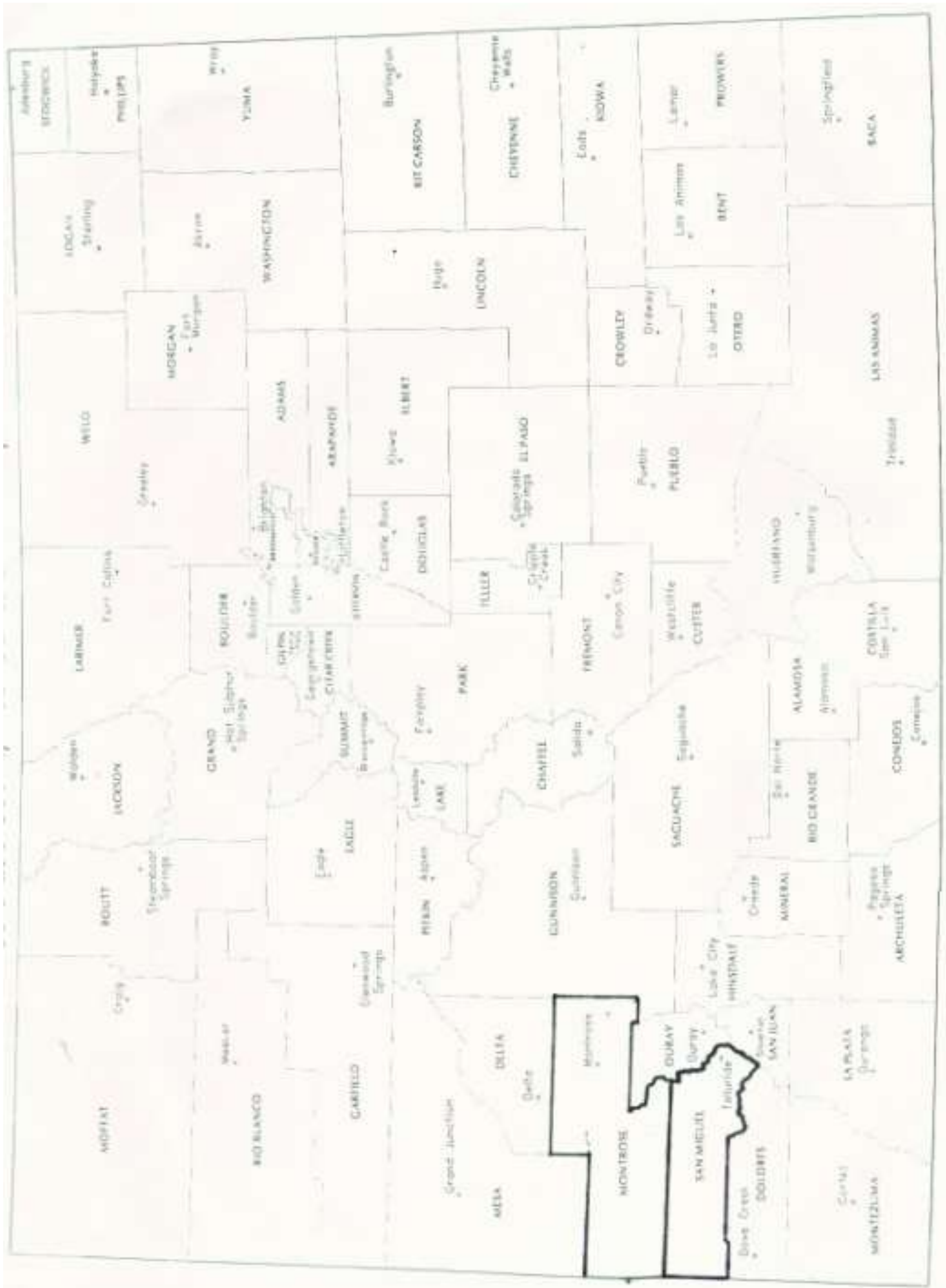

Figure E 2.1: Geographic location of Montrose and San Miguel counties.

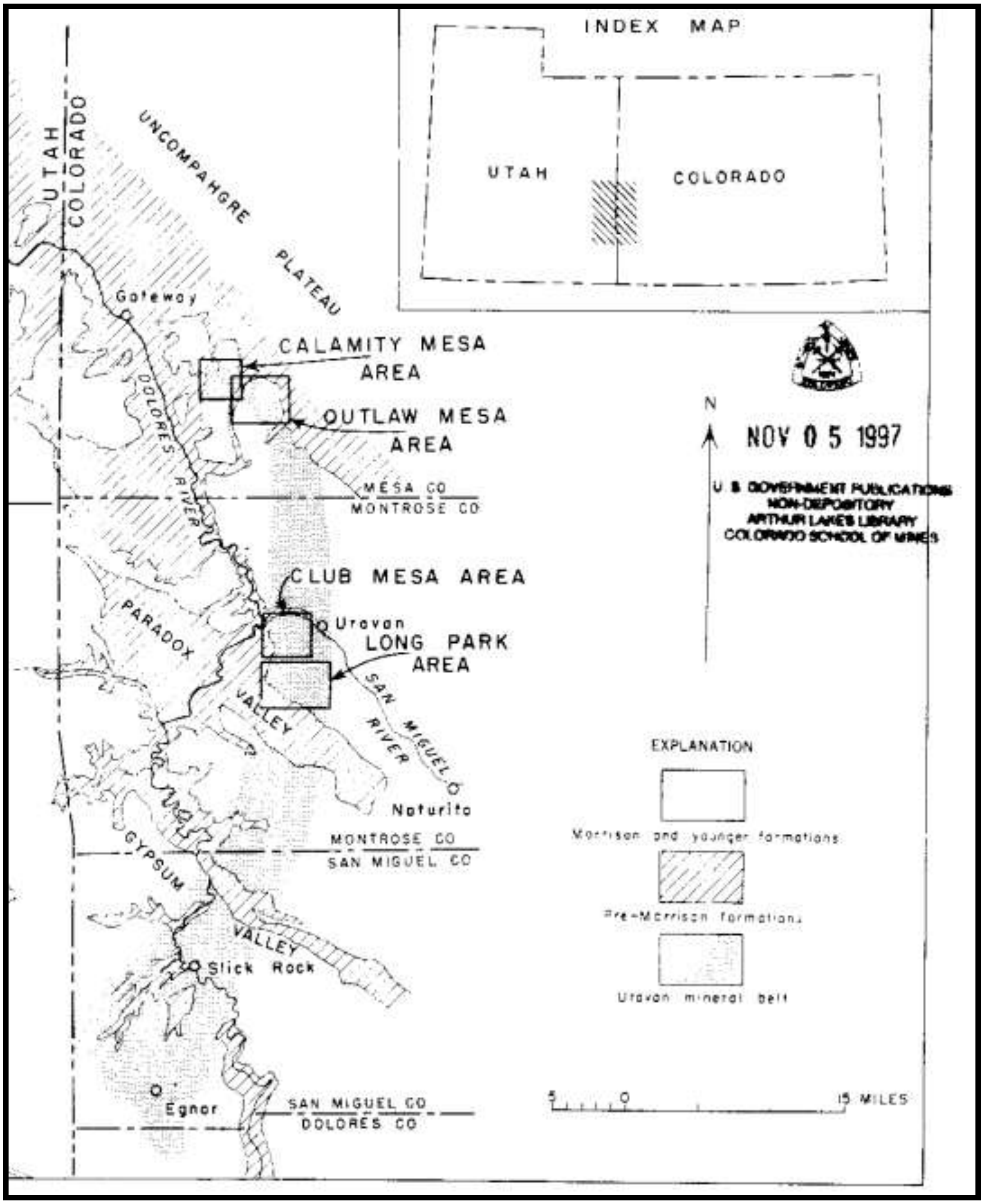

Figure E 2.2: The historic map depicts the central portion (shaded) of the Uravan Mineral Belt, which was one of the most important sources of uranium and vanadium in the United States. The index map at upper right outlines the entire mineral belt. Calamity, Outlaw, and Club mesas, and Long Park featured some of the richest and most numerous uranium mines in the mineral belt. Source: Fischer and Hilpert, 1952:plate 3.

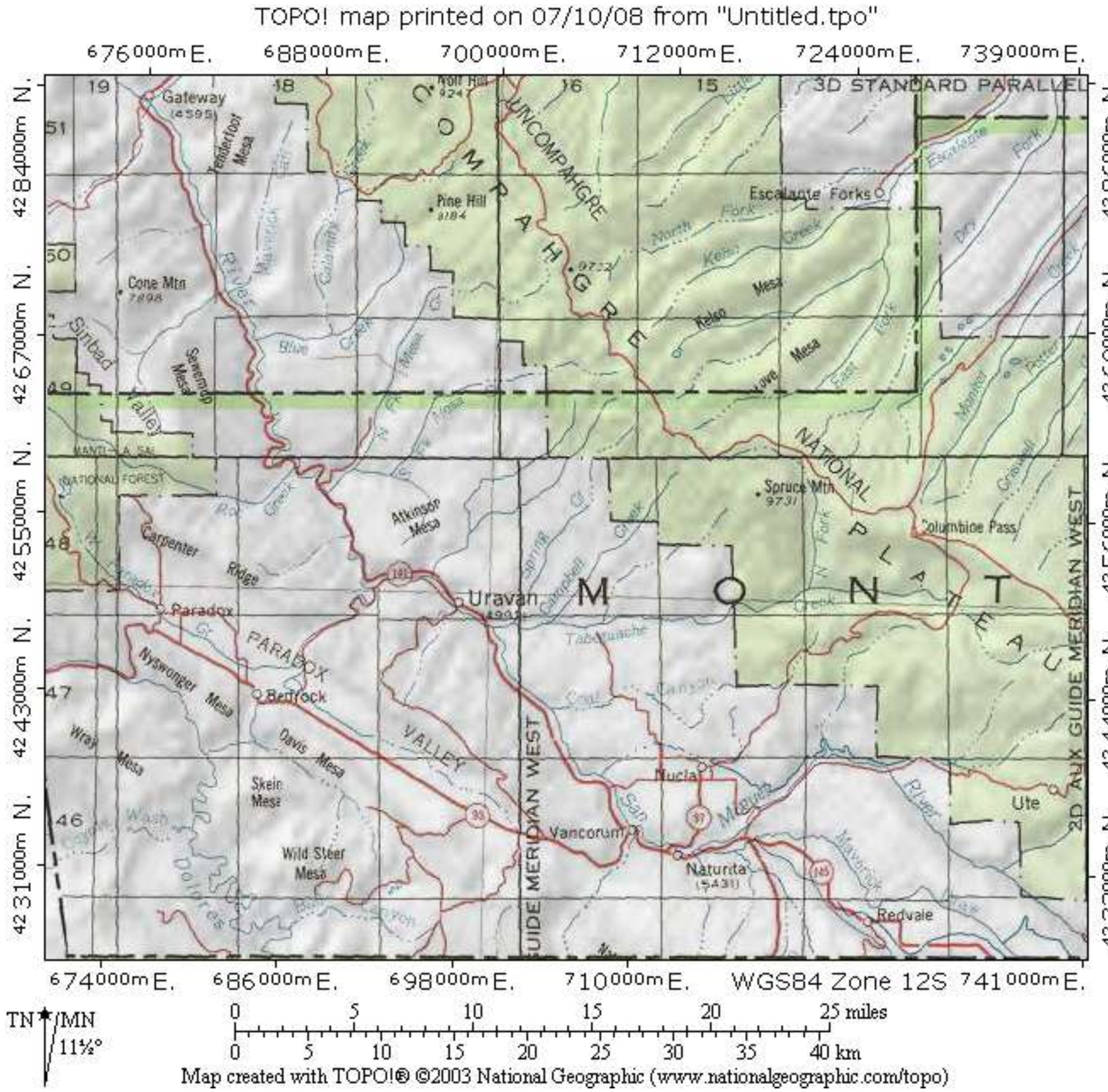

Figure E 2.3: The topographic map shows the principal geographic points in western Montrose County and southwestern Mesa County, at upper left. Gateway is at upper left, Uravan is center, and Naturita and Nucla are at lower right. Club, Long Park, and Sawtooth mesas are unmarked immediately south of Uravan.

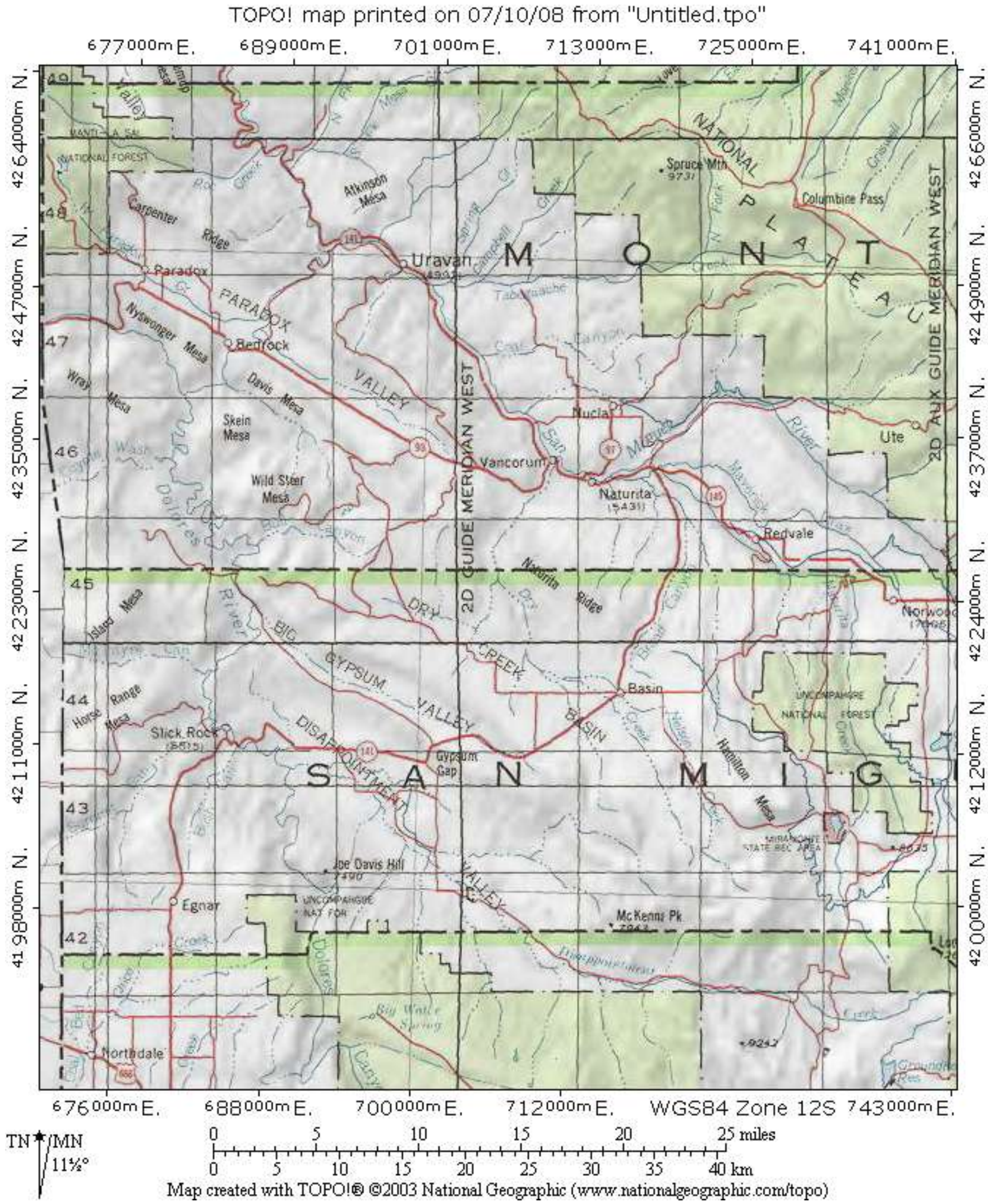

Figure E 2.4: Principal geographic points in western Montrose and San Miguel counties. Roc Creek, site of North America's first uranium mine, is at upper left, and Slick Rock, site of the earliest commercial uranium mill, is at lower left. Uravan, Vancorum, and Naturita lie along the San Miguel River at upper center. The highways are products of the region's Cold War uranium boom.

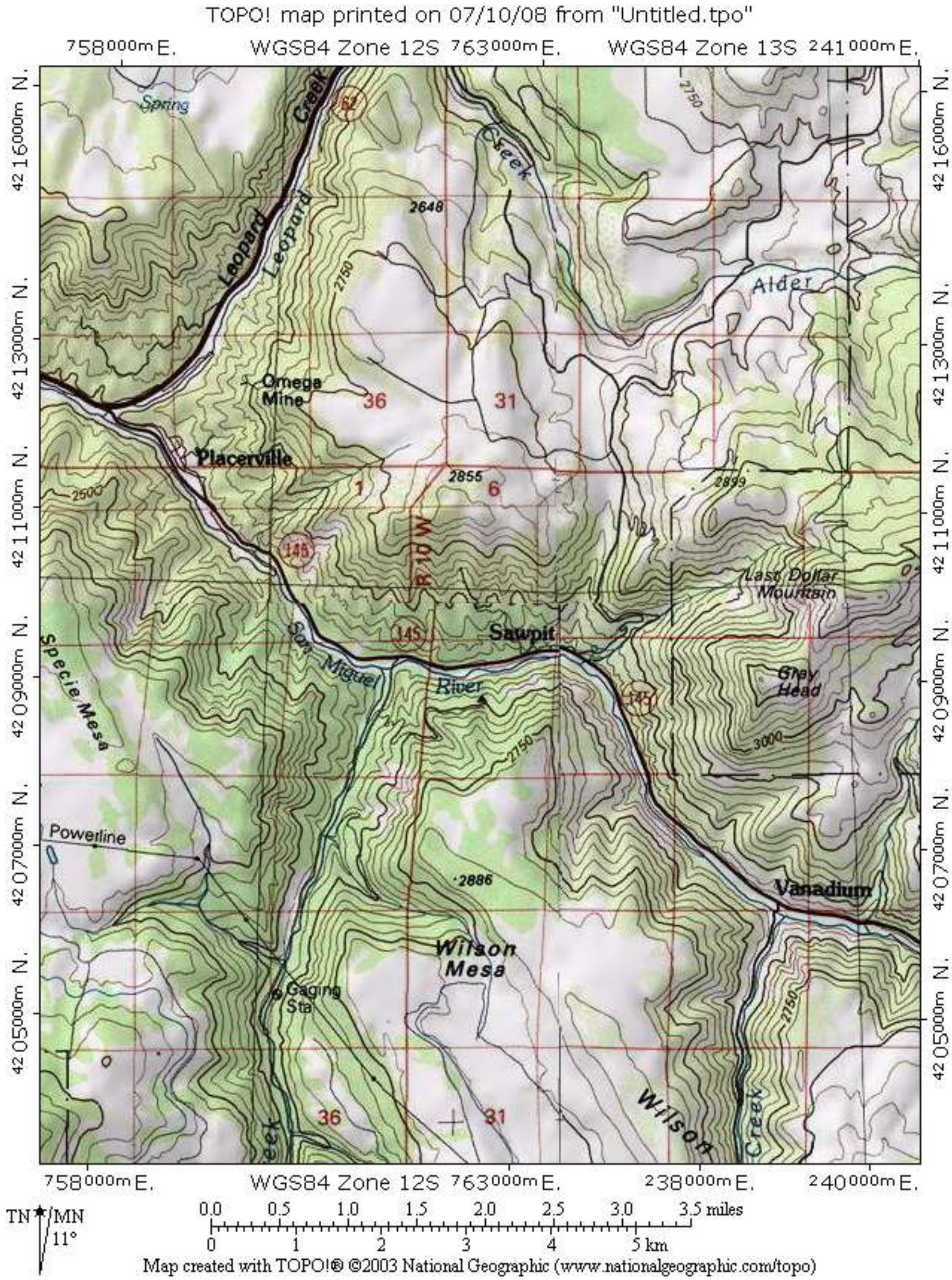

Figure E 2.5: Principal geographic points within San Miguel County's vanadium mining area.

The rivers, the valleys, and the clusters of mesas between, were important areas for the uranium industry. The valleys featured most of the important towns. Slick Rock grew at the west end of Disappointment Valley and Basin was at the east end of Dry Creek Basin. Settlers established Paradox at the west end of Paradox Valley, Bedrock was where the Dolores River crossed the valley, and Coke Ovens lay at the valley's east end. Standard Chemical developed Uravan on the San Miguel River a short distance east of its confluence with the Dolores. Pioneers founded Naturita in the San Miguel River valley around 20 miles to the east, and also Nucla a short distance north of Naturita.

Nearly all the mines were located around the upper edges of the mesas and the incised Dolores and San Miguel river channels. The reason is that this was where the above-mentioned sedimentary rock layers were exposed and accessible. As the U.S. Geological Survey and the mining companies discovered, some mesas featured particularly important concentrations of carnotite deposits. The entire area south of Slick Rock was highly productive, and it was dissected by Summit, Stevens, Bush, and other canyons. Wedding Bell and Radium mountains, and Monogram and Davis mesas, between Big Gypsum and Paradox valleys, were heavily mined. The Uravan Mining District, between Paradox Valley and the San Miguel River, may have been the most important area. Long Park, Sawtooth, and Club mesas were within the district. San Miguel Bench followed the north side of the San Miguel River from Tabeguache Creek to the Dolores River, and then along the Dolores for a number of miles. Carpenter Flats and adjoining Martin Mesa rose on the opposite, western side of the river, and they featured numerous mines, as well.

San Miguel County featured a second historically important center of mining around 30 miles east of the Uravan Mineral Belt. Instead of carnotite, the area's sandstone beds offered roscoelite, which was a rare form of vanadium ore that carried minor amounts of uranium, as well. The deposits were so large and rich that, during the 1910s, the area was one of the world's most important sources of vanadium. The small logging town of Saw Pit on the San Miguel River was near the middle of the 8-by-8-mile area. Placerville existed several miles northwest and down-gradient, and Vanadium, formerly Newmire, was several miles southeast and up-gradient. These three towns were important to the vanadium industry as milling, residential, and commercial nodes. Some of the most productive mines were located on Big Bear Creek ascending south from Vanadium, on Fall Creek south of Saw Pit, and on Leopard Creek north of Placerville.

The physical environment of western Montrose and San Miguel counties is a microcosm of the greater Western Slope. As alluded to, mesas and canyon lands dominate the topography, and they give way to plateaus and the foothills of the San Juan Mountains around Placerville. The mesas rise in an almost stairstep manner from around 5,400 feet elevation near the rivers and valley floors to around 7,000 feet. Distinct canyons separate the mesas, and they are usually bordered by the steep slopes of soft, eroded mudstone and shale, and the vertical cliffs of resistant sandstone, which often manifest in alternating series. The floor of the San Miguel River canyon near Placerville is around 7,500 feet elevation, and on both sides, the walls climb steeply to plateau land around 9,000 feet in elevation.

As can be surmised, climate of western Montrose and San Miguel counties is very arid, although less so toward Placerville. The summers tend to be hot with temperatures commonly in the high nineties, Fahrenheit, and the winters can force temperatures down into the single digits. Wind is omnipresent, usually blows from the west, and can attain near-hurricane force with the arrival of powerful Pacific storms. Such weather fronts can deliver rain or snow, but usually in limited quantities. Occasionally, weather fronts from the south carry enough moisture to provide a rare and needed saturation, and such events tend to contribute enough water to cause highly erosive runoff. During the summer, thunderhead clouds usually tower over the region, but the topography influences the track that the cells follow and causes most to avoid the carnotite-bearing area. Once the soil becomes wet, it turns to a heavy, clayey mud that sticks firmly on contact. Historically, the mud was a significant problem for the uranium mining industry because it rendered roads impassable. During prolonged wet periods, remote mines became impossible to reach, and in preparation for this, workers living on-site often cached up to several weeks of provisions.[8]

The region's climate and the lack of surface water, even in the deep canyons, foster an ecosystem typical of the high desert. An old-growth, juniper-pinion forest blankets the region, and the trees are largest in the drainages. Open areas feature an understory of rabbit brush, grasses, cacti, and yucca, and cryptobiotic soil is ubiquitous. The river valleys support oasis-like riparian habitats of grasses, forbes, and brush shaded by mature cottonwoods, and similar but reduced versions line the region's few creeks. Among the mesas, springs are rare and can be marked by grasses, green brush, and a few cottonwoods.

Overall, the region's arid climate and hostile terrain discouraged permanent subsistence and barely supported ranches. But, vehicles, modern conveniences, and rapid transportation allowed a twentieth century uranium and vanadium boom to overcome the Western Slope's difficult environment.

E 3: ECONOMIC GEOLOGY OF RADIOACTIVE METAL ORES

Carnotite was unlike any other metal-bearing ore sought by the mining industry. The ore's content was one of its most unusual characteristics. Carnotite featured a blend of three rare, radioactive metals, all of which were prized for their properties. Vanadium was highest in percentage and was used as an alloy in hardened steel. The uranium content, when separated and then enriched, became fission material for atomic weapons and fuel in nuclear powerplants. Radium, present in miniscule amounts, offered medical benefits and saw application as a luminous paint.

The ore's geological occurrence was another characteristic that made it unique. In general, the metal-bearing ores with which the mining industry was familiar were usually found in metamorphic and igneous rock formations. Further, it was understood that, in Colorado, most of these formations constituted the Rocky Mountains. As a result, metal mining came to be associated with and even became a function of mountain geology. Not so with carnotite. In contrast, carnotite occurred in sedimentary geology along the western skirt of the Rockies, where no one initially expected to find important metal-bearing ores.

Carnotite ore was not limited exclusively to western Colorado and instead could be found in specific areas on a landform known as the Colorado Plateau. Ovoid in shape, the Plateau was

[8] Davis, 2007; Holland, 2007.

an elevated layer-cake of sedimentary beds that radiated outward from the Four Corners, where Colorado, New Mexico, Arizona, and Utah met. By far, the most productive and important concentration of carnotite deposits was what the U.S. Geological Survey defined in 1943 as the Uravan Mineral Belt, on the Plateau's northeast portion. The Belt was approximately 20 miles wide, 60 feet long, and extended south from the town of Gateway, Mesa County, through Montrose, San Miguel, and Dolores counties, and into Utah. The Belt's western portion went across the Colorado state line into San Juan County, Utah.

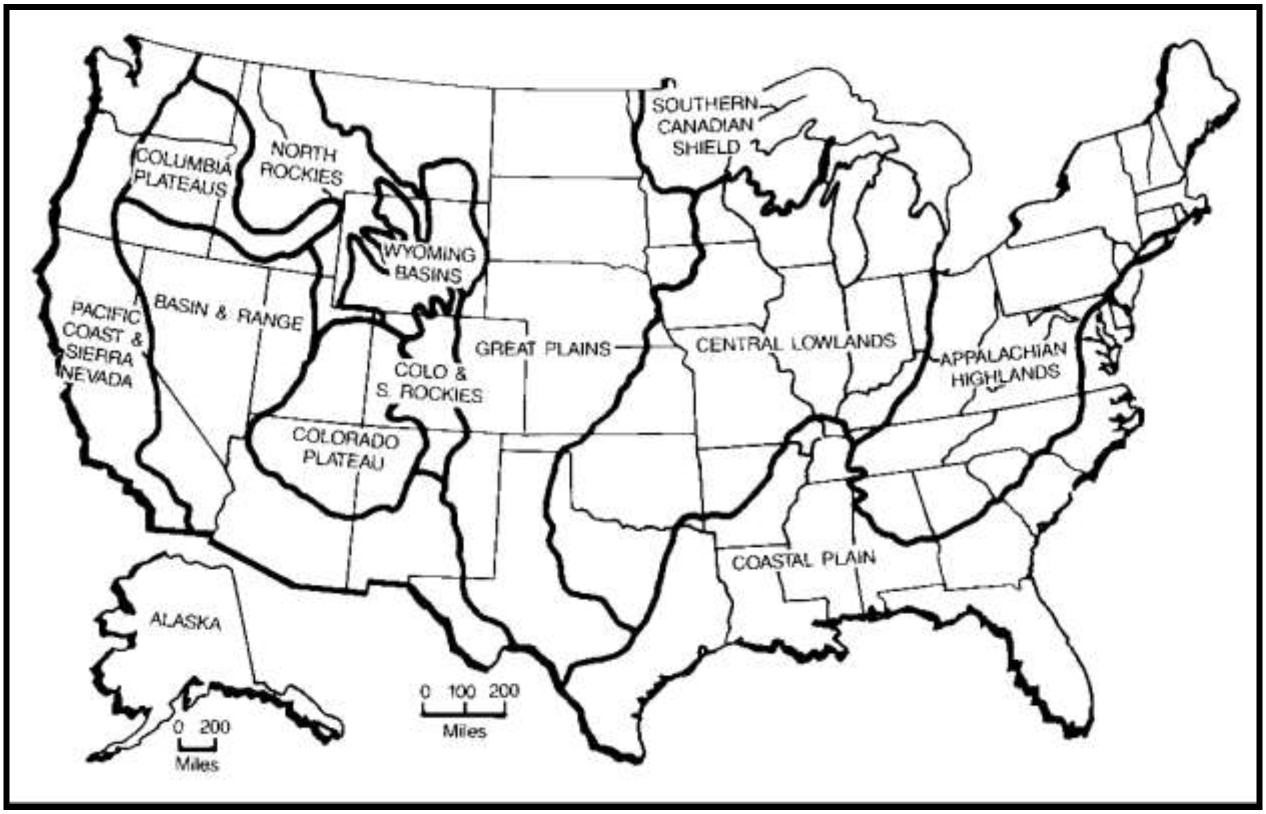

Figure E 3.1: The map illustrates North America's principal geological regions. The Colorado Plateau radiates outward from the Four Corners area, at lower right. Colorado, and in particular Montrose and San Miguel counties, featured most of the ore bodies on the Plateau. Source: U.S. Uranium Mining, 1984:22.

The main portion of the Belt crossed north-south through Paradox Basin, which was a geological feature within primarily Montrose and San Miguel counties. Paradox Basin, like the rest of the Plateau, initially took form as a shallow seabed during the Precambrian Era, around 4 billion years ago. As the region gently subsided during the Paleozoic and Mesozoic eras, sediments washed in from distant mountain ranges and formed layers of sand, silt, and mud

5,000 feet in thickness. Time, mineral solutions, and compression solidified these layers into sandstone, siltstone, and shale.[9]

Based on today's stairstep mesas, incised stream canyons, and broad valleys, it is difficult to perceive the original submarine sedimentary basin. This is because a sequence of events radically changed the region, and the first was tectonic in origin. Around 16 million years ago, the sedimentary basin began slowly ascending and tilting northward as one massive unit. Geologists speculate on exactly what forces were responsible, but most agree that they were probably related to the Laramide Revolution, which built the existing Rocky Mountains to the east. When the sedimentary beds became exposed, erosion immediately began its attack from two fronts. On the surface, rain and runoff planed off the soft, upper layers and incised stream channels into the lower, harder beds. Deep underneath, slowly moving groundwater dissolved massive salt deposits that formed when the basin was a shallow sea floor. The salt deposits were elongated, trended northwest-southeast, and were miles in length. Once the salt and soft rocks were gone, the overlying sedimentary beds collapsed and formed a number of linear synclines, exemplified by Paradox, Big Gypsum, Dry Creek, and Sinbad valleys.[10]

As the climate dried toward present day and less surface water washed over the region, the pattern of erosion changed. The universal sheet wash, planing down, and mass-wasting slowed, and runoff emphasized the existing drainages, which increased in depth and vertical relief. At the same time, because the softer shale and mudstone layers were susceptible to erosion, they disintegrated faster than the harder sandstone beds. As a result, the mesas assumed an appearance of alternating slopes and sandstone cliffs.

It was in one of these sandstone beds that prospectors found carnotite. During the 1910s, the 1940s, and the 1950s, geologists classified nearly all the sedimentary layers comprising the Colorado Plateau. They named the ore-bearing bed the Morrison Formation and divided it into distinct sublayers known as members. The Salt Wash and Brushy Basin members formed the upper portion of the Morrison Formation, and these hosted the region's carnotite deposits.

In Montrose and San Miguel counties, the Salt Wash member features eight alternating layers of sandstone and mudstone, which express themselves as cliffs, benches, and slopes in the mesas. While the member ranges from 280 to 400 feet in thickness, mining companies found nearly all the carnotite deposits in the upper 100 feet. The sandstone was slightly different in appearance than the reddish Morrison material and instead was grayish-yellow to pale orange. The Brushy Basin member, which overlay the Salt Wash, was similar in thickness and layering, although the Brushy Basin member had more siltstone and shale beds.[11]

[9] Baars, 2002:31; Fischer, 1950:6; Baars and Stevenson, 1981:23; Fischer, 1968:738; Joesting and Byerly, 1958:5.
[10] Baars and Stevenson, 1981:30; Del Rio, 1960:336.
[11] Baars, 2002:33; Boardman, 1956:15; Craig, 1955:157; Craig and Catigan, 1958:187, 190; Motica, 1968:808; Wood and Lekas, 1958:208.

Figure E 3.2: The Salt Wash Member of the Morrison Formation consisted of alternating layers of sandstone and mudstone and was clearly exposed in the valleys and mesas of western Montrose and San Miguel counties. The upper layers of the Salt Wash, above the thick sandstone horizon in the photo, contained most of the region's carnotite ore deposits. The photo is a westerly view of the confluence of the Dolores and San Miguel rivers. Source: Author.

The vanadium deposits in San Miguel County share with carnotite the theme of sedimentary geology, although the details are different. During the early 1900s, prospectors around Placerville found a rare mineral named roscoelite, which occurred in sandstone as did carnotite. Known as the Entrada Formation, the sedimentary layers around Placerville were younger than the Morrison and dated to the Jurassic Period, around 54 million years ago. Geologists usually found economical deposits of the vanadium ore within the upper 15 feet of the formation, which, of course, was underneath additional sedimentary beds.[12]

[12] Fischer, 1942:371; Moore and Kithil, 1914:51; Wilmarth, 1958:3.

One of the most fundamental differences between carnotite and traditional metal ores was carnotite's physical makeup. Traditional metal ores usually consisted of metal compounds in chemical combinations bound to either metamorphic or igneous rock. Carnotite, on the other hand, was the matrix that bound together the grains of sand in sandstone. Miners found that carnotite assumed several additional forms in unusually rich deposits. One, known as spotted ore, featured dark masses and blotches with few sand grains and much vanadium. Another was the replacement of entire geological microfeatures such as petrified trees. The last was in the form of seams, vugs, crusts, and elongated masses that miners termed bug holes.[13]

As noted, carnotite's principal constituents were vanadium and uranium, in order of proportion. Ore rich with uranium tended to be canary-yellow, and when impurities were present, it ranged from greenish-yellow to light-brown. Ore with a high vanadium content tended to be olive-green to brick-red, and geologists recognized compounds that were blue-black to black by the 1950s.[14]

The mining industry recognized several constants associated with the unique ore and even used them to identify promising areas for prospecting. One reliable aspect was that the sandstone in the vicinity of ore bodies tended to be light-yellow, light-brown, or light-gray, and mineralized with showings of pyrite and limonite. In contrast, sandstone unlikely to feature ore bodies was reddish like the rest of the Morrison Formation. During the 1910s and the 1950s, prospectors used these aspects to identify areas worth searching.[15]

Another reliable predictor, as noted above, was that carnotite was restricted largely to the Salt Wash and Brushy Basis members. However, within these beds, the ore bodies assumed random shapes and sizes. In terms of size, the ore bodies ranged from small pockets of 10 to 500 tons to masses of 100,000 tons, which were as much as one-half mile long, several hundred feet wide, and 5 to 100 feet thick. Medium-sized ore bodies contained up to around 25,000 tons. The mining industry found that these ore bodies assumed three general structures. Continuous deposits were the most common and tended to manifest as tabular beds 1 to 4 feet thick with minor irregularities. Discontinuous deposits were also beds, but they tapered and possessed highly amorphous features. Cylindrical masses tended to be rounded, elongated, and inconsistent. While the mining industry sought the large deposits, it understood that the small ones were equally important because they possessed a higher tonnage on a cumulative basis.[16]

Carnotite beds shared a few characteristics with other types of replacement ore bodies. The most significant was that carnotite did not feature a clearly defined and abrupt contact with the rest of the sandstone. Rather, carnotite bodies increased in purity toward their center and decreased toward their margins. In many cases, once a mining outfit exhausted the high-grade ore, it often suspended operations because the remaining material was uneconomical at that time. As the costs of production decreased and the value of uranium increased in later years, the surrounding low-grade ore then became profitable to mine. As a result, many mines saw successions of operators over the course of decades until even the low-grade ore was gone.

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13 Aurand, 1920:60; Coffin, 1921:165.

14 Amundson, 2002:2; Boardman, et al, 1956:18; Motica, 1968:811.

15 Boardman, et al, 1956:6, 18; Fischer, 1968:743; Motica, 1968:811; Wood and Lekas, 1958:210.

16 Clark and Kerr, 1974:26; Coffin, 1921:159-164; Fischer, 1942:363; Fischer and Hilpert, 1952:3; Hampton, 1955:77; Motica, 1968:810; Wood and Lekas, 1958:210; Wright and Everhart, 1960:339.

Roscoelite was a replacement deposit like carnotite, but the replacement occurred on a mineral-specific basis. Specifically, vanadium replaced the aluminum content of muscovite (white mica) that formed in metamorphic veins. Overall, the ore was light to dull green, and rich material featured dark blotches of vanadium. Unlike the irregular carnotite beds, roscoelite ore bodies tended to be well-defined and easy to track. Specifically, the roscoelite accompanied several other minerals that filled faults that trended northwest in the Placerville area. These characteristics made the ore relatively easy to find, develop, and exploit, which is why mining maintained production for around 15 years.[17]

E 4: HISTORY OF RADIOACTIVE METALS MINING IN MONTROSE AND SAN MIGUEL COUNTIES

E 4.1: The Chrome Copper Discovery

Ordinarily, sedimentary geology and canyon lands held as little interest for prospectors as the Great Plains did for loggers. The reason was simple. In opposition to the igneous and metamorphic geology of the Rocky Mountains, sedimentary formations were a highly unlikely environment for the occurrence of metalliferous ores. Yet, the Talbert brothers, and especially Tom, perused the sedimentary canyons of western Montrose County for silver and gold during the late 1870s. Why the Talberts chose this region with its limited potential remains uncertain, but they were probably interested in the placer gold that various parties discovered and mined along the San Miguel River as early as the mid-1870s.

In 1879 or 1881, depending on the reference, the Talberts were examining the confluence of the Dolores River and Roc Creek, west of the San Miguel River, and discovered parrot-yellow mineralization in a sandstone bed. While they could not readily identify the mineralization, the Talberts knew it was unusual and staked a claim. After sinking the 10 foot shaft required by mining law, they sent samples to an assayer in Leadville for analysis, and his reports were disappointing. The assayer found only traces of gold and silver, and even though he was unable to identify some of the constituents, the find was obviously not a bonanza. When other assayers tested subsequent samples and came to similar conclusions, the Talberts lost interest and sold the property to Robert W. Johnson, a local cattle baron.[18]

Johnson was part of a small movement that settled the San Miguel and Dolores River basins during the early 1880s. Adventurous individuals and families staked homestead claims in the principal stream valleys and along the rivers, which flowed northwest. Ranchers, in need of tracts large enough to feed cattle, claimed as much land as possible and purchased and consolidated homesteads. The sparse population fostered enough demand for goods, services, and administration to support the development of several small towns in 1881. Naturita, the Spanish word for nature, was established on the San Miguel River around 20 miles east of its

[17] Curran, 1912; Moore and Kithil, 1914:51; Wilmarth, 1958:4.
[18] Coffin, 1921:151; Hamrick, et al, 2002:12.

confluence with the Dolores in 1881. Nucla grew on open terrain several miles to the north, and Norwood became center to farms and ranches on plateau land approximately 15 miles to the southeast. Settlers founded two more agricultural communities far to the west in Paradox Valley. They organized the town of Paradox at the valley's northwest end in 1882 and Bedrock on the Dolores River the following year. The Paradox Valley was so named because it trended northwest-southeast and featured a meager stream, while the substantial Dolores River cut through the valley at around 90 degrees. The river, the local settlers observed, paradoxically did not follow along the valley as it should have and instead cut across the valley.

The Talberts staked their claim on the lower reaches of Roc Creek, which was close to and west of Johnson's Club Ranch, located at the confluence of the San Miguel and Dolores rivers. Johnson acquired the property in 1880 or 1881, organized the San Miguel Cattle Company, and commuted seasonally between the ranch and his other interest in New Jersey, the Johnson & Johnson Surgical Supply Company. While Johnson and the Talberts were unaware of exactly what the yellow mineralization was, some of Johnson's cowboys found more on Club Mesa, which rose along the San Miguel's southwest side, and other local residents noted similar material around the rim of Paradox Valley.[19]

During the late 1880s, another party of prospectors took an interest in the yellow mineralization. They relocated the Talberts' claim, which Johnson let lapse, and named it the Copper Prince. They chose this name on the presumption that the mineralization was a chromate of copper, which seemed to be as likely an assumption as most other obscure minerals. The problem, however, was that additional assays found no copper nor other profitable metals, and the prospectors let the claim lapse.[20]

E 4.2: The Radium Interest, 1898-1905

In 1896, two events unfolded on opposite shores of the Atlantic Ocean, and they not only addressed the mystery of the yellow mineralization, but also attached great significance to the material. In Montrose County, prospector Tom Dullan relocated the abandoned claim and was experienced enough to call upon experts to identify the yellow mineralization. Dullan appealed to the scientific community instead of the industrial sector and sent samples to the Smithsonian Institute in Washington, D.C., for assay. The samples perplexed the Smithsonian assayers, but after extensive tests they confirmed that the mineralization was an extremely rare form of uranium and vanadium ore. Dullan knew he had claim of scientific importance at the least and maintained title, but was unsure how the uranium and vanadium could turn a profit.[21]

Meanwhile, on the opposite side of the Atlantic, French scientists Pierre and Marie Currie and Antoine Henri Becuerel were conducting experiments with pitchblende specimens from mines in eastern Germany. Marie found that pitchblende, an igneous rock, emitted energy rays, and after experimentation, the three scientists named the energy radioactivity. Further, they

[19] Coffin, 1921:150; Hamrick, et al, 2002:10.
[20] Coffin, 1921:151.
[21] Coffin, 1921:151; Hamrick, et al, 2002:12.

identified uranium as the principal source, and news of the discovery quickly drifted to North America. During the following two years, the Curries found that thorium was also radioactive; they isolated radium from uranium and realized that radium had the potential to cure some forms of cancer.[22]

The novelty, curiosity, and potential applications of radioactive minerals stimulated interest among the scientific communities in both Europe and the United States. Scientists, principally the Curries and Becuerel, sought uranium sources that were superior to those in eastern Germany. They found them in the mines of Central City, Colorado, which passed through zones of pitchblende, and sent samples to France in for further experimentation.[23]

Happenstance connected the Curries and fellow scientists with the Roc Creek ore. Around 1897, California investors secured an option to buy the Copper Prince claim because they were aware of the growing interest in uranium, and the investors entrusted William Hamilton with the assessment work to retain title. Instead of completing his tasks, Hamilton absconded with the funds and allowed the claim to revert back to public ownership. Jack Manning immediately relocated the claim and named it the Rajah.[24]

At the same time, a group of Michigan investors acquired the Cashin Mine on La Sal Creek, south and on the other side of Paradox Valley from Roc Creek. The investors hired French metallurgist Charles Poulot to build a mill for the mine’s copper ore, and Poulot was aware of the growing interest in radioactive ores in his homeland. While in Denver, Poulot made the acquaintance of Gordon Kimball, who ran an ore-buying agency in Ouray. Poulot then explained to Kimball his interest in rare metals and especially uranium, and he taught Kimball distinguishing characteristics for identifying the metal. Kimball had long been aware of the Roc Creek claim and its supposed chrome copper, which he now knew was a uranium compound, and obtained samples from Manning.[25]

In 1898, Kimball sent some of the specimens to Poulot, who repeated the Smithsonian Institute’s assays, and found that the ore not only offered uranium in commercial quantities, but also in higher proportions than the pitchblende used up to that time. Excited, Poulot sent samples to Prussian assayers M.M.C. Friedel and E. Cumenge, who named the ore carnotite after compatriot Adolphe Carnot, and then forwarded some of the samples to the Curries. In an attempt to include the American scientific community, Kimball sent samples to the Colorado School of Mines, which conducted its own experiments.[26]

When the European scientists were able to isolate uranium and radium from the ore, their interest was piqued. They probably conveyed the ore’s importance to Gordon Kimball, who then leased the claim in 1898. Poulot offered Kimball an astounding $26,000 for 10 tons of ore, which had to be shipped to France for treatment and isolation of radium. Kimball set about developing the claim as the Roc Creek Mine and enjoyed handsome profits in part because the ore cropped out on a sandstone ledge and required little capital to extract.[27]

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[22] Amundson, 2002:2; Bruyn, 1955:34-37; Coffin, 1921:151; Hamrick, et al, 2002:iv; "Radium" *EMJ*.
[23] Bruyn, 1955:34-37.
[24] Bruyn, 1955:31.
[25] Kimball, 1904.
[26] Bruyn, 1955:30; Coffin, 1921:150; Kimball, 1904; “Uranium in Colorado” *EMJ*.
[27] Kimball, 1904.

When the news of Kimball's deal circulated, a number of prospectors, probably local to southwestern Colorado, came to the confluence of the Dolores and San Miguel rivers, although the region's remote location and novelty of the ore ensured that their numbers were limited. In 1899, Ike Hallet found the first carnotite outside of Roc Creek on Club Mesa, and other prospectors discovered more at the old camp of Hydraulic a short distance northwest on the Dolores River. These strikes stimulated a small rush, and prospectors named their collection of residences Shamrock Camp and organized the Vixen Mining District to administer to the area south to Long Park. The town of Bedrock became a supply point for prospectors who developed claims at the confluence of La Sal Creek and the Dolores River. Slick Rock, on the Dolores in San Miguel County, saw a wave of discoveries, the organization of McIntyre Mining District, and the camp of Snyder's.[28]

A handful of parties purchased many of the claims as quickly as prospectors staked them, which reinforced the general search for ore. In 1899, Poulot and F. Voilleque formed a partnership and bought and developed 42 claims at the mouth of Disappointment Creek, near Slick Rock. The partners also operated the Wood Mine in Central City for pitchblende. A.B. Frenzel and Wood Galloway, of Placerville, purchased a group of claims at Bedrock in 1899 and prepared them for production. Pierre Currie joined the Welsh-Lofftus Uranium & Rare Metals Company to work a small mine at Richardson, Grand County, Utah.[29]

Unlike the deep Rocky Mountains, the relatively mild climate of the Colorado Plateau allowed prospectors to work nearly all year. Because the carnotite pockets were directly exposed in sandstone ledges, the actual mining was relatively easy and inexpensive. These factors were important steps in regular ore production, but a combination of problems had yet to be addressed before mining could be profitable. While the ore was rich with uranium, this metal was of interest only because it was a host for the embedded radium, which was miniscule by proportion. On average, 300 tons of carnotite were required to produce 1 gram of radium, and since no treatment facilities existed in North America, the mining companies had to ship the ore to Europe. The ore had to be sacked, packed on mules to the nearest railroad station at Placerville, sent by train to the east coast, and freighted overseas. Even though radium fetched a high price, this was a logistic and economic nightmare that suppressed meaningful production.[30]

Poulot and Voilleque reasoned that if the ore could not be shipped to a European treatment facility, then one would have to be brought to western Colorado. With French financing, they erected North America's first radioactive metals mill on La Sal Creek in 1900. The mill began as an experimental facility in which the partners applied European technology to separate the uranium from carnotite. When they settled on a successful method in 1901, Poulot and Voilleque organized the American Rare Metals Mining & Milling Company and built a commercial mill at Camp Snyder, near the mouth of Summit Creek. This was North America's second radioactive metals mill and the first full-scale version.[31]

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[28] Bruyn, 1955:32; Coffin, 1921:152; Elevatorski, 1978:15.
[29] Coffin, 1921:153; Hamrick, et al, 2002:13.; "Mining News" *EMJ* 3/18/99 p328; "Mining News" *EMJ* 9/30/99 p406.
[30] Amundson, 2002:2.
[31] Bruyn, 1955:49; Coffin, 1921:152; Metal Mining, 1961:76; "Mining News" *EMJ* 6/30/1900 p778; Moore and Kithil, 1914:18.

Known as the American Rare Metals Mill, the facility was based on the patented European Haynes-Engle process pioneered to concentrate radium. The ore was crushed, ground in a ball mill, screened, reduced to a slurry in a second ball mill, and leached in sulfuric acid. Workers decanted the liquor, precipitated the uranium with sodium carbonate, filtered the concentrates, and dried then sacked them. As was common with mills, the spent liquor was discharged as waste into the nearest drainage.[32]

The mills proved to be successes, but only with high-grade ore, and they produced several hundred tons of concentrates that the company shipped to France. The impact to the region was significant. It reinforced the value of carnotite ore, proved that profits could be made, and served as local treatment facilities. The result was growth of the region's carnotite mining industry. With proof that carnotite was in demand, prospectors continued to search the rims of the San Miguel and Dolores rivers and the major valleys such as Paradox and Big Gypsum. The Roc Creek (Rajah) Mine sent ore to the mill, and this and other operations in the canyon supported the town of Uranium, which received a post office in 1900. The camp of Hydraulic, on the San Miguel River, followed a similar pattern. Mines there sent ore to the American Rare Metals Mill, and the Postal Service recognized that settlement with a post office in 1901. Elsewhere, and especially around Slick Rock, a number of small outfits found ore rich enough either to sell to American Rare Metals or ship it in crude form to Europe. All the mines were small, pocket operations, and their production should not be overstated. For context, only 375 tons of crude ore, which was nearly all the nation's total, came from Montrose and San Miguel counties during 1901.[33]

The following year, a young but genuine carnotite mining industry took shape. Both of the American Rare Metals mills operated, mining outfits shipped ore to the railroad at Placerville, and a number of camps grew near centers of activity. Hoping to capture some of the ore bound for Europe, Colorado metallurgists Herman Fleck and Charles E. Carpenter leased the Cashin Mill, which was apparently idle. They attempted to concentrate carnotite there but met with failure because they lacked the experience of Poulot, who now focused on his successful American Rare Metals company. During 1902, the interest in uranium spread throughout the prospecting community, and individuals extended their search to other counties. Reports circulated of carnotite in counties throughout the Western Slope, and even in El Paso and Teller counties. Few if any of these, however, materialized into anything of substance.[34]

Table E 4.1: Mining and Milling Companies, 1898-1905

Company Name	Operating Timeframe	Operating Location	Facilities, Properties
Poulot & Voilleque	1899-1904	Slick Rock, Roc Creek Canyon	Various mines; nation's principal radium agent
American Rare Metals Mining	1901-1903	Camp Snyder, Slick Rock	Concentration mill

[32] Bruyn, 1955:49; Coffin, 1921:152; Curran, 1913 p1165; Metal Mining, 1961:76.
[33] Bauer, et al., 1990:76, 145; Coffin, 1921:152; *Mineral Resources*, 1901:270; "Mining News" *EMJ* 11/23/01 p677; "Uranium in Colorado" *EMJ*; "Uranium and Vanadium" *EMJ*.
[34] Hamrick, et al, 2002:15; "Uranium in Colorado" *EMJ*.

& Milling Company			
Western Refining Company	1903-1904	Camp Snyder, Slick Rock	Concentration mill
Dolores Refining Company	1904-1911	Camp Snyder, Slick Rock	Concentration mill

Figure E 4.1: Because carnotite beds cropped out in the cliffs of the region's mesas and river valleys, they were easy to access and hence required little capital to work. The photo illustrates one of the many small mines developed during the 1900s. Source: Denver Public Library, CHS.X5629.

A.B. Frenzel, however, made several discoveries near Newmire in San Miguel County that did become highly important. Specifically, he found several massive roscoelite deposits in 1901, and he was interested in the ore's vanadium content. As early as the late 1890s, steel makers both in the United States and Europe understood that vanadium was an excellent alloy material for making hardened steel. They conducted experiments through the early 1900s but resigned themselves to the fact that vanadium was too exotic and costly for practical use. When Frenzel identified the roscoelite as a vanadium ore, he realized that he possessed a material that the steel industry would consume if the price was right. Few if any people around Newmire knew what vanadium was, and Frenzel apparently did not say much. Instead, he returned to Denver to puzzle out a means of separating out the vanadium from the ore. In need of capital, Frenzel interested investors who organized the United States Vanadium Company, which then funded the development of the Newmire claims.[35]

[35] *Mineral Resources*, 1899:308, 314; *Mineral Resources*, 1902:287; "Mining News" *EMJ* 8/18/1900 p192; "Mining News" *EMJ* 11/29/02 p724; "Questions and Answers" *EMJ* 2/24/1900 p234.

In 1903, Charles Poulot, the father of the American uranium mining industry, resigned his various positions and probably returned to France. His sudden departure left a vacuum in two key arenas. First, he no longer ran the American Rare Metals Mill, and second, Poulot & Voilleque relinquished its role as the principal agent connecting American carnotite with the European market. Frenzel quickly filled the latter void and assumed the role as the principal buyer of uranium ore in the United States. At the same time, Charles E. Carpenter and Justin H. Haynes took over the mill. Both were metallurgists, and Haynes was a valuable asset because he helped develop the uranium recovery process that the mill employed. The partners organized the Western Refining Company, bought the mill, and continued to treat ore.[36]

It appears that by 1903, the mill began to lose its efficiency. The Haynes-Engle process was far from perfect, but it was the best method for separating uranium from carnotite at the time. It may be that the process was not adaptable to ores of differing character, and it certainly required the ore to be of a high grade. Whatever the problem, in 1904, Carpenter and Haynes sold the mill to the Dolores Refining Company, which was interested in a complete mining and milling operation. The Dolores company initially used the American Rare Metals Mill as a pilot project for a larger facility, and when satisfied with tests, erected a better mill a short distance up the Dolores River. To provide the new mill with plenty of ore, the company also purchased Poulot & Voilleque's scattered collection of mines. It remains unknown whether the company continued to run the American Rare Metals Mill in conjunction with the new facility, which was a complete success.[37]

In 1905, several factors stunted the young carnotite mining industry and prevented A.B. Frenzel's vanadium operation at Newmire from blossoming. The United States lacked the experts and technology required to recover uranium and vanadium from any type of ore. Those resources lay in Europe, but an enormous distance separated Europe from Montrose and San Miguel counties. Because of this, carnotite mining outfits had great difficulty securing the investments and technical assistance that they needed. In addition, the remote nature of the carnotite region complicated operations and translated into high production costs. Under these circumstances, Europe turned to the pitchblende ores of Joachimsthal and Schneeberg, Germany, for its radium. In parallel with the loss of European support for carnotite mining, production in Montrose and San Miguel counties collapsed to only around 4 tons of ore in 1905.[38]

First Period of Significance, 1898-1905

The temporary collapse of carnotite mining brought an end to the first Period of Significance in Montrose and San Miguel counties. While carnotite ore was discovered around 1880, the first Period actually began in 1898 when the ore was recognized and purposefully sought after for its radium content. A growing demand at first among the scientific community and then the medical industry stimulated a minor wave of prospecting on the San Miguel and

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[36] Bruyn, 1955:50; Metal Mining, 1961:76; Moore and Kithil, 1914:18; "Questions and Answers" *EMJ* 3/14/03 p416.
[37] Bruyn, 1955:50; Metal Mining, 1961:76; *Mineral Resources*, 1906:526; Moore and Kithil, 1914:18.
[38] *Mineral Resources*, 1905:420.

Dolores rivers. A nascent but important mining industry came of the interest, and it offered several fundamental contributions. First, the world had never seen carnotite until 1897, and the recognition of this rare mineral was a direct addition to science. Second, prospectors and mining outfits began assembling a body of data regarding the distribution and occurrence of carnotite ore formations. This would become highly important in later decades. Third, the first three uranium mills in North America were built to process the ore. These mills pioneered uranium recovery methods and established a technological foundation that would ultimately allow uranium and vanadium mining to thrive.

E 4.3: The Radium and Vanadium Boom, 1906-1922

With carnotite mining in suspension, activity shifted over to Frenzel's vanadium deposits near Newmire, San Miguel County. The reason was that a few steel companies in Pennsylvania finally began to imitate the European industry in the metallurgy of vanadium alloys. Because vanadium was not widely available, these companies surveyed the potential sources and identified two. One was the Minaragra Mine in Peru and the other was at Newmire, possibly through Frenzel's promotion. Around 1904, investors organized the Vanadium Alloys Company to develop the Newmire roscoelite deposits into something usable by the steel industry. The Vanadium Alloys venture was risky at the time because no precedent existed for winning vanadium from roscoelite, and the company would have to develop effective separation methods before it could offer anything to the steel industry. In 1904, manager William T. Rynard purchased a number of claims near Newmire to provide ore while engineer H.A. Hillman designed an experimental mill to test recovery methods.[39]

Hillman calculated that the Haynes-Engle process could separate vanadium from roscoelite ore, with a few modifications. According to Hillman's design, a jaw crusher reduced crude ore to gravel, a device known as a crushing rolls pulverized it to sand, and then the material was roasted with salt in a furnace. This converted the ore into a vanadium chloride, which was water-soluble. Workers leached the ore in vats of water, decanted the liquid, and added iron to precipitate out the vanadium. The workers then dried and sacked the concentrates for shipment.[40]

Hillman finished the mill under great pressure in 1907 and must have felt relief when it functioned correctly and proved his calculations correct. Following the original plan, Hillman oversaw the construction of a commercial mill that employed the same process as the experimental facility. With the new mill, Vanadium Alloys began production and assumed the role of what was probably North America's first vanadium operation.[41]

Vanadium Alloys was not alone in its attempt to produce vanadium during the mid-1900s. Instead, the company was on the forefront of a larger movement. The American Vanadium Company, the other major vanadium interest during this time, developed the

[39] *Daily Journal* 1/26/05.
[40] *Mineral Resources*, 1906:526; "Mining News" *EMJ* 4/14/06 p733.
[41] *Mineral Resources*, 1907:721; *Telluride Journal* 1/23/08.

Minaragra Mine in Peru and conducted its own processing experiments in Pennsylvania. This was the beginning of competition from Peru, which would plague the American vanadium industry in later years.

In 1909, four new vanadium ventures prepared for production. British investors organized the General Vanadium Company to supply their steel mills in Liverpool. Instead of targeting Newmire roscoelite, of which they knew little, the investors sought carnotite because it was a more familiar a type of ore. The company then purchased the Jo Dandy, Valley View, Canary Bird, and other mines on Monogram Mesa, on the south side of Paradox Valley. The Primos Chemical Company, based in Pennsylvania, imitated the Vanadium Alloys strategy of assembling a mining and milling operation. The company purchased a group of claims on Big Bear Creek near Placerville, as well as the Vanadium Alloys experimental mill at Newmire, and enlarged the mill to a commercial scale. At the same time, the firm of Wolcott & Waltemeyer purchased a group of claims at Newmire and developed them for production. The Colorado Vanadium Company lagged behind the others and established a lab in Boulder to study processes for treating roscoelite. Even though Boulder was on the opposite side of the Rockies from Newmire, the company probably chose Boulder because it was a center of tungsten mining, which was another important and rare alloy metal.[42]

[42] Coffin, 1921:152; Curran, 1913 p1165; *Mineral Resources*, 1909:584; *Mineral Resources*, 1910:759; "Mining News" *EMJ* 8/28/09 p431; Moore and Kithil, 1914:19.

Table E 4.2: Mining and Milling Companies, 1906-1922

Company Name	Operating Timeframe	Operating Location	Facilities, Properties
American Rare Metals Company	1911-1921	Slick Rock	Various mines; Dolores Refining Mill
Arden M. Wilson	1911-1919	Bull Canyon; Club Mesa, Placerville	Cliff Mine; other mines
Carnotite Products Company (merged with Radium Company of Colorado)	1921	Mesa, Montrose, San Miguel counties	Various mines; mill in Denver
Carnotite Reduction Company (merged with Tungsten Products to form Carnotite Products)	1915-1920	Gateway, Placerville	Various mines; mill in Chicago
Chemical Products Company	1918-1921	Slick Rock	Various mines
Colorado Carnotite Association	1913-1922	Colorado Western Slope	Promoted mining
Colorado Carnotite Company	1912-1920	Long Park, Disappointment Creek	Various mines
Colorado Vanadium Company	1909-1913	Newmire	Various mines
Colorado Vanadium Corporation	1918-1921	Bear, Fall, and Leopard creeks, Sawpit	Various mines; mill at Sawpit; mill at Fall Creek
Crucible Steel Company	1910-1917	Long Park, Paradox Valley, Newmire	Mines (sold to Radium Company of Colorado)
General Vanadium Company	1909-1912	Paradox Valley, Fall Creek, Placerville	Various mines
International Vanadium Company	1912	Montrose and San Miguel counties	Various mines
Pittsburgh Radium Company	1918	Denver	Mill in Denver
Primos Chemical Company	1908-1922	Bear and Fall creeks; Newmire	Mines; mill at Sawpit
Radium Company of America	1913-1915		Mill in Pennsylvania
Radium Company of Colorado (Was Schlesinger)	1915-1921	Bitter Creek, Carpenter Flats, Eagle Canyon, Hydraulic, Long Park, Paradox Valley, Red Canyon, Roc Creek, Newmire	Florence, Great Western, Henry Clay, Maggie C, Rajah and other mines; Bitter Creek and Hart Groups; mill in Denver
Radium Luminous Company (reorganized as U.S. Radium)	1914-1921	Long Park	Doctor, Cripple Creek, Honeymoon, Phonograph mines; mill in New Jersey
Radium Ores Company	1916-1919	Club Mesa	Cliff Mine and Mill
Radium Ore Sampling Company	1918-1922	Montrose	Rare metals sampler
Radium Products Company	1918-	Paradox Valley	Various mines
Schlesinger Radium Company	1914-1917	Roc Creek	Rajah Mine; mill in Denver
Shattuck Chemical Company	1918-1920s	Denver	Mill in Denver
Standard Chemical Company	1911-1923	Club Mesa, Long Park, Coke Ovens	Mines and mill Test mill at Coke Ovens

Table E 4.2, cont.

Company Name	Operating Timeframe	Operating Location	Facilities, Properties
Tungsten Products Company	1918-1921	Gateway, Boulder	Various mines; mill in Boulder
Vanadium Alloys Company	1904-1911	Newmire	Concentration mill
United States Radium Company	1921-1923		(Was Radium Luminous)
United Vanadium Company	1910	Placerville	
W.L. Cummings Chemical Company	1915-1920	Paradox Valley	Various mines
Wolcott & Waltemeyer	1909-1913	Newmire	Various mines

Table E 4.3: Ore Treatment Mills, 1900-1922

Mill Name	Mill Type	Operator	Timeframe	Location	Ore Type
Carnotite Reduction Mill	Concentration and refining	Carnotite Reduction Company	1915-1920	Chicago	Carnotite for radium
Colorado Vanadium Mill	Concentration	Colorado Vanadium Company	1918	Saw Pit	Roscoelite for vanadium
Colorado Vanadium Mill	Concentration	Colorado Vanadium Company	1919	Fall Creek	Roscoelite for vanadium
National Radium Mill	Concentration	National Radium Institute	1914-1916	Long Park	Carnotite for radium
National Radium Refinery	Radium refinery	National Radium Institute	1914-1916	Denver	Mill concentrates for radium
Radium Company of America Refinery	Radium refinery	Radium Company of America	1914-1922	Pennsylvania	Mill concentrates for radium
Radium Company of Colorado Mill	Radium refinery	Radium Company of Colorado	1915-1922	Denver	Carnotite for radium
Radium Ores Mill	Concentration	Radium Ores Company	1916-1918	Tramp Mine	Carnotite for radium
Radium Ore Sampler	Ore sampling and testing	Radium Ore Sampling Company	1918-1921	Montrose	All rare metals
Rare Metals Mill	Experimental concentration	Rare Metals Mining & Milling Company	1899-1903	La Sal Creek & Dolores River	Carnotite for radium
Rare Metals Mill	Concentration	Rare Metals Mining & Milling Company	1900-1903	Camp Snyder, Slick Rock	Carnotite for radium

Table E 4.3, cont.

Mill Name	Mill Type	Operator	Timeframe	Location	Ore Type
Rare Metals Mill	Concentration	Western Refining Company	1903-1904	Camp Snyder, Slick Rock	Carnotite for radium
Rare Metals Mill	Concentration	Dolores Refining Company	1904-1909	Camp Snyder, Slick Rock	Carnotite for radium
Rare Metals Mill	Concentration	Rare Metals Company	1911-1922	Camp Snyder, Slick Rock	Carnotite for radium
Schlesinger Radium Mill	Concentration and refining	Schlesinger Radium Company	1914-1917	Denver	Carnotite for radium
Schlesinger Radium Mill	Concentration and refining	Radium Company of Colorado	1917-1923	Denver	Carnotite for radium
Shattuck Mill	Concentration and refining	Shattuck Chemical Company	1918-1922	Denver	Carnotite for radium
Standard Chemical Experimental Mill	Concentration	Standard Chemical Company	1910-1912	Coke Ovens, western Paradox Valley	Carnotite for radium
Standard Chemical Experimental Mill	Concentration	Standard Chemical Company	1912-1914	Joe Jr. Camp	Carnotite for radium
Standard Chemical Experimental Refinery	Radium refining	Standard Chemical Company	1910-1912	Canonsburg, Pennsylvania	Mill concentrates for radium
Standard Chemical Mill	Concentration	Standard Chemical Company	1914-1923	Joe Jr. Camp, Club Mesa	Carnotite for radium and vanadium
Standard Chemical Refinery	Radium refining	Standard Chemical Company	1912-1923	Canonsburg, Pennsylvania	Mill concentrates for radium
Vanadium Alloys Experimental Mill	Experimental concentration	Vanadium Alloys Company	1906-1907	Vanadium	Roscoelite for vanadium
Vanadium Alloys Experimental Mill	Experimental concentration	Primos Chemical Company	1908	Vanadium	Roscoelite for vanadium
Vanadium Alloys Mill	Concentration	Vanadium Alloys Company	1909-1911	Vanadium	Roscoelite for vanadium
Vanadium Alloys Mill	Concentration	Primos Chemical Company	1911-1922	Vanadium	Roscoelite for vanadium

During the next several years, Newmire became the center of vanadium mining in the United States. An increase in demand for vanadium among steel makers coupled with successful mining around Newmire and Placerville stimulated a small boom. This not only reinforced the existing operations, but also drew additional companies and a wave of prospectors. In 1910 and 1911, the United Vanadium Company and the Crucible Steel Company of America (Crusca) arrived with enough capital to develop several substantial mines. Colorado Vanadium finished with its tests in Boulder and brought a mine into production, as well. The Primos Chemical Company and General Vanadium, however, maintained title as the largest operations. In 1910, General Vanadium finally took an interest in roscoelite and purchased several groups of rich claims on Fall Creek. Primos, which already operated a large mine on Bear Creek, added 2,000 acres of claims to its holdings, leased the second Vanadium Alloys Mill at Newmire, and improved the facility. The activity was so pronounced that the mining industry began referring to Newmire as Vanadium, which the Postal Service officially recognized in 1913.[43]

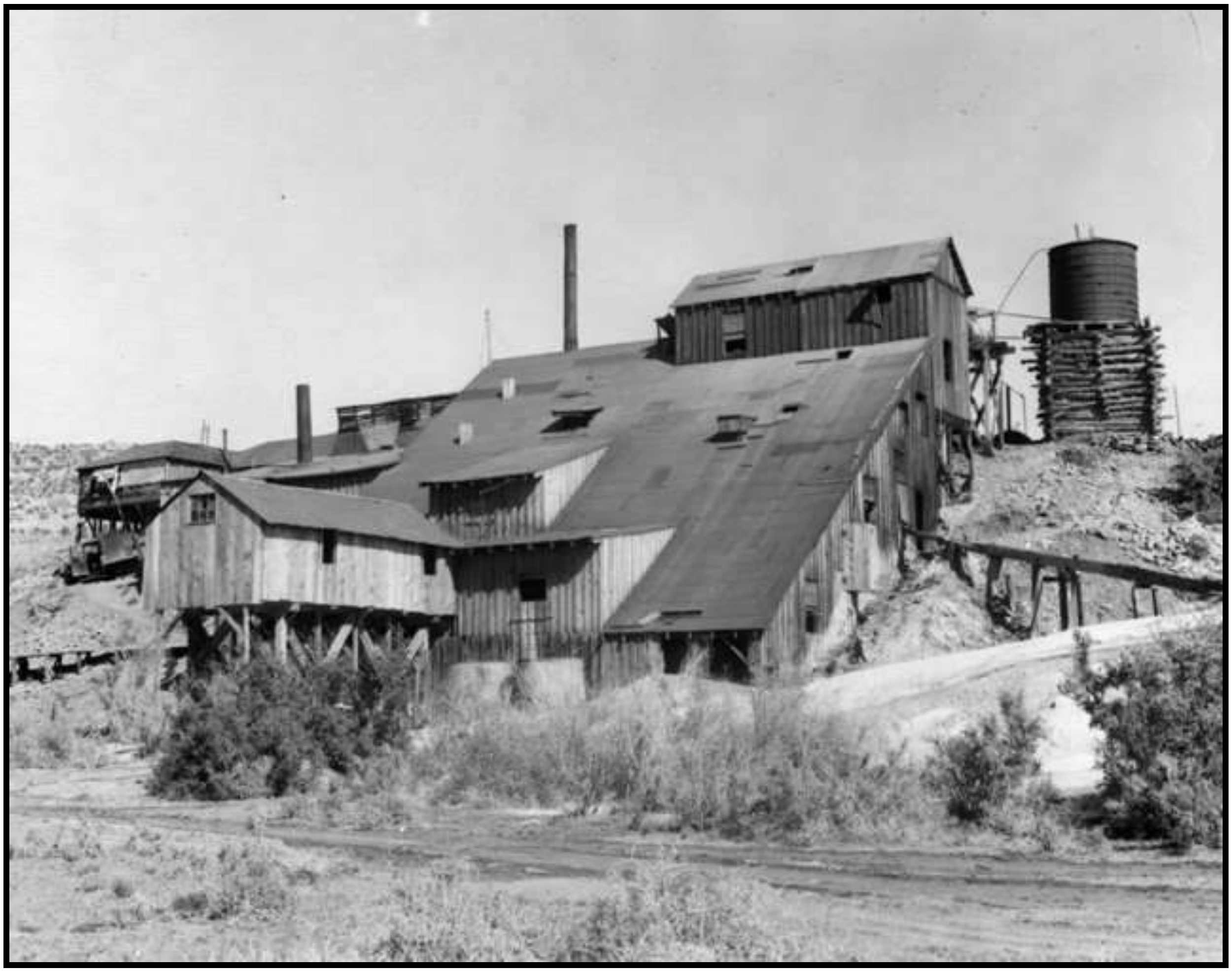

Figure E 4.2: The Rare Metals Mill, built in 1903, was North America's first commercial uranium concentration facility. A succession of companies operated the mill, which apparently burned during the 1920s. The exact date of the photograph is unknown, although most likely during the 1910s. Source: Denver Public Library, X-61965.

[43] Bauer, et al., 1990:146; Curran, 1911 p1287; *Daily Journal* 3/28/10; *Daily Journal* 5/26/11; *Mineral Resources*, 1911:949; *Mineral Resources*, 1913:364; "Mining News" *EMJ* 6/24/11 p1272; "Mining News" *EMJ* 3/30/12 p667.

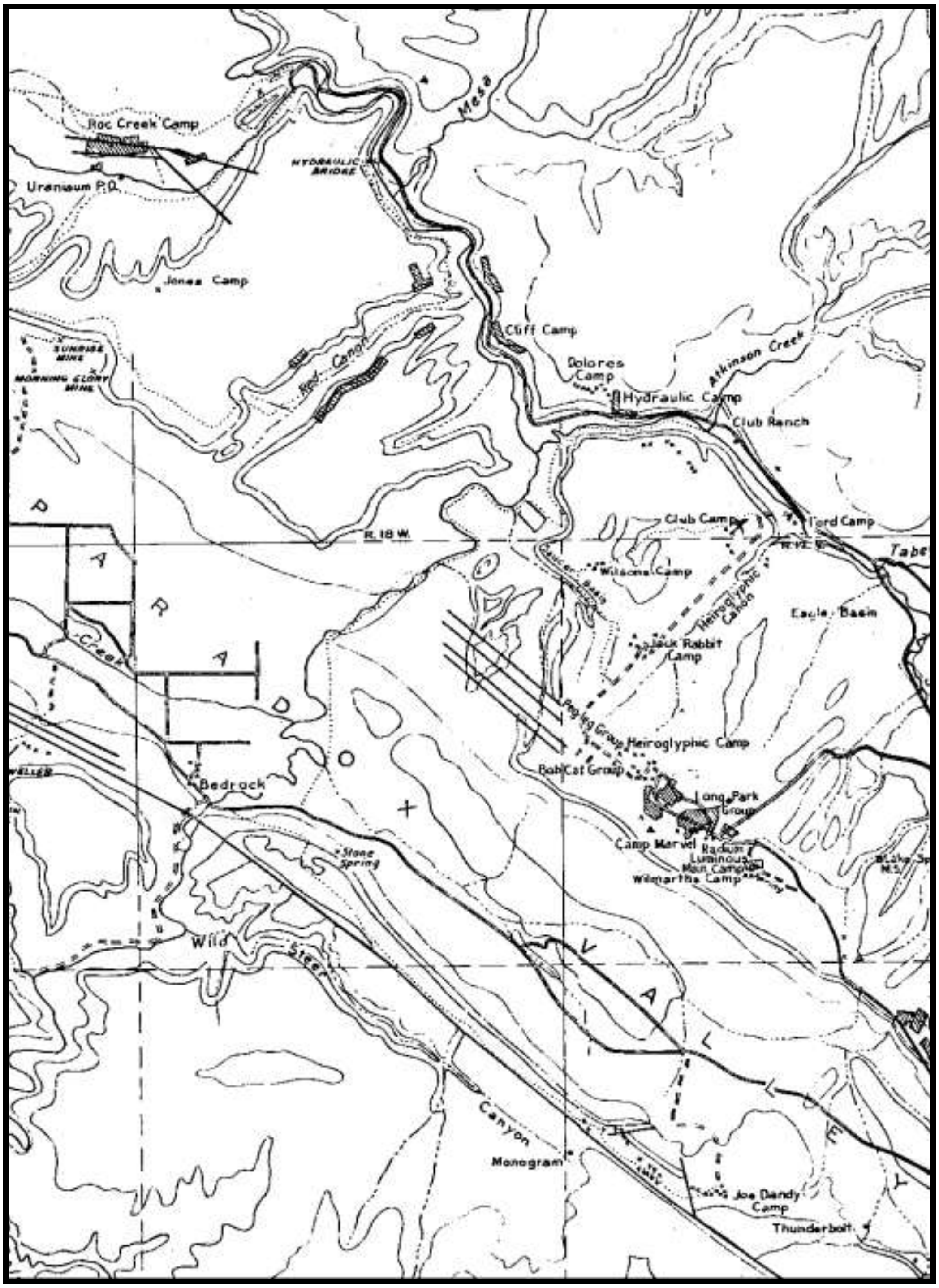

Figure E 4.3: The western half of this historic map depicts the principal mining centers and camps in western Montrose County during the 1910s. The map is continued below. Source: Grant, 1920.

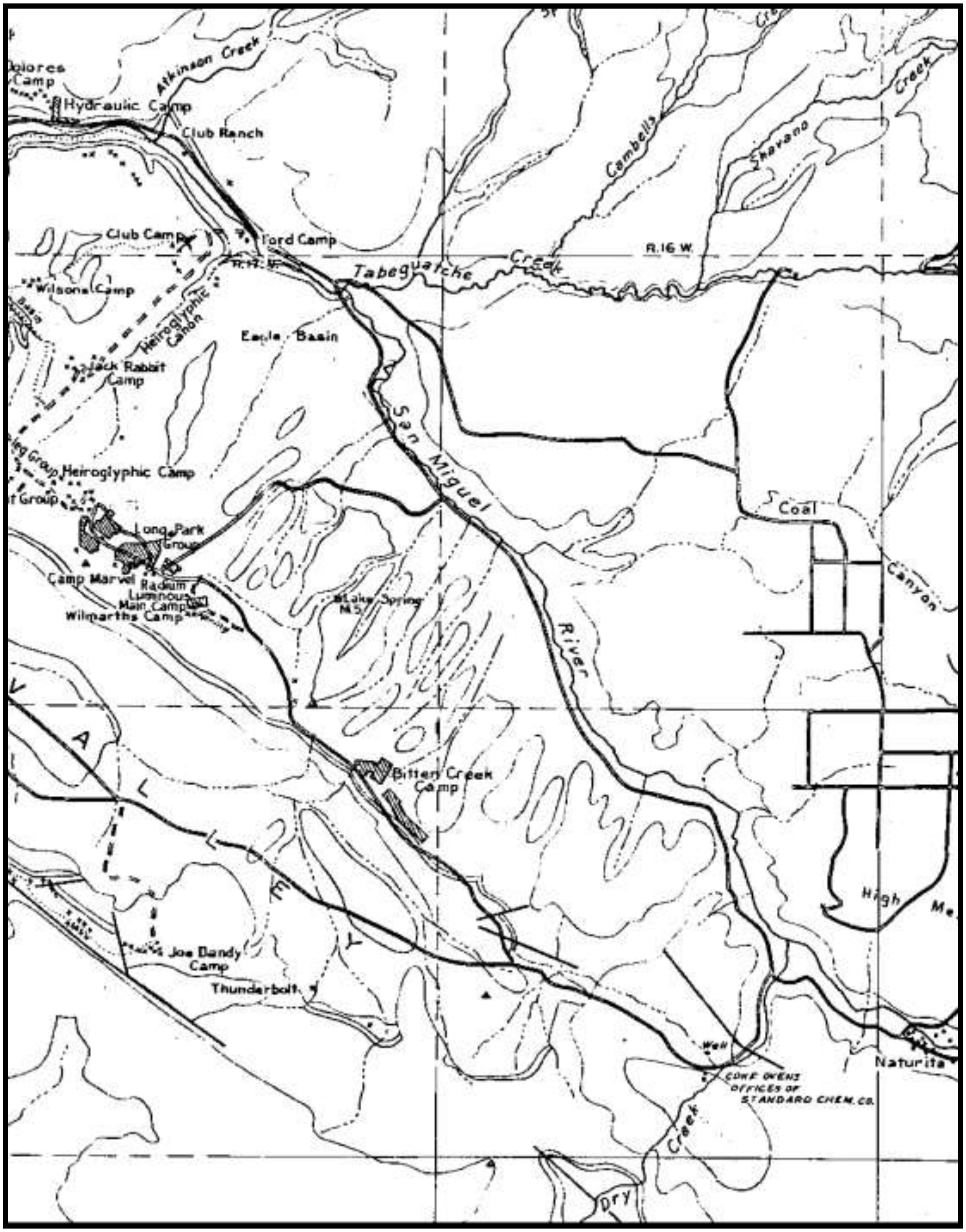

Figure E 4.3, continued. Some features have been overlapped from the map above for visual reference.

Around 1910, the carnotite region awoke from its dormancy in response to several factors. First, the medical applications of radium had been clearly proven, and its demand increased both in Europe and the United States. Second, a number of European firms developed refining processes that were more effective than ever. Third, through its Monogram Mesa operations, General Vanadium demonstrated that carnotite was rich with vanadium in addition to radium. Last, several prominent individuals promoted carnotite and attempted to revive its production in Colorado. In particular, Thomas F.V. Curran, manager for General Vanadium, reminded European firms that carnotite was an economical alternative for radium to the pitchblende ore mined in Germany. Thomas F. Walsh, who realized a fortune from the Camp Bird Mine near Telluride, funded a program to encourage the awareness and discovery of radium ores in Colorado.[44]

The revival began on a small scale on the mesas flanking Paradox Valley. On the cliffs of Monogram Mesa, on the valley's south side, General Vanadium invested in its Jo Dandy Mine and prepared for increased production. The company erected a camp that featured bunkhouses for an increased workforce and lab to test the richness of carnotite samples. In Long Park, on the valley's north side, Crusca acquired three claims rich with ore and developed them as the Maggie C, Henry Clay, and Swindler (later known as the Vanadate).[45]

But the death of a young woman in Pennsylvania was the event that gave the greatest momentum to the revival. The woman was sister to Joseph M. Flannery, who was connected to the American Vanadium Company, and she died of cancer with little hope of survival because therapeutic radium was scarce in the United States. Devastated by the loss, Flannery vowed to make radium available for others and educated himself on the issues of radium production and refining. Flannery realized that carnotite was the only domestic source and would not only provide the curative material, but also vanadium for his company. He also understood that the lack of adequate concentration and refining facilities were at the root of the supply problem, and if a facility could be built, radium would be available.[46]

In 1910, Flannery devised an aggressive plan to develop effective concentration and refining methods, and build a small radium empire. He started by organizing the Standard Chemical Company for funding, moved on to an experimental radium refinery at Canonsburg, Pennsylvania, and when this proved successful, Flannery built a full-scale version. At the same time, Flannery dispatched expert engineers to Colorado to arrange for production and an ore concentration facility. To provide ore, they secured several mines in Long Park and the Thunderbolt Group adjacent to General Vanadium's Jo Dandy Mine. To support mining and house a workforce of 40 at the Thunderbolt, the engineers erected Camp Hequembourg, which they equipped with an office, a lab, bunkhouses, and one of only several telephones in western Montrose County. The engineers also constructed a pilot concentration mill at Coke Ovens in the east end of Paradox Valley. According to the plan, ore from the Thunderbolt Group was packed to the concentration mill, which was supposed to separate out waste, and the concentrates could then be sent by railroad to the refinery at Canonsburg, which should have produced the

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[44] Curran, 1913, p1165; "Special Correspondence" *EMJ* 9/4/09 p477.
[45] Coffin, 1921:152; Curran, 12/30/11.
[46] Hamrick, et al, 2002:16.

final radium. Flannery and associates spent most of 1911 testing this strategy to see if it was both technologically feasible and economical.[47]

Even though Standard Chemical was not yet formally in production, Flannery's major interest and investment inspired confidence in the carnotite region. Prospectors returned and made a number of discoveries on the San Miguel Bench near Hydraulic, in Long Park, on Monogram Mesa, and in Bull Canyon. Many of these were developed on a small scale by partnerships. At Slick Rock, the American Rare Metals Company purchased the idle Dolores Refining Mill and refitted it to recover uranium in addition to vanadium. O. Barlow Wilmarth and other investors organized the Colorado Carnotite Company primarily as an ore brokerage firm. The company mined a few of its own claims but purchased most of its ore from independent outfits at Slick Rock and in Long Park. One of the most promising operations was the Radium Company of America, which imitated Flannery's mining and refining strategy. Like Flannery, the Radium Company erected a test refinery in Pennsylvania, and when the facility was successful, began building another on a commercial scale. But because Standard Chemical and the Radium Company were not yet ready to accept custom business, the various mining outfits in the carnotite region had to ship their total of 1,515 tons of ore to Europe for treatment.[48]

The journey from western Montrose County to Europe had three segments that consumed nearly all the profits and limited the mining outfits to the highest grades of ore. The ore had to be hauled by wagon to the railroad at Placerville, which cost between $20 and $30 per ton. An ore broker then received the payrock and loaded it onto rail cars for the trip to the New York City waterfront for a fee of around $12 per ton. A shipping company completed the final leg of the journey to Europe or England for an additional $15. After subtracting milling and other fees, and the costs of operating in deep western Montrose County, the mining outfits had little money left over. In general, the industry found that carnotite with less than two percent uranium content was uneconomical to produce. Given this, it is obvious why the mining outfits eagerly waited for Standard Chemical and the Radium Company to finish their refineries and reduce the shipping expenses.[49]

Standard Chemical and the Radium Company had as much interest in completing their refineries as did the mining outfits. Progress on the refineries was slow, however, because little technological precedent existed for recovering radium, and carnotite was unlike any ore that the mining industry had experience with. In 1912, Standard Chemical and the Radium Company finally developed effective and economical methods not only for recovering radium, but also for concentrating carnotite ore in the field. The next step for these companies was to apply their theoretical practices on a commercial level, which would cause further delays. Meanwhile, the mining outfits in Montrose and San Miguel counties continued to send their ore to Europe while the overall industry stagnated, and radium remained scarce and costly in the United States.[50]

These trends and the European control over what could have been an American radium industry deeply concerned private and government interests. In 1912, the U.S. Bureau of Mines

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[47] Bruyn, 1955:44; Coffin, 1921:152; Curran, 12/30/11; Hamrick, et al, 2002:16; *Mineral Resources*, 1910:760.

[48] Alvord, 1956:5; Coffin, 1921:194; *Daily Journal* 3/31/11; Hamrick, et al, 2002:5; Metal Mining, 1961:79; "Mining News" *EMJ* 3/30/12 p667; "Mining News" *EMJ* 9/28/12 p614; Moore and Kithil, 1914:19; *Telluride Journal* 12/14/11.

[49] Moore and Kithil, 1914:34.

[50] *Mineral Resources*, 1912:1008.

launched a study to survey the state of the domestic uranium mining industry, quantify known uranium deposits, and track the flow of uranium ore to Europe. In the private sector, Thomas F.V. Curran continued his promotional efforts and rallied Colorado carnotite producers together. In early 1913, they established the Colorado Carnotite Association to organize and fund support for their industry. The press was active, as well, and published trends, facts, and findings as they developed.[51]

Based on the studies, the Bureau came to several important conclusions, some of which were obvious while others reinforced the gravity of the nation's radium situation. Among the obvious findings, the Bureau confirmed that, except for the Dolores Refining Mill, and the Standard Chemical and Radium Company experimental facilities, the United States lacked treatment facilities capable of concentrating carnotite ore and refining radium from the products. The Bureau also found that nearly all the uranium ore went to European firms, which then sold radium back to the United States at extremely high costs. The economics astounded some of the experts. Radium fetched $70 per milligram, which was $70,000 per gram or $2 million per ounce! The Bureau found that European firms purchased carnotite almost exclusively for its radium content and considered the vanadium as an afterthought to be recovered if convenient. Given this, American companies lost a significant share of the ore's true value.[52]

Both the Bureau and the mining industry press then reported additional findings that drew Colorado and the radium industry into a spotlight. In particular, European radium experts acknowledged that carnotite was superior to German pitchblende. Yet, Germany produced most of the uranium ore up to 1911, but only because Montrose County's carnotite deposits had not been sufficiently developed. Further, the Bureau estimated that the Colorado Plateau possessed far more uranium than any other region in the world, and Montrose County was already the leading supplier in the nation. It took little effort for American radium industrialists and investors to pull the above facts together and come to their own conclusions. If the United States had its own effective radium refining and marketing capabilities, then the domestic industry could surpass that of Europe.[53]

The slow pace of the American radium industry reinforced concerns among legislators regarding European control. The lack of serious response to the Bureau's findings roused the ire of the Department of the Interior, which controlled nearly all the carnotite-bearing land. In 1913, the secretary issued a formal statement to the House Mines Committee suggesting that the Federal Government should withdraw carnotite lands from the public domain and preserve them for those companies with a serious intent to mine. This goaded the radium companies to issue a howl of protests in which they accused the government of a communistic nationalization of mining. Yet, the procontrol elements continued their campaign and reached an apex with Senate Bill 4405. The bill stipulated that the Federal Government would assume all radium ore deposits, withdraw all radium-bearing lands from the public domain, be the sole buyer of ore, and act as the only distributor of refined radium.[54]

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51 Kithil and Davis, 1917:7; *Mineral Resources*, 1914:943; Parsons, et al, 1916:7; *Telluride Journal* 3/13/13.

52 Coffin, 1921:151; Moore and Kithil, 1914:62; "The Uranium and Vanadium Situation" *EMJ*; "Uranium and Vanadium in 1912" *EMJ*.

53 "Carnotite as a Source of Radium" *EMJ*; *Mineral Resources*, 1913:364; Parsons, et al, 1916:7.

54 *Daily Journal* 8/20/14; "Government to Hunt Radium" *EMJ*; "Government Radium Plans" *EMJ*.

When the bill came up for a vote in early 1914, it was naturally defeated because the measures were perceived as too radical. The bill's backers never expected it to pass and instead merely used the bill as tool to frighten the radium industry into more action than it had taken up to that time. The bill served its purpose, and the carnotite mining industry began to boom in 1914. Curiously, the bill was the Federal Government's first attempt at influencing and even controlling radioactive metals mining and was a portent of legislation to come.[55]

The government did not expect the private sector to bear the entire responsibility of solving the technological problems that confounded the industry. Instead, the Bureau of Mines established the National Radium Institute to identify the best practices for uranium and vanadium ore mining and milling and to assist American companies in their application. In 1914, the Institute began a multiyear study that focused on carnotite production and treatment. In terms of treatment, the Institute designed two experimental facilities to reduce carnotite and then separate out the radium content. Because Colorado was the domestic center of radium mining, the Institute naturally sited the facilities in the state. One of the facilities was a small concentration mill built in Long Park to be near the mines and the other was a refinery near the main office in Denver. The Institute also leased the Vanadate, Maggie C, and Henry Clay mines from Crusca, and when the Institute worked them, it used the opportunity to study mining methods.[56]

The private sector and the government consumed an entire year mobilizing, but by 1914, they laid a foundation for a carnotite boom. Standard Chemical and the Radium Company were on the forefront of the boom in large part because they finally finished their refining facilities. Standard Chemical had the potential to greatly lower production costs because it was a local operation. During 1911, Flannery acquired a large tract of the Club Ranch on the San Miguel River and built another experimental mill, a laboratory, a boardinghouse, and a small tent colony for workers, and he named the complex Joe Jr. Camp after his son. When the second mill confirmed an effective process, Flannery moved quickly to build a full-scale facility at the camp. By the middle of 1914, the Standard Chemical Mill began treating local carnotite while manager J.J. Mullen encouraged mining outfits to send overflow ore directly to the refinery in Pennsylvania.[57]

Three more companies in addition to Standard Chemical solicited carnotite ore for treatment in 1914. One was American Rare Metals, which continued to operate its Dolores Refining Mill on ore produced around Slick Rock. The Radium Company was the second, and it solicited ore for its new Pennsylvania refinery. The last was Schlesinger Radium Company, a Colorado startup organized in 1914 by university chemists William A. Schlesinger and Henry T. Koenig. As the company name implies, Schlesinger was the outfit's driving force and began in the industry with a radium lab at Princeton University. With funding supplied by Victor C. Thorne of New York City, Schlesinger built an effective refinery in Denver and then advertised among the Montrose and San Miguel county carnotite producers for their ore.[58]

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[55] "Colorado's Radium" *EMJ*.

[56] "Bureau of Mines Radium Production" *EMJ*; Hamrick, et al, 2002:16; Kithil and Davis, 1917:61; Parsons, et al, 1916:10.

[57] *Daily Journal* 3/21/14; *Daily Journal* 7/17/14; Hamrick, et al, 2002:17; "Mining News" *EMJ* 11/21/14 p935.

[58] Bruyn, 1955:66; *Mineral Resources*, 1915:832; "Mining News" *EMJ* 1/24/14 p252; Moore and Kithil, 1914:29, 74.

Over the course of a year, the carnotite mining industry finally saw the number of commercial ore treatment facilities quadruple. American Rare Metals and Standard Chemical operated two local concentration mills, Schlesinger built its refinery in Denver, and Standard Chemical and the Radium Company ran refineries in Pennsylvania. However, for the independent mining outfits, the impact was not as grand as expected. The reason was that all the above companies also had their own mines and treated the ore in-house. When Standard Chemical was building its experimental mills, Flannery purchased around 300 claims, and by 1913, the company amassed around 1,100 acres in Montrose County. Similarly, the Radium Company aggressively acquired mines to supply enough ore to keep its refinery busy. American Rare Metals owned several mines on Disappointment Creek, and Thorne bought the Rajah Mine on Roc Creek for the Schlesinger refinery.[59]

Naturally, the above companies treated their own ores first and accepted custom ores from the independent outfits secondarily. The independent outfits realized that the milling capacity available to them was limited, and while the outfits were free to send their ore to the mills, some faced long delays in payment. The net result was twofold. First, the shortage of milling capacity suppressed the growing carnotite boom, and second, those mining outfits in need of regular income continued to ship their high-grade ore to Europe.

Another problem was that the refining companies designed their facilities to recover the radium content of carnotite because radium fetched the highest price and enjoyed the greatest demand. The refineries recovered none of the vanadium, which perpetuated the economic loss of shipping the ore to the European firms. Of this trend, mining statisticians noted:

> "Although carnotite contains three times as much uranium oxide as vanadium oxide, the Colorado and Utah carnotite ores generally contain other vanadium minerals in quantity so large that the vanadium oxide content of the ores is larger than that of uranium oxide. Little is paid for the vanadium, however, as its separation from uranium is troublesome, and only a few thousand dollars was received in 1914 by brokers or producers for the vanadium in the ores sold."[60]

Overall, the Federal Government's machinations, the Bureau of Mines' efforts, and the advances made by the private sector brought the slow and steady growth into a small boom. Ore production almost doubled from 2,270 tons in 1913 to 4,300 tons during 1914, and nearly all of this came from the Paradox Valley area.[61] The increase in both production and interest in radium and vanadium prompted records-keepers to state:

> "The year 1914 was an eventful one in the industry of mining ores of radium, uranium, and vanadium, and showed by far the largest annual output yet made, amounting to 4,294 short tons of dry ore carrying 87.2 tons of uranium oxide, and 22.3 grams of metallic radium."[62]

In less than one year after overcoming their most important problems, the intertwined American radium and vanadium industries stalled in the face of a severe blow. By 1914, the

[59] Bruyn, 1955:51, 66; *Daily Journal* 9/27/13; *Mineral Resources*, 1915:832; "Radium from American Carnotite" *EMJ*.
[60] *Mineral Resources*, 1914:943.
[61] *EMJ* 10/24/14; *Mineral Resources*, 1913:363; *Mineral Resources*, 1914:943; "Mining in Utah in 1914" *EMJ*.
[62] *Mineral Resources*, 1914:943.

vanadium industry, based on both Newmire roscoelite and carnotite, was second in world importance only to American Vanadium's Peru operations. Similarly, the radium industry was second in importance to that of Europe and held the promise of surpassing Europe's production capacity. However, the American industries still relied to a great degree on Europe's radium and vanadium markets and on its ore treatment firms. When World War I erupted, the European radium and vanadium markets collapsed, the economy soured, ore treatment facilities converted to wartime needs, and shipping was interrupted. Now unable to rely on Europe, the American radium and vanadium industries were threatened with implosion.[63]

The short-term response among both industries was turn to the domestic demand, which was very limited. Within a short time, the national radium and vanadium markets approached saturation, and in response, the industries scaled back operations. In 1915, San Miguel County saw few if any new vanadium ventures, and production contracted to the large and entrenched firms such as the Primos Chemical Company, the General Vanadium Company, and Crusca.

The carnotite operations split and went in two different directions. Most of the large firms either reduced operations or suspended altogether, exemplified by Standard Chemical, which shut down its new mill. However, some companies continued the momentum of 1914 and carried their major projects to completion, despite the poor radium market. Sabin A. Von Sochochy, of German origin, patented a glow-in-the-dark paint that utilized the luminous properties of radium, and sold it for use on watches, instrument dials, and surveying equipment. In 1914, he organized the Radium Luminous Company in New Jersey, built a refining mill, and purchased several mines in Long Park. By 1915, the Radium Luminous Company had these mines in production, established Radium Luminous Camp in Long Park as an administrative center, and bought more claims. Dr. H.N. McCoy of the University of Chicago, and Galloway & Belisle, organized the Carnotite Reduction Company and built a radium facility in Chicago. In 1915, the firm purchased carnotite that had been stockpiled at Placerville and acquired claims. In the same timeframe, investors organized the Radium Company of Colorado and built Denver's second radium refinery. With seven radium mills in place, numerous mines at the ready, and undeveloped ore deposits, the carnotite operations were poised for the radium revival that was inevitable. While a revival was, in fact, inevitable, it was by no means immediate.[64]

Because vanadium was a key ingredient for the hardened steel alloys used in weapons and armor, the vanadium industry was able to maintain a low level of production. Primos employed a workforce of around 100 at its mines and mill, and General Vanadium operated roscoelite mines at the town of Vanadium and several carnotite mines in the Paradox Valley. The radium industry, however, declined through 1916. In hopes of bolstering the industry, the National Radium Institute hastened its studies and planned to release the results in aid of private industry. Thomas F.V. Curran continued his tireless promotion efforts and established the Radium Ore Association in 1916. The organization, similar to his earlier Colorado Carnotite Association, promoted carnotite, marketed the ore, and attempted to maintain high prices.[65]

[63] Coffin, 1921:151; "Mining News" *EMJ* 8/22/14 p369; "Metal Mining in Colorado in 1914" *EMJ*; "Unusual Ores and Metals in 1917" *EMJ*.
[64] Amundson, 2002:2; Aurand, 1920; Chenoweth, 1993:12; Grant, 1920; *Mineral Resources*, 1915:832; "Mining News" *EMJ* 4/30/21 p759.
[65] "Mining News" *EMJ* 2/12/16 p333.

Figure E 4.4: Several Radium Luminous Company cabins still stand at the Long Park headquarters site today. The cabin illustrated may have been an office. Source: Author.

World War I, which brought the radium industry to the brink of ruin and suppressed the vanadium industry, finally reversed the ill fortunes of western Montrose and San Miguel counties. When Europe went to war in 1914, the various powers assumed that the conflict would last no more than a year. Instead, the war dragged on and slowly drained Europe's manpower and resources. By 1917, Europe's radium stores were gone and the arms manufacturers had exhausted their alloy materials. The Allies naturally turned to the United States for alloy vanadium, which was of the utmost importance, and also sought radium for those individuals still able to afford medical care. At the same time, the Federal Government mobilized to supply arms to the Allies and meet the needs of its own military.

Figure E 4.5: View west of the Standard Chemical Company mill and boardinghouse during the late 1910s. The mill was critical to uranium and vanadium mining in Montrose County because it offered local ore treatment. The mill was among the nation's largest uranium concentration facilities. Source: Denver Public Library, CHS.X5634.

The net result was that the demand for and value of radium and especially vanadium ascended quickly. In early 1916, carnotite fetched around $36 per unit, climbed to $50 per unit by the year's end, and more than doubled to $110 per unit in 1917. In general, a unit was a standard of measure that the mining industry reserved for alloy ores such as carnotite and tungsten. Whereas the precious metals mining industry measured its production in terms of ounces of metal per ton of ore, and copper and lead was measured in pounds, carnotite was measured by the unit. The industry defined one unit as twenty pounds of ore, which was one percent of a ton.[66]

The climate that the radium and vanadium industries awaited finally arrived, and it fostered a boom in western Montrose and San Miguel counties. The Primos Chemical Company continued to dominate vanadium mining around Placerville and the town of Vanadium. Primos took advantage of the industry slump in 1915 and 1916 and acquired the properties of those companies leaving the region. As Primos added to its empire, it assumed the role as the nation's principal domestic vanadium producer.[67]

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66 Amundson, 2002:4; "Unusual Ores and Metals in 1917" *EMJ*.
67 *Mineral Resources*, 1917:955.

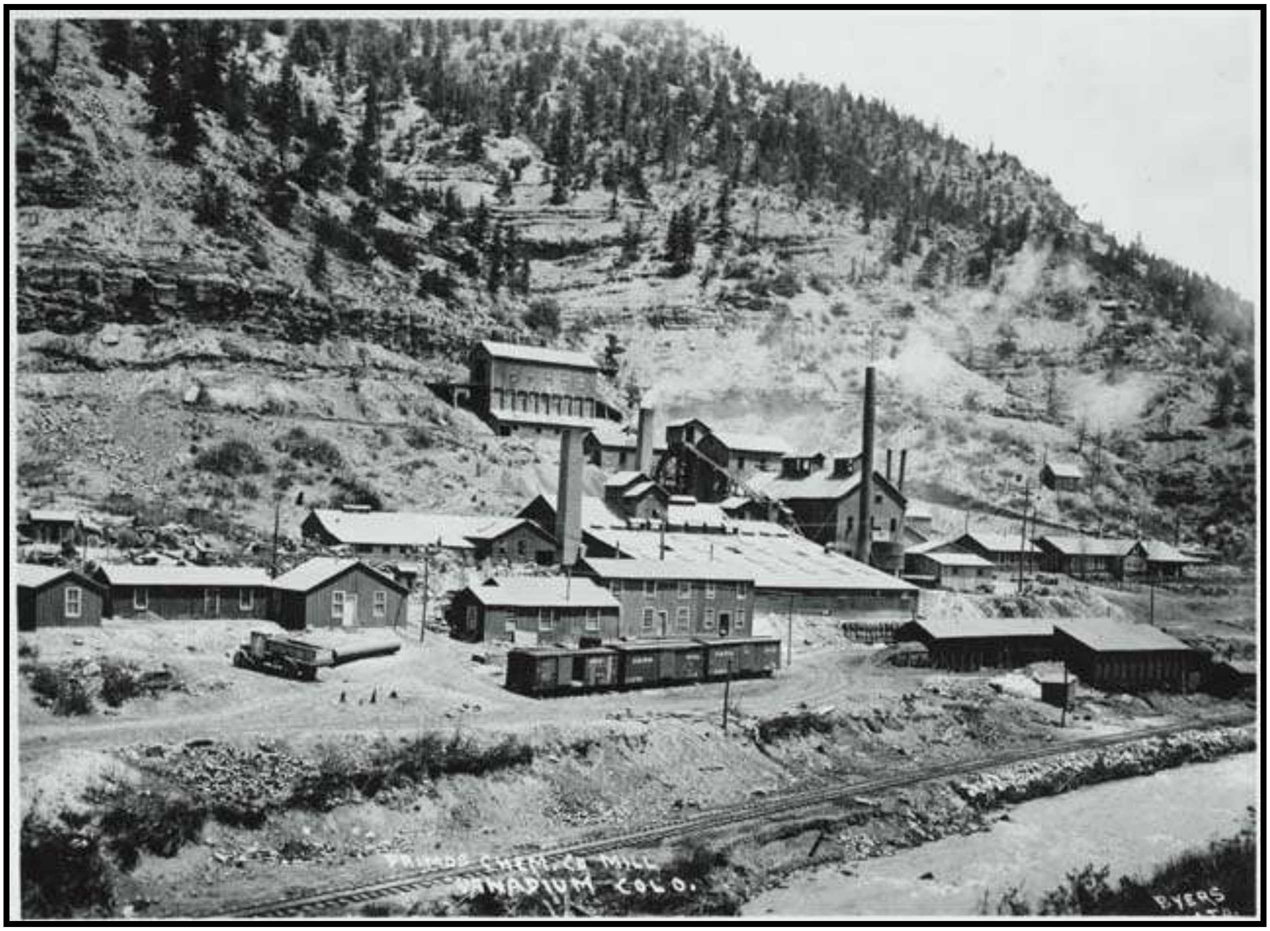

Figure E 4.6: During the latter half of the 1910s, the Primos Chemical Company operated North America's largest vanadium mill at the town of Vanadium. At the time, the vanadium mining industry experienced a boom due to a heavy wartime demand for vanadium. Source: Denver Public Library, CHS.X5701.

Because carnotite carried both vanadium and radium, the ore enjoyed a demand that was heavier than ever. This time, however, the roles of the metal constituents were reversed. In the past, companies produced carnotite for its radium and considered the vanadium as an afterthought. By 1917, the large companies refitted their mills to recover vanadium first and radium only as a byproduct. In so doing, the companies found carnotite to be highly profitable because the ore featured four times more vanadium than uranium.[68]

Repeating the pattern of the past carnotite excitements, the World War I boom provided opportunities for both large companies and independent parties. Prospectors were quick to sense the potential and congregated in the areas known for production. Some worked out of Standard Chemical's Joe Jr. and Ford camps, and others stayed in Julian Camp, on the San Miguel River

[68] Amundson, 2002:4; Boardman, 1956, et al.:17.

at the mouth of Tabegauche Creek. Further down the river, more prospectors occupied Hydraulic Camp, at the abandoned hydraulic placer workings. On the west side of Hieroglyphic Canyon, which was incised into Long Park Mesa, they established Jack Rabbit Camp, and more lived in Hart Camp in nearby Eagle Canyon. On Monogram Mesa to the south, prospectors contributed heavily to the formation of Monogram Mesa Camp and Wedding Bell Camp on the west side of Wedding Bell Mountain. They also worked out of Bed Rock and Slick Rock. From these bases of operation, both independent prospectors and professionals employed by the large companies found additional ore deposits.

Ultimately, the carnotite boom remained the domain of the large, heavily capitalized mining companies. Operating costs were high, freighting distances to the railroad at Placerville were lengthy, the ore had to be handled in economies of scale, and ore processing was beyond the means of the independent mining outfits. However, many independent outfits found a niche among the large companies. Specifically, they focused on the ore pockets that were too small to interest the large companies. In some cases, the large companies owned the claims and leased them to the independent outfits, or the outfits acquired the properties themselves. In both cases, the independent outfits began to thrive in 1917 and contributed a significant volume of ore on a collective basis.

The large companies, which already controlled extensive tracts of claims, focused on the richest ore bodies and developed them through groups of mines. Standard Chemical assumed the role as the region's leading producer because it had been acquiring claims since 1911 and ran the mill at Joe Jr. Camp. By 1917, Standard Chemical operated the Outlaw Group of mines on Outlaw Mesa, the Julian Group on Tabeguache Creek, the Wright Group, and the Shamrock Group on Club Mesa above the mill. The company also worked the Sunny Jim Group in Long Park and the Thunderbolt Group on Monogram Mesa. To improve the efficiency of such an extensive operation, Standard Chemical graded roads from the various camps to its mill and hauled ore in trucks. In so doing, Standard Chemical made the first major investment in the region's infrastructure.[69]

Long Park became a center of mining and prospecting, and it hosted a number of independent outfits as well as several large companies. Besides Standard Chemical, the Radium Luminous Company operated some of the richest mines including the Cripple Creek, Honeymoon, and Doctor. In some cases, investors who came late to the region's boom found that nearly all the important ground had already been claimed, although not necessarily in production. Their solution for joining the excitement was to purchase entire mining companies that possessed sound assets. In 1917, the Radium Company of Colorado employed this strategy and acquired the Schlesinger Radium Company and the claims owned by Crusca. In so doing, the Radium Company of Colorado assumed ownership over some of the best groups of mines, including those at Bitter Creek, Red Canyon, Hydraulic, Carpenter Flats, and Long Park.[70]

The mining industry employed a larger labor force than the region had ever seen, and all the miners needed places of residence close to their points of work. Settlements that the industry termed mining camps began to materialize on the mesas and in drainages near concentrations of

[69] Coffin, 1921:203.
[70] Bruyn, 1955:67; Colorado Mine Inspectors' Reports, Montrose County: Misc. C.

rim deposits. Some of the camps were started by prospectors and partnerships working pocket mines, and these settlements remained independent. Most of the camps, however, were company affairs. Given the intensity of the boom, even the company camps hosted at least a few unaffiliated prospectors and miners.

In general, the camps were loose collections of vernacular residences and had little organization, few if any businesses, and no infrastructure. The camps were not established as a uniform movement in 1917 and instead were products of localized claim development between 1900 and 1916. But nearly all were occupied by 1917. Long Park, the epicenter of the boom, featured the highest number of settlements that included Wilmarth's Camp established by the Colorado Carnotite Company, the Radium Luminous Company's camp, Standard Chemical's Sunny Jim Camp, the company establishment of Camp Marvel, and Long Park Camp. The San Miguel River also had a high density of settlements, including Standard Chemical's Joe Jr. and Ford camps around the mill, Club Camp at the mines on Club Mesa, and Julian Camp at the confluence of the San Miguel and Tabeguache Creek. Hydraulic Camp, established in 1900 at the confluence of the San Miguel and Dolores rivers, became a base of operations for the Radium Company of Colorado by 1917. Slick Rock was one of the principal settlements on the Dolores River in San Miguel County and was center to several satellite camps including Camp Snyder and Steven's Camp, which was largely a function of the Rare Metals Mill. Other company camps were scattered throughout the region.

As World War I dragged on into 1918, the demand for vanadium and radium increased. By now, the United States was fully committed to the Allies in terms of not only arms and other goods, but also direct military involvement. Vanadium continued to be a vital alloy material, and radium saw increased industrial use as a luminous paint. Uranium, which the mills piped out as waste, even came under demand as a secondary alloy metal. The war completely ruined Europe's ability to produce radium and refine vanadium ores, and the United States had more than enough milling capacity to offset this loss. The war reversed the dependency that the United States had on Europe for its ore treatment and markets, and Europe now relied on the United States for refined radium and vanadium. The United States was the world's center of radium and uranium production and was as important as Peru in terms of vanadium. Accordingly, a mining statistician observed: "One-half of the world's vanadium comes from Peru. Most of the other half comes from the roscoelite and carnotite fields of southwestern Colorado and southeastern Utah."[71] The above trends ensured that the boom in western Montrose and San Miguel counties would continue.

During 1918, the heavy demand for ore, additional discoveries of carnotite and roscoelite, and a general interest among investors fostered an expansion of the mining industry. The existing companies enjoyed sound profitability as they increased production levels, and they reinvested in additional ore-bearing claims. A number of new ventures arrived, as well. The Colorado Vanadium Company purchased undeveloped roscoelite claims on Bear and Leopard creeks, brought them into production, and treated the ore in a refitted mill at Saw Pit. The Chemical Products Company of Denver and the Radium Products Company began mining

[71] *Mineral Resources*, 1918:815.

carnotite in San Miguel County, where undeveloped ore bodies still existed. The Tungsten Products Company was one of the most important of the new arrivals, and it had extensive experience producing alloy materials. Specifically, the company was among the principal tungsten interests in Boulder County, which was the nation's center of tungsten mining. Tungsten Products purchased several mines on Calamity Mesa near Gateway and shipped the ore to its mill in Boulder. The Shattuck Chemical Company saw opportunity in the increased production among the independent outfits and built a radium refinery at its Denver complex.[72]

O. Barlow Wilmarth, who established the Colorado Carnotite Company in 1911, organized one of the most unusual businesses to come of the World War I boom. In 1918, he and fellow investors backed the Radium Ore Sampling Company, which built what was reported to be the world's only rare metals sampling facility. Located in Montrose, the company sampled and assayed all types of rare metal ores, stockpiled small batches of ore, and shipped them to appropriate treatment mills.[73]

Whereas World War I initially fostered the boom in Montrose and San Miguel counties, it also was the boom's undoing. When the Allies forced the Axis into an armistice on November 11, 1918, the United States and European nations suspended the manufacture of arms, which caused the demand for vanadium to collapse. In parallel, the consumption of radium as an industrial material declined, and the market for the metal then reverted to the medical industry, which few individuals could afford to patronize in the confused economic climate of the war. None of these trends, however, was permanent.[74]

Late 1918 and 1919 was a time of readjustment for the vanadium and radium industries. Standard Chemical was one of the first companies to respond to the changed economic and market conditions by suspending its mill. This caused a ripple effect in Montrose County because many independent outfits came to rely on Standard Chemical as a buyer for their ores. A few other substantial carnotite producers then lost confidence and left the business.[75]

The dark cloud for the vanadium and radium industries lasted only several months. Post-war reconstruction, equipping exhausted military forces, and an arms buildup in the United States revived a sound demand for vanadium. Similarly, the medical professions in both Europe and the United States were able to turn their attention back to civilian work, which boosted the need for radium. In response to the above, the Colorado Plateau maintained its role as the world's principal source of radium, and was still second in vanadium only to American Vanadium's Minaragra Mine in Peru.[76]

Despite the sound markets, the vanadium and radium industries still adjusted through 1919. Standard Chemical resumed its operations, but the Radium Ores Company shut down its Tramp Mine, which was one of the largest carnotite producers around Long Park. Independent outfits sent more ore than ever to the Shattuck Chemical Company in Denver and the Radium

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[72] Bruyn, 1955:98; Colorado Mine Inspectors' Reports, San Miguel County: Colorado Vanadium Corp.; *Mineral Resources*, 1919:727; "War Minerals of Colorado" *EMJ*.
[73] "Mining News" *EMJ* 9/14/18 p511; "Mining News" *EMJ* 8/2/19 p201.
[74] "Vanadium in 1918" *EMJ*.
[75] "Mining News" *EMJ* 1/25/19 p213.
[76] *Mineral Resources*, 1919:728; Moore, 1920 p214.

Ore Sampling Company in Montrose for treatment. The towns of Placerville and Vanadium saw the most activity as a result of a strong interest in vanadium. The Colorado Vanadium Company built a second concentration mill on Fall Creek, near its mines. The Primos Mill, the largest vanadium concentration facility in Colorado, was lost to fire, and the company was so confident in the vanadium market that it rebuilt the mill within the year.[77]

The Primos Chemical Company was premature in its optimism and investment in a new mill. Primos was not alone. Early in 1920, the Radium Ore Sampling Company enlarged its sampler to keep pace with the volume of ore submitted by the independent mining outfits. At the same time, the Pittsburgh Radium Company purchased the Overland Mills in Denver and began converting the complex into a radium refinery. But later in the year, a post World War I depression finally caught up with the nation's economy, and the demand for vanadium and radium gradually declined. Carnotite mining suffered, and the Carnotite Reduction and the W.L. Cummings Chemical companies, both large producers, suspended operations, and within a short time, a number of smaller companies followed.[78]

Not only did the vanadium mining industry have to confront a tightening market, but also new competition from within. In 1919, a group of powerful investors used the poor market and economic conditions to gain control over steel alloys in general, which included the vanadium industry. They started by organizing the Vanadium Corporation of America (VCA) as an umbrella organization and then targeted the American Vanadium Company and the Primos Chemical Company, which were the world's two largest vanadium producers, for acquisition. Primos was not only the most important vanadium company in the nation, but it also held the richest tungsten mines in Boulder County. The American Vanadium Company, as noted above, operated the Minaragra Mine in Peru and supplied around 60 percent of the world's vanadium.[79]

VCA was relatively quiet about its transactions and kept Primos as an intact subsidiary. VCA allowed Primos to continue operating in San Miguel County while it aggressively developed the Minaragra Mine for heavy production in economies of scale. Then, in 1920, VCA began shipping so much vanadium from Peru to the United States that VCA saturated the market and caused vanadium prices to plummet. The vanadium industry understood that VCA controlled Primos, but failed to make the connection with the Minaragra Mine. For this reason, the mining industry press noted of the Primos operation in San Miguel County:

> "The Vanadium Corporation of America has shut down its reduction plant and has laid off most of its miners. It is reported that the company cannot market its product from this district in competition with foreign vanadium products, which are richer than those mined in the United States, and it appears that steel men are giving the foreign product a preference."[80]

[77] Colorado Mine Inspectors' Reports, Montrose County: Radium Ores Co.; Colorado Mine Inspectors' Reports, San Miguel County: Colorado Vanadium Corp.; "Mining News" *EMJ* 5/3/19 p811; "Mining News" *EMJ* 6/14/19 p1063.
[78] "Mining News" *EMJ* 3/6/20 p621; "Mining News" *EMJ* 4/3/20 p819; "Mining News" *EMJ* 12/25/20 p1237; Moore, 1921 p151.
[79] Bruyn, 1955:97; Colorado Mine Inspectors' Reports, San Miguel County: Leopard Creek; *Mineral Resources*, 1919:727; Moore, 1921, p152.
[80] "Mining News" *EMJ* 11/27/20 p1059.

What the vanadium industry and the mining press missed was that VCA was the organization responsible for importing and selling the foreign vanadium to the steel men. Ultimately, VCA restarted the Primos mining and milling operation in 1921, but the other vanadium companies in the area were unable to compete and closed. As VCA continued to import vanadium from Peru at reduced costs, it saw no further need for the Primos operation. In 1922, VCA shut down the plant and with it, the last and greatest vanadium producer in the United States. The Placerville area was devastated. Hundreds of workers were suddenly jobless and left to find employment elsewhere. With a significant segment of the population gone, businesses closed and towns such as Leopard Creek, Saw Pit, and Vanadium disintegrated.[81]

VCA's takeover strategy not only affected the Placerville area, but also the carnotite mining region. During World War I, many of the large companies came to rely on the vanadium content of carnotite as much as the radium content. When vanadium became unprofitable, the companies were forced to subsist on radium, and only extremely rich ore possessed enough radium to support operations. High-grade ore was rare, and those companies that had none were forced to close, leaving a handful of the largest operations. During 1921, some of the solvent companies reorganized or merged in attempt to survive. The Radium Luminous Company was in economic trouble and drew in new investors, who reorganized the outfit as the United States Radium Company. The Tungsten Products Company merged with the Carnotite Reduction Company to form the Carnotite Products Company. When this proved insufficient, the firm merged again with the Radium Company of Colorado. Only Standard Chemical remained intact, and this company initially responded to the collapse of vanadium prices by suspending its mill and laying off most of its employees.[82]

Out of at least one dozen major companies, only the Radium Company of Colorado, United States Radium, and Standard Chemical weathered 1921. Reliant on radium alone, these companies paused and calculated the best course of action to remain solvent, which exacerbated a growing economic crisis in the region. A U.S. Geological Survey regional expert noted: "The Standard Chemical Co., the largest operator, closed its mines late in October. The Radium Co. of Colorado closed its camp in Long Park early in the fall and carried on only minor operations at its Calamity Creek camp."[83]

Meanwhile, European geologists made a discovery in the Belgian Congo that shook the radium industry to its core. In 1921, they discovered the world's largest deposit of pitchblende, which was rich with urananite ore. The Belgian government kept the find a secret while it developed the formation and waited until its Shinkolobwe Mine was in production to release the news. In 1922, Belgium then flooded the radium market and greatly undercut the price from around $120,000 to $70,000 per gram. Unable to compete, the three American radium companies suspended all operations and brought to an end what was the world's most important radium industry. Standard Chemical and the Radium Company of Colorado were the only

81 Metal Mining, 1961:80; *Mineral Resources*, 1922:579; "Producers of Radium-Bearing Ores and Radium" *EMJ*.
82 Chenoweth, 1993:12; *Daily Journal* 9/10/21; *Mineral Resources*, 1921:225; "Mining News" *EMJ* 4/30/21 p759.
83 *Mineral Resources*, 1921:225.

survivors because they adapted to the new conditions. Ironically, they became the sole domestic distributors of Belgian radium products.[84]

Second Period of Significance, 1906-1922

In 1922, the second Period of Significance for uranium and vanadium mining in western Montrose and San Miguel counties came to an end. The Period began in 1906 when the Vanadium Alloys Company built the first successful vanadium concentration mill in North America, and possibly the world, at Newmire (renamed Vanadium). At the time, the steel industry understood that vanadium was an excellent ingredient for hardened alloys, but considered vanadium an exotic metal because no economical sources had yet been identified. Within a few years, several companies proved commercial deposits around Newmire and nearby Placerville and brought them into production. Between 1910 and 1922, the Placerville area rose to prominence as the world's second-most important center of vanadium mining and ore concentration, with the Minaragra Mine in Peru as the most significant. From the start, substantial companies dominated the vanadium mining industry because capital and large-scale operations were required to produce enough roscoelite ore and concentrate it into an economical commodity.

During the second Period of Significance, the vanadium mining industry around Placerville became directly involved in trends that were important on several levels. On a broad scale, the area was North America's proving ground for vanadium recovery and was the site of the first vanadium mills. Until 1922, the region was also North America's principal source of vanadium and hosted the largest producer, which was the Primos Chemical Company. The Placerville area was vital to the steel industry because it yielded vanadium in quantities that were large enough to make the metal an economical alloy material. With vanadium alloys, manufacturers then produced durable goods and weaponry that were superior to versions made in the past. This was particularly important during World War I and contributed to the victory of the Allies over the Axis.

On a local level, the vanadium mining industry served as the Placerville area's economic cornerstone, supported several small towns, and drew a larger population than at any other time. The population of Placerville soared from 100 in 1910 to 287 in 1920, and Saw Pit saw an increase from 220 to 262 inhabitants. The town of Leopard Creek was a direct product of mining, and its population increased from 130 in 1910 to 153 in 1920. The town of Newmire was so integrally tied to vanadium mining that it was designated Vanadium by the Postal Service. When the vanadium industry collapsed in the early 1920s, the region was devastated and never attained the same status.[85]

Carnotite mining, distributed throughout western Montrose and San Miguel counties, shared many trends with the vanadium industry. Carnotite rose in importance around 1910 as a source of radium, which was in high demand in Europe. Germany was the world's most

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[84] *Daily Journal* 11/27/22; *Mineral Resources*, 1921:225; *Mineral Resources*, 1922:576; *Mineral Resources*, 1923:244; "Radium Now $70,000 per Gram; Was $120,000" *EMJ*; "Radium Reported Discovered in Belgian Congo" *EMJ*.
[85] Schulz, 1977:1910-16; Schulz, 1977:1920-11.

important radium producer into 1914, and Montrose and San Miguel counties were second. Were it not for a lack of ore treatment technology in the United States, the region had the potential to become the world's most significant source. World War I finally granted the two counties this status because the war disrupted Europe's ability to refine radium, forcing Europe to turn to the United States. In 1915 and 1916, American companies refined carnotite into radium and recovered little vanadium because the existing mills were poorly equipped. In 1917, the demand for vanadium skyrocketed as the United States provided the Allies with arms and materials, and then directly entered the war. Those companies with mills responded by expanding their facilities to recover both the radium and vanadium content of carnotite. From 1917 until 1922, Montrose and San Miguel counties remained the world's most important source of radium and one of its most significant vanadium producers. In 1922, the counties lost their status in both arenas to imported radium and vanadium.

The carnotite mining industry directly contributed to trends that were important on national, statewide, and local levels. On a broad level, western Montrose and San Miguel counties were the cradle of carnotite mining and milling. Both private industry and the Federal Government developed efficient methods for finding and extracting the ore, and then concentrating it for shipment to refineries. This would play a fundamental role for the nuclear weapons programs of the 1940s and 1950s. Between 1910 and 1914, the two counties were the world's second-most important source of radium, with Germany the most significant. They surpassed Germany in 1914 and retained the title of most important until Belgium flooded the market with radium in 1922. In addition, the vanadium won from carnotite contributed to the trends noted above for the Placerville area.

The radium that came from the two counties was vital to advances in several fields of science. First was the medical industry, which used radium to treat cancer and other ailments. The second was nuclear physics, in which radium played a key role in the understanding of radiation and atomic theory. The last was mineralogy, and chemists and geologists used radium and carnotite to characterize the properties of radioactive minerals.

The carnotite produced in the two counties was important to the Ally victory in World War I. Luminous paint made from radium saw application on instrument dials, gunsights, and surveying and navigation equipment. The vanadium recovered from carnotite was used for the same purposes as the material produced in the Placerville area.

Carnotite mining belonged to a radium industry that involved greater Colorado. In particular, some of the carnotite produced in Montrose and San Miguel counties went to radium refineries in Boulder and Denver. Given this, the radium industry featured a statewide aspect, which drew the world's attention to Colorado.

On a local level, carnotite mining served as the economic cornerstone for western Montrose and San Miguel counties. The mining industry provided jobs in and derived income from regions that had few alternative forms of economy. The industry also drew a population to portions of the counties that would have otherwise remained unsettled. The population consisted of miners and others who lived in a number of camps scattered among centers of production and milling. The increase in population and economic activity also affected the established towns. The Postal Service opened post offices in Bedrock in 1911 and Sinbad during 1914. The number of residents in Naturita climbed from 119 in 1900 to 134 in 1910, and then swelled to 326 by

1920. The population of Paradox rose from 100 in 1900 to 235 in 1910 and jumped to 381 by 1920. The town of Disappointment Creek was a direct product of mining, and its population more than doubled from 122 in 1910 to 229 in 1920. United States Vanadium established the sister camps of Ford's and Joe Jr. in 1912, and they became permanent with a combined population of 119 mill workers and miners. When the vanadium and radium industries collapsed in the early 1920s, the region was devastated and did not attain a similar status until 30 years later.[86]

E 4.4: The Quiet Years, 1923-1934

The Colorado Plateau lay quiet through the 1920s, and yet the world, and especially the United States, still hungered for radium and vanadium. Belgium continued to dominate the radium market, and Standard Chemical and the Radium Company of Colorado remained the domestic distributors for the Belgian products. VCA's hold on the vanadium supply, however, began to slip as its Minaragra Mine in Peru neared exhaustion, which made room for American companies. Further, as the decade progressed, steel makers increasingly relied on alloys, which strengthened the demand for vanadium.[87]

These conditions set the stage for a resumption of domestic vanadium production, although the Minaragra Mine still presented stiff competition. In 1924, the United States Vanadium Corporation (USV) was the first company to respond and developed a new mine and mill at Rifle instead of the Colorado Plateau. Two years later, the Union Carbide & Carbon Corporation surveyed the torpid American vanadium industry and planned to assemble a small mining and milling empire from the best intact elements. In 1926, Union Carbide acquired USV as the first piece of its empire and maintained the company as an independent subsidiary. Union Carbide then identified Standard Chemical as the second component because Standard Chemical still possessed its idle mill and camp at Joe Jr., and its quiltwork of carnotite-bearing claims. In 1928, Union Carbide then empowered USV to buy not only Standard Chemical, but also dozens of claims owned by the defunct Vanadium Alloys Company. Through these acquisitions, Union Carbide built a modest empire that included vanadium mines and a mill at Rifle, an extensive assemblage of claims, camps, and the mill in western Montrose County, and a vanadium distributorship.[88]

Unfortunately for Union Carbide, the Great Depression descended on the nation in 1929, which confounded the final effort to challenge VCA for the vanadium market. As the nation's economy collapsed, manufacturing slowed and almost stopped, and steel makers cancelled their orders for vanadium. Union Carbide was, however, diversified and strong enough to wait for the economy to rebound. Little did the company directors know that they would wait for years.

Union Carbide was not the only company that rushed to fill the void in the vanadium supply. The Rare Metals Company attempted a similar but reduced strategy in Montrose

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[86] Bauer, et al., 1990:19, 132; Schulz, 1977:1900-9; Schulz, 1977:1910-16; Schulz, 1977:1920-11.
[87] *Mineral Resources*, 1922:576.
[88] Amundson, 2002:5; Hamrick, et al, 2002:6, 28; Metal Mining, 1961:85; *Mineral Resources*, 1929:112.

County. The company planned a mill at the confluence of Dry Creek and the San Miguel River, around one mile west of Naturita, but before construction could begin, the Depression halted the effort. In 1930, possibly based on a forecasted economic recovery, the company invested $350,000 in the new mill and finished it within the year, much to the delight of the destitute community. The company then leased nearly all the principal mines in Long Park from USV, including the Colorado, Coloradium, Henry Clay, Maggie C, Tripod, and Vanadate, and obtained rights to a few scattered properties such as the Rajah and Cliff Dweller. In addition, the company built a camp at the Tripod that featured a centralized shop, a compressor station, ore bins, and boardinghouses. To be self-sufficient, the company also purchased a coal mine for fuel and a salt refinery to provide chemicals to the mill. Such an investment was nothing less than impressive in the context of the Depression and imparted a sense of success to the region. Before the mines were brought into meaningful production, however, the entire operation collapsed. The company blamed its problems on the mill and at first claimed that the water supply was inadequate. After engineers resolved this, the company then faulted the boilers. When it was found that the boilers were functional, management finally admitted that the underlying problem was financial. In the poor economic climate of the Depression, the monetary issues were almost impossible to resolve, and this ensured that the company would generate no vanadium.[89]

While the Depression discouraged mining in the short-run, it created conditions that large, heavily capitalized companies used to their benefit. VCA was the most important of these companies. Its directors realized that they had to steer operations back to Montrose County because the Minaragra Mine was finished. Ironically, VCA helped to destroy carnotite mining during the early 1920s, but returned ten years later as its salvation. VCA adopted the Rare Metals template and assembled a local carnotite mining and milling operation. Around 1932, VCA purchased the idle Rare Metals Mill near Naturita, refitted it, and began building the town of Vancorum around the facility. To provide plenty of ore, VCA brought its capital to bear and purchased a vast assemblage of claims from the United States Radium Corporation and the Colorado Radium Company. VCA kept the mines and mill on standby and waited for the vanadium market to improve.[90]

The North Continent Mines Company was the other principal outfit in the region that used the Depression to advantage. During the early 1930s, the company purchased numerous claims around Slick Rock and a site near the Dolores River for a mill. In 1934, North Continent completed the mill, constructed a water infrastructure, and built a workers' camp. Miners then spent much of the year developing the claims but produced little ore as North Continent imitated VCA and waited for a better economic climate.[91]

E 4.5: Depression-Era Revival, 1935-1940

[89] Colorado Mine Inspectors' Reports, Montrose County: Rare Metals; Merritt, 1971:541; Metal Mining, 1961:87; *Mineral Resources*, 1929:112; 1930:134; 1931:185.
[90] Amundson, 2002:5.
[91] Colorado Mine Inspectors' Reports, Montrose County: North Continent.

In 1935, the economic climate finally recovered enough to stimulate carnotite mining on a limited scale. Due primarily to President Franklin Delano Roosevelt's raft of public works programs and secondarily to tepid manufacturing, a measurable demand for alloy metals including vanadium returned. Even uranium now enjoyed a small market. Howard Balsley of Moab organized a uranium ore brokerage company in 1935 and contracted with independent miners on Colorado Plateau for ore. He bought the ore, stored it in warehouses in Grand Junction, Montrose, Meeker, Naturita, Dove Creek, and Egnar, and shipped it to the Vitro Manufacturing Company in Pennsylvania for use in glass and ceramic pigments.[92]

VCA was unsatisfied with the low vanadium prices in 1935 and still waited for conditions to improve further. North Continent, however, began production and assumed the role of San Miguel County's principal operation. At this time, the Legin Group of mines, southwest of Slick Rock, was brought back into meaningful production, most likely by North Continent.[93]

USV, with its mines and mills at the ready, quickly became the most important entity in Montrose County. So confident was the company in the potential of both its own abilities and the vanadium market that, in 1935, it built a new mill at Joe Jr. Camp, rebuilt the camp as a complete town, and moved its operations from Rifle. The mill went up on the river's southwest side, houses were built across the river, and the company provided a theater, medical clinic, store, community hall, churches, a school, and guest houses. Trucks brought supplies daily for a unionized workforce of 250. The supplies, however, did not include alcohol because the town was dry according to company policy, forcing workers to import their own liquor. Searching for a name for the town, USV contracted the words uranium and vanadium into Uravan, which the Postal Service formalized in 1936.[94]

The state-of-the-art mill at Uravan separated vanadium, radium, and uranium. The ore was crushed, roasted with salt, and the high-grade was material leached in water to extract the vanadium. The low-grade ore was leached in sulfuric acid to remove additional vanadium, as well as uranium and radium. The vanadium was precipitated out as redcake, the radium was precipitated separately, and the concentrates were washed in a filter press, dried, and sent to the Shattuck Chemical Company in Denver for refining. Nearly all the uranium was discharged as tailings, but some was saved for glaze pigment and experiments with steel alloys. To provide the mill with the high volume of salt necessary for roasting, the company erected a brine evaporation plant in Paradox Valley and piped the solution to Uravan. Ore came from a variety of mines large and small within a 50 mile radius of the mill, and most were worked by the company while independent operations contributed a significant proportion. USV rehabilitated the centralized compressor station, shop, and boardinghouses at the Tripod Mine to support its operations in Long Park, which was the center of ore production.[95]

By 1937, after a 15 year hiatus, the Colorado Plateau resumed its role as the world's leading vanadium supplier. The region, however, could not reclaim the title as the most

[92] Amundson, 2002:5; *Minerals Yearbook*, 1935:557.
[93] Bell, 1952:8.
[94] Amundson, 2002:6; Bauer, et al., 1990:145; Hamrick, et al, 2002:29; *Minerals Yearbook*, 1937:664; Metal Mining, 1961:78.
[95] Colorado Mine Inspectors' Reports, Montrose County: various; Hamrick, et al, 2002:6, 29; Gupta and Krishnamurthy, 1992:264.

important uranium and radium source. The Shinkolobwe Mine in the Belgian Congo and a pitchblende deposit developed as the Eldorado Mine in Canada in 1933, were richer.[96]

By the late 1930s, carnotite production began to exceed the capacity of the region's only two mills. USV's Uravan mill was the largest and received ore from throughout western Montrose County. USV operated the greatest number, the richest, and the most productive mines, located primarily on Club and Long Park mesas. USV also brought additional mines into production on the San Miguel Bench, which lined the northeast side of the San Miguel River across from Uravan. USV was a driving force behind designating its unofficial territory the Uravan Mining District to govern claim activity. At the same time, North Continent operated the region's second mill and continued its operations around Slick Rock, which was now center to the Gypsum Valley, Slick Rock, and Dolores River mining districts. In addition to operating their own mines, these two companies accepted ore from a number of independent outfits.[97]

The problem with only two mills in the region was that peripheral mining outfits had to haul their ore a considerable distance. In some cases this distance was too great to justify mining. A group of investors realized that a mill at Gateway could capture the business in northern Montrose and Mesa counties, especially because Calamity Mesa in Mesa County featured a number of rich mines that languished. In 1939, they organized Gateway Alloys, Incorporated, and erected a concentration facility at Gateway. A year later, VCA responded to the need for ore treatment and finally started its mill at Vancorum, much to the relief of Naturita, which was the nearest commercial center. VCA then brought many of its idle mines into production to provide a continuous feed of ore.[98]

[96] *Minerals Yearbook*, 1939:629, 1941:635; Gabelman, 1974:73; Griffith, 1967:8.
[97] Alvord, 1956:5; Colorado Mine Inspectors' Reports, San Miguel County: North Continent; Henderson, et al., 1940.
[98] Merritt, 1971:541; Metal Mining, 1961:87; *Minerals Yearbook*, 1940:626, 634; "Vanadium for Victory" 1943; Wright and Everhart, 1960:333.

Figure E 4.7: The Gateway Alloys mill began recovering vanadium from carnotite ore in 1939. By accepting ore from independent companies, the mill directly supported mining in Montrose and Mesa counties. Source: Author.

Third Period of Significance, 1935-1940

In 1940, the third Period of Significance in western Montrose and San Miguel counties came to an end. The Period began in 1935 when the national economy and manufacturing recovered just enough to revive an interest in vanadium. The interest was minor at first and gained momentum as the decade progressed. In addition to domestic consumption, European nations also purchased some of the vanadium as they prepared for World War II. Increasing numbers of mines were reopened through the decade, primarily by the region's two principal operators, which were the North Continent Mines Company and USV. At first, North Continent and USV operated the region's only two ore treatment mills. In 1939, Gateway Alloys, Incorporated, built a third and smaller mill at Gateway to serve the northern mines, and a year later, VCA brought its idle mill at Vancorum into operation. The region was once again of world importance, due in part to a significant initial capital investment by a few large companies. The demand for vanadium and the milling capacity offered by the large entities provided a foundation for small, independent partnerships and mining companies, and even a minor amount of prospecting. Just as World War I ushered in the 1910s boom, a similar event would radically change mining on the Colorado Plateau during the 1940s. That event was the Second World War, and its beginning defines the end of the third Period of Significance.

During the third Period of Significance, western Montrose and San Miguel counties were center to a number of important trends. On a broad scale, the counties were once again on the forefront of vanadium recovery technology, as they were during the 1910s boom. USV, North Continent, VCA, and Gateway Alloys erected mills designed to recover vanadium from carnotite. Because most of the region's high-grade ore had long been exhausted, these mills treated medium- and low-grade ores. To do so, the mills were efficient, well-engineered, and based on calculation and advanced chemistry. This became a key foundation for the recovery of uranium, which contributed greatly to the success of the Manhattan Project and its nuclear weapons programs during World War II.

The counties resumed their status as the world's most important source of vanadium during the 1930s and the principal domestic producer of radium. The vanadium became a direct contribution to the steel industry, which manufactured hardware and equipment for the public works projects that helped bolster the nation's dismal economy. The medical industry used the radium to treat illnesses such as cancer, just as the industry did during the 1910s.

The last broad-scale trend was the rise of a few large mining companies and their control over the vanadium and radium industries. During the 1930s, USV, VCA, and North Continent acquired most of the productive mines and operated the only mills. During the 1910s, a greater number of companies constituted the vanadium and radium industries, and by the 1930s, this figure fell to the three mentioned above. The economic conditions of the Great Depression combined with the necessity of capital for successful operations shut out all but a handful of companies, which dominated the industry.

On a local level, carnotite mining, while relatively limited, revived the region's economy, which was important given the poor climate of the Great Depression. Prior to 1935, the region had few sources of income and no significant industries. Mining provided dearly needed jobs and a stream of financial support that made its way into the local communities. In association with this, the region's population rebounded after the early 1920s collapse. Naturita's population increased from 199 people in 1930 to 302 by 1940. Paradox followed a like pattern, and its population rose from 216 people in 1930 to 323 in 1940. The Nucla area's inhabitants doubled from around 400 to 935, and Norwood saw a major increase, as well. Placerville saw growth, and its population tripled from 104 people to 300. The Cedar area, which included Slick Rock, almost tripled from 129 to 312 people. While archival sources make little mention of mining around Placerville, the dramatic increase in residents indicates that some of the vanadium mines there were reopened. Uravan, established in 1936, was a direct product of the 1930s revival, and by 1940, the town and surrounding camps were home to an impressive figure of 862 people.[99]

E 4.6: World War II, 1941-1945

[99] Schulz, 1977:1930-16; Schulz, 1977:1940-14.

In 1941, the United States entered World War II, and this reshaped the industrial, political, and social fabric of the nation. The United States was completely unprepared and lagged behind Europe in both involvement and preparation. Germany, which stormed Europe by surprise, had already assembled a massive military machine and was on the cutting edge of weapons development. The genius behind Germany's military programs was nothing less than impressive, and experts based a variety of weapons programs on advanced science. One of the most important programs attempted to apply a decade of peaceful nuclear research toward building an atomic bomb. In the early 1930s, physicists developed the hypothesis that splitting atoms could produce intense energy. In 1934, Italian physicist Enrico Fermi postulated that neutrons moving at high speeds could cause the split, free additional subatomic particles, and cause a chain-reaction known as fission. Around the same time, Marie Currie's daughter Irene and husband Frederic Joliot calculated that uranium was the best material for fission. The Nazis were quite interested in the energy potential of fission for the production of both power and bombs, and they launched a secret program to bring fission into practicality. Albert Einstein, one of the world's leading nuclear physicists, was aware of these developments and grew deeply concerned that if the Nazis successfully devised an atomic bomb, they might be unstoppable. In 1939, he sent a letter to President Franklin Delano Roosevelt warning of the Nazi effort and suggested that the United States should consider pursuing a similar program.[100]

Because the United States had not yet entered the war at that time, Roosevelt postponed direct action for several years, although he may have discussed the idea with advisors. The Japanese attack on December 7, 1941, and the subsequent declaration of war against Germany changed Roosevelt's hesitation, although he was preoccupied for several months mobilizing American's military. In 1942, Roosevelt and advisors finally established a top-secret atomic weapons program and entered the United States in a direct race against Germany. His advisors placed the program in the hands of the Army Corps of Engineers, which then assigned it to the Manhattan Engineer District (MED) under the name of Manhattan Project. The MED then mapped out a strategy to gather top scientists, some of whom defected from Germany, and to locate all potential sources of radioactive minerals, to produce uranium, and refine it into material for experimentation and ultimately a bomb. Such a strategy naturally included the Colorado Plateau because it was one of the world's most important uranium sources, and the MED knew this.

[100] Amundson, 2002:7; Hamrick, et al, 2002:iv, 30.

Table E 4.4: Acronyms of Uranium Industry Agencies and Organizations

Acronym	Organization Name	Organization Function
AEC	Atomic Energy Commission	Lead federal agency created in 1946 that oversaw the production and refining of uranium ore.
EPA	Environmental Protection Agency	The agency, created in 1974, oversaw the cleanup of hazardous waste sites.
MED	Manhattan Engineering District	Federal agency that administered the Manhattan Project from 1942 to 1945.
MRC	Metals Reserve Company	Federal agency that promoted the production of strategic metals during World War II.
RFC	Reconstruction Finance Corporation	Federal agency that managed the production of strategic metals during World War II.
UMTRA	Uranium Mill Tailings Radiation Control Act	A 1978 Act of Congress that charged the EPA and Nuclear Regulatory Agency with cleanup of radioactive waste sites.
USGS	U.S. Geological Survey	Federal agency charged with understanding, finding, and quantifying ore bodies.
USV	United States Vanadium Corporation	Principal mining and milling company in Montrose County.
VCA	Vanadium Corporation of America	Principal mining and milling company in Montrose County.

In addition to uranium, the Colorado Plateau still offered vanadium, which became an alloy material absolutely necessary for military production. Vanadium was so important to the war effort that, in 1942, the War Production Board, a Federal agency, classified it as a strategic metal subject to control and regulation by a subsidiary agency, the Reconstruction Finance Corporation (RFC). A third agency under the RFC, the Metals Reserve Company (MRC), created several programs to regulate the vanadium industry and enhance production by private companies. Specifically, the MRC fixed the price of vanadium at a rate that was high enough to interest the private sector but low enough to prevent enervating profiteering. The MRC then charged the U.S. Geological Survey and the U.S. Bureau of Mines with developing programs to study known vanadium deposits and find new ones. Both agencies did not have to look far, for it was already understood that the Colorado Plateau was still the principal domestic source of vanadium, and they engaged in extensive exploration. Geologists combed the Plateau, studied existing ore deposits, and dispatched drill-rigs to sample likely areas. At the same time, the Plateau, especially the Uravan Mining District, saw unprecedented production of vanadium.[101]

What the MED kept secret was that exploration for uranium was embedded in the vanadium studies, since the two metals were sister constituents of carnotite. When the MED quietly surveyed the known uranium sources, it came to the conclusion that three key deposits existed in the world, including the Shinkolobwe Mine in the Belgian Congo, the Eldorado Mine in Canada, and the Colorado Plateau. While the Plateau's carnotite was not as rich as the pitchblende ore in the Congo and Canada, it was the only viable domestic source and therefore commanded attention. The MED planned to collect 86 percent of its forecasted need for uranium

[101] Amundson, 2002:8; Fischer and Hilpert, 1952:3; Hamrick, et al, 2002:31; *Minerals Yearbook*, 1943:661.

from the two foreign sources and the rest from the Colorado Plateau, provided additional richer deposits were not found.[102]

To obtain uranium from the Colorado Plateau, the MED was forced to divulge aspects of its secret program to the United States Vanadium Corporation (USV) and the Vanadium Corporation of America (VCA), the region's two top producers. USV was the first to respond and sent a proposal to the MED suggesting that USV act as the prime contractor in a joint venture with VCA. The latter company balked and refuted that it should be the prime contractor instead, and both companies were ultimately given separate contracts. Experts from the companies and the MED then considered the data from the studies of local uranium sources and came to the startling conclusion that, for a while, crude ore would not be needed. Instead, plenty of unrefined uranium concentrates already existed in the form of tailings at every vanadium mill in the region, and the material merely had to be collected and refined. The MED was satisfied because the tailings could be converted into uranium quickly, and USV and VCA were pleased because converting the tailings into uranium translated into substantial profits since most of the processing had already been done. To maximize both uranium production and income, USV and VCA wisely designed new ore treatment paths at their existing mills to recover uranium and vanadium from crude ore, as well.

With an administrative structure in place, in 1942 the MED dispatched a team of agents to the mills on the Colorado Plateau to secure their tailings under the auspices of an interest in vanadium. Once this had been done, the MED quietly released the first contract in the United States specifically for the production of uranium to VCA. To then meet its obligations, VCA refitted its Vancorum mill with two separate recovery processes for uranium and for vanadium. Almost at the same time, MED signed a second contract with USV to concentrate the uranium tailings that already lay around at the Uravan Mill and began trucking additional tailings from facilities at Vancorum, Loma, Gateway, Slick Rock, Durango, and Blanding, Utah. The tailings taxed USV's and VCA's mills to capacity, and in response, MED authorized each company to build one additional mill each. USV chose Durango because the town was proximal to several new mining districts, and USV then purchased and refitted the idle American Smelting & Refining smelter to process both crude ore and tailings. VCA sited a new mill at Monticello, Utah, to capture Utah's growing carnotite mining industry. Both companies obtained federal funds for these facilities.[103]

Milling capacity was only one concern in a larger strategy that the MED implemented to increase the production of both uranium and vanadium. Whereas the MED directly oversaw milling, the agency placed the MRC in charge of mining and the handling of crude ore. One of the first projects that the MRC undertook was a widespread improvement of the region's transportation infrastructure. As of 1942, western Montrose and San Miguel counties featured a network of barely passable roads that dated to the 1920s and 1930s, and they restricted the amount of ore flowing from the mines to the mills. The MRC obtained a lofty $500,000 from the Federal Bureau of Roads to widen and surface Highway 141 from Naturita to Gateway, Highway

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[102] Amundson, 2002:8; Hamrick, et al, 2002:32.

[103] Amundson, 2002:8; *Colorado Mining Year Book* 1944, p88; Merritt, 1971:41; "Vanadium Production in Colorado" 1942; "Vanadium Production in Colorado" 1942.

80 from Naturita to Dove Creek, and Highway 90 from Naturita through Paradox to Utah. The Department of Grazing then graded gravel roads from these highways up to the mines on the various mesas. The improved road network allowed mining companies to haul more ore in larger trucks to the mills than in previous years.[104]

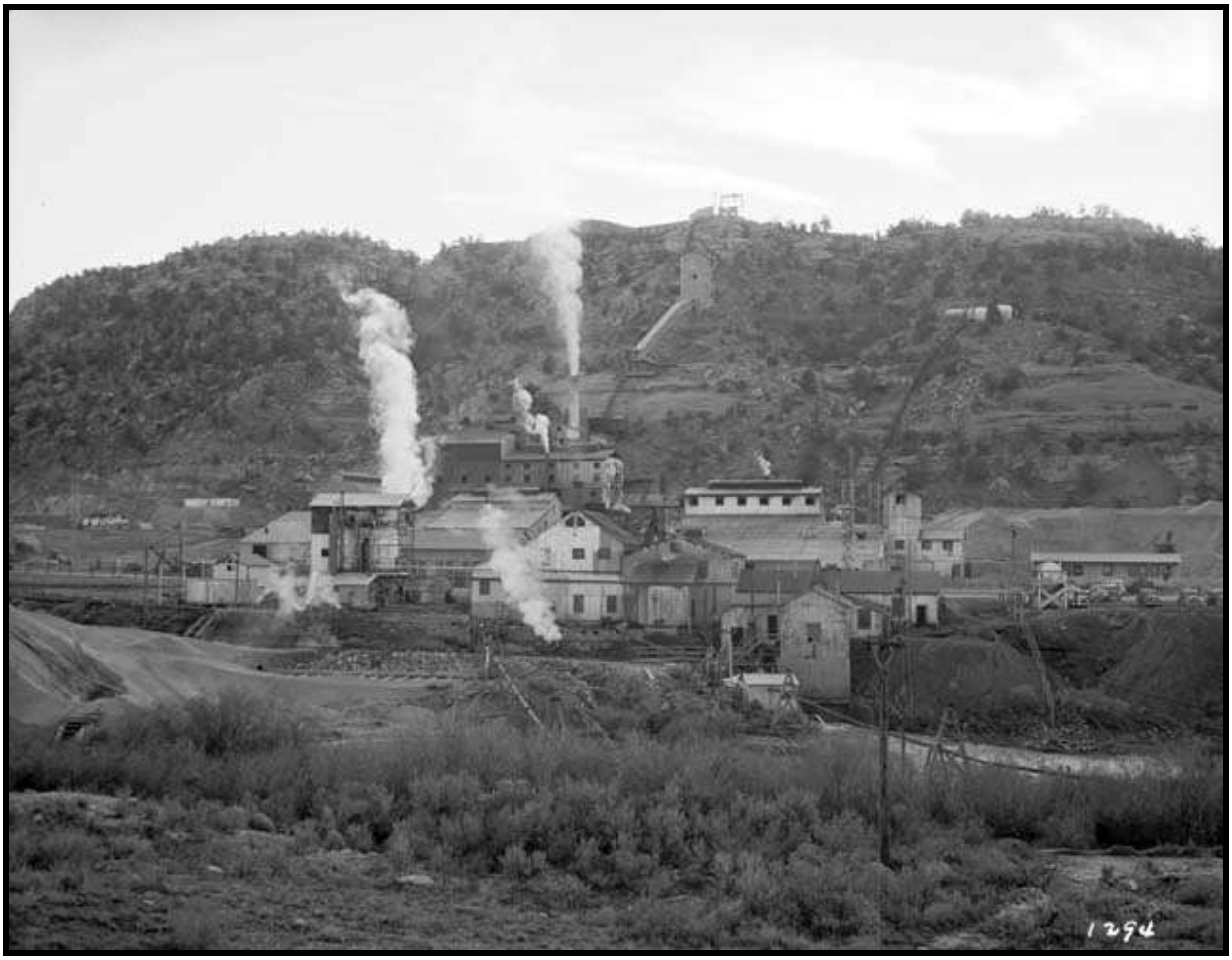

Figure E 4.8: The Uravan mill, operated by United States Vanadium Corporation, was a centerpiece of the Manhattan Project's uranium acquisitions during World War II. The facility treated tailings trucked in from other mills in western Colorado and Utah. The mill was among North America's largest and most advanced uranium facilities and had been subject to incremental expansions since the 1910s. Source: Denver Public Library, CHS.X5525.

[104] "Vanadium for Victory" 1943.

Figure E 4.9: This easterly overview shows how large and complex United States Vanadium's Uravan Mill was during World War II. The mill recovered vanadium from crude ore for armor and weapons, and, under secrecy, uranium for the Manhattan Project. Source: Denver Public Library, CHS.X6203.

The MRC acknowledged that VCA, USV, and North Continent were the region's principal ore producers. The MRC also understood that the small mining outfits were almost as important because they had the potential to produce significant tonnages of ore on a collective basis. Yet, these small outfits suffered from a lack of capital and had few of the resources that the large companies possessed. To empower the small outfits, the MRC provided direct support in the forms of financial assistance, equipment, and supplies. The MRC also established ore buying stations at Grand Junction, Dove Creek, and Durango in Colorado and at Thompson, Moab, and Monticello in Utah. Independent miners dropped off ore, which contractors then trucked to the mills. All this was done under the auspices of vanadium, while the ore's uranium content was in actuality more important.[105]

[105] "Vanadium for Victory" 1943.

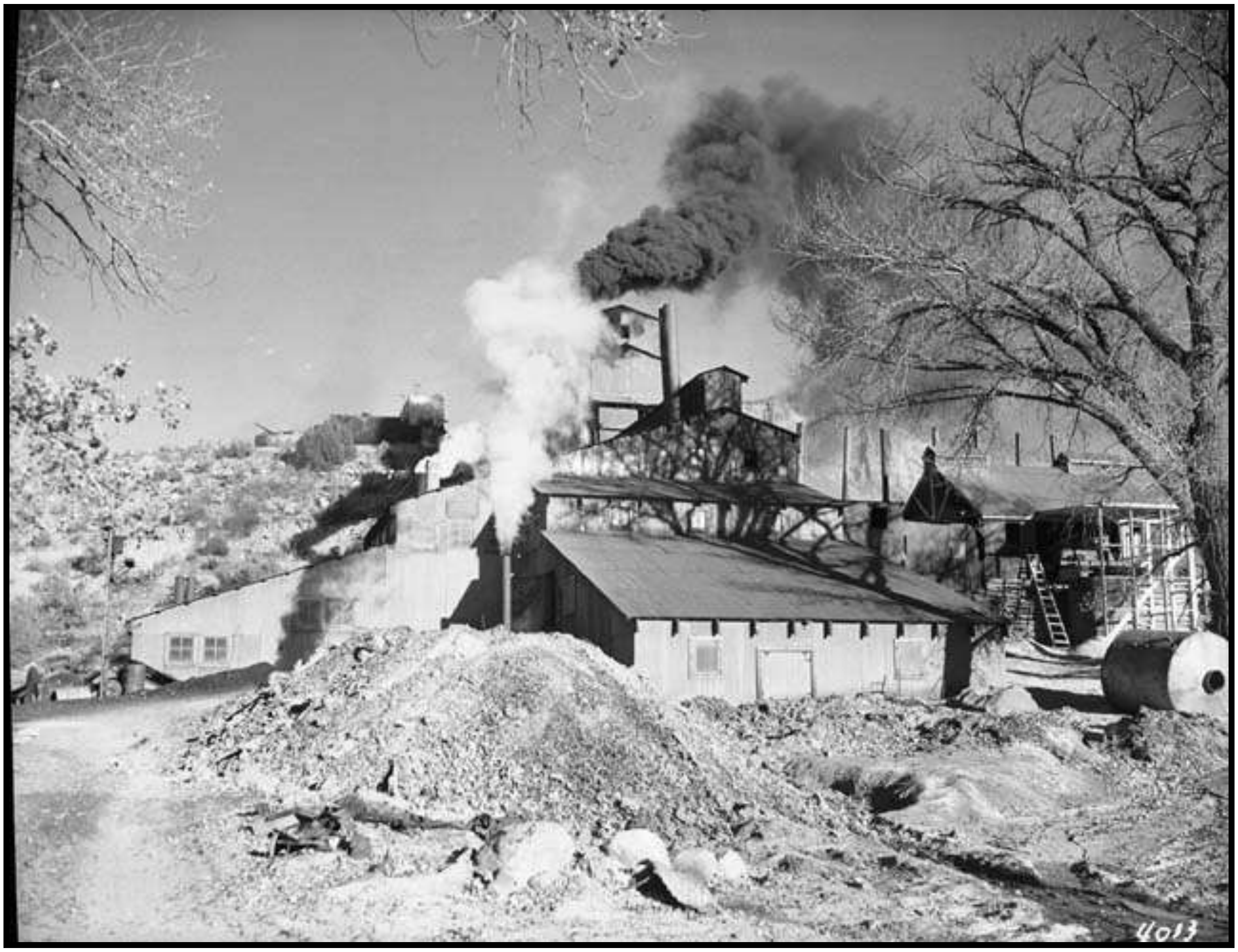

Figure E 4.10: During World War II, the Vanadium Corporation of America operated its mill at Vancorum. The mill was built in 1930 to recover vanadium from crude ore, and it stood idle until the Vanadium Corporation of America started it during the late 1930s. During the war, the facility not only produced vanadium as designed, but also recovered uranium from crude ore and tailings brought in from other mills. Like the Uravan mill, the uranium operations were secret. Source: Denver Public Library, CHS.X6201.

During 1943, the MED and the MRC completed additional projects that increased vanadium and uranium production. USV and VCA continued to separate out the uranium content of the tailings trucked in from elsewhere, and now North Continent did likewise with its own tailings at Slick Rock. The product generated by these mills was far from refined uranium and instead came in a form known as green sludge. To convert this into something usable, the MED contracted with USV again in 1943 to erect and operate an advanced concentration facility at Grand Junction. The end product was a radioactive uranium oxide powder known as yellowcake, which was compressed into pellets and shipped to the Manhattan Project's top secret laboratories.[106]

The MED forecasted that at some point, the tailings would be exhausted and uranium would have to be recovered from crude ore instead. The MRC's programs enhanced the production from the existing mines, but they possessed finite ore bodies. To ensure an adequate supply of ore in the future, the MED consulted with the U.S. Geological Survey (USGS) on a large-scale exploration program. The USGS then began extensive drilling in the areas already known to feature ore bodies, such as Long Park, Club Mesa, San Miguel Bench, and the Slick Rock area. The USGS coordinated with VCA and USV, which sampled their groups of claims by drilling. The program proved to be highly successful and cost-effective, and one ton of ore was developed for every foot of hole bored.[107]

Ore production and milling were not the only arenas that the MED sought to improve. The booming uranium and vanadium industries required a large workforce that lived primarily in the established towns and secondarily in a few camps near the mines. As the populations of the towns grew, the Federal Housing Authority erected 50 residences at Naturita and 68 at Uravan to address a growing housing shortage. In response to the population pressure, USV, VCA, and the MRC contributed to improvements such as water and sewer systems, which endeared the companies to the local residents.[108]

In the beginning, 1944 showed signs of surpassing the previous year in terms of production. The MRC's projects to enhance mining were both a burden and a blessing because they allowed the companies to deliver more ore than was otherwise possible. The increased tonnages taxed the region's mills, which translated into a need for even more milling capacity. The MED targeted Uravan as the site of the next expansion and erected a second mill above the original facility, and it was specifically designed to treat tailings. USV was then able to process greater amounts of crude ore in the original facility below. The MED issued additional contracts to several other companies such as North Continent to recover uranium concentrates from their tailings.[109]

After two years of scraping, trucking, and processing, the deposits of mill tailings on the Colorado Plateau showed signs of exhaustion. Even those at the Uravan Mill were almost depleted, and in response, USV and VCA began emphasizing crude ore as a uranium source. For USV, this meant increasing production from its most important mines, located primarily in Long Park, on Club Mesa, and on San Miguel Bench. VCA responded similarly at its major mines such as the Bitter Creek Group at the east end of Long Park Mesa and the Rajah (formerly Roc Creek) in the Roc Creek drainage.

In mid-1944, the Federal Government reversed the upward trend that it initially fostered in the vanadium and uranium mining industry. The MED informed USV and VCA that its

[106] Amundson, 2002:8; Hamrick, et al, 2002:33; Metal Mining, 1961:79.
[107] Hamrick, et al, 2002:31; USV, 1945; "Vanadium" 1944.
[108] Holland, 2007; "Vanadium for Victory" 1943.
[109] Amundson, 2002:8-11; Hamrick, et al, 2002:33; Metal Mining, 1961:89; Taylor and Yokell, 1979:23.

uranium goals had been met, and the MRC publicly announced that it had stockpiled enough vanadium for the war effort. Just as quickly as the government launched its uranium and vanadium production programs, it repealed them. The private sector still purchased vanadium, but more than enough was available due to overproduction of the metal. Uranium, by contrast, was suddenly without any market at all, which was exclusively a function of the MED. The result was an abrupt, painful halt to the World War II boom on the Colorado Plateau.[110]

Most of the small companies had to close their mines, and USV and VCA cut back their operations significantly. USV and VCA survived by continuing to treat tailings and keeping several of their mines in limited production. Companies such as Gateway Alloys, North Continent, and the Blanding Mines Company did not fair as well and shut down their mills. But the MRC paid these companies to keep their mills on standby because the agency still considered vanadium to be a strategic metal whose demand could return at any time. This suggested to the major companies that the Federal Government might soon reinstitute its demand for vanadium. In 1945, however, the War Production Board sent the industry a clear message that this was not to be. The Board repealed General Preference Order M-21, which strictly regulated the production, sales, and distribution of vanadium. The metal was now officially on free market, which was almost nonexistent. Western Montrose and San Miguel counties had grown used to Federal assistance, full employment, and a sound economy, and they now braced for hard times.[111]

Toward the end of 1945, the miners and mill workers who labored on the Colorado Plateau finally realized the product of their efforts. On August 6, 1945, the United States dropped the world's first atomic bomb, Little Boy, on Hiroshima, and on August 7, detonated the first plutonium bomb, Fat Man, over Nagasaki. Within one month, Japan surrendered and brought World War II to an end. Many of the Colorado Plateau workers felt a sense of awe and pride in their contributions to such a dramatic event. However, they also suffered under the capriciousness of the MED, which left them jobless.

Western Montrose and San Miguel counties passed into 1946 with little economic support. Nearly all the mines were silent, all the mills were idle, the ore buying stations were gone, and the MED dismantled its tailings processing facilities. Even if demand for uranium and vanadium existed, the ore bodies discovered in 1942 and 1943 had been exhausted, and no tailings remained for reprocessing. Nuclear arms development was, however, by no means over, and the Federal Government merely put its weapons programs on hold while it made adjustments for a postwar world.

Fourth Period of Significance, 1941-1945

In 1945, the fourth Period of Significance for the uranium and vanadium mining industries in western Montrose and San Miguel counties came to an end. The Period began in 1941 when the United States entered World War II and immediately designated vanadium a

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[110] Amundson, 2002:9, 11; *Minerals Yearbook*, 1944:642.
[111] Amundson, 2002:9; *Colorado Mining Year Book* 1944, p88; *Minerals Yearbook*, 1944:642; *Minerals Yearbook*, 1945; "Vanadium" 1944.

strategic metal for the war effort. From 1941 through 1945, the government aggressively pursued vanadium production because the metal was a key alloy for weapons and armor.

Early in 1942, the Federal Government established the revolutionary and top-secret Manhattan Project to race the Nazis for the atomic bomb. The government secured three sources of uranium for its program, including the Shinkolobwe Mine in the Belgian Congo, the Eldorado Mine in Canada, and the Colorado Plateau. While the Plateau satisfied only 15 percent of the project's uranium needs, the Plateau was extremely important because it was the third largest and the only domestic source of uranium. Under the Manhattan Project, the government assumed total control over the production, milling, refining, and use of uranium. This was done under the guise of an interest in vanadium, which was allied with uranium in the Plateau's carnotite ore. At first, the government derived most of its uranium from mill tailings that were byproducts of vanadium processing, and when these were exhausted, the government then turned to carnotite ore. Once the government had amassed enough uranium and vanadium by the middle of 1944, it suspended its purchase programs and effectively nullified the market for these metals. Without a market or government support, the mining industry in the counties collapsed and ushered in a region-wide depression.

Uranium and vanadium mining brought to western Montrose and San Miguel counties several trends that were important on worldwide, national, and local levels. On a national level, the counties were the most important domestic source of vanadium, which was a key alloy used in weapons and armor. By producing vanadium, the region's mines and mills contributed directly to the war effort. While the largest mines and the mills are strongly associated with this trend, the role of the small mines should not be discounted. They greatly outnumbered the large mines and contributed a significant amount of ore on a cumulative basis.

On both national and worldwide levels, western Montrose and San Miguel counties were directly involved in the Manhattan Project. These and small portions of surrounding counties generated 15 percent of the Manhattan Project's uranium. Most of the uranium came from mill tailings that were a byproduct of vanadium concentration. When the tailings had been exhausted, mining companies then recovered uranium directly from crude ore, which they produced from the region's mines. By producing uranium, the region's mines and mills contributed directly to the Manhattan Project, the development of the world's first nuclear bombs, and the only detonation of such weapons in history.

The uranium and vanadium mining industry played several fundamental roles on a local level. During World War II, the industry was the region's economic backbone and principal employer. Because the industry required a substantial workforce, it affected the region's population. In 1940, at the end of the Great Depression, Naturita had a population of 300 people. By 1950, the industry drew 183 more residents to the town. Nucla's population increased by around 150 people, and Uravan's population increased slightly, as well. When VCA reopened its Fall Creek Mine, the population of the Placerville area climbed beyond 300 people. This was short-lived, however, and when VCA closed the mine around 1943, nearly all the residents left.[112]

[112] Schulz, 1977:1940-14; Schulz, 1977:1950-13.

In support of the industry and its workers, the Federal Government instituted numerous civic and infrastructure improvements, such as housing, community services, utilities, communication, and roads. These aspects were not only important to uranium and vanadium production during the 1940s, but also served as a foundation for the Cold War uranium boom of the 1950s.

The uranium and vanadium mining industry shaped the cultural climate of the two counties. The prosperity that the industry brought lifted the region out of the Great Depression and improved the living conditions of the residents. The industry also unified the communities because they embraced their role as direct contributors to the war effort. They understood that their contribution was vanadium and only later realized that the uranium used in the atomic bombs was a part of this.

E 4.7: The Atomic-Era, 1946-1963

When World War II ended, the Federal Government had no intention of canceling its nuclear weapons programs. Further, the government was acutely aware that when the Soviet Union invaded Germany, the Soviets captured some of the leading Nazi nuclear physicists. It was therefore only a matter of time before the Soviets would develop their own atomic bomb. The Federal Government prepared for this by reformatting its nuclear weapons programs during a postwar adjustment period.

The government continued to refrain from purchasing uranium, but private industry was now free to purchase vanadium because the government restored the metal to the free market. Beginning in 1946, a demand for vanadium slowly returned as manufacturers responded to a growing postwar consumerism. The demand, however, was too small to revive the mining industry, and only USV and VCA showed any signs of life in western Colorado. Both companies retained skeleton crews that maintained facilities and conducted minor development in several of the largest mines.

All was not quiet, however, in Washington, D.C., and the Pacific Ocean during 1946. Despite the two successful detonations in Japan, the atomic bomb was still in a developmental state, and even though the government was reorganizing its nuclear weapons programs, the military continued its own experiments. As part of this, it tested the first postwar device on Bikini Atoll, overtly communicating to the world and especially the Soviets a continued interest in nuclear arms.

In Washington, D.C., MED directors met with Congress and the Senate to discuss the need for an agency to govern and control atomic energy for military and peaceful uses. Within months, Congress and the Senate passed the Atomic Energy Act, which created the Atomic Energy Commission (AEC). This new agency consisted of a civilian panel, and another panel of senators and representatives who were the Joint Committee on Atomic Energy. While peaceful uses of nuclear technology were discussed, military applications were actually the focus, and to this end, the committee often met in secret. The Act placed all nuclear reactors, production equipment, minerals, and prices under federal control, and the government could be the only producer, refiner, and buyer for fissionable materials. Mining and ore concentration, however, were left to the private industry, but the government was the sole consumer and in this capacity had total control over the industry.[113]

One of the new administration's first tasks was to survey the state of the nuclear production industry, which was based on mining, milling, and refining. The AEC realized that most uranium came from Canada and the Congo, and that the United States was dependent on foreign sources, which the AEC perceived as a threat to national security. Like previous studies, the AEC determined that the Colorado Plateau was the world's third most important and the only meaningful domestic source of uranium at the time, which justified special action. In 1947, the AEC took action to resuscitate the Colorado Plateau's mining industry.[114]

The AEC's first step was to reopen some of the mills, which were necessary to convert crude carnotite ore into uranium concentrates known as yellowcake. In May of 1947, the AEC signed the first post-war milling contract with VCA, which reopened its Vancorum facility. The AEC then contracted with USV to restart the Rifle and Uravan mills, and USV then began rehabilitating the town of Uravan for what would be a substantial workforce. At the same time, the AEC also created the Colorado Raw Materials Agency, whose mission was to support the small mining outfits. The agency administered to all of southwestern Colorado from its office in Grand Junction. Last, the AEC commissioned the U.S.G.S. with finding, understanding, and quantifying the uranium deposits on the Colorado Plateau. This was no small task and would evolve over the course of more than a decade. The U.S.G.S. began an intensive drilling campaign around the peripheries of ore-bearing areas to locate outlying carnotite beds. A small army of U.S.G.S. geologists then clambered over the Plateau and commenced a protracted study of the sedimentary layers, the Morrison Formation, and its carnotite occurrences.[115]

Once the AEC had these foundation elements in place, it was finally ready to revive the entire mining industry. In 1948, the AEC launched a raft of programs intended to stimulate prospecting, support mining, provide milling, control the resources, and administer to finances. The AEC's approach to prospecting and mining was simple, as one guidebook author noted:

> "The door was opened to uranium prospecting on April 11, 1948 in an announcement by the United States Atomic Energy Commission of a three-point program intended to stimulate the discovery and production of domestic uranium by private competitive enterprises. This program utilizes the most effective incentive known to humanity - money."[116]

The AEC officially defined terms and conditions in a set of four Domestic Uranium Program circulars published in April. Circular No.1 did not apply to carnotite and instead guaranteed a minimum price for other types of uranium ore. Circular No.2 provided a bonus for any type of high-grade ore, as well as mill concentrates derived from noncarnotite ore. The AEC drafted Circulars No.1 and No.2 to encourage the discovery of pitchblende ore similar to that in Canada and the Congo. As an added incentive, the AEC also offered a $10,000 reward. Circular No.3 provided bonuses for high-grade ore, including carnotite, delivered to VCA's mill at

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[113] Amundson, 2002:20; Nelson-Moore, 1978:1039.
[114] Amundson, 2002:21.
[115] Blackman, 1951:4; Craig, et al, 1955:127; Hamrick, et al, 2002:61; McWhorter, 1977:B-1; Nelson-Moore, 1978:1039.
[116] Weiss and Orlandi, 1948:74.

Monticello, Utah. Through Circular No.3, the AEC encouraged the development of Utah's uranium deposits. Circular No.4, the last, provided allowances for the development of ore bodies and haulage. The Circulars and other incentives established the price for yellowcake at $3.50 per pound and paid $20.40 per ton of crude carnotite that held 2 percent vanadium and 0.2 percent uranium oxide. By comparison, the same ore fetched $13.80 per ton on the free market.[117]

In terms of control over the resources, the AEC withdrew from the public domain thousands of acres with a high potential for ore and designated them as reserves. The most important reserves were on Club, Long Park, and Monogram mesas, adjoining Wedding Bell and Radium mountains, and San Miguel Bench. The USGS then drilled these reserves for ore deposits, and if carnotite was discovered, the AEC leased the land from the Department of the Interior for mining by private companies. If nothing was found, the AEC returned the land to the public domain.[118]

The AEC imitated the World War II development projects in its support of mining. Specifically, the AEC graded roads to both the existing centers of mining and the newly discovered ore-bearing areas. The AEC also established a series of ore buying stations where independent miners could deliver carnotite in volumes as small as one ton. The ore was weighed, assayed, and the seller paid according to the ore's richness. These two contributions were primarily in support of small outfits, which tended to lack funds and resources.[119]

The programs exceeded AEC expectations and fostered an atomic-era boom that was similar in scale to some of Colorado's other major mining rushes. The boom began during 1949 in the Uravan Mining District, rippled outward to the rest of western Montrose and San Miguel counties, and ultimately spread to other portions of the Colorado Plateau. As the boom took form, the Soviet Union tested its first atomic bomb, which only contributed to the excitement.

Individuals of all strata came to the Plateau in search of carnotite. The first were workers employed by the established companies such as USV and VCA. These companies immediately reopened their most promising mines, developed ore beds discovered through drilling, and hauled ore to the Uravan and Vancorum mills. At the same time, the USGS dispatched more geologists to the region, and they intensified the AEC's drilling campaign. In 1949 and 1950, the geologists found additional carnotite beds around Long Park, Club Mesa, and Monogram Bench. Groups of weekend prospectors brought their families, jeeps, and camp trailers, and combed the Plateau's mesa rims. In parallel, professional prospectors arrived, set up permanent camps, and applied knowledge to find ore formations. Last, the region saw a wave of roustabouts who came looking for work.

[117] Gabelman, 1974:74; McWhorter, 1977:B-5-9; Nelson-Moore, 1978:1039; Taylor and Yokell, 1979:24; Weiss and Orlandi, 1948:75-80.
[118] Amundson, 2002:22; Taylor and Yokell, 1979:24; Weiss and Orlandi, 1948:75-80.
[119] Amundson, 2002:22; Taylor and Yokell, 1979:24; Weiss and Orlandi, 1948:75-80.

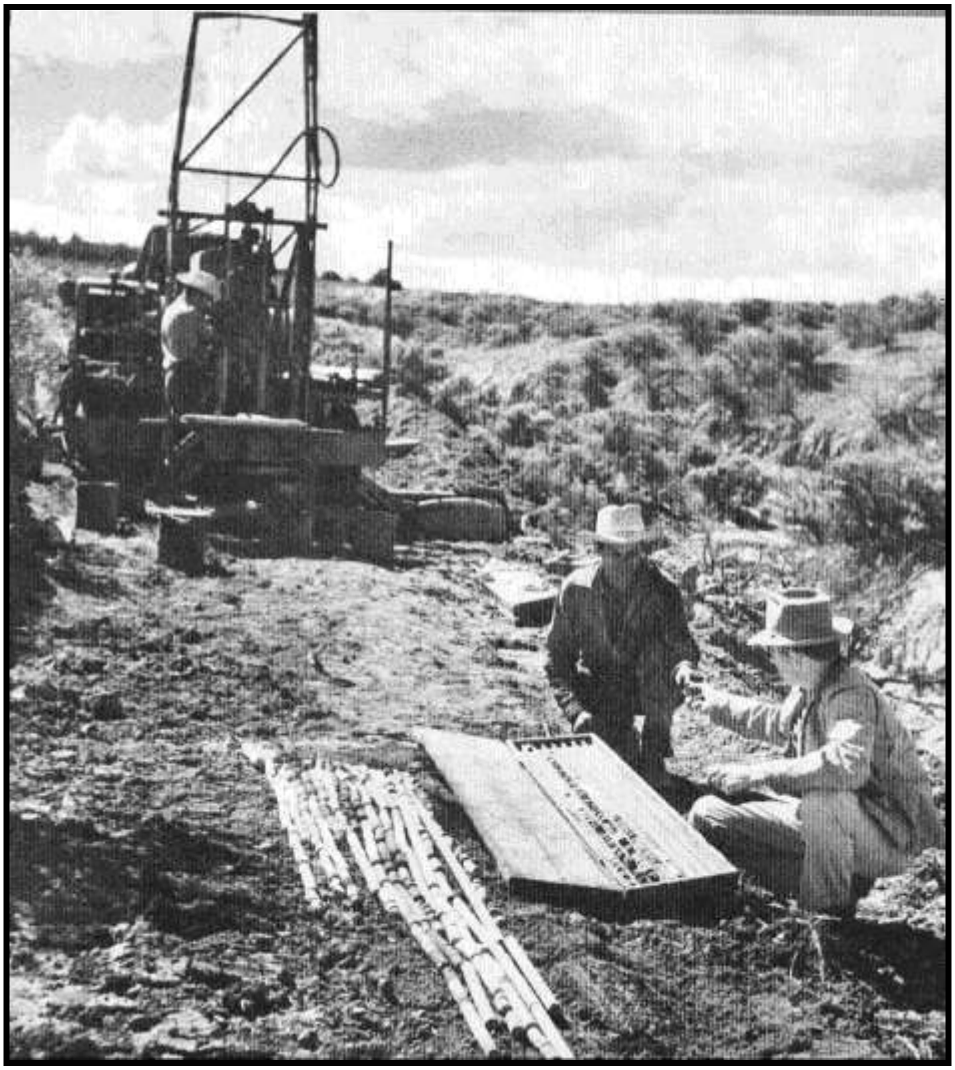

Figure E 4.11: During the 1950s, sample drilling became the single most important method for locating and quantifying beds of carnotite ore. Through drilling, geologists found ore beds that were concealed underneath sandstone cap rock. Drilling rendered conventional prospecting an anachronism. Source: Mesa Miracle, 1952:22.

Several factors made the uranium boom different from Colorado's early gold and silver rushes in the mountains. First, advanced technology empowered both professional and avocational prospectors and greatly increased the rate by which they discovered carnotite beds. Sample drilling was one improvement, and it decreased exploration costs and allowed companies to find ore beds that were landlocked underneath sandstone cap rock. Drilling rendered the blind, prospect shafts and tunnels of the nineteenth century obsolete. In 1949, handheld Geiger counters were introduced, and they were designed specifically to detect radiation in faint emissions. Professional and avocational prospectors, and geologists, relied on Geiger counters to identify invisible and concealed ore beds. These devices proved so important that a uranium prospecting guidebook aptly noted: "History will probably record the fact that the Geiger Counter instrument deserves foremost credit in the development of the atomic revolution in the twentieth century."[120] With four-wheel drive vehicles, greater numbers of individuals traversed more ground in much less time than in mining rushes of the past. Even more so, the AEC and USGS mounted Geiger counters and scintillometers to light aircraft and flew transects over the region to identify likely areas worthy of intense examination.[121]

The second factor was direct support by the Federal Government in addition to the Circulars and programs outlined above. In particular, the AEC and the Colorado Raw Materials Agency purposefully disseminated the results of drilling, air sorties, and geological studies in hopes of advising prospectors. The two agencies updated exploration summaries on a biweekly basis at the Naturita, Nucla, Uravan, Gateway, and Paradox post offices. The agencies also published drilling reports and maps, printed guidebooks, and encouraged a flurry of articles in the mining industry press.[122]

There were similarities, as well as differences, between the uranium boom and Colorado's early mining rushes. Prospectors still combed the region by foot and some engaged in rim-walking, which was a pedestrian survey along the Morrison Formation's cliffs and ledges. Those prospectors who lacked Geiger counters employed the ages-old method of finding ore by sight and picking at discolored sandstone. Because carnotite was slightly radioactive, prospectors also tested samples with photography film. If a sample exposed the film, the prospector knew it was most likely a form of ore.

At the same time that independent prospectors were rim-walking and traversing the mesas in jeeps, the capitalized companies employed heavy machinery to find deep deposits unavailable for surface examination. Following the lead of the USGS, private contractors bored drill-holes on nearly every flat surface, and, similar to the 1910s exploration efforts, the companies used rockdrills, diamond drills, and churn drills to exhume samples from underneath sandstone cap layers. During the early 1950s, rotary drills became increasingly popular, and although they were able to bore deeper holes faster than any other method, rotary drills were costly. To maximize the acreage sampled and to minimize the costs, many companies employed a three-tiered sampling strategy that began with drill-holes bored around 1,000 feet apart to characterize an area's geology. When a hole proved positive, workers drilled additional bores according to a grid, and the holes were spaced 50 to 200 feet apart. After roughly defining the ore body, the workers then peppered the area to clearly delineate its boundaries and find the richest portions.[123]

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120 Weiss and Orlandi, 1948:47.
121 Hampton, 1955:18; Knoerr, 1955:135; Taylor and Yokell, 1979:27.
122 McKay, 1953:5; Taylor and Yokell, 1979:27.
123 Dare, et al, 1955:12; Fischer and Hilpert, 1952:1; Motica, 1968:812.

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Drilling equipment required vehicles, trailers, and open ground, which only the mesa tops offered. Therefore, mining companies used bulldozers to clear paths and drill pads, and contractors conducted most work at a high profit. They charged $125 per mile to bulldoze roads through gentle terrain and as much as $2,500 per mile to grade roads across ledges and through boulder-ridden slopes. Hundreds of miles of crude roads were pushed across the Plateau, and heavily drilled areas became scarred with web-like networks of swaths, cuts, and pads.[125]

The uranium boom shared with Colorado's early rushes an atmosphere of haste, competition, and speculation. Prospectors looked for hotspots of activity as much as they searched for ore. Intense drilling and repeated low passes by aircraft tipped off observant individuals to areas of interest, and they flocked in response. Small crowds gathered at the post offices and awaited the biweekly exploration summaries. Prospectors rarely waited for photographic film tests or assay results to stake claims, and instead, they did so merely on the presumption of ore. To stake a claim, the atomic-era prospectors followed the same 1872 mining laws that applied to hardrock ore formations, even though carnotite occurred in flat sandstone beds. A claim had to be 300 feet on both sides of the discovery point and 1,500 feet long, and the prospector was obligated to erect four corner posts and display a location notice. If the ore deposit was not obvious, the prospector had to sink a 10 foot discovery shaft or adit and conduct $100 worth of labor. Unlike most hardrock mining districts, prospectors on the Plateau could stake as many claims as they wished.[126]

Once an ore body was discovered, the claim had to be developed for production, and the methods depended on who found the formation and who owned the claim. If an independent prospector found the ore and retained title to the claim, he often sold the property to a mining company, since development usually required more capital than the prospector possessed. In a few cases, prospectors formed partnerships for joint development, solicited capital from business interests, and worked the claims themselves. Ultimately, however, the large companies acquired most of the ore-bearing claims, leaving relatively few for the independent outfits. The companies then usually leased the claims out to those independent outfits that lacked their own properties. When necessary, the companies conducted the initial claim development and

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[124] Dare, et al, 1955:12; Fischer and Hilpert, 1952:1; Motica, 1968:812.
[125] Hampton, 1955:43.
[126] Hampton, 1955:60; Knoerr, 1955:56; Taylor and Yokell, 1979:27; *Uranium Prospectors' Handbook*, 1954:40; Weiss and Orlandi, 1948:99-102.

provided some equipment. USV in particular practiced this system and was loved by the community for its perceived support and generosity. By 1952, USV leased claims to 50 independent parties, purchased ore from an additional 90 small outfits, and provided them with most of the materials they needed. USV benefited, of course, because the outfits tended to work deposits that were uneconomical for the large companies.[127]

The nature of the ore deposit and the claim owner governed how the ore was actually mined. Where the ore body cropped out on a sandstone cliff or lay a short distance beyond, miners preferred to develop the formation through a tunnel because it cost the least. Where the ore body lay underneath sandstone cap rock, however, a shaft was necessary. If the vertical distance was minor, companies drove what the industry recognized as an inclined adit, which descended between 10 and 25 degrees. If the distance was great, an inclined shaft was necessary. Where possible, companies preferred inclined adits because the gradient was gentle enough to allow ordinary ore cars to be winched with a simple and inexpensive hoist and uncoupled on the surface. Inclined shafts, however, required a stronger hoist fixed to a structure.[128]

Underground, miners often adapted the room-and-pillar system of stoping from coal mines, and used the same drilling and blasting methods employed in hardrock mines. For horizontal work, they drilled blast-holes with jackleg drills, and used stopers for vertical work. Even the largest mines had portable compressors to power the drills, draglines for scraping ore to loading stations, and compressed air winches and hoists. Stationary compressors, substantial shops, and aspects of the infrastructure found at metal mines were uncommon except at the largest uranium operations. The size of the ore body determined how the ore was hauled out of the mine. Large ore bodies justified ore trains pulled by compressed air locomotives. Capital-poor operations continued to use ore cars and even horse-drawn carts on rubber tires.[129]

The boom intensified during the early 1950s, and the wave of exploration began to yield tangible results. By 1950, the AEC and the USGS outlined a number of new ore beds on Club, Long Park, and Monogram mesas, and around Slick Rock. Between 1951 and 1953, the USGS bored 92,000 feet of sample holes on San Miguel Bench alone, many of which proved positive. USV and VCA developed most of the discoveries, although they no longer held a monopoly over the region. In 1950, the Climax Molybdenum Company and the Minerals Engineering Company, of Grand Junction, organized the joint Climax Uranium Company. This new organization had enough capital not only to purchase numerous groups of claims, but also to build a uranium mill at Grand Junction. Within a short time, Climax Uranium became one of the region's top producers.[130]

USV, VCA, and Climax Uranium developed the discoveries and brought them into production almost as quickly as they were found. The number of operating mines in the two counties increased more than 100 percent. During the late 1940s, Montrose County featured 7

[127] *Mesa Miracle*, 1952:29; "Mesa, Montrose, and San Miguel Counties" 1952; "Uranium Activity on the Colorado Plateau" 1952; "Uranium Mining Activity" 1953.
[128] Dare, et al, 1955:21.
[129] Clark and Kerr, 1974:26; Dare, et al, 1955:34, 38, 40, 44; Fischer, 1942:394.
[130] Alvord, 1956:4; Bruyn, 1955:71; Fischer, 1950:6; Nelson-Moore, 1978:1040; Blackman, 1951:5.

medium-sized and 27 small mines, and San Miguel County had almost as many. By the early 1950s, these figures jumped to 1 large, 19 medium, and 68 small mines in Montrose County. San Miguel County possessed as many small mines as well as 8 medium and 4 large mines. In addition, 21 new mines were being developed in Montrose County and 14 more in San Miguel County.[131]

To keep pace with increasing production, USV, VCA, and the AEC reopened all five of the uranium mills that were active during World War II. VCA operated the Vancorum and Durango mills, USV ran its Uravan and Rifle plants, and the AEC assumed the Monticello, Utah, facility. Mining outfits generated enough ore to support the Climax Uranium mill at Grand Junction and the new Atlas Mill in Moab, Utah, as well.[132]

Within a short time, Montrose and San Miguel counties reclaimed their worldwide status of importance. Montrose County now yielded most of Colorado's uranium, and the Colorado Plateau assumed the title of the free-world's second greatest producer.[133] This was due in large part to the coordinated efforts of the AEC and private industry, as a promotional publication observed.

> "If you spend any time in the Plateau area, you cannot help but be impressed by the speed and efficiency with which the people are carrying out the uranium program there. You will find a spirit of remarkable teamwork displayed throughout every phase of uranium production: by the individual workers and many independent miners in the field; by the small companies in the area that furnish the materials, supplies, and services that are needed; by the larger companies brought into the program because of some special skill or 'know-how', and, of course, by those working for the Atomic Energy Commission, itself, and an associate agency of the Government, the United States Geological Survey."[134]

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[131] According to a statistical analysis of Colorado Mine Inspectors' Reports.
[132] Amundson, 2002:23; Robison, 1969:76; Western States, 1954.
[133] "Mesa, Montrose, and San Miguel Counties" 1952; *Minerals Yearbook*, 1951:1299.
[134] *Mesa Miracle*, 1952:5.

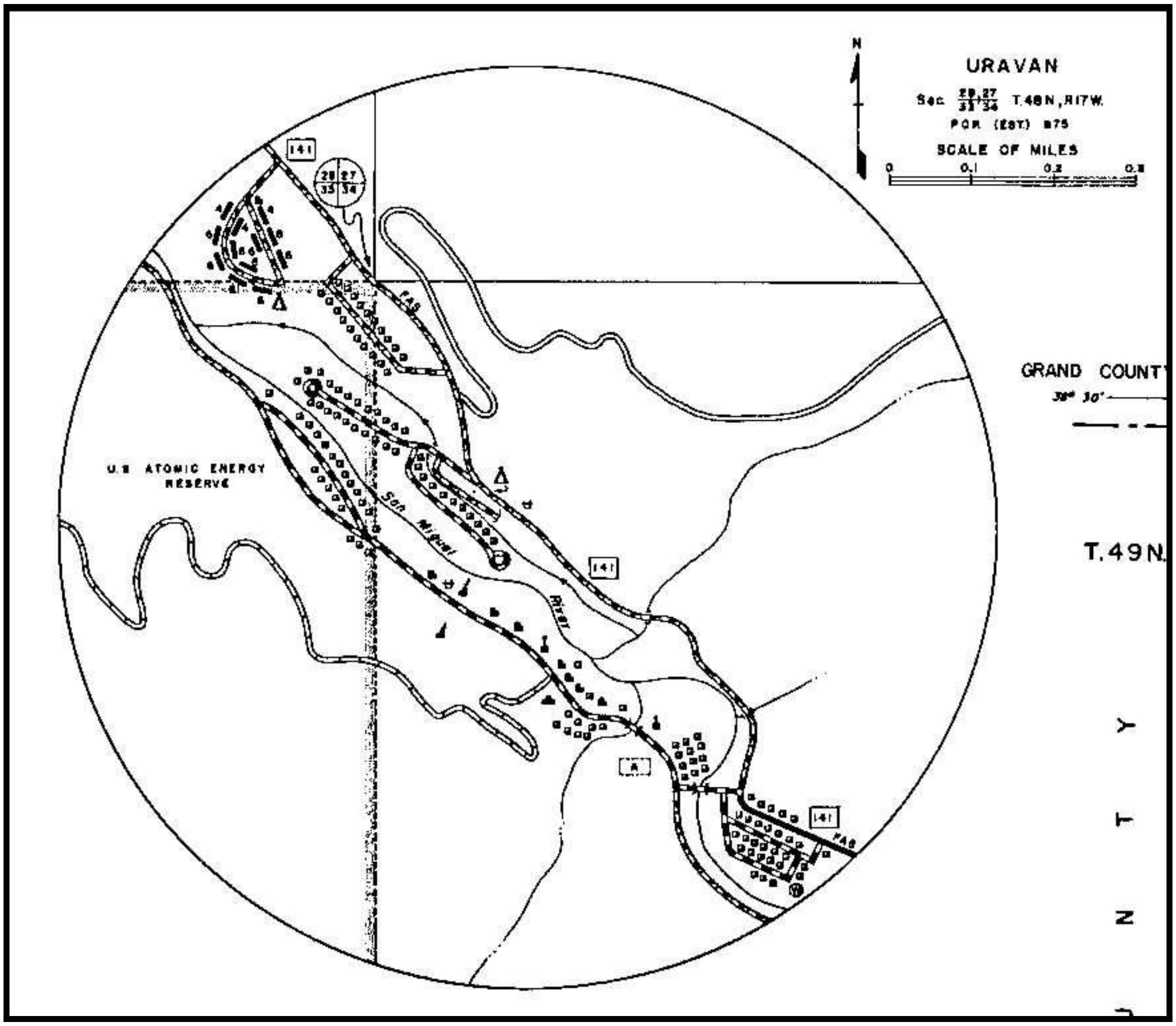

Figure E 4.12: The 1951 road map illustrates Uravan. The town is completely gone, but Highway 141 remains largely unchanged today. The mill stood near center. Source: Colorado Department of Highways, 1951.

By the early 1950s, the mining industry employed between 4,000 and 5,000 people. Of these, around 1,000 were miners, mostly lessees, 250 worked on drill-rigs, and 150 trucked ore to the mills. Within the private sector, USV had the most influence and was recognized as the largest domestic uranium producer. In 1951 alone, USV spent $6 million on pay, supplies, materials, and services in and around Grand Junction for operations.[135]

[135] *Mesa Miracle*, 1952:7, 29; “Mesa, Montrose, and San Miguel Counties” 1952; “Uranium Activity on the Colorado Plateau” 1952; “Uranium Mining Activity” 1953.

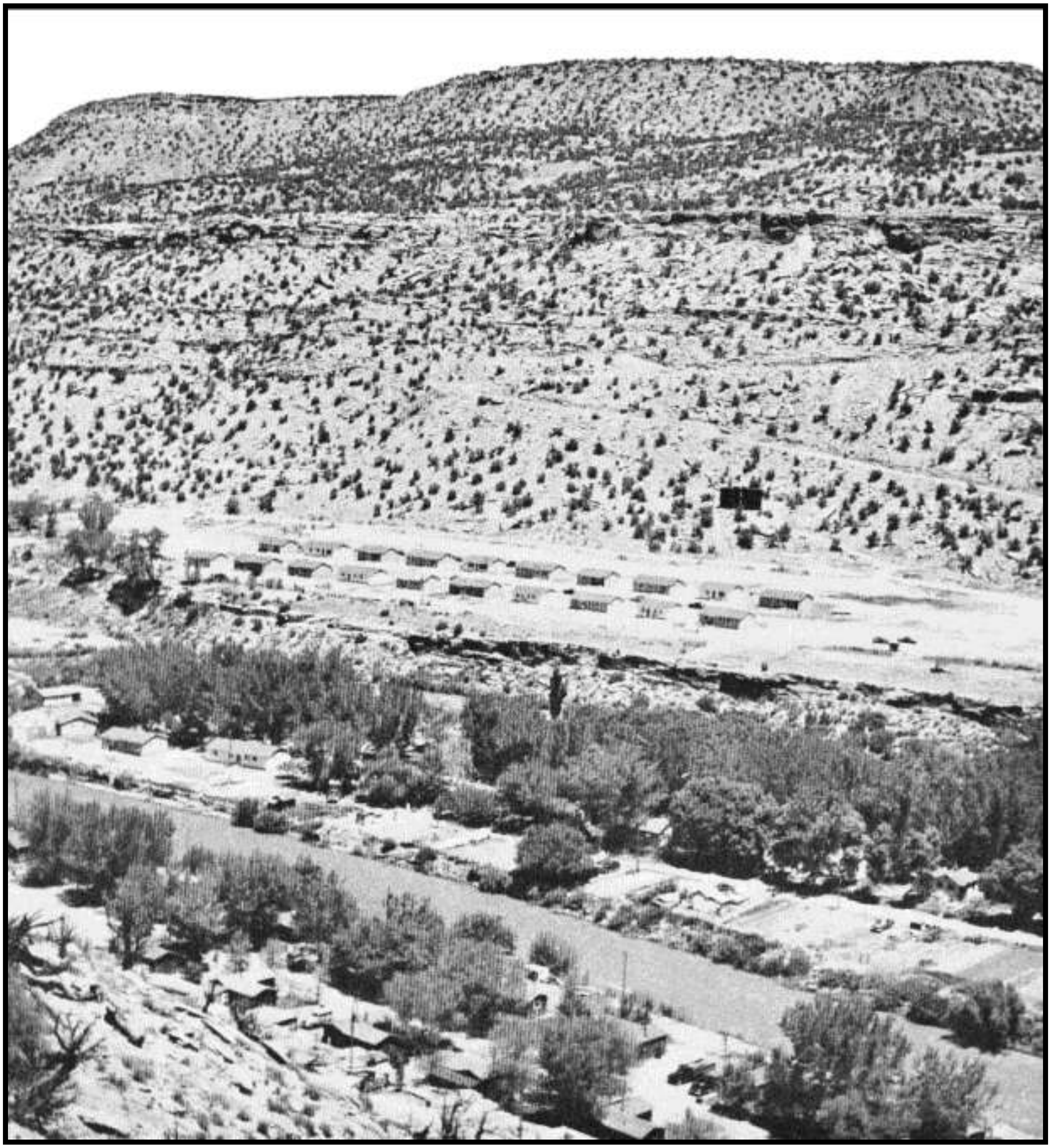

Figure E 4.13: The northwest overview depicts Uravan around 1951. The row of houses at center is the same as the row at the upper left corner of the road map, above. Uravan was exclusively a company town maintained for United States Vanadium workers. The mill is left and out of view. Source: Mesa Miracle, 1951:27.

The exponential rate of growth in the mining industry was still not enough for the AEC, which pursued both long-term and short-run production strategies. To encourage immediate development, the AEC opened 42 square miles of its carnotite-bearing reserves in 1951. Independent and company-employed prospectors were on hand and rushed to stake claims. The general excitement throughout the region threatened to exceed the AEC's coordination abilities, and in response, the AEC opened a central operations office in Grand Junction. During the early 1950s, the AEC also continued its original programs in preparation for long-term production. In particular, the AEC invested around $2 million grading roads to the areas of high potential, withdrew more land for its reserves, and released Domestic Uranium Program Circular No.6, which provided additional bonuses for the development of ore beds.[136]

The towns of Naturita, Nucla, Gateway, and Paradox acutely felt the boom as their populations grew, mining companies established offices, and commerce exploded. Naturita in particular was completely swept up in the excitement, and an invasion of mining rush participants shattered the town's quiet atmosphere. When recently asked about how the boom affected Naturita, long-time resident Anna Cotter answered simply: "nuts."[137]

Naturita was the closest commercial center of importance to the uranium region in western Montrose and San Miguel counties, and so the community assumed a central role in the mining industry. The town was a congregation node for prospectors, miners, drilling outfits, and mining companies, which came and went with frequency. An entire neighborhood was built at the east end of town to accommodate the influx of workers who commuted to various mines on the nearby mesas. The neighborhood attracted a demography characteristic of Colorado's early mining rushes, and the new residents tended to be transient, rough, and troublesome. Fights were common, and in 1955, a miner shot at his own house-trailer thinking that his wife was at home with another man. The trailer was empty at the time. Naturita's established residents informally designated the neighborhood as the Snake Pit and Nasty-rita.[138]

The growing population offered plenty of opportunity for new businesses. Entrepreneurs opened several gasoline stations, grocery stores, hardware supplies, and clothing shops. Like many of Colorado's nineteenth century mining camps, Naturita's bars became key community centers where prospectors sold claims, miners found jobs, and speculators consummated deals. Drinking was heavy, the town was wild on the weekends, and parties and cookouts were common. Live bands played at dances every Saturday night, and the latest movies were shown in the town hall three times per week. As the region's largest employers, USV and VCA contributed heavily to community improvements in an attempt to alleviate some of the population pressures. In particular, they enlarged the town's plumbing system and operated a medical clinic.[139]

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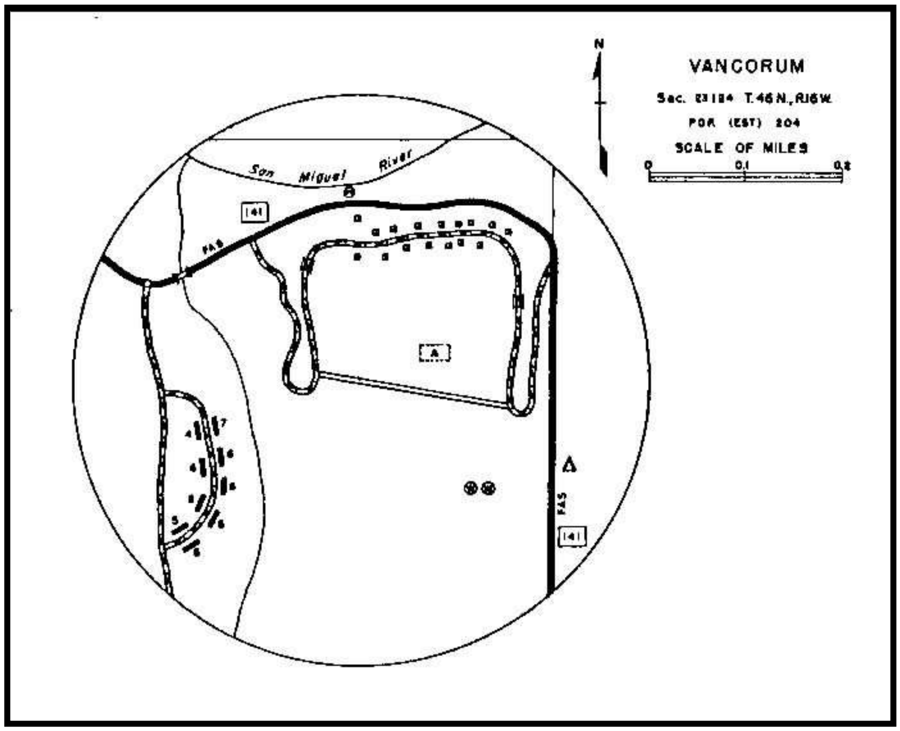
[136] Gabelman, 1974:74; Hampton, 1955:63; *Mesa Miracle*, 1952:21; Nelson-Moore, 1978:1040.
[137] Cotter, 2007.
[138] Cotter, 2007; Davis, 2007; Moore, 2007.
[139] Bonner, 2007; Casto, 2007; Davis, 2007; Holland, 2007.


N
VANCORUM
T.46N., R16W.
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SCALE OF MILES
0
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Figure E 4.12: The 1951 road map illustrates Vancorum, which was a company settlement erected by the Vanadium Corporation of America for its mill workers and miners. Vancorum was one mile west of Naturita on Highway 141, and it was based around a concentration mill that was important during World War II and the Cold War uranium boom. The mill stood at upper left. Source: Colorado Department of Highways, 1951.

USV and VCA took a similar approach to Nucla, which was Naturita's quieter sister town several miles to the north. The two companies improved Nucla's water system, organized a sanitation district, and built a high school. As Nucla's population grew, entrepreneurs opened grocery, hardware, and clothing stores there, as well as the ubiquitous bars. Nulca's residents were not quite as energetic as those in Naturita, and they found entertainment primarily in a new movie theater.[140]

The town of Gateway remained small, featured several businesses, and was primarily a bedroom community for the nearby mines. Most of the workers lived in several new trailer parks, which experienced problems similar to Naturita's Snake Pit. The principal difference, however, was that Gateway lacked law enforcement, leaving the local residents to settle disagreements themselves.[141]

Uravan, center to the boom, ironically continued to be the most stabile and orderly town. The reason was that USV retained complete control over Uravan and prohibited the sale of liquor in either stores or bars. Further, USV rented out houses only to company employees, who tended to be married, peaceful, and reliable. Uravan experienced record growth in 1955, and USV responded with two boardinghouses, single residences, natural gas and water systems, and a gymnasium.[142]

During the early 1950s, the uranium boom spilled over onto portions of the Colorado Plateau within neighboring states. Prospectors found more rich ore deposits, and the number of active mines kept increasing. A series of discoveries in the Four Corners area diverted attention away from Montrose and San Miguel counties, although years would pass before Colorado lost its stature. In 1948, prospectors found carnotite at White Canyon, Utah, and in 1950, a Navajo located extremely rich pitchblende ore at Grants, New Mexico. Professional prospector Charlie Steen realized a dream and developed another rich pitchblende deposit near Moab, which was a highly convenient location given the proximity to roads and mills. In the subsequent five years, Laguna and Ambrosia Lake, New Mexico; the Lisbon Valley and Moab, Utah; and Cameron, Arizona, all became centers of uranium mining. By the mid-1950s, a USGS expert claimed that the United States assumed the role of the world's leading uranium producer because of these and other discoveries.[143] Sensational publications drew attention to the spreading excitement, and one author noted:

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[140] *Colorado Mining Year Book* 1955 p101; Holland, 2007.
[141] Casto, 2007.
[142] Amundson, 2002:39; *Colorado Mining Year Book* 1956 c.2 p42; *Colorado Mining Year Book* 1957 c.2 p43; Hamrick, et al, 2002:47.
[143] Amundson, 2002:23; Fischer, 1968:738; *Minerals Yearbook*, 1949:1248; *Minerals Yearbook*, 1956, V.1:1245; *Minerals Yearbook*, 1957, V.3:298.

> "Few people realize the vast extent of the uranium deposits on the Colorado Plateau. It is only a matter of time until production will exceed that of the Belgian Congo and South Africa and the United States will become entirely independent of foreign sources of atoms for war."[144]

Such predictions finally came true in 1956 when the United States eclipsed the rest of the free world in terms of uranium production. Western Montrose and San Miguel counties played significant roles in this trend, primarily because the boom matured away from prospecting and speculation to ore production and milling. As a direct reflection, the number of mines that were active between 1956 and 1960 increased exponentially from the previous five years. In Montrose County the small mines skyrocketed from 68 to 188, the medium-sized mines more than doubled from 19 to 52, and the large mines mushroomed from 1 to 12. San Miguel County experienced a like phenomenon. The small mines jumped from 67 to 107, the medium-sized mines more than doubled from 8 to 19, and the large mines increased from 4 to 6.[145]

The explosive rate of ore production threatened to exceed the milling capacity offered by USV and VCA. USV responded in 1956 by enlarging its Uravan mill with a new facility built above the original complex. Known as B Plant, the new facility featured hot acid leaching that prepared the carnotite for a revolutionary ion exchange process installed in the original mill. The ion exchange recovered uranium, and a separate solvent extraction stage then stripped away the vanadium. USV also added thickening tanks, better filters, and other equipment to enhance metals recovery. At the same time, VCA increased the capacity of its Vancorum mill to accommodate the ore generated from its mines. A year later, USV purchased the North Continent mill at Slick Rock, used it to concentrate local ore, and sent the material to Uravan for final treatment.[146]

Other aspects of the region's industry continued to grow in tandem with mining and milling. In 1956, the San Miguel Power Association began constructing an electrical grid in the Paradox Valley area and extended lines to many of the principal mines. In search of ore beds, private companies bored a record number of sample holes, which reached a peak of 9.2 million feet in 1957. Grand Junction became the financial and organizational center of uranium mining on the Colorado Plateau, mostly because it was the nearest city to Montrose and San Miguel counties. The Colorado Raw Materials Agency, the AEC, and most of the largest mining companies had their offices and laboratories in Grand Junction.[147]

The movement toward uranium production continued during the latter half of the decade, and 1957 was a record year for Colorado with a jump of nearly 50 percent. Large companies continued to dominate the industry, although small outfits still found opportunities to thrive. USV, VCA, and Climax Uranium were the largest operators and enjoyed record expansions. In San Miguel County, the Minerals Engineering Company, the Skidmore Mining Company, the La Salle Mining Company, and the Gayno Mining Company were the most significant of the small

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144 Look, 1955:120.
145 According to a statistical analysis of Colorado Mine Inspectors' Reports.
146 Chenoweth, 1993:50; *Colorado Mining Year Book* 1956 c.2 p41; Hamrick, et al, 2002:48; Merritt, 1971:271; McWhorter, 1977:B-40; Nelson-Moore, 1978:1042.
147 Chenoweth, 1993:35; Hampton, 1955:8; *Mesa Miracle*, 1952:7; McWhorter, 1977:B-16.

operators. Montrose County was home to the Blake, Power, & Stocklass Company, Bunker & Company, the Dulaney Mining Company, the Four Corners Uranium Corporation, and Golden Cycle.[148]

In 1957, the Uravan Mining District hosted one of the Colorado Plateau's last frenetic rushes that provided equal opportunity for both independent miners and large companies. After the USGS finished its exploration campaign in Long Park, the AEC opened the reserve to anyone willing to stake a claim. Within days, hundreds of hopeful wealth-seekers flooded the area and staked over 1,000 claims, most of which were ultimately acquired by the large companies.[149]

With their deep financial reserves, the large companies acquired a clear majority of the productive mines throughout the region. Their dominance was, however, in ownership and milling only, because they relied heavily on partnerships and small outfits to actually produce the ore. The large companies found that the small ore deposits were too troublesome to directly work themselves because of the logistics involved. The small deposits were scattered and difficult to coordinate within the context of a large organization. As a result, the companies increasingly relied on lessees to work the small deposits, but continued to operate the major mines. This two-tiered system of mining proved beneficial for the industry because the lessees collectively provided the companies with record production, and the companies offered the lessees the potential to earn more money than daily wages as employees. For comparison, company miners often received $3.00 per hour while lessees could bring in as much as $10.00 per hour if they were efficient and the ore high in grade. The lessees also enjoyed one additional factor above company employees, which was a greater level of freedom and autonomy.[150]

One of the principal detriments for lessees was housing because they were responsible for providing their own. Lessees preferred to live in the established towns to be with their families and to enjoy community. But if the roads to the mines were poor and the commute longer than one hour, the lessees usually lived near their points of work. In such cases, those lessees with families faced the difficult choice of either billeting their wives and children in town or providing them with acceptable housing at the mines. The preferred alternative was for the family to stay with local relatives, and when this was not an option, the miner had to pay his family's lodging, as well as his own. According to retired miners David Chiles and Michael Holland, lessees commonly lived in the field during the weekdays and returned to family on weekends.[151]

Another alternative that some miners practiced was to split up the family. The children stayed with relatives in town, while the husband and wife lived together at the mine. In so doing, the children had access to school, the couple could enjoy their companionship, and they formed a team that eased the burdens of life in the field. While the miner worked, the wife attended to domestic duties that not only included preparing meals and cleaning, but also hauling water and chopping wood. In some senses, the lifestyles of many uranium miners changed little from nineteenth century practices.[152]

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[148] Colorado Mine Inspectors' Reports: various; *Colorado Mining Year Book* 1956 c.2 p91, 97, 105, 125, 177.
[149] *Minerals Yearbook*, 1957, V.3:298.
[150] Ringholz, 1989:87.
[151] Chiles, 2007; Cotter, 2007; Holland, 2007; McLeroy, 2007; Moore, 2007.
[152] Holland, 2007; Moore, 2007.

The best alternative to living in town was a place in one of the many mining camps that grew on the mesas. When a cluster of mines or a large operation had enough of a workforce, the miners usually arranged their residences together to form a camp. Some of the camps were company affairs, most were established by one or more parties of lessees, and they were usually no more than collections of simple dwellings. Because company camps were built in a single episode, they tended to be somewhat organized in terms of the orientation and spacing of residences. The lessee camps, by contrast, were often haphazard because specific parties came and went with frequency.

The camps were important social institutions, which is why they were the most desirable alternative to living in town. Miners had a much easier time accommodating their families in the camps than at the individual mines for several reasons. The women and children had social opportunities, developed relationships, and provided each other with support. At least on Long Park and Monogram mesas, buses picked up children and delivered them to schools in Paradox and Naturita. During adverse times such as isolation due to impassable roads, the residents came together as a community, pooled their resources, and saw to everyone's needs. The camps also allowed single miners and families to save income because nearly all of the settlements except for Long Park Camp lacked businesses. For this reason, camp residents usually trekked to town once per week to purchase food and clean laundry.[153]

Because of their remoteness and impermanence, the mines and the camps offered primitive housing and few amenities. Wall tents and trailers were popular among lessees because these types of residences were inexpensive and portable. The well-developed camps tended to feature frame buildings, and a few even had running water, septic systems, and electricity, although these were by far in the minority. At the camps without power, the residents relied on gas lanterns for light, propane stoves for cooking, and propane refrigerators to keep food.[154]

Such conditions forced the residents to consume a limited diet of preserved foods that required no refrigeration. Canned meat, soup, stew, vegetables, and fruit were the foundation of most meals, which the residents supplemented with potatoes, corn, apples, and other types of produce that stored well. Those households with power or propane appliances were able to enjoy a wider variety of fresh foods, although these were limited to items that would keep between the weekly journeys to market. Preserved liquids proved very popular because of the region's aridity and hot summers. Canned soft drinks were universal among workers and their families, and juice and broth were popular, as well. Coffee was another beverage of choice, especially during winter. Alcohol was as common at the mines and camps as it was in the towns, although few residents drank to excess. Beer was a favorite because it was cold and satisfying, and liquor was a second choice due to its high cost. Alcohol was a lubricant of uranium mining, and Uravan may have been the only settlement where it was banned.

The demography of the workforce amid the mines and camps was the uranium industry's truly unique aspect. As the uranium boom spread into the Four Corners region during the early 1950s, mining companies found that particularly important ore deposits lay on reservations

[153] Davis, 2007.
[154] Davis, 2007; McLeroy, 2007.

inhabited by Navajo, Hopi, and Ute Indian tribes. Because these tribes were sovereign and controlled the reservation lands, the mining companies had to negotiate prior to exploration and claim development. The tribes exacted several agreements from the mining companies, including a stipulation that the companies hire and train tribal members as surface workers and miners. This became a gateway through which primarily Navajo and secondarily the Ute Indians established a strong presence in the uranium mining industry.

The importance of Indian workers is often overlooked, but the industry came to depend on them. Similarly, the industry was a significant agent of change for the tribes, and this trend has received little attention, as well. Specifically, uranium mining was the first heavy industry to become deeply involved with the tribes, became a major employer, and introduced many members to the wage economy. In essence, uranium mining provided many Indians with opportunities to learn industrial trades and to transition away from poverty and a subsistence lifestyle. This came at a price, however. Uranium mining also brought grave health and environmental problems, and the benefits lasted only as long as the mines operated.[155]

Indians began their presence in the uranium mining during the early 1950s when a relatively small number of workers were hired at the mines and mills on the reservations. The companies had difficulty with this initial wave of employees because they were new to industry and the concept of wage labor. These early workers proved to be unreliable, failed to show at times, and stayed in their positions only until they satisfied their immediate needs and then quit.[156]

However, this trend reversed itself within a few years, due in large part to a contingent of dedicated and reliable individuals. They imparted their understanding of the industrial work ethic to others, whom the companies then hired and trained primarily as miners. Through a combination of training and experience, the Indians, mostly Navajos, gained a reputation throughout the uranium industry as experts underground. As word of their capabilities spread, companies outside of the reservations began to actively recruit them until, by the latter half of the 1950s, around 2,500 of the 10,000 miners employed across the Colorado Plateau were Navajos.[157]

As early as the mid-1950s, mining companies in Montrose and San Miguel counties actively recruited Navajos, drawing them northward. In the mines, the Indians were a minority but were usually considered equal to Whites because of their skill and efficiency. Retired miner Robert W. McLeroy jokingly observed that he never caught a Navajo in the act of working, but that they always finished their tasks ahead of schedule. Due to cultural differences and a language barrier, the Navajos tended to be clannish. Retired miner Ralph Casto recounted how interpreters often accompanied parties of Navajo workers, and some White miners like him learned to speak a little Navajo. Most Indian miners lived on-site among the Whites and returned to their reservations for the weekends. In general, Indians maintained their presence in the uranium industry into the 1970s.[158]

[155] Brugge and Goble, 2002:1411.
[156] Eichstaedt, 1994:44.
[157] Brugge and Goble, 2002:1417.
[158] Anderson, 2007; Casto, 2007; Holland, 2007; McLeroy, 2007.

While the Navajos were contributing to the increase of ore production during the 1950s, the AEC was already laying the groundwork to at first slow and then end the uranium boom. The AEC realized that several of its fundamental goals had been met due to the success of its programs. There were now enough ore bodies either in production or within the strategic reserves to satisfy the Department of Defense in the coming years. In addition, the industry was on solid footing and was capable of meeting short-term and long-term demands. The AEC decided that the time was right to stop throwing money at the industry and discourage over-production. In 1956, the AEC announced that it would no longer purchase crude ore and instead would only buy yellowcake produced by the mills.[159]

This policy increased the dominance of the large companies, which operated all the mills. Many of the small mining outfits were dependent on the AEC's generous ore prices and now had to sell their ore to the large companies instead. But, the large companies paid much less for the ore, which rendered some of the small operations profitless. As a result, the small companies either sold their properties and became lessees, or focused their efforts on only the highest grades of carnotite. The captains of the uranium industry understood that AEC's abrupt change was a portent of decisions to come, and they steeled themselves for further cutbacks. Any doubts were dispelled in 1957 when Jessie C. Johnson, director of the Colorado Division of Raw Materials, announced at the Atomic Industrial Forum in New York City that it was no longer in the interest of the Federal Government to continue increasing the rate of production.[160]

The uranium industry, the direct product of AEC programs, was rattled again in 1958 by two more announcements from the Federal Government. The Department of Defense declared that its uranium stockpile goals were within sight and would end its purchases in the future. Acting on this, Congress authorized a cutback on acquisitions, which was influenced by a nuclear test ban treaty with the Soviet Union. Congress even held discussions of limiting the number of yellowcake producers. In response, the AEC announced that it would only purchase yellowcake produced from deposits discovered prior to 1958 and no material from any new discoveries. The AEC then claimed that it would no longer guarantee prices for crude ore and cancelled its exploration campaigns. As a result, the demand for uranium slowed, and a sense of insecurity crept over the mining industry.[161]

Aware that the changes would prove detrimental to the uranium mining industry, the AEC took remedial action. In an attempt to simulate the use of uranium for nuclear power, Congress and the AEC loosened the restrictions for corporations to own and use nuclear material and reactors. The problem with this, however, was a considerable lag between 1958 and when nuclear powerplants would create enough demand to support mining. To help mining and milling companies weather the transition, the AEC introduced its stretch-out program in 1960, which extended the deadlines for delivering tonnages of yellowcake specified by contract. In essence, companies were able to extend their contract income into the late 1960s, and while they would have to reduce their operations, the companies, it was hoped, would survive until the

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[159] Amundson, 2002:106; Gabelman, 1974:76.
[160] Nelson-Moore, 1978:1043.
[161] McWhorter, 1977:A-3, B-7; *Minerals Yearbook*, 1958, V.1:1102; *Minerals Yearbook*, 1959, V.1:1131; Robison, 1969:76; Taylor and Yokell, 1979:31.

demand for uranium returned. Last, the AEC protected the existing uranium demand by shutting out foreign competition except from Canada.[162]

The AEC's sweeping changes impacted mining on the Colorado Plateau in several ways, although the full effects were delayed by several years. Union Carbide, which absorbed its subsidiary USV, responded at first to the announcements and slumping demand by reducing its ore production. Even more so, VCA suspended its Vancorum mill in 1958, but maintained the offices and shops there. These reactions were short-lived, however, and the mining industry produced record tonnages of ore in 1959 and 1960. From outward appearances, the boom on the Plateau showed few signs of abating.[163]

The uranium industry experts were not fooled and were instead acutely aware of an impending slowdown. Their forecasts manifested during the early 1960s, when several factors came together and brought the uranium boom to an end. The first was a slump in the vanadium market, which occurred in 1961. As demand for the alloy metal decreased, so did prices, and hence, the profitability of ore production and milling. In the following year, the AEC dismantled more of its industry support program. Specifically, in 1962, the AEC allowed Domestic Uranium Program Circular No.5 to expire, which offered production incentives and high prices for carnotite. At the same time, the AEC also allowed the mining leases on its uranium reserves to lapse, effectively taking a number of mines out of action. In 1963, the AEC dealt the uranium industry another blow. The agency announced that it would no longer purchase the vanadium byproduct of uranium production, forcing the metal to respond to free-market conditions. Originally, the AEC purchased vanadium in support of uranium production because the two metals were sister constituents of carnotite ore. By allowing vanadium to revert to the free market, which paid lower prices for the metal, the AEC hoped that uranium production would decrease in tandem.[164]

On the Colorado Plateau, the boom did not implode abruptly and instead gradually disintegrated. As a reflection of this, Montrose and San Miguel counties featured more than twice as many mines between 1961 and 1965 than during the first years of the boom. In addition, most of the mills on the Plateau still treated ore. While Union Carbide closed the North Continent mill at Slick Rock in 1961, VCA reopened its Vancorum mill as a vanadium concentration facility.[165]

The mining industry continued to contract through the rest of the early 1960s as the AEC incrementally repealed its programs. In 1963, VCA closed its Vancorum and Durango mills in favor of a new facility at Ship Rock, New Mexico. Union Carbide reduced its ore production and revised its milling processes to emphasize vanadium instead of uranium and sent the concentrates to the Rifle plant for refining into redcake and yellowcake. The long shipping distances to Ship Rock and Rifle rendered marginal ores uneconomical, which forced many

[162] Gabelman, 1974:76; *Minerals Yearbook*, 1960, V.1:1153, 1181; Taylor and Yokell, 1979:33.

[163] Amundson, 2002:119; Gabelman, 1974:76; Merritt, 1971:542; *Minerals Yearbook*, 1958, V.3:215; *Minerals Yearbook*, 1960, V.1:1153, 1181; Robison, 1969:76; Wright and Everhart, 1960:333.

[164] Hamrick, et al, 2002:48; Nelson-Moore, 1978:1046; *Minerals Yearbook*, 1963, V.1:1195.

[165] Colorado Mine Inspectors' Reports, Montrose County: Foote Mineral; McWhorter, 1977:B-40; Merritt, 1971:542; *Minerals Yearbook*, 1960, V.3:243; the numbers of mines were derived from Colorado Mine Inspectors' Reports.

mines to close. In the Uravan district, USV focused on the higher grades of ore in its mines, and the profit margin for lessees shrank again.[166]

Three principal reasons explain the boom's gradual dissipation instead of an abrupt collapse. First, the AEC's stretch-out program supported a continuous but reduced level of mining because companies were able to mete out their production quotas over the course of ten years. Second, the large companies were deeply invested in mining and milling and were unwilling to simply shut down operations. Last, the numerous leasing parties had nowhere to go, were dependent on the income from mining, and were willing to make the necessary adjustments to survive. And many would do just that until another boom developed ten years later.

Fifth Period of Significance, 1946-1963

In 1963, the fifth Period of Significance for the uranium mining industry in western Montrose and San Miguel counties came to an end. The Period began in 1947 when the Federal Government formulated a strategy to stimulate the discovery, production, and milling of uranium ore. When the Soviet Union detonated its first bomb, the Federal Government responded with a raft of programs that ushered in a Cold War boom on the Colorado Plateau. The uranium mining industry was completely dependent on the government, which strictly regulated the exploration, production, purchase, concentration, and refining of ore. This dependency became painfully apparent during the early 1960s when the Department of Defense's needs approached fulfillment. The AEC repealed its support programs and reduced acquisitions, which forced the mining industry to contract gradually. By 1963, the boom was not only over, but also the mining industry entered a transition period rife with uncertainty.

During the fifth Period, the mining industry in western Montrose and San Miguel counties became associated with trends that were important on worldwide, national, and local levels. On a national level, the counties were among the most important domestic sources of vanadium, which the Department of Defense still sanctioned as a key strategic metal. As in the past, weapons and armor manufacturers used vanadium to make hardened steel alloys. By producing vanadium, the region's mines and mills contributed directly to the nation's arsenal of conventional weapons, which were important during the Cold War. While the largest mines and the mills are strongly associated with this trend, the role of the small mines should not be discounted. They greatly outnumbered the large mines and contributed a significant amount of ore on a cumulative basis.

On both national and worldwide levels, western Montrose and San Miguel counties were directly involved in the AEC's Cold War nuclear weapons programs. During the first half of the 1950s, the two counties constituted one of the most important sources of uranium in the free world. During the latter half of the decade, the counties shared this status with other regions on the Colorado Plateau but remained vitally important. Nearly all the uranium ultimately came from crude ore. Large companies and a preponderance of small lessees produced the ore from the region's mines, and Union Carbide, VCA, and Climax Uranium then concentrated the material into yellowcake in their mills. The AEC purchased all the yellowcake and used most of

[166] Hamrick, et al, 2002:48; McWhorter, 1977:B-40; Merritt, 1971:542; *Minerals Yearbook*, 1963, V.1:1195; Nelson-Moore, 1978:1046.

the material for the development of the nation's Cold War nuclear arsenal. By producing uranium, the region's mines and mills contributed directly to the development of nuclear weapons, the Cold War, and the resultant impacts on the world's social and political structures.

The uranium and vanadium mining industry established trends and events that were important on statewide and local levels. First, western Montrose and San Miguel counties were the epicenter of a boom that lasted through the decade of the 1950s. The boom was so intense that it rivaled most of Colorado's past mineral excitements and brought explosions in population, commerce, community growth, income, popular culture, and social issues. In 1950, at the boom's beginning, Naturita had a population of 483 adults. By 1960, the number of people doubled. Uravan's population increased from 628 adults in 1950 to 1,005 in 1960. These figures only account for permanent residents and fail to include the boom's transient participants.[167]

In the second trend, the AEC and private industry shaped the cultural geography of the Colorado Plateau and left a permanent imprint in Montrose and San Miguel counties. In support of mining, the Federal Government and industry improved the highway system, graded over 1,000 miles of gravel roads, expanded the electrical grid, completed civic improvements, provided medical services, and built schools. Industry invaded most of the formerly empty mesas, and mining camps and isolated residences became home to a disbursed population of workers.

Third, the Federal Government and the mining industry provided some stability to the fluctuations of the boom. Specifically, the industry was the region's economic backbone and principal employer. The economy prospered as never before, and the employment rate remained high.

Last, the Federal Government and private industry created a variety of environmental problems that would last into the present. Massive waste rock dumps at the mines began eroding into drainages and contributed radioactive metals to the San Miguel and Dolores rivers. The millsites became centers of hazardous waste compounded by tailings, chemicals, and heavy metals. Some of this material became airborne while much made its way into local streams and rivers. Ultimately, this contributed to passage of modern environmental legislation.

E 4.8: The Transition Period, 1964-1973

During the mid-1960s, a ray of optimism lifted the mining industry out of its gathering gloom, even though the uranium market remained relatively stagnant. The reasons were twofold. First, the demand for vanadium rebounded and continued upward as national prosperity and consumerism fostered manufacturing. Vanadium was one of the principal constituents of the Colorado Plateau's carnotite ore. Second and most important, nuclear power came close to becoming a reality.

Nearly ten years passed since 1957 when the first commercial nuclear power plant went online at Shippingport, Pennsylvania. By the mid-1960s, the technology was finally advanced

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[167] Schulz, 1977:1950-13; Schulz, 1977:1960-12.

enough to deliver on its promise of widespread application, giving the mining industry its renewed optimism. Nuclear power plants required uranium for fuel, which meant that the new demand for uranium would offset the AEC's acquisition cutbacks. Further, the new demand would be long-term because utility companies sought fuel contracts in five- and ten-year increments for power plants that were designed to last for decades. To help push the uranium demand from weapons over to power, Congress amended the Atomic Energy Act in 1964 to ease some of the Federal control. The Private Ownership of Special Nuclear Materials Act allowed private companies to purchase uranium directly from domestic mills and mines for energy use. The purchases were on paper only, and the AEC still regulated the actual materials-handling and conducted all enrichment of yellowcake into fuel-grade uranium. The Act also prevented the Federal Government from enriching any foreign uranium, thereby protecting the domestic mining industry from competition.[168]

Despite the genuine movement toward an alternative uranium market, the mining industry faced one major problem. Years would pass before the utility companies were ready for uranium shipments because the complex power plants required time to permit and then construct. Regardless, many of the large uranium companies prepared for the future demand by launching exploration campaigns. The Colorado Plateau became busy with drill-rigs, bulldozers, and geologists locating and defining ore formations and preparing them for mining. At the same time, some uranium production continued as the large companies fulfilled their extended AEC contracts and supplied fuel to the few existing nuclear power plants.

Had anyone looked beneath the optimism, however, they would have perceived a mining industry still in immediate trouble. Few independent mining companies existed and even the lessees working corporate claims struggled. As a symptom of the industry's poor state, both overall uranium production and the number of active mines decreased a substantial 30 percent. Between 1961 and 1965, Montrose County had 137 small, 36 medium, and 12 large mines. By the late 1960s, these figures fell to 103 small, 24 medium, and 10 large operations. Similarly, between 1961 and 1965, San Miguel County featured 66 small, 9 medium, and 3 large mines. By the late 1960s, the numbers fell to 50 small, 4 medium, and 3 large mines. Most of these mines produced ore to fulfill the AEC's extended stretch-out contracts and not the nascent nuclear power industry.[169]

The large companies continued their trend of domination as many of the remaining small outfits sold their interests. In particular, a handful of massive corporations used the poor climate to gain a considerable share of the industry. Acutely aware that uranium mining would eventually rise out of the doldrums, Exxon, Gulf Oil, Kerr-McGee, and others that could afford a lengthy wait bought uranium assets and evolved into energy companies. By 1970, oil companies had acquired 50 percent of the best reserves, 70 percent of the low-grade reserves, and 50 percent of the mills on an industry-wide basis. In Montrose and San Miguel counties, however, Union Carbide, Climax Uranium, the Foote Mineral Company, and VCA were still the principal companies, and they leased out all but their most productive mines. Independent outfits and partnerships worked the small pockets of ore while a few leasing companies operated the

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[168] *Minerals Yearbook*, 1964, V.3:1120; Taylor and Yokell, 1979:33; *United States Uranium Mining*, 1984:1, 7.
[169] *Minerals Yearbook*, 1965, V.3:187; the number of mines was derived from Colorado Mine Inspectors' Reports.

medium-sized mines. Of these, the E.J. Johannsen Mining Company of Nucla and the Dade & Shumway Mining Company were the most important.[170]

In 1967, VCA, one of the oldest and largest companies on the Colorado Plateau, succumbed to the uranium industry's dismal climate. The company directors grew discouraged with the stagnant market and proposed a merger with the Foote Mineral Company, which operated throughout the Four Corners region. By merging, the two companies pooled their resources, streamlined their overhead, and strengthened their ability to wait for conditions to improve. The company retained the name of Foote Mineral, leased nearly all the VCA properties in Montrose and San Miguel counties to Climax Uranium, and based its central offices and shops at the Vancorum mill. What amounted to the loss of VCA contributed to a dour atmosphere in western Montrose and San Miguel counties.[171]

During the early 1970s, the uranium mining industry lost the last vestiges of its optimism as market conditions declined from bad to worse, due to a harmonic convergence of factors. First, most of the AEC's stretch-out contracts expired, and the agency made no provisions for additional uranium purchases. The uranium market was now a function of the nuclear power industry, as a government report summarized in retrospect: "Since 1971, the domestic market demand for uranium has come exclusively from utilities for generating electricity with nuclear power."[172] What the report failed to mention was that nuclear power constituted a very limited market.

The second factor that was detrimental to the mining industry explains why the market was limited. Specifically, during the late 1960s, utility companies tantalized the mining industry by placing a number of orders for nuclear power plants, but then cancelled most of these by 1970. Unanticipated costs and passage of the National Environmental Policy Act discouraged the utility companies from building the power plants that they initially ordered.[173]

The third factor was more of a psychological blow than an actual impact. The AEC and Department of Defense turned from mining industry supporter into potential competitors. Until 1970, the Department of Defense had been stockpiling uranium as a strategic material, but now began consuming its reserves instead of soliciting more from the mining industry. In addition, the AEC proposed releasing some of the uranium onto the free market, which would drive prices down farther than they already were. Overall, the uranium mining industry was in its worst state since 1946, which was the last time that the Federal Government stopped its acquisitions.[174]

The Colorado Plateau took the brunt of the mining industry's problems and went bust. Workers lost their jobs as companies closed the marginal mines in favor of the large operations that could produce ore in economies of scale. The low uranium prices offered little incentive for companies to risk capital on exploration and development, which kept the industry from finding ore deposits rich enough to justify production. More than one-half of the mines in Montrose and

[170] Amundson, 2002:111, 136; Clark and Kerr, 1974:20; Colorado Mine Inspectors' Reports: various.
[171] Colorado Mine Inspectors' Reports, Montrose County: Foote Mineral.
[172] *United States Uranium Mining*, 1984:7.
[173] Amundson, 2002:111; *Colorado Mining Year Book* 1970 c.2 p5; *Minerals Yearbook*, 1970, V.1:1139; Taylor and Yokell, 1979:34.
[174] *Colorado Mining Year Book* 1970 c.2 p5; U.S. Department of Energy, 1984:7; *United States Uranium Mining*, 1984:3.

San Miguel counties closed in 1971, and only one-half of this reduced number continued operations into 1973. The total number of mines that were active in Montrose County plummeted from 137 in the late 1960s down to a mere 32 by 1973. San Miguel County suffered a similar trend. As a result, the lack of employment forced many of the region's miners to leave in an exodus. In 1960, approximately 2,900 permanent adults lived in Naturita, Nucla, and Uravan, and by 1970, only 1,700 of these people remained. The economy was devastated and a depression swept the region. Numerous businesses closed and local governments cut back their services for want of tax revenue.[175]

Decisions made by the directors of Climax Uranium played heavily into the wave of mine closures and growing unemployment. Climax Uranium closed nearly all its mines and shuttered the Grand Junction mill in 1970. These mines were now unavailable for lease, and Union Carbide's Uravan mill and Foote Mineral's Vancorum station became the only local ore receiving stations available to miners in Montrose and San Miguel counties.[176]

Unlike Climax Uranium, Union Carbide had no intention of exiting the mining industry and was financially equipped to wait for the market to improve. The company directors understood that nuclear power and its uranium demand would come of age in the near future, and confirming this, utility companies placed a wave of power plant orders during the early 1970s. In preparation, Union Carbide used its resources to strengthen its position in Montrose and San Miguel counties. In late 1970 and 1971, the company took over Climax Uranium's mines, leased some out, but kept many idle for later production. All was not well for Union Carbide in the short-term, however. The limited uranium market forced Union Carbide to close one of its two mills, and the company chose to suspend the Rifle plant instead of Uravan. The reason was that the company's mines generated enough ore to keep the Uravan mill operating, and this mill would be center to the coming revival. In 1973, Union Carbide shut down its Eula Belle Mine on the San Miguel Bench, pulled the pumps, and allowed the underground workings to flood. The mine had been one of the company's largest and most important producers, and the workplace of around 50 miners who lived in nearby Uravan. Union Carbide allowed the Eula Belle to flood because after decades of heavy production, the ore bodies were finally exhausted. This not only reminded the region of the mining industry's abysmal state, but also that the bellwether mines had limited lives.[177]

After reviewing reports and attending meetings with mining industry experts, the AEC realized that the entire domestic uranium industry was on the brink of collapse. Even though the situation was a product of AEC policy, the agency took action to manipulate the uranium market yet again and save the industry. In 1972, the AEC met with Congress and passed another embargo on foreign uranium that minimized competition, which was perceived as a cornerstone of the industry's problems. Much to the relief of the industry, the action ultimately resulted in a revival, but not in the manner expected.[178]

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[175] "Mineral Activities in Colorado - 1970"; "Mineral Activities in Colorado - 1973"; Schulz, 1977:1960-12; Schulz, 1977:1970-13.

[176] McWhorter, 1977:B-43; "Mineral Activities in Colorado - 1970".

[177] Colorado Mine Inspectors' Reports, Montrose County: Eula Belle; *Colorado Mining Year Book* 1970 c.2 p5; McWhorter, 1977:B-21, B-43; "Mineral Activities in Colorado - 1970".

[178] Taylor and Yokell, 1979:55.

When the embargo was announced, foreign uranium producers reacted angrily and petitioned their home governments to block American uranium imports. When this had been done, the principal producers in Australia, Great Britain, and South Africa formed a secret cartel to dominate the international uranium market, control the world supply, and set prices to their liking. Through cooperation, the cartel members succeeded in constricting the global uranium supply and drove prices up, which both increased their profits and inadvertently delivered the American uranium industry from ruin instead of furthering its demise.[179]

As world uranium prices rose, the increase crept into the American market and caused the value of domestic uranium to ascend in tandem, which benefited the American uranium industry in two principal ways. First, utility companies quickly secured long-term fuel contracts with uranium mining companies before the prices increased significantly. Over the course of five to ten years, the typical timespan for contracts, even small price increases translated into lost profits for the utility companies. Their rush for contracts in essence restored a domestic demand for uranium. Second, the overall increase in prices finally rendered American uranium competitive with foreign sources, and the American companies could again operate at a profit.

E 4.9: The Last Boom, 1974-1980

Just as the uranium market began to rematerialize and prices returned to levels conducive to mining, several additional events created the conditions for a boom. In 1974, the Organization of Petroleum Exporting Countries instituted an oil embargo against the United States, which created oil shortages and forced prices to record levels. Suddenly, the nation viewed nuclear power not only as an economic alternative to oil, but also as a domestic power source not subject to the vagaries of foreign entities. As a result, utility companies placed even more orders for nuclear power plants, and to ensure that the move held some permanency, the Federal Government required utility companies both in the United States and abroad to secure long-term contracts for uranium fuel. By 1978, a total of 78 nuclear power plants operated in the United States alone.[180]

High times returned to the uranium mining industry and the dependent communities on the Colorado Plateau. The value of yellowcake surged from $8 to $40 per pound in 1974 and kept climbing to $60 by 1976. At such prices, low-grade carnotite was economical to produce, and medium-grade material was now bonanza-quality ore. The large mining companies such as Union Carbide and Foote Mineral brought their principal mines back into full production while a wave of lessees reopened many of the lesser operations. Independent partnerships focused on the small ore pockets, while a handful of substantial companies worked the medium-sized mines. In Montrose and San Miguel counties, the Sage & Sage Mining Company, the Mendisco Mining Company, and Cleghorn & Washburn were the most important of these outfits, and each held multiple leases. Long Park, Monogram Mesa, and Bull Canyon were the busiest areas on the Plateau during the revival's first several years. As a reflection of this, the number of active

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179 Amundson, 2002:139; Taylor and Yokell, 1979:57.

180 Amundson, 2002:137; McWhorter, 1977:B-23; National Energy Administration, 1984:7; Taylor and Yokell, 1979:6, 9.

mines in Montrose County more than doubled from 32 in 1973 to 79 by 1975. San Miguel County was not as fortunate, and the number of active mines only increased from 20 to 26.[181]

Union Carbide was finally rewarded for its patience and saw its long-term plans come to fruition during the revival. By keeping the Uravan mill open during the last several years, Union Carbide became the region's principal ore buyer. The company not only set records for yellowcake production at Uravan, but also reopened its Rifle mill to receive Uravan's overflow carnotite. General Electric assumed the role of the region's second-most important ore buyer. In 1975, the electrical giant organized the Plateau Uranium Operations division and leased the ore buying station at the old Vancorum mill from Foote Mineral. The mill remained idle, but Plateau Uranium used the station as a staging area to ship ore to an efficient treatment facility elsewhere.[182]

The Eula Belle Mine, closed by Union Carbide in 1973, had been a bellwether for one significant problem that began to undermine the boom. Specifically, the principal ore bodies neared exhaustion after around 25 years of mining. A few industry experts conducted studies and came to the alarming conclusion that the uranium reserves known to exist as of 1974 would not fulfill the long-term demands of nuclear power. Companies resumed intensive exploration during the revival and bored a record number of sample holes, but found relatively few ore deposits of significance. According to projected ore production, the American uranium industry ultimately would be able to meet only one-half of the needs of nuclear power. As a result, in 1977, the Federal Government began to phase out its recently instituted embargo on foreign uranium to make up for the shortfall. In so doing, the Federal Government opened a gate for foreign competition.[183]

Environmental regulations were another issue that undermined the uranium boom. Between the 1930s and the 1960s, Union Carbide, VCA, North Continent, and Gateway Alloys exercised minimal controls over the waste from their mills. Most of the waste was in the form of fine tailings, while the rest was either liquid or dry dust released by ore treatment and handling. The volume of waste was staggering. Treatment of one ton of ore generated approximately 1,960 pounds of solid waste, primarily tailings, as well as 1,000 gallons of water and spent acid. According to conventional milling methods and policies, the companies shunted this effluent either into unlined tailings ponds or directly onto open ground.[184]

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[181] Amundson, 2002:137, 140, 142; Colorado Mine Inspectors' Reports: various; McWhorter, 1977:A-5, B-23; "Mineral Activities in Colorado - 1973"; "Mineral Activities in Colorado - 1975"; *United States Uranium Mining*, 1984:41.

[182] Amundson, 2002:150; Colorado Mine Inspectors' Reports: Foote Mineral; "Mineral Activities in Colorado - 1975" ; "Mineral Activities in Colorado - 1976".

[183] Gabelman, 1974:78; Rodgers, 1974:84; Taylor and Yokell, 1979:9; U.S. Department of Energy, 1984:7, 10; *United States Uranium Mining*, 1984:19.

[184] Clark and Kerr, 1974:50, 63, 67.

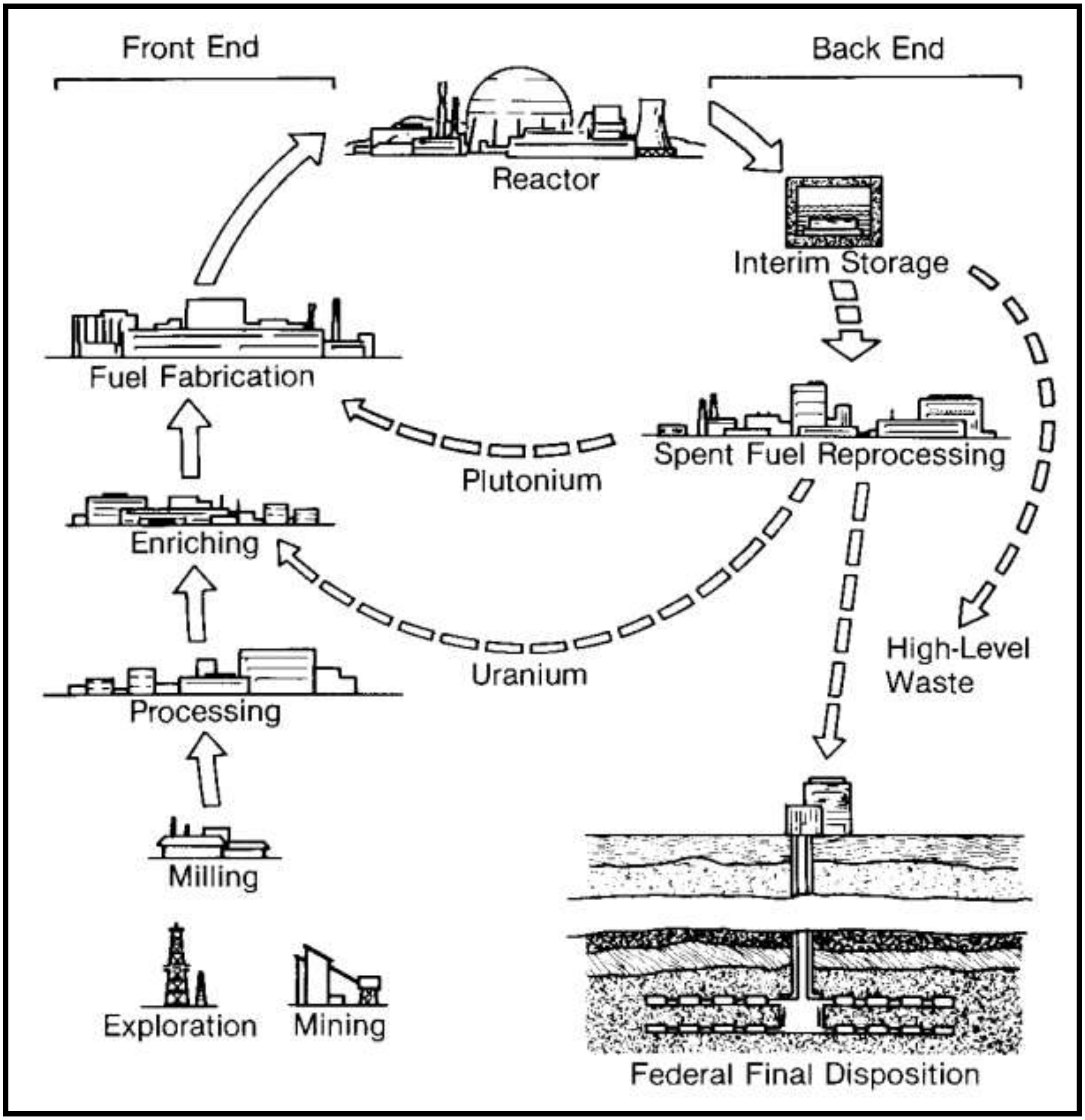

Figure E 4.15: The diagram neatly illustrates the lifecycle of uranium fuel for the nuclear power industry. Western Montrose and San Miguel counties were important centers of exploration, mining, and milling. The Atomic Energy Commission oversaw all steps. Source: U.S. Uranium Mining, 1984:73.

Most of the effluent was laden with heavy metals, chemicals, and radioactive material. Due to inefficient processing, the tailings and liquid waste still contained acid and around 1 to 3 percent of the ore's uranium content. Even when stored in the tailings ponds, the waste made its way into the region's rivers and was mobilized by the wind when dry. As a result, the river corridors and milling communities became heavily contaminated, and the effects were tangible. Effluent from the Durango mill destroyed aquatic life along several miles of the Animas River. At Vancorum, dust that escaped the VCA mill stained rocks and brush carnotite yellow within a one-half mile of the plant. During the 1960s and 1970s, Naturita residents Louise Schad and Ralph Casto saw fish with sores and lumps in the San Miguel and Dolores rivers. Further, Schad's son developed sores after swimming repeatedly in the San Miguel. The communities in western Montrose and San Miguel counties were aware of the radioactive contamination but accepted it because they depended on the mining industry.[185]

The residents of Grand Junction, however, felt otherwise. During the 1960s and 1970s, tailings from the Climax Uranium and other mills were used to backfill utility trenches, and as sand in concrete and construction mortar. After studies found that Grand Junction featured a handful of 5,000 sites that were radioactive, Congress passed the Uranium Mill Tailings Radiation Control Act (UMTRA) in 1978. UMTRA charged the EPA with regulating and cleaning up mill tailings, and required the Department of Energy to publish a list of contaminated sites and identify repositories for the waste. The Federal Government accepted responsibility for the millsites abandoned prior to 1971 and burdened the mining industry with those active afterward. In addition, uranium mining companies had to comply with strict waste disposal regulations beginning in 1981.[186]

While the regulation and cleanups were good for the public, they saddled the mining industry with new layers of costs and complicated their operations. For example, Uravan was engulfed in tailings ponds and Union Carbide ran out of space for more tailings there. During the late 1970s, company engineers designed an innovative pumping system to lift additional tailings up to ponds on edge of Club Mesa, immediately above town. Federal inspectors, however, ordered Union Carbide to stop the practice and find an alternative, which forced the company to suspend the mill for several days. Around the same time, the EPA determined that the entire town of Uravan was radioactive with wind-blown tailings and radon gas wafting off the surrounding ponds, and Union Carbide then had to spend $12 million on tailings stabilization efforts.[187]

Vancorum was only slightly better off, and the river floor around the VCA mill there featured tailings ponds similar to those at Uravan. The tailings, though, were even more radioactive because they retained a higher proportion of uranium and vanadium. This was perceived as a problem until engineers and metallurgists employed by the Ranchers' Exploration & Development Corporation used the uranium as the basis for a solution. The company proposed to recover the uranium still remaining in the tailings, much like the MED had done for the Manhattan Project during World War II. From 1977 through 1979, the Durita Development

[185] Bonner, 2007; Casto, 2007; Clark and Kerr, 1974:50, 63; Eichstaedt, 1994:58; McLeroy, 2007; Schad, 2007.
[186] Eichstaedt, 1994:128; Hamrick, et al, 2002:50; Jackson, et al, 1979:39.
[187] Amundson, 2002:160.

Corporation, a subsidiary, moved the tailings to new ponds and treated them with a heap-leach process. The project was heralded as an innovative success when finished.[188]

In 1979, a gathering undercurrent of problems surfaced and brought Colorado's last uranium boom to an end. One of the subtlest and yet most significant to Montrose and San Miguel counties was the exhaustion of known ore reserves. After almost 30 years of production, mining companies gutted the premier ore beds and were unable to find more that were equal in size and richness. The high uranium prices of the 1970s boom provided mining companies with a strong incentive to produce as much carnotite ore as possible. But because many of the ore bodies were exhausted, the two counties featured only a fraction of the mines that were active during the slump of the 1960s.

The cost of producing and milling ore was another problem that affected the uranium industry during the late 1970s. Compliance with environmental and safety regulations consumed manpower and increased production costs beyond those that the mining industry expected. At the same time, uncontrolled inflation reduced profits significantly, despite soaring uranium prices. Because of these factors, foreign uranium producers were once again competitive with the domestic companies, which were slowly squeezed out of the market.

As if foreign competition was not enough, the domestic mining industry saw the uranium market contract. At first, utility companies cancelled some of their orders for nuclear powerplants due to unforeseen operating costs and inflation, which reduced the demand for uranium. Then, in 1979, a meltdown at the Three Mile Island power plant shook public and government confidence in nuclear power to the core, and utility companies canceled power plant orders outright, even in the face of contract penalties. This devastated the mining industry because it lost both short-run and long-term uranium sales. The utility companies already had more than enough yellowcake to meet their short-run needs and consumed their existing stockpiles, and then dumped the surplus material on an already depressed market, forcing uranium prices down even farther. With few nuclear powerplants expected in the future, the long-term market assumed a bleak appearance, as well. Validating this, the utility companies released only a handful of ten-year contracts for yellowcake, which the mining industry had relied on for stability, and instead solicited five-year contracts and on-demand purchases. Exacerbating a downward spiral, the utility companies increasingly courted foreign producers for immediate sales. The net result was that the price of yellowcake toppled from $60 to only $25 per pound by 1981.[189]

On the Colorado Plateau, the mining industry contracted one last, painful time in a broad sweep. Companies closed most of the marginal mines, scaled back production at the large operations, and shut down one-half of the mills. Montrose and San Miguel counties in particular lost more than one-half of their operating mines by 1981, and around 40 percent of the survivors were abandoned the following year. Union Carbide closed the Uravan mill for the first time in

[188] Colorado Mine Inspectors' Reports, Montrose County: Foote Mineral; "Mineral Activities in Colorado - 1977"; Zambrana and Heath, 1980:141.
[189] Amundson, 2002:142; *Hearing*, 1985:107; U.S. Department of Energy, 1984:10; *United States Uranium Mining*, 1984:9, 39, 41, 45.

40 years and laid off almost half of its workforce, then tried reopening the mill in 1981 and again in 1983, but the price for yellowcake remained too low to sustain operations. Union Carbide closed the mill permanently, which had a profound and compounded effect on the region. With no place to ship ore, most of the remaining mining outfits ceased ore production and suspended exploratory drilling. The lack of jobs stimulated an exodus of workers and their families, who left the region in a depression from which it never recovered.[190]

By the early 1980s, the domestic uranium mining industry was in ruins, and its captains pleaded with the Federal Government for assistance. In response, the government conducted a survey of the industry and found that it was so troubled after uranium prices fell that it was no longer a viable force. Instead of help and protection, however, the government reduced restrictions on foreign uranium to ensure that utilities had enough fuel and that electricity consumers would not, in essence, pay high rates to subsidize the very domestic uranium industry that the government created. The uranium industry had passed the point of a return to prosperity, and on the Colorado Plateau, only 3 of what had been 25 mills treated ore from a handful of mines. Colorado also had the Cotter Mill at Canon City, but this was too far away. In Montrose and San Miguel counties, activity shifted away from uranium production and over to the environmental legacy left from 80 years of mining. The counties featured a number of sites that required environmental cleanup, and heavily contaminated Uravan was the most egregious. In 1984, Union Carbide, its successor Umetco, and the EPA hammered out a 15 year cleanup plan to move and seal the mill, the buildings, and 12.5 million tons of mill tailings. The town's last resident was removed in 1986, all surface manifestations except for the USV boardinghouse were dismantled, and the very ground on which the town stood was scraped away. The VCA mill at Vancorum and the North Continent mill at Slick suffered similar fates. The other communities that had been dependent on uranium, including Naturita, Nucla, Paradox, and Gateway, reverted to their ranching roots and turned toward tourism, which celebrated in part the uranium mining industry.[191]

Sixth Period of Significance, 1974-1980

In 1980, the last Period of Significance for western Montrose and San Miguel counties came to an end. Beginning in 1974, the Period saw the uranium mining industry experience a brief boom as the nation looked toward nuclear power as an energy alternative to foreign oil. Rapid increases in uranium prices and the popularity of nuclear power delivered the flagging industry from the brink of failure and into a substantial boom. The Colorado Plateau, and Montrose and San Miguel counties in particular, rose out of a depression and returned to a state of prosperity. The boom was, however, short-lived and collapsed by 1980. In Montrose and San Miguel counties, the largest and richest ore bodies were exhausted after 30 years of continuous mining, and exploratory drilling found few replacements despite the fact that a record number of sample-holes were bored. At the same time, utility companies cancelled orders for nuclear

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[190] Amundson, 2002:151, 160; Hamrick, et al, 2002:49; "Mineral Activities in Colorado - 1980"; "Mineral Activities in Colorado - 1981"; "Mineral Activities in Colorado - 1982".
[191] Amundson, 2002:143; Hamrick, et al, 2002:50; *Hearing*, 1985:7, 8, 100.

power plants, which greatly restricted both short-run and long-term demands, and dumped their stockpiles of yellowcake onto a shrinking market. As uranium prices fell, the production costs for domestic companies rose, and the domestic companies had difficultly competing with foreign producers. The utility companies then increasingly turned to the foreign producers for their needs, which further squeezed the domestic mining industry. In 1984, the Federal Government repealed nearly all tariffs on foreign uranium to ensure that the utility companies had a reliable supply of fuel, which finished marginalizing the domestic mining industry.

Even though the 1970s uranium boom was short-lived, the event is associated with trends that were important on local, statewide, and national levels. On a local level, the boom resuscitated the mining industry in western Montrose and San Miguel counties. As occurred during the 1950s boom, the mining industry was the most important employer, economic foundation, agent of growth, and source of population for the two counties. In addition, the mining industry reinforced the cultural geography of the Colorado Plateau.

On a statewide level, the boom allowed Colorado to retain its title as one of the most important sources of uranium and vanadium in the free world. A significant proportion of the uranium produced during the boom came from Colorado, and in particular Montrose and San Miguel counties.

On a national level, the boom fostered the rise of nuclear power. The domestic mining industry made nuclear power possible because it was the principal supplier of uranium fuel. The nation's utility companies in turn encouraged domestic uranium mining because they constituted a market for the industry's products. Even though nuclear power lost some of its popularity after the Three Mile Island meltdown in 1979, it remained, and still is, a major source of electricity in the nation. Because Montrose and San Miguel counties were important uranium contributors during the boom, the mines and millsites that were active during the late 1970s are associated with the above trend.

E 4.10: Epilog

The history of mining on the Colorado Plateau did not end during the early 1980s and instead entered another cycle of bust in between periods of boom. The energy crisis of the early twenty-first century and China's rise as an industrial power has renewed a strong interest in both uranium and vanadium. The region still offers carnotite left in place because it was too low of a grade to be economical to produce as of the early 1980s. Escalating metals values combined with improved milling methods, and even the potential of a new mill in Paradox Valley, have created the conditions for another boom on the Colorado Plateau. The present wave of claim activity and mining permits may be the beginning of the region's next Period of Significance.

E 5: MINING AND MILLING TECHNOLOGY, METHODS, AND EQUIPMENT

E 5.1: Introduction

Western Montrose and San Miguel counties were celebrated as some of the world's most important sources of radium, uranium, and vanadium. These radioactive metals occurred together in carnotite ore, which was largely an altered form of sandstone. Roscoelite, also in sandstone, carried high proportions of vanadium and small amounts of uranium, and it was limited primarily to the area around Placerville in San Miguel County. The host sandstone beds for both types of ore were geologically similar to the conditions associated with coal beds. They were relatively flat and predictable, and they lay underneath layers of cap rock. Because of this, mining companies adapted coal mining methods to develop and extract carnotite deposits from the beginning of uranium production in the 1900s. However, carnotite and roscoelite mines tended to be simpler, smaller, and equipped with lighter duty facilities than coal mines. The methods used to produce carnotite and concentrate the radioactive content were fairly universal and saw broad application across the Colorado Plateau. Below is a discussion of the general methods and technologies used to find, extract, and concentrate carnotite and roscoelite ore.

E 5.2: Carnotite and Roscoelite Mining

E 5.2.1: Prospecting for Carnotite Ore

Finding beds of carnotite was the first step in uranium mining, and three methods were used, depending on timeframe. Between the late 1890s and the early 1920s, prospectors adapted traditional methods to the sedimentary geology of Montrose and San Miguel counties. During the late 1890s and early 1900s, the first years of uranium exploration, prospectors learned to identify carnotite ore by its canary-yellow appearance. At the same time, assayers became aware that uranium was the principal constituent of interest in carnotite and tested samples for the metal. Through visual conformation and submitting samples to assayers, prospectors discovered a number of carnotite ore formations exposed in the sandstone cliffs and ledges of the region's mesas. Within a short time, they realized that the distribution of the formations followed a predictable pattern. Specifically, the deposits were limited to what geologists later termed the Salt Wash Member (component) of the Morrison Formation, which was a sandstone layer well-defined in the region's mesas.

Once prospectors identified this pattern, they knew to limit their searches to the horizontal Morrison Formation. Further, educated individuals also understood that beds of green shale sandwiched the ore-bearing portion of the Salt Wash Member, and they restricted their examinations to this stratum. Because the Morrison Formation was well-exposed, the prospectors merely had to clamber along its cliffs and ledges and watch for the yellow staining of carnotite or the dark gray of vanadium oxide.[192]

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[192] Coffin, 1921:188.

When prospectors encountered color, they applied traditional nineteenth century methods to determine the ore body's size and quality, and track its extent. Specifically, the prospectors used picks to pry loose overlying sandstone slabs and dynamite to blast exploratory pits and trenches into solid rock. When these excavations proved positive, the prospectors may have driven short adits into the cliff to probe the ore body's horizontal extent. If the ore body was large, as every prospector hoped, the party abandoned the adits, moved some distance away from the cliff, and sank shallow shafts through the overlying sandstone cap rock. With the shafts, the prospectors were able to track the ore body and find its limits.[193]

During the 1900s and 1910s, the prospectors employed conventional drilling and blasting practices to drive the underground workings. After clearing away as much fractured, loose bedrock as possible with pick and shovel, a pair of prospectors began boring blast-holes with a hammer and drill-steels. They often bored between 12 and 18 holes, 18 to 24 inches deep, in a special pattern designed to maximize the force of the explosive charges they loaded. Some parties used blasting powder because it was effective in sandstone and inexpensive, and most relied on stronger but more costly dynamite. Until the party confirmed that the ore body possessed carnotite in economic volumes, the operation was classified as a *prospect*.

Individuals and small parties were by no means alone in the search for carnotite. Large companies such as the Radium Company of Colorado and Standard Chemical hired professional prospectors and engaged in systematic explorations of both their existing claims and new ground. Company geologists reasoned that carnotite deposits were not limited to cliffs and ledges and instead occurred throughout the Salt Wash Member, even when underneath cap rock. During the vanadium boom of the 1910s, they began strategic drilling and sampling in Long Park, on claims where ore-bearing sandstone was not exposed. As expected, drilling crews encountered ore, and the companies then carried this new prospecting method to other mesas in the region.[194]

The companies used four general methods to bore sample holes, depending on anticipated depth and location. For depths less than 15 feet, workers manually bored holes with drill-steels or weighted chisels suspended on ropes. Most companies, however, used rockdrills. Conventional drills had depth limitations of 35 feet and required the support of trailer-mounted, portable air compressors. Gasoline-powered units could bore deeper holes but consumed water, which was in short supply on the arid mesas. The companies used churn drills and diamond drills for deep exploration, and these apparatuses provided positive samples from measurable depths. In most cases, companies planned the holes according to a grid so that the exact shape, size, and hence volume of the ore body could be accurately measured. In all cases, workers watched the drill-cuttings for color as they came out of the holes.[195]

[193] Kithil and Davis, 1917:18.
[194] Coffin, 1921:191; *Mineral Resources*, 1918:812.
[195] Coffin, 1921:191.

Figure E 5.1: This 1910s diamond drilling crew embarked for a lengthy exploration campaign in Montrose County. The truck and trailer carried camp supplies and drilling equipment. The amount of capital required for drilling limited this exploration method to the region's large companies. Source: Denver Public Library, Z-7844.

Drilling for samples established a precedent and changed the landscape of prospecting across the Colorado Plateau. While individuals and small parties continued to peruse the mesa rims for color, the use of mechanical drills diminished the role of the traditional prospector in the uranium mining industry. Because the drills required more capital than most prospectors were willing to spend, the bore-hole method remained the domain of organized companies.[196]

The trend toward sample drilling and away from traditional prospecting increased during the 1950s uranium boom, although individual prospectors did enjoy an important role in the beginning. Science and technological developments gave nuclear-era prospectors with little capital the tools to make meaningful discoveries of ore.

Through intensive studies of the Morrison Formation, the U.S. Geological Survey (USGS) identified specific indicators of ore and published the findings for prospectors. The USGS also confirmed local lore and found that milk vetch, a plant species, favored uranium-rich soils, and those plants with a high uranium content took on a purplish hue.[197]

In terms of affordable technology, prospectors used photographic plates, Geiger counters, and scintillometers to detect radiation. While each instrument had a role in prospecting, the Geiger counter had the greatest impact. Invented by Hans Geiger in 1908, the device registered

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[196] *Mineral Resources*, 1918:812.

[197] Blackman, 1951:9; Boardman, et al, 1956:22; Bruyn, 1955:95; *Uranium Prospectors' Handbook*, 1954:44; Weir, 1952:26; Wood and Lekas, 1958:213.

beta and gamma radiation but remained strictly a scientific instrument for decades due to its cost and cumbersome size. The first semiportable model weighing 40 pounds was developed in 1939, and a handheld unit was released six years later. The uranium boom fostered a demand for light and durable types that ran on standard dry-cell batteries, which manufacturers offered in abundance by the late 1940s.[198]

With Geiger counters, prospectors engaged in rim-walking, which was the boom-era term for traversing sandstone cliffs in search of carnotite. Where sandstone bedrock was exposed, Geiger counters were unsurpassed, but only several feet of soil blocked radiation readings. Therefore, when examining soil-covered terraces and mesa tops, expert prospectors knew to walk transects or take readings according to a grid and isolate areas with high background readings. Once on a likely tract, the prospectors had to revert to the nineteenth century practice of excavating trenches and pits to expose fresh rock for accurate readings. If loose specimens seemed radioactive but bright yellow carnotite was not immediately obvious, the prospectors often brought them to camp or home to test their richness with photographic plates. Radioactive minerals had the ability to expose photographic film, and an intense exposure suggested that the specimen was rich.[199]

Scintillometers performed similar to Geiger counters and were so sensitive that they could read the subtle radiation filtered by overburden soils. The devices required exacting attention, fine adjustments, and their purchase prices started at $290, which placed them beyond the means of most prospectors. The superior performances of Scintillometers gave capitalized mining companies an advantage in the search for radioactive ores. By mounting the scintillation tube on a jeep or an airplane, transects could be traversed over areas unreadable with Geiger counters, and hence more acreage could be sampled.[200]

Both Geiger counters and scintillometers were powerless to find ore beds concealed underneath sandstone cap-rock, as most deposits were. As a result, sample drilling remained the primary means for discovering economical carnotite formations. The general methodology of drilling changed little from the 1910s, although the technology and hole-spacing had. Rockdrills were still favored because of their low cost, and they were used to bore at least half of all sample-holes during the early 1950s. By this time, powerful units mounted on trucks and trailers could draw core samples from depths of 250 feet. Geologists considered diamond drills to be the best because of a greater depth-capacity, but they were costly to purchase and operate. Rotary drill-rigs replaced churn drills for deep holes. Rotary rigs were the fastest and were mounted to tracked vehicles capable of crawling over the worst terrain, but they were extremely expensive. Churn drills were still used during the 1950s, mostly for the specialized task of pounding holes through loose and unconsolidated ground.[201]

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198 Barnes, 1956:7; Gittus, 1963:21; Grainger, 1958:19; *Uranium Prospectors' Handbook*, 1954:4; Weiss and Orlandi, 1948:47.

199 Barnes, 1956:18; Gittus, 1963:22; Hampton, 1955:17; Knoerr, 1955:125; Proctor, et al, 1954:68; *Uranium Prospectors' Handbook*, 1954:68; Weiss and Orlandi, 1948:51.

200 Grainger, 1958:19; Hampton, 1955:17, 29-30; Knoerr, 1955:135; *Uranium Prospectors' Handbook*, 1954:71.

201 Dare, et al, 1955:14; Fischer, 1942:393; Hampton, 1955:20, 33; McWhorter, 1977:B-10; *Minerals Yearbook*, 1957, V.1:1252.

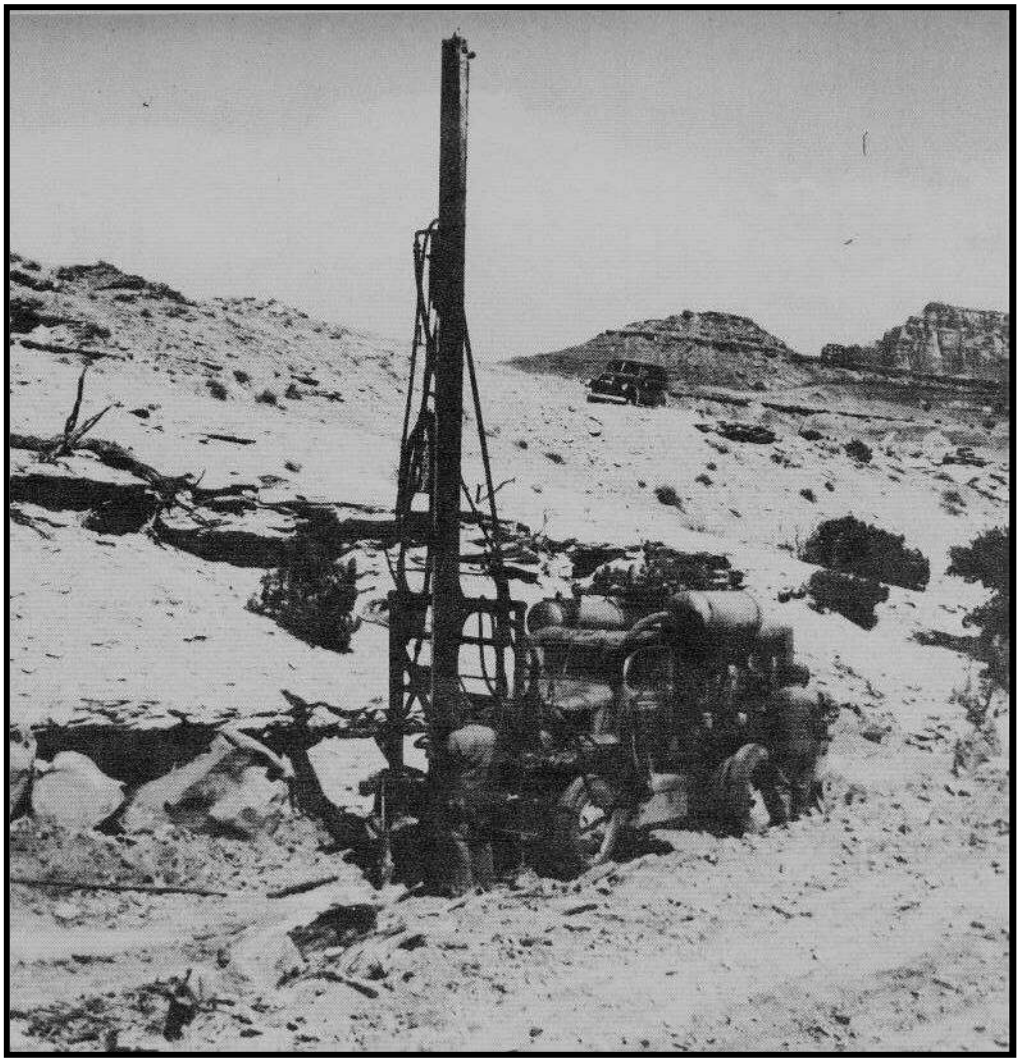

Figure E 5.2: Sample drilling became the most important method for finding beds of carnotite ore by the 1940s. Powerful drills mounted on trucks were able to draw cores from as deep as 250 feet. Source: Dare, 1955:15.

Figure E 5.3: Drill trucks can still be found in the uranium mining region and should be recorded and evaluated. This retrofitted World War II military truck is near the Hanging Flume. Source: Author.

Figure E 5.4: Wagon drills were used to bore relatively shallow sample holes during the 1940s and 1950s. Source: Author.

The Atomic Energy Commission (AEC), the USGS, and exploration companies employed all types of drilling equipment to pepper the region's mesas with sample-holes. Instead of boring the holes at random, however, these entities followed a general strategy. First, they focused on those mesas that featured the Morrison Formation. Then geologists planned survey grids in which holes were bored 500 to 1,000 feet apart. When ore was encountered, the geologists drafted a second, localized grid to determine the extent of the deposit, and spaced the holes 50 to 200 feet apart. Once they knew the ore body's general location, they may have bored numerous holes to quantify exactly how much ore existed, and hence the body's economical value.[202]

Because drilling depended on vehicles, roads were a necessary aspect of every exploration program. Exploration companies and private contractors hired by the AEC bulldozed thousands of miles of minor roads across the region's mesas to make way for the drill-rigs, only at great cost. Contractors usually charged around $125 per mile in gentle terrain and up to $2,500 per mile when the conditions featured ledges and boulders. Overall, most of the roads in the region were a product of exploration drilling, and some saw secondary use as access to mines.[203]

E 5.2.2: Types of Mines and the Development and Production of Ore Bodies

As a general category, uranium mines were mostly underground operations that produced carnotite ore. Depending on the era, the carnotite was refined for radium, vanadium, or uranium. The area around Placerville, San Miguel County, featured mines that yielded roscoelite ore, which was almost exclusively a vanadium ore with some uranium. Most of the uranium operations in western Montrose and San Miguel counties belong to six general types, which are rim mines, tunnel mines, inclined tunnels, inclined shafts, vertical shafts, and open-cuts.

Regardless of exact type, most uranium and vanadium mines shared a few basic similarities. One of the most fundamental was the physical manifestation of the ore bodies, which affected the mining process. Specifically, the ore bodies were flat to gently sloped beds sandwiched between layers of sandstone and mudstone (see description of geology at beginning of Section E). These geological conditions were similar to those of coal seams, and for this reason, mining companies adapted coal mining methods to carnotite and roscoelite beds.

At the point where a tunnel or shaft penetrated the ore bed, miners *developed* the formation with internal workings. A main *haulageway* passed deep into the bed, and it accommodated traffic to the surface. *Crosscuts* extended 90 degrees off the haulageway and into the ore body, and these were both exploratory and the points from which the miners stoped (extracted) the ore. As with coal mining, miners employed the room-and-pillar system of stoping. As they removed the ore, the miners created rooms and left pillars of native rock between to support the relatively flat ceiling. When a mine was on the brink of exhaustion, the miners then pulled (blasted out) the pillars for the ore that they offered. Because carnotite beds were irregular in shape and size, the room-and-pillar was only approximate.

Another similarity among uranium and vanadium mines was that they were much simpler and more austere than their hardrock counterparts in the mountains. The physical conditions of carnotite deposits were one reason for the simplicity. Because sandstone was relatively soft rock and the carnotite deposits were shallow, advanced, heavily equipped surface plants were not

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[202] Dare, et al, 1955:12; Fischer and Hilpert, 1952:1; Motica, 1968:812; Wood and Lekas, 1958:213.
[203] Hampton, 1955:43.

necessary. Economic factors were another reason for simplicity, and they discouraged the installation of costly and complex equipment. Because carnotite ore fetched a relatively low value per ton, as opposed to hardrock ores, the income from uranium mining was limited and outfits had less to reinvest in their mines. In addition, lessees with little capital operated most of the mines, and they tended to lack economic resources. During the 1950s, for example, the typical small outfit had little more than a portable air compressor, several rockdrills, and a wheelbarrow or ore car.[204]

The widespread used of portable equipment was a third similarity among uranium and vanadium mines. The uranium industry employed portable equipment perhaps more than any other type of mining, and the industry absolutely depended on trucks for transportation. Portable equipment was self-contained, free-standing, and ready to use. Trucks allowed the operators to service their equipment and dull drill-steels at central shops in Uravan, Vancorum, and Naturita.

The above factors and conditions directly influenced the surface expressions of uranium and vanadium mines. In general, the mines were very basic and had few permanent surface facilities. Small and medium-sized mines often lacked buildings, blacksmith shops, and stationary machinery of any sort. Only the largest operations featured surface plants with stationary equipment and buildings, and even these were limited in scale relative to the volume of production.

The principal difference between the six general categories of uranium and vanadium mines was the specific means of penetrating and accessing the ore bed. Topographic conditions, closeness to the surface, and anticipated production were the most influential factors. Each type of uranium and vanadium mine possessed clearly distinguishable characteristics.

A rim mine was a specific type of operation located amid the cliffs and ledges of the region’s mesas. The cliffs and ledges formed abrupt boundaries between the mesas and valleys, which is why they were recognized as rims. In rim mines, outfits produced ore from carnotite pockets either directly exposed in the cliffs or embedded a short distance behind. The easily accessed ore pockets required almost no formal development beyond short tunnels, flat working areas, and ore storage structures. Miners merely stoped the ore directly from the sandstone formations as they encountered the material until the pockets were exhausted. Because of this, rim mines required little infrastructure and therefore tended to be very simple and shallow.

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[204] *Mesa Miracle,* 1952:17; “Uranium Activity on the Colorado Plateau” 1952.

Figure E 5.5: Rim mines were so named because they were developed in the sandstone cliffs, or rims, of the region's mesas. As the photo illustrates, rim mines were confined to the same horizontal beds, were relatively limited in size, and were developed through tunnels. Source: Author.

A tunnel mine was an operation based around a lengthy horizontal opening known as a tunnel. When a body of carnotite ore was discovered through sample drilling, a mining outfit had the choice of developing it either through a tunnel or a shaft. If the ore body was within one-thousand feet of a mesa rim or underneath thick layers of cap-rock, the outfit often chose a tunnel. The reason was that tunnels were easier and less costly to bore and operate than shafts. In general, tunnels were at least several hundred feet long and at least 3 by 6 feet in-the-clear to accommodate mine traffic.

Figure E 5.6: The Rex No.38 Mine in Eagle Canyon is a sound example of a tunnel operation. Distinguishing characteristics include a lengthy tunnel, a voluminous waste rock dump, an ore bin, and a trestle. Source: Author.

An inclined shaft mine was an operation based around a shaft that descended underground at a steep but not vertical angle. The uranium mining industry distinguished an inclined shaft by the pitch of descent, which had to be 25 degrees or more.[205] Inclined shafts were a product of exploratory drilling, and mining outfits sank them to develop ore beds landlocked underneath layers of sandstone cap-rock. Mining outfits chose inclined shafts over horizontal tunnels and vertical shafts due to economic and environmental conditions. Vertical

[205] Dare, et al, 1955:21.

shafts were superior in performance and production capabilities, but they were much more costly to sink, engineer, and equip. Similarly, tunnels were uneconomical and even impossible if the ore beds were far from mesa rims. Inclined shafts were well-suited when the ore beds were relatively close to the surface, which allowed the associated hoisting systems to be light in duty. Because uranium mines tended to be remote, such light and easily installed equipment translated into capital savings. An additional benefit to the simplicity was that experienced miners instead of formally trained engineers were able to assemble the surface facilities. As a result, parties that leased claims from large holding companies favored inclined shafts.

Figure E 5.7: The Donna K Mine exemplifies a typical inclined shaft site. An inclined trestle ascends out of the shaft and terminates on a hoist frame. The trestle carried a track that forked on the substantial waste rock dump, and one branch extended to an ore bin while the other ended on the dump. Miners parked a portable air compressor, now gone, to the right of the shaft, and a frame hoist house stood on the hoist frame. Source: Author.

An inclined tunnel mine was a type of operation based around a tunnel that descended underground at a gentle angle. The uranium mining industry distinguished an inclined tunnel from an inclined shaft or a horizontal tunnel by the pitch of descent. Specifically, for an entry to qualify, its angle had to be between 10 and 25 degrees. Mining companies drove inclined tunnels to develop landlocked ore beds discovered underneath layers of sandstone cap-rock by exploratory drilling. Companies chose inclined tunnels to reach the ore beds because they were an economical compromise between shafts and horizontal tunnels. Inclined tunnels proved effective when the ore body was too far from a mesa rim for a horizontal a tunnel and yet too close to ground-surface to justify the expense of a shaft.[206]

Figure E 5.8: The Long Park No.1 Mine is an excellent example of a large, formally engineered vertical shaft dating to the 1950s Cold War uranium boom. The mine features a lofty four-post derrick steel headframe, a frame hoist house, and a factory-made ore bin. A skip hoisting vehicle automatically dumped rock into the chute. If the material was ore, a swinging gate diverted it into the bin. If the material was waste rock, it accumulated on the ground and then was bulldozed away. Source: Author.

A vertical shaft mine was an operation based around an opening that descended straight down. Mining companies sank vertical shafts to develop deep ore beds discovered through exploratory drilling. Vertical shafts were superior in performance and production capabilities to inclined shafts, and they were the shortest route through sandstone cap-rock to a given ore bed.

[206] Dare, et al, 1955:21.

Because vertical shafts required formal engineering and were much more costly to sink, engineer, and equip, they were the domain of large, well-capitalized companies.

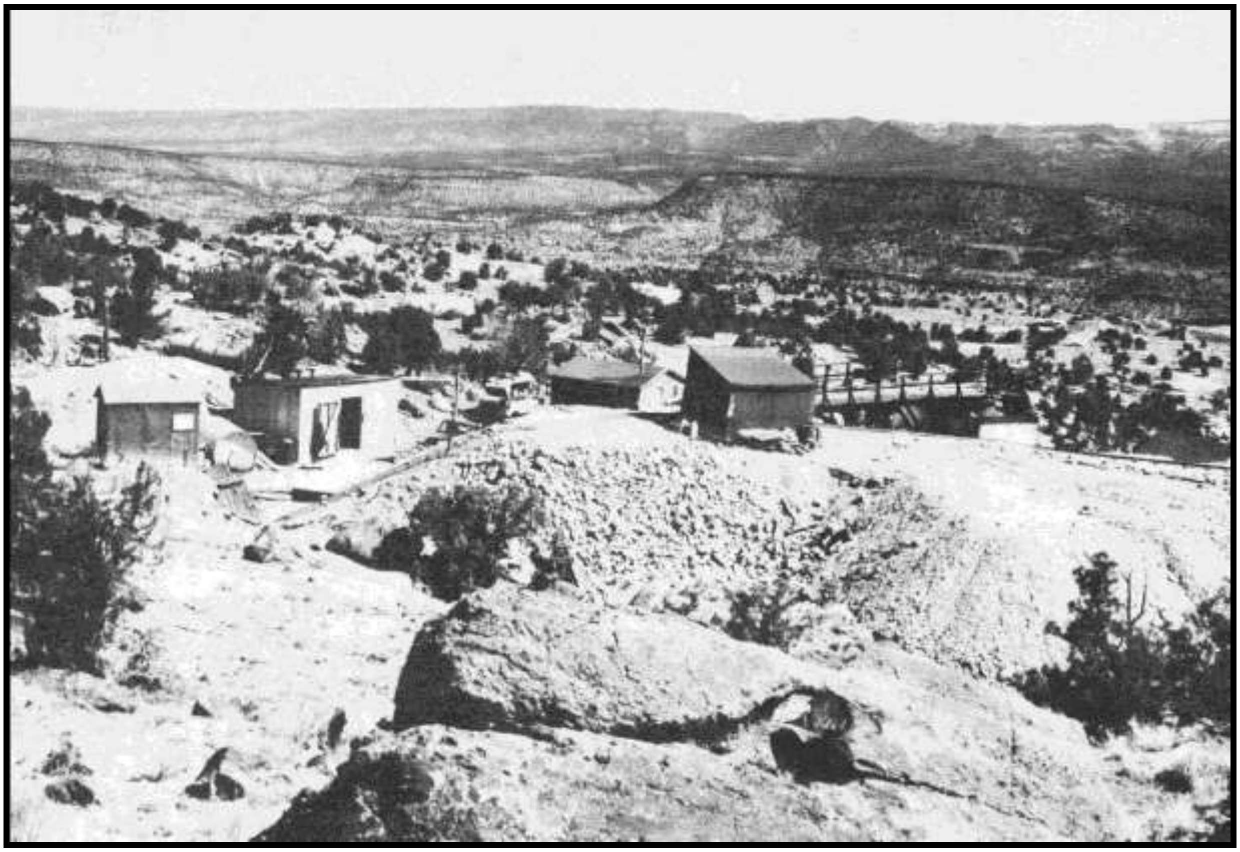

Figure E 5.9: The photo illustrates a surface plant typical of medium-sized and large mines. The mine in the photo may be either a horizontal or inclined tunnel operation. The surface plant features several frame buildings, an ore bin and trestle, and a portable air compressor. Note the small sizes and simplicity of the buildings, which appear to be of frame construction sided with tarpaper. Dare, 1955:22.

E 5.2.3: The Mine Surface Plant

Driving underground workings required support from on-site facilities. Known among miners and engineers as the *surface plant*, these facilities were equipped to meet the needs of the work underground. Regardless of whether the operation was small or large, the surface plant had to meet several fundamental needs. First, the plant had to provide a stable and unobstructed entry into the underground workings. Second, it had to allow for the transportation of materials into and waste rock out of the underground workings. Third, the workings had to be ventilated, and fifth, the plant had to facilitate the storage of up to hundreds of tons of ore between shipments. Productive mines had additional needs that depended on the type of entry bored into the ore bed.

The surface plants for the six general types of mines shared many of the same components. Rim and tunnel mines possessed the simplest surface plants, and their facilities were universal. The principal difference with inclined tunnels and shafts was their additional need for hoisting systems. Following is a list and description of the principal components found at most uranium and vanadium mines. The definitions are based on standards recognized by the hardrock mining industry.

E 5.2.3.1: The Tunnel Portal

The tunnel portal was a primary component of rim and tunnel mines. Professionally trained engineers recognized a difference between prospect adits and production-class tunnels. Height and width were the primary defining criteria. A production-class tunnel was wide enough to permit an outgoing ore car to pass an in-going miner, and headroom had to be ample enough to house compressed air lines and ventilation tubing. By the 1910s, most mining engineers defined production-class tunnels as being at least 3½ to 4 feet wide and 6 to 6½ feet high. Anything smaller, they claimed, was merely a prospect adit.[207]

Mining engineers paid due attention to the tunnel portal because it guarded against cave-ins of loose rock and soil. Engineers recognized *cap-and-post timber sets* to be best suited for supporting both the portal and areas of fractured rock further in. This ubiquitous means of support consisted of two upright posts and a cross-member. To assemble the set, miners cut square notches into the posts, nailed on the cap, and raised the set into place. Afterward, the miners hammered wooden wedges between the cap and the tunnel ceiling to make the set weight-bearing.

[207] Twitty, 2002:25, 36.

E 5.2.3.2: Mine Transportation

Miners working underground generated tons of waste rock that had to be hauled out, while tools, timbers, and explosives had to be brought in. As a result, mining companies had to rely on some form of a transportation system. The smallest and most primitive operations employed wheelbarrows, which were inexpensive but offered a limited carrying capacity. Ore cars on steel rails were the most common system from the 1900s through the 1970s. In mines with extensive underground workings and high volumes of production, some outfits used compressed air-powered locomotives to pull trains of ore cars to the surface. Battery and trolley locomotives, however, saw little use because of their broad gauge and need for large-radius curves.[208]

Figure E 5.10: Wheelbarrows were among the most commonly used conveyance for hauling rock out of small mines. Wheelbarrows were inexpensive and maneuverable but had a limited carrying capacity. Source: Dare: 1955:39.

Ore cars ran on rails that mine supply houses sold in a variety of standard sizes. The units of measure were based on the rail's weight-per-yard. Light-duty rail ranged from 6 to 12 pounds-per-yard, medium-duty weight rails included 12, 16, 18, and 20 pounds-per-yard, and heavy rail weighed from 24 to 50 pounds-per-yard. Leasing outfits usually purchased light-duty rail because of its transportability and low cost. Mining engineers erecting production-class transportation systems had used at least medium-duty rail because it lasted longer.[209]

[208] Dare, et al, 1955:40; Fischer, 1942:394; Wood and Lekas, 1958:215.
[209] Twitty, 2002:37, 114, 116.

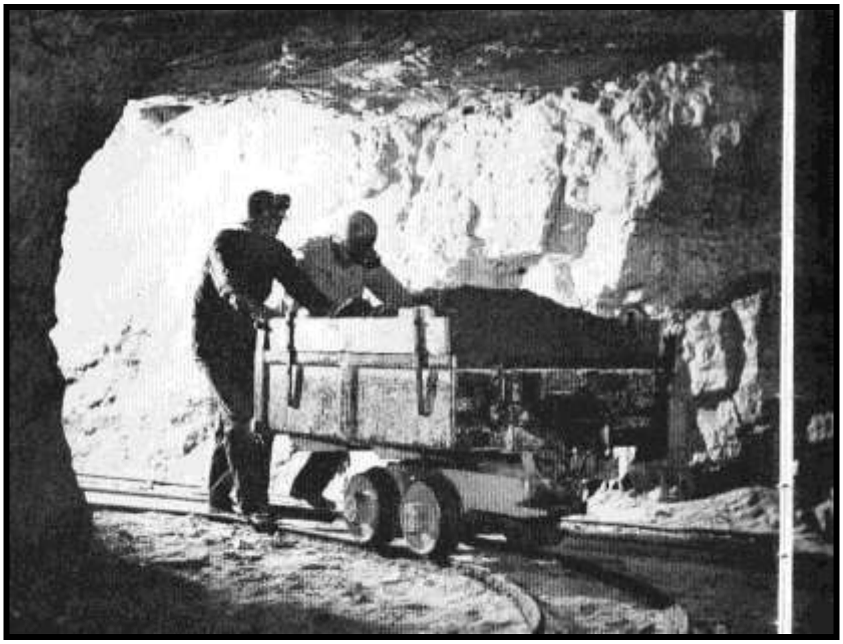

Figure E 5.11: Ore cars were the most popular means used to haul rock out of productive mines during the uranium industry's history. They carried between one and two tons of material. Mesa Miracle, 1951:6.

Trackless haulage vehicles were a popular alternative to the ore cars in uranium mines. Equipment manufacturers offered a few models of vehicles during the 1940s, and as the variety increased through the 1950s, uranium mining companies began adopting the technology. By the 1960s, the mining industry made extensive use of several basic types of vehicles. One was a self-contained buggy with three or four tires, a dumping bed for the ore, and a driver's seat. Another was a small tractor that pulled trailers with dumping beds. A third was a low truck with four wheels and a large bed that dumped. All four types of vehicles held distinct advantages over traditional ore cars. Because they were not limited to tracks, miners could drive them throughout underground workings. In addition, the vehicles could easily be relocated to another mine once a property had been exhausted. However, the vehicles were not economical for small operations because they were costly, required maintenance, and fouled mine atmospheres with exhaust, which then required ventilation systems to mitigate. In addition, a mine's underground workings had to be wide enough to allow the vehicles' passage, which increased the initial costs of underground development. Tunnels had to be at least 6 feet wide and 6 feet high, and their floors smooth.[210]

[210] Casto, 2007; Chenoweth, 1993:34; Dare, et al, 1955:44; Dare, 1959:9; Perry, 1981:120.

Figure E 5.12: The uranium industry began using trackless haulage vehicles during the 1950s. The vehicles replaced ore cars, required no tracks, and allowed miners to haul out more rock. Source: Author.

E 5.2.3.3: Compressed Air Systems

Blasting was of supreme importance to mining because it was the prime mover of rock underground. During the 1900s and 1910s, miners drilled holes by hand, loaded them with explosives, and fired the rounds. Even though sandstone was relatively soft rock, hand-drilling proved slow, but few mining companies were willing to employ faster mechanical rockdrills. The remote nature of western Montrose and San Miguel counties made the costs of hauling in and installing the necessary compressed air systems high. Regardless, some of the largest companies such as Standard Chemical provided their miners with rockdrills in an effort to increase ore production.

By the 1930s, mining companies accepted rockdrills as the universal machine for boring blast-holes. In large mines, workers also used drag-lines to scrape ore to loading areas, and pulled trains of ore cars to the surface with compressed air locomotives. All but the early, labor-intensive mines featured compressed air systems to run such machinery.

While exact configuration, complexity, and constitution varied by mine, the general format for compressed air systems were the same. The air compressor lay at the heart of the system, and it compressed air filtered from the atmosphere. The machine's compression cylinders pushed the air through valves into plumbing connected to an air receiving tank, which moderated the flow of air and pulsations created by the compression pistons. A compressed air main then left the tank and carried the air to points of use underground.

Air compressors operated off a basic principal in which the movement of its pistons compressed and then pushed the air into the system's plumbing. The volume of air that a compressor delivered, measured as *cubic feet of air per minute* (cfm), depended on the cylinder's diameter and stroke, as well as how fast the machine operated. The pressure capacity, measured as *pounds per square inch* (psi), depended in part on the above qualities as well as how stout the machine was, its driving mechanism, and on check valves in the plumbing. Generally, high pressure, high volume compressors were large, strong, durable, complex, and as a result, expensive.

Table E 5.1: Air Compressor Types, Timeframes, and Capital Investment

Compressor Type	Age Range	Capital Investment
Upright: two cylinders, belt-driven	1900s-1940s	Low
Straight-line, single cylinder, gasoline engine driven	1900s-1930s	Low
Straight-line, single cylinder, belt driven by motor	1900s-1940s	Low
Duplex, dual cylinders, belt-driven	1900s-1950s	Moderate to high
V Pattern, belt-driven by motor or gasoline engine	1930s-Present	Moderate to high
Portable, two cylinders	1910s-1970ss	Low
Portable, four cylinders	1930s-1970s	Moderate

The uranium mining industry employed the general types of air compressors that were popular from the 1900s through the 1970s. As noted above, most mining outfits favored portable equipment over stationary machinery, and they continued this preference with compressors. The principal mining outfits made use of portable compressors as early as the 1910s because they were mounted on trailer frames that could be towed to the mines. The common design consisted of an upright two-cylinder compression unit powered by a gasoline engine. While machine tolerances and efficiencies improved, this configuration changed little for small portable compressors through the 1970s. By the 1930s, high-capacity units with four cylinders and more powerful engines were available.

Figure E 5.13: Most uranium operations employed portable compressors instead of stationary units because of their mobility. The unit in the photo is typical of the compressors used from the 1910s through the 1930s. Source: Author.

Figure E 5.14: Between the 1950s and 1970s, mining companies used portable compressors similar to the unit in the photo. Source: Author.

At particularly large mines with heavy air demands, portable compressors were insufficient, and in response, mining outfits employed stationary units. *Straight-line gasoline compressors* were popular from the 1910s into the 1930s because they were ideal for remote operations. These machines consisted of a large horizontal compression cylinder linked to a single cylinder gas engine, which required a substantial foundation capable of withstanding intense vibration. Large gasoline machines were capable of producing up to 150 cubic feet of air at 90 pounds per square inch, which permitted mining companies to run up to two small rockdrills.[211]

At the same time, an *upright two-cylinder compressor* with valves and a crankshaft like an automobile engine became popular. These units were inexpensive, adaptable to any form of power, and weighed little. Further, mining machinery makers had mounted them onto simple wood frames for mobility.

Between the 1900s and 1950s, *duplex compressors* were the most popular stationary units at medium-sized and large mines because of their high air capacity. These machines featured dual compression cylinders in a parallel configuration. A main driveshaft with a massive flywheel linked the cylinders, and a belt passed around the flywheel to the drive engine.

The popularization of the automobile engine gave rise to several alternative forms of compressors based on engine mechanics. *V-cylinder compressors*, also known as *feather valve compressors*, were adaptations of large-displacement truck engines and featured three to eight cylinders arranged in a "V" configuration. This design, which gained popularity during the 1930s, relied on a grossly enlarged radiator for cooling and was powered by a gasoline engine or electric motor.

E 5.2.3.4: Ore Storage

Ore production was the principal purpose behind uranium mining. When miners brought ore out of a mine, they rarely dumped it directly on the ground because it was difficult to load into trucks for shipment and became mixed with waste. Instead, mining companies erected storage structures that neatly contained the ore and facilitated its transfer. The uranium mining industry employed four general storage structures, and the specific type depended on production levels, the mine's transportation system, and era.

The *ore platform* was the simplest, least costly, and can usually be found at small, rim mines. The platform was little more than a plank floor elevated over a road, and miners input ore by dumping wheelbarrows. Because platforms contained only small volumes of ore, they reflect minor production.

The *ore chute* was another primitive structure usually found at rim mines. A chute consisted of a floor and two walls supported by joists and posts, and miners input ore by emptying wheelbarrows or ore cars into the top. The chute descended down to a road for unloading into a parked truck. In some cases, a chute merely directed ore down into a bin.

Most mines with meaningful production featured *ore bins*, and they were always elevated over a road so ore could be transferred into a truck. Ore bins saw extensive use at all types of uranium mines, and they reflect the use of either rail systems or trackless haulage vehicles.

Ore dumps were almost exclusively associated with heavy equipment. Trackless haulage vehicles dumped the ore and front-end loaders scooped it into trucks for shipment. To allow the

[211] Twitty, 2002:311.

vehicles to deposit payrock, ore dumps were at or slightly below ground-level. Plank borders, walls, or backstops retained the ore from spreading when scooped by the front-end loaders.

Figure E 5.15. Capitalized mining companies often erected formally designed and well-built sloped-floor bins, such as the one at the Republican Mine in Long Park. Miners input ore by pushing ore cars across the trestle and dumping them directly into the bin. A truck parked underneath the chutes to receive loads of ore for shipment. The sloped floor allowed the ore to pour into the truck with minimal handling. Source: Author.

Figure E 5.16: Most uranium mines featured simple flat-bottom ore bins, such as this example at the Margie Mine on Club Mesa. The bin is a little more than an elevated box constructed with salvaged materials and no formal support system. A truck parked underneath to receive ore for shipment. Source: Author.

E 5.2.3.5: The Mine Shop

Mining was extremely hard on equipment. Miners dulled hundreds of drill-steels when boring blast-holes, compressed air plumbing developed leaks, and machinery broke and had to be repaired. In addition, mines usually required custom hardware such as curved rails and parts. Mining companies often kept shops to sharpen the dull drill-steels, repair equipment, and fabricate hardware. Shops, however, were not universal among uranium and vanadium mines, as they were at hardrock operations.

During the 1910s, mining outfits generally maintained centralized shops near their groups of mines. The shops were primitive and emphasized blacksmithing because the primary need was sharpening drill-steels. A typical basic field shop consisted of a forge, bellows or blower, anvil, anvil block, quenching tank, several hammers, tongs, a swage, a cutter, a chisel, a hacksaw, snips, a small drill, a workbench, iron stock, hardware, and basic woodworking tools. Prior to the 1910s, some mining outfits working deep in the backcountry dispensed with factory-made forges, both to save money and because they were cumbersome to pack, and used local building materials to make vernacular forges. The most popular type of custom-made forge consisted of a gravel-filled dry-laid rock enclosure usually 3 by 3 feet in area and 2 feet high. A tuyere, often made of a 2 foot length of pipe with a hole punched through the side, was carefully embedded in the gravel, and its function was to direct the air blast from the blower or bellows upward into the fire in the forge.

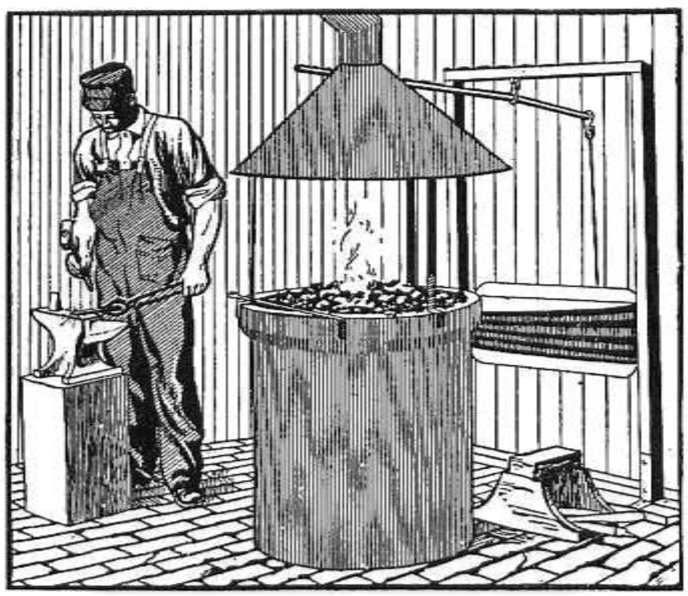

Figure E 5.17. During the 1910s, mining outfits tended to construct basic shops such as the one illustrated. These shops usually consisted of little more than a forge, an anvil, and hand-tools, which restricted the type of work that the blacksmith could accomplish. Source: Drew, 1910:1.

By the 1940s, advances in technology, truck transportation, and centralization among a few large companies reduced shop workloads. Mining equipment was more reliable, and drill-steels now featured either replaceable or tungsten-carbide bits, which lasted longer. As a result, shops were unnecessary at all but the largest mines, which fostered enough demand for on-site services to justify dedicated facilities. Some medium-sized mining outfits had very simple repair facilities such as a workbench and tools. Most companies, however, trucked their drill-steels and equipment to centralized shops maintained by USV in Long Park and Uravan, or by VCA at Bitter Creek Camp and Vancorum. Those companies that relied on USV and VCA often had no shop facilities of their own.

The Long Park, Bitter Creek, and similar field shops featured blacksmithing equipment, machining appliances, and compressed air-powered drill-steel sharpeners. USV's Uravan shop was part of the milling complex there, and it was equipped for advanced machine work, repair, fabrication, and carpentry. VCA's Vancorum shop was similar and was so vital to the region's mining operations, that VCA maintained the shop long after it closed the mill in the early 1960s.

E 5.2.3.6: Mine Ventilation

The uranium industry shared with other types of mining the need to replenish fresh air in the underground workings. As was common, byproducts from blasting, natural gases, respiration of miners, and the use of open flame lights quickly fouled mine atmospheres. Uranium mining, however, suffered one additional problem unique to the industry. Specifically, high volumes of radon filtered out of the surrounding rock and permeated the air, and its slight radioactivity caused lung cancer over time.

The AEC was aware of the link between cancer and radon in uranium mines as early as the 1940s but concealed the problem to avoid liability. As a result, safety standards were long in coming. When a wave of lung cancer struck uranium miners in 1960, the Colorado legislature took action and passed exposure limits for miners who worked in the state.[212] The limits required that mining companies reduce radon levels in the mines, and in response, the companies installed ventilation systems superior to those that had been used into the 1950s.

Until the legislature passed the radon limits, the conventional ventilation systems were designed to expel foul gases and merely render mine air breathable. In mines that were shallow or featured multiple openings, operators assumed that natural air currents provided sufficient ventilation. Only deep mines were equipped with blowers that forced fresh air underground. The blowers were small, powered by gasoline engines, and forced air through tubing.

These systems were inadequate to move air in the volumes necessary to reduce radon levels, which mine inspectors regularly tested. Instead, the post-1960 systems usually combined large and powerful blowers with multiple openings to the surface. The blowers forced high volumes of fresh air underground, and the multiple openings served as exhaust conduits. When possible, companies connected their workings with adjacent mines and constructed bulkheads at underground intersections to create complex circuits for the air currents. When no other mines were nearby, the companies bored ventilation holes and circular shafts from the surface down to strategic points in the workings. In some cases, the blower was at the mine opening, and in other instances, it was installed over the ventilation shaft. Because each mine was unique, the associated ventilation system was a custom but formally engineered affair.

E 5.2.4: Hoisting Systems for Inclined Tunnels and Shafts

The surface plants that supported work in shafts incorporated many of the same components as those for adit mines. However, inclined tunnels, inclined shafts, and vertical shafts required hoisting systems to pull vehicles laden with rock to the surface. The exact type of system depended on the depth of the shaft, whether it was vertical or inclined, and the era of the operation.

[212] Ringholz, 1989:38, 48-50.

Inclined tunnels and shafts featured the simplest systems, and for this reason, these types of mines were among the most popular in the uranium industry. In overview, a miner on the surface used a light-duty hoist to pull one or two ore cars up a rail line to the surface, where he uncoupled them from the hoist cable. The hoist was mounted to an elevated timber frame aligned with the shaft collar. By elevating the hoist, the cable was able to pass unimpeded down into the shaft. While most hoist frames were vernacular designs, they followed a similar format. Specifically, they featured a timber skeleton or a heavy plank floor supported by posts, all of which was usually nailed together. The hoist was either nailed or bolted to timber bolsters on the frame's top. As the miners sank the shaft, they at first used waste rock to grade a ramp up to the hoist frame, and then buried the structure for stability. The miners laid a rail line up the ramp to the hoist and installed a curve around the hoist to an ore bin. In many cases, however, the hoist frame was nailed directly to the top of the bin so the ore cars could be winched over the structure and then emptied. In either case, the mining outfit usually erected a hoist house over the frame or bin to shelter the machine and operator from the elements. Once the cars had been winched to the hoist, a worker uncoupled them from the cable and pushed the cars to their respective destinations.

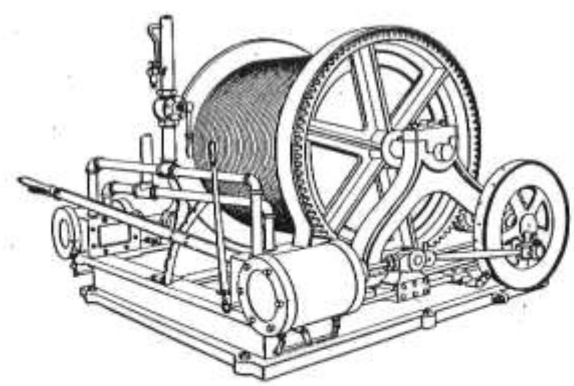

Figure E 5.18. Single-drum steam hoists were commonly employed at inclined and vertical shaft mines during the 1900s and 1910s. These hoists required boilers for steam power. Source: International Text Book Company, 1906, A50:8.

Mining outfits used several types of hoists, depending on their available capital and the depth of the shaft. Steam-driven and gasoline hoists were conventionally used during the 1910s. The *geared single-drum duplex steam hoist*, known simply as a single-drum steam hoist, was the most popular of the steam-driven types. These hoists featured a cable drum, two steam cylinders flanking the drum, reduction gears, a clutch, a brake mechanism, and a throttle. They required sound foundations, which workers usually constructed with buried timber cribbing or concrete. Models intended for deep exploration were less than 6 by 6 feet in area while production-class units were larger.

Boilers were a necessary component of steam-powered hoisting systems. While uranium mining companies employed several types of boilers during the 1900s and 1910s, the basic principle and function remained the same. Boilers were iron vessels in which intense heat converted large volumes of water into steam under great pressure. Such specialized devices had to be constructed of heavy boilerplate iron riveted to exacting specifications, and they had to to withstand neglect and abuse.

Uranium mining outfits preferred the *Pennsylvania boiler*, the *locomotive boiler*, and the *upright boiler*, also known as the *vertical boiler*, because they were well-suited to the physical environment of western Montrose and San Miguel counties. The boilers were self-contained, freestanding, ready for use, and able to withstand mistreatment. Above all, the boilers were designed to be portable and easy to install.

Upright boilers were the least costly, the easiest to transport, and the most popular of the portable types. Upright boilers featured a vertical, cylindrical shell over a firebox, and a smokestack. Flue gases left the firebox, rose through a cluster of tubes that perforated the shell lengthwise, and exited the smokestack. Upright boilers stood on a cast iron base and ranged from 2 feet in diameter and 7 feet up to 5 feet in diameter and 12 feet high. Because they were self-contained, upright boilers required no formal foundations, although workers often placed them on rock pads.

The locomotive boiler was the second-most popular and derived its name from its use in railroad locomotives. This type of boiler consisted of a horizontal shell perforated with flue tubes, a firebox underneath one end, and a flange for a smokestack at the other. The firebox and shell were manufactured as a single, riveted iron unit, and brackets and skids supported the apparatus. Hot flue gases left the firebox, traveled through the tubes, and exited the smokestack. Small boilers featured a shell 2 feet in diameter, stood 4 feet high, and were up to 10 feet in length. Large units featured a 5 foot diameter shell, stood 9 feet high, and were up to 23 feet long. Boilers commonly employed at mines were usually in between in size.

To overcome inefficiencies of the locomotive boiler, manufacturers offered the Pennsylvania boiler, which was self-contained and portable. While Pennsylvania boilers were similar in appearance to locomotive units, the path that the flue gases traveled differed. They left the firebox, traveled through a set of lower tubes, gathered in a chamber at the boiler’s rear, returned through a set of upper tubes, and exited the smokestack located over, but sealed from, the firebox. As a general description, Pennsylvania boilers featured a horizontal shell with a firebox under one end, a sealed rear, and a manifold for a smokestack over the firebox.

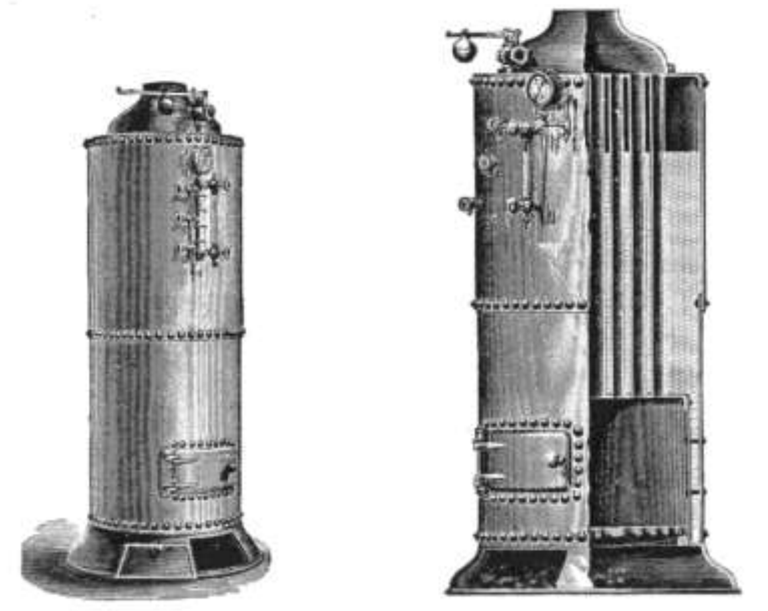

Figure E 5.19. Upright boilers were the least expensive and most portable type of boiler, but they were also inefficient. Flue gases rose from the firebox at bottom, through the flue tubes, and out a smokestack at top. Note the water level sight tube, pressure gauge, and pressure valve. Source: Rand Drill Company, 1886:47.

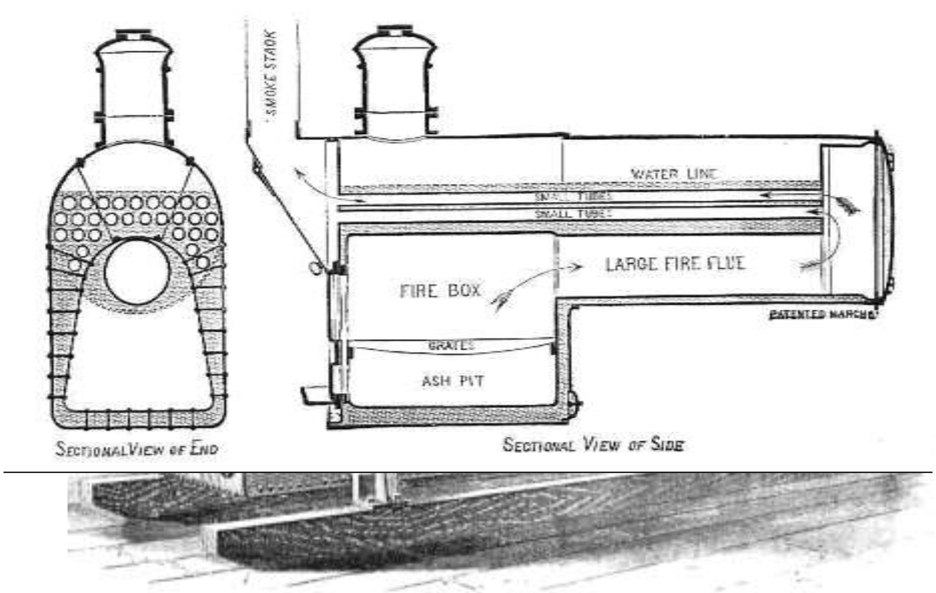

Figure E 5.20. The locomotive boiler was one of the most popular steam generators. Flue gases traveled from the firebox at left through flue tubes in the tank and out a smokestack at right. Source: Rand Drill Company, 1886:45.

Figure E 5.21. The Pennsylvania boiler was portable, stood on skids, and provided greater fuel economy than the locomotive type. Note the path traveled by the flue gases, which prolonged contact with the boiler surfaces. Source: Rand Drill Company, 1886:46.

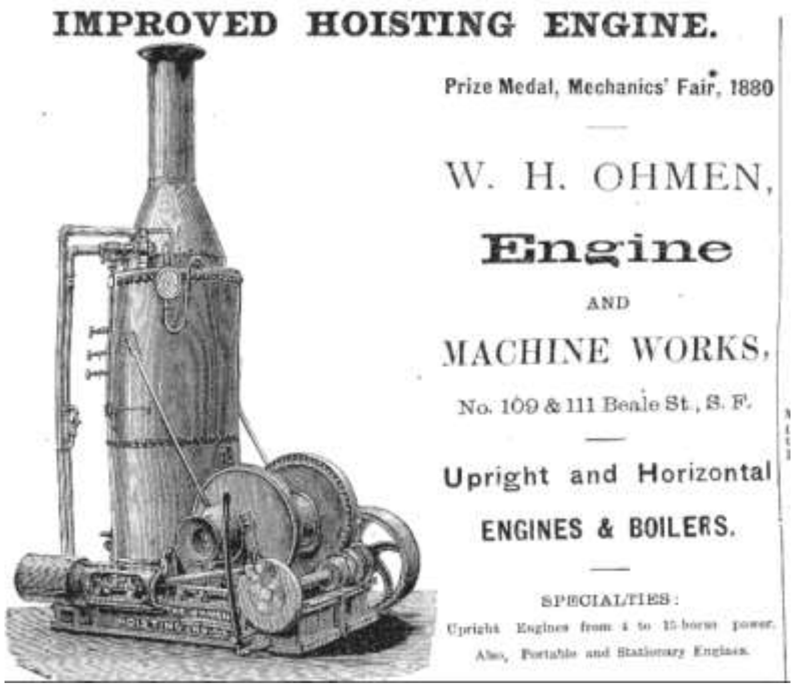

Figure E 5.22. Donkey hoists combined a hoist and upright boiler on a common bedplate. They were self-contained and required little site preparation other than a flat area. Source: *Mining & Scientific Press* 1881.

While steam hoists were fairly inexpensive, easy to operate, and readily available, their boilers required consumed water and bulky fuel. Water was precious on the mesas, and along with boiler fuel, was costly to haul. For this reason, mining outfits employed factory-made gasoline hoists as frequently if not more often. The petroleum hoists were self-contained and relatively simple. A large single cylinder engine was fixed to the rear of a heavy cast iron frame and its piston rod connected to a heavy crankshaft located in the frame's center. Manufacturers located the cable drum, turned by reduction gearing, at the front, and the hoistman stood to one side and operated the controls. Because the early petroleum engines were incapable of starting and stopping under load, they had to run continuously, requiring the hoistman to delicately work the clutch when hoisting and to disengage the drum and lower the ore bucket via the brake.

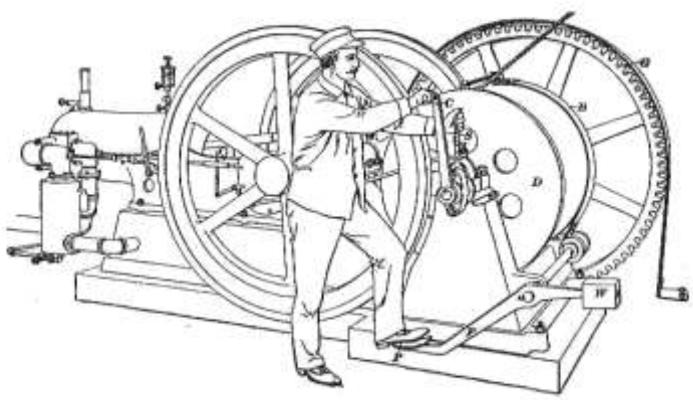

Figure E 5.23. This type of gasoline hoist was employed at vertical and inclined shafts from the 1900s to the 1930s. A single-cylinder engine is at left, dual flywheels are at center, and the cable drum is at right. Source: International Textbook Company, 1906, A50:31.

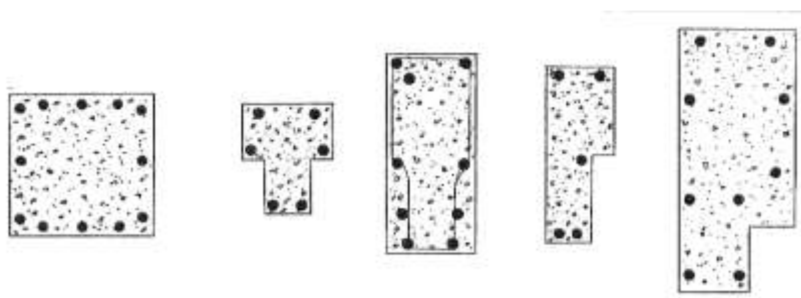

Figure E 5.24. Hoist foundation plan views. Single-drum steam hoists were bolted to foundations like the one at left, and the other foundations were for various types of gasoline hoists. Source: Twitty, 2002:187, 241.

By the 1930s, the mining industry employed different types of hoists, although the template for the overall hoisting systems remained unchanged. At shallow shafts, mining companies now employed compressed air hoists known as tuggers. These machines were compact and much lighter than the older hoists, and they could easily be mounted on structures such as ore bins. Their winding power was limited but sufficient for short inclined shafts and tunnels.

For deeper shafts, mining outfits favored custom-made gasoline hoists cobbled together from odd and unlikely pieces of machinery. A favorite version involved coupling a factory-made cable drum to a salvaged automobile engine. Another type consisted of a steam hoist, stripped of everything except for the cable drum and controls, geared to a retrofitted engine. Slow, noisy, and of questionable reliability, these contraptions worked well enough to allow many mining operations to turn a small profit. Lacking money and possibly the knowledge of how to construct proper foundations, miners simply bolted these contraptions to flimsy timber frames nailed to the hoist platform. Some mining outfits with capital were able to afford factory-made gasoline hoists. The typical version consisted of a small utility engine geared to a cable drum, all of which was bolted to a common frame.

Figure E 5.24. The Mary Ann Mine on Davis Mesa featured a factory-made gasoline hoist. The cable drum, left, and engine mount, right, were bolted to a steel frame. The engine, now gone, turned the drum via the reduction gearing. Source: Author.

E 5.2.5: Hoisting Systems for Vertical Shafts

In contrast to inclined shafts, vertical shafts required formally engineered hoisting systems with substantial components. The costs of the equipment, engineering, and shaft sinking were much higher than those for inclined entries, and yet, vertical shafts often facilitated greater production. For this reason, vertical shafts were almost always the domain of large companies instead of lessees.

The typical hoisting system included a headframe over the shaft, a hoist some distance away from and aligned with the headframe, the hoist's power source, a hoisting vehicle, and a frame hoist house that enclosed the equipment. The specific types of components that an engineer chose depended on era, available capital, expected production levels, and the depth of the shaft.

The hoisting systems installed during the 1910s tended to be relatively simple and limited in scale. Mining companies employed the same types of hoists at vertical shafts as they did at inclined shafts. In terms of headframes, companies often erected *two-post gallows* structures because they were inexpensive and easy to build. This type of headframe consisted of two posts on timber footers, backbraces that supported the posts, and cross-members at top. The cross-members featured a large pulley known as a *sheave* that guided the hoist cable into the shaft. Two-post gallows headframes were inadequate for substantial ore production, and instead, some companies constructed superior *four-post derrick* headframes. These structures consisted of four posts joined with cross-braces and diagonal beams, all supported by two backbraces.

By the 1940s, the general design of hoisting systems remained the same, but the components changed. Because a wider variety of construction materials were available at lower prices, mining outfits built larger headframes with stout timbers. In some cases, the outfits even used steel, although they reserved this costly practice for highly productive mines. Between the 1940s and 1970s, engineers favored the *four-post derrick*, the *six-post derrick*, and the *A-frame*.

Depending on the depth of the shaft and the anticipated level of production, mining companies relied on either gasoline or electric hoists. For relatively shallow shafts, they often employed the same factory-made gasoline hoists used at inclined shafts. For deep shafts and high levels of production, companies chose from two general forms of electric hoists. The most common for limited duty was a cable drum and motor bolted to a single bedplate, which was usually anchored to a concrete pad. At deep shafts, the hoist was larger and consisted of a cable drum and powerful motor mounted on separate foundations.

The size of the hoist and the number of cable drums were matched to the shaft and the depth of work. Deep shafts naturally required larger hoists than shallow shafts, and hoists greater than 6 by 6 feet in area were intended to facilitate production at depth. Because most shafts featured one hoisting compartment and a smaller utility compartment, hoists generally featured one corresponding cable drum. Mining companies intent on heavy production, however, found that the common two-compartment shaft restricted the volume of ore that could be hoisted out. To overcome this, they sank three-compartment shafts that featured two for hoisting and one as the utility compartment, all totaling 4 feet wide and at least 10 feet long, not including the support timbering. In conjunction with such shafts, these companies installed *double-drum hoists*, which raised and lowered two hoisting vehicles in a balanced fashion.

The *skip* was the most common hoisting vehicle for ore production, and it was little more than a steel box with an open top. Guide rails bolted to timbering the length of the shaft served as a track that steadied a skip during its ascent and descent. Miners loaded the skip with ore at a station in the shaft, and the hoist operator then raised the vehicle up out of the shaft and into headframe. There, curved guide rails upset the skip, which then emptied its contents into a chute. Today, shafts and headframes that feature guide rails reflect the use of skips for hoisting.

Figure E 5.25: Two-post gallows headframes were the simplest and least costly, and were popular for this reason. Sinking-class headframes tend to be less than 25 feet high and stand on timber footers. Source: Carol Beam.

Figure E 5.26: Four-post derrick headframes saw use from the 1930s through the 1970s. Production-class headframes such as the one illustrated tend to be higher than 25 feet. Source: Carol Beam.

Table E 5.2: Headframe Specifications: Type, Material, Class

Headframe Type	Material	Class	Capital Investment
Tripod	Hewn Logs	Sinking	Very Low
Tripod	Light Timber	Sinking	Very Low
Two Post (Gallows Frame): Small	Timber	Sinking	Low
Two Post (Gallows Frame): Large	Timber	Production	Low to Moderate
Two Post (Gallows Frame): Large	Steel	Production	Moderate to High
Four Post: Small	Light Timber	Sinking	Low
Four Post	Timber	Production	Moderate
Six Post	Timber	Production	Moderate to High
Four and Six Post	Steel	Production	High
A-Frame	Timber	Production	Moderate to High
A-Frame	Steel	Production	High

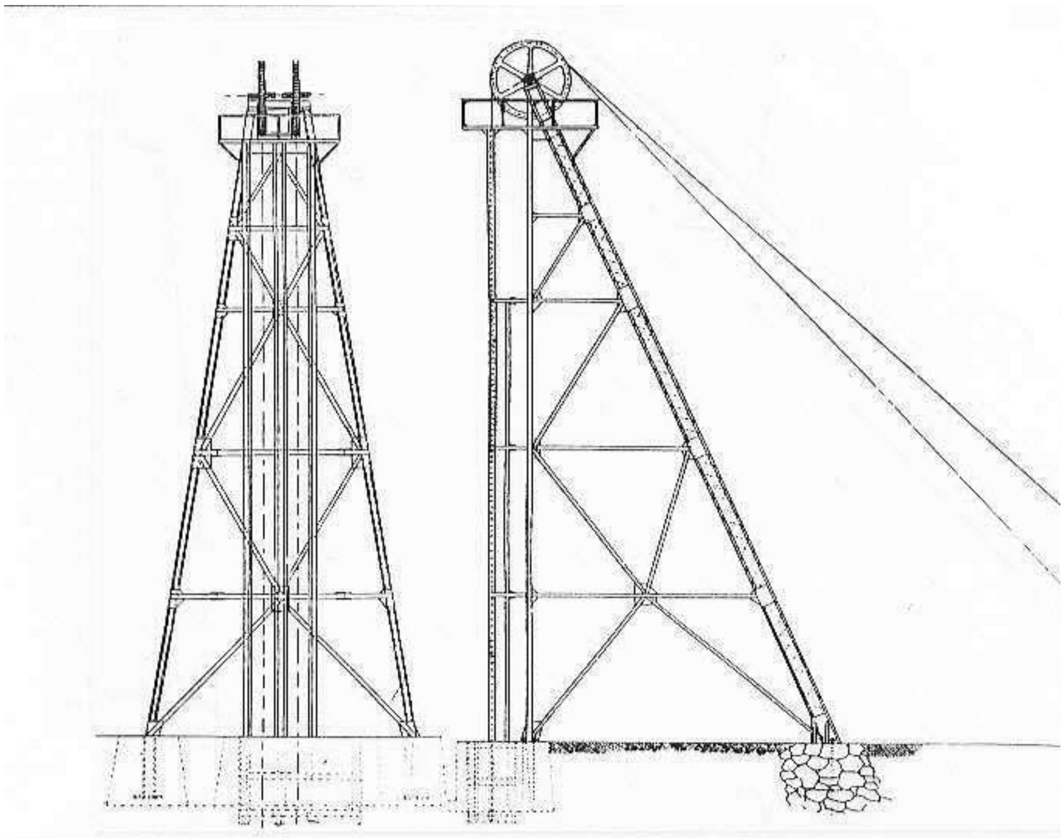

Figure E 5.27. The illustrated headframe is a production-class two-post gallows structure made of steel. These headframes were usually tall, well-built, and stood over deep shafts. Source: Twitty, 2002:233.

E 5.2.6: Mine Architecture

Uranium mines were not celebrated for their architectural grandeur. Further, most of the small mines, no matter the exact type, completely lacked buildings of any sort. The medium-sized and large operations often included buildings amid their surface plants, but the buildings were few in number, small, and utilitarian. Mining companies intended for their buildings to serve two broad purposes. One was to provide for the physical needs of the mine crew, and the other was to shelter facilities that were intolerant of or performed poorly when exposed to adverse weather.

Professionally trained mining engineers considered four basic factors that influenced the type, size, and constitution of the buildings they chose to erect. First, time had to be spent designing the structure. Second, construction materials had to be purchased and some items fabricated. Third, the materials had to be hauled to the site, and fourth, the mining company had to pay a crew to build the structure.

The general forms, types, and floorplans of mine structures followed a few general patterns. The buildings tended to be relatively small, utilitarian, conform to simple rectangular floorplans, and impermanent in appearance. Multiple functions were often crowded within a single structure. For example, hoist houses included the mine's hoist, a workbench, an electrical junction, and a change area. Compressor houses may have enclosed an air compressor, a change room for the miners, and equipment storage.

The general construction methods and architectural styles changed little from the 1900s through the 1970s. Mining companies with funding tended to erect buildings that were spacious with gabled or shed-style roofs, and appeared more formal and tidy than the structures built by companies with little capital. Engineers placed windows to take advantage of natural light and provided broad custom-made doors at important points of entry. Engineers either floored principle structures with poured portland concrete or stood the buildings on proper foundations and used wood planking. The construction materials of preference included virgin lumber, virgin sheet iron, and factory-made hardware. The workers, often skilled in their trade, built lasting structures with a solid, tidy, and orderly industrial appearance. In most cases, mining engineers emphasized function and cost in their designs and added no ornamentation.

Figure E 5.28: The hoist house in the photo exemplifies the typical mine structure. The building is utilitarian, rectangular, based on a frame, and sided with ribbed steel siding. Source: Author.

Poorly funded mining outfits, by contrast, were economically forced to keep construction within a tight budget, and within their skills. These outfits could not afford quality construction materials and tools, they were not able to hire experienced engineers or architects, and they lacked the funding to hire skilled workers. As a result, the buildings that many marginally funded companies erected tended to be small, low, made with high proportions of salvaged materials, and poorly constructed overall. Such buildings were personal and unique to each mining operation, being a true expression of the outfit's nature, and assembled as the builder saw fit.

The structures erected by poorly capitalized mining companies can be divided into two categories. Small outfits with at least some capital and a crew with modest carpentry skills built structures that consisted of a crude but sound frame, often of the post-and-girt variety, sided with salvaged, mismatched lumber and sheet iron. Doors and windows also were salvaged from elsewhere such as abandoned residences. Some structures even had mismatched walls, each face of the building having been sided differently from the others. Overall, these buildings appeared rough and battered even when relatively new, but they were fairly well-built and offered miners and equipment shelter.

For the second category, the mine buildings appeared even cruder, were poor quality, and had dubious structural integrity. Laborers frequently constructed such buildings with no formal frames. Instead, the workers often preassembled the walls, stood them up, and nailed them together, or established four corner-posts, added cross braces, and fastened siding to the boards. The builders may have used a patchwork of planks and sheet iron for siding, which was often layered to prevent being ripped apart by high winds. Many mining outfits favored the shed structural style, which featured four walls and a roof that slanted from one side of the building to the other, because it was simplest to erect. The architectural style of the mine buildings erected by such mining companies may be termed *uranium mining vernacular*.

E 5.3: The Nature of Ore Concentration Mills

One of the main objectives of uranium and vanadium mining was to recover metals from carnotite and roscoelite ore. Facilities technically termed *concentration mills*, and informally known as *uranium* and *vanadium mills*, separated as much waste as possible and concentrated the ore's metal-bearing constituents. The end-products of milling were *yellowcake* and *redcake*, which were uranium and vanadium concentrates, respectively. The radioactive yellowcake was shipped to Atomic Energy Commission facilities and refined into pure uranium. Steel companies were the principal consumers of redcake for use in alloy steels, although the Department of Defense purchased and stockpiled a huge proportion as a strategic metal.

In overview, the concentration process began when mining companies delivered crude ore to the mill and dumped the material into piles of differing purity, or grade. Workers input the ore into a receiving bin at the head of the mill, and then fed the material into a series of crushers. These devices physically reduced the ore to sand and slurry, which descended down to revolving screens. Particles that were too big for the screens returned to the crushers, and those that passed through proceeded on to concentration. In this processing phase, a combination of equipment and chemical reactions separated waste from the ore's uranium and vanadium content, leaving liquid solutions. At the process end, additional chemical reactions precipitated out yellowcake and redcake, which furnaces dried for shipment.

Concentration mills ranged in scale from small facilities to sprawling industrial complexes, and the size depended on treatment capacity and the sophistication of the processes. In the Uravan Mineral Belt, the Uravan Mill, operated by USV, was by far the largest, and the Gateway Alloys Mill at Gateway was the smallest. All the mills followed a similar design that relied on gravity to draw the ore through the various stages of treatment. To facilitate this, the mills were built on stairstep foundations with the first stages of processing at the top and the final stages at the bottom. Conveyors and bucket-lines elevated the ore for reprocessing in some cases.

While the ore treatment process seems simple in overview, it was actually complex and specific to carnotite and roscoelite. Western Montrose and San Miguel counties were the cradle of uranium and vanadium milling, and they hosted the first processes developed by European chemists and metallurgists. The theory behind the early processes was so sound that, while the technology improved over time, the basic chemistry remained the same for more than 70 years.

The American Rare Metals Mill near Slick Rock in San Miguel County was the first commercial application of uranium-specific recovery processes in North America, if not the world. The process, as built in 1901, began when wagons delivered crude ore and miners sorted it by grade. The ore was crushed with conventional equipment, ground to a slurry in a ball mill (type of crusher), and screened. The fine material passed into a series of leaching tanks filled with sulfuric acid, which dissolved the uranium content. Workers tapped the resultant *liquor* into a set of precipitating tanks and added sodium carbonate (a form of lime) to force the uranium out of solution. Workers then discharged the exhausted solution into the Dolores River and dried the uranium concentrates for shipment to Europe.[213]

While the American Rare Metals Mill was effective, its process was highly inefficient and lost a substantial proportion of the uranium. Around 1903, chemists Justin H. Haynes and W.D. Engle developed the Haynes-Engle process and installed it in the American Rare Metals Mill. The crushed ore was boiled in an alkaline solution while churning in a revolving steel cylinder, which dissolved the uranium and vanadium content. Workers tapped the solution into tanks and added sodium hydroxide, which precipitated out the uranium as sodium uranate. The solution was decanted into another set of tanks where workers precipitated out the vanadium by adding lime. Supposedly, this method recovered 85 percent of the uranium as yellowcake and 65 percent of the vanadium as redcake, and because of this, the method saw use into the 1910s.[214]

In 1907, Herman Fleck, William G. Haldane, and Edwin L. White, Colorado chemists, improved the process with an important addition that continues to this day. They mixed the crushed ore with salt and roasted it, which increased the solubility of the uranium and vanadium constituents. During the 1910s, other chemists patented variations of the above treatment methods, and all relied on either hot acid or basic solutions to leach out the metals, and the addition of chemicals, mostly basic, to precipitate out the uranium and vanadium separately. Some of the methods, such as the Bleeker Process, were intended to extract vanadium from both carnotite and the roscoelite ores of the Placerville area.[215]

[213] Metal Mining, 1961:77; Moore and Kithil, 1914:74.
[214] Metal Mining, 1961:76; *Mineral Resources*, 1906:531; Moore and Kithil, 1914:72; Parsons, et al, 1916:18.
[215] Moore and Kithil, 1914:70; Parsons, et al, 1916:18.

The National Radium Institute, a subsidiary of the U.S. Bureau of Mines, took a different approach to treating carnotite ore. Because the chemical-intensive methods required a continuous supply of water, the mills had to be located near reliable streams. This saddled the mining companies with the high costs of transporting tons of crude ore down from the mesas to mills in the river valleys. In response, the Institute developed a method of concentrating the carnotite content of ore into a powder that was easier to ship down to the mills for final processing. In 1914, the Institute built an experimental mill in remote Long Park, and it relied on mechanical means to separate the carnotite off the sand grains of sandstone. One method that required no water began with gentle crushing, which liberated some of the carnotite while preserving the integrity of the sand grains. After the sand was screened, it entered a series of rotating discs that slowly ground and scrubbed more carnotite off the grains. All the while, blowers created a vacuum that sucked away the carnotite dust as it was produced and forced the material into collection filters. The various steps were fully enclosed to retain the fine carnotite dust. The Institute developed a second, wet process that relied on conventional milling equipment. Specifically, agitation tanks worked the sand, and the constant tumbling and abrading ground off the carnotite, which settled to the bottom. While the Institute's hypothesis of mechanical concentration was a good one, it proved ineffective for ores outside of Long Park.[216]

Among all the milling companies on the Colorado Plateau, USV can be credited with the principal improvements to the ore treatment processes following the 1910s. During World War II, the AEC required that USV simultaneously produce both redcake and yellowcake at its Uravan mill. Further, USV had to do so from low-grade ore and depleted mill tailings, which required the mill to be highly efficient. To meet the challenge, USV improved its processes with AEC assistance, and other companies in the region, including VCA at Vancorum and North Continent Mines at Slick Rock, then followed.

According to the revised process, trucks delivered crude ore from the mines to a receiving station at the head of the mill. The trucks were weighed, the tonnage credited to the producer (mine lessee), and the ore was dumped into the mill's receiving bins. Machinery fed the crude ore into a series of crushers that reduced it to sand and gravel, which workers mixed with salt. The blend was transferred into a large, rotary kiln for roasting and heated to temperatures above 800 degrees, Centigrade. This step was critical and required constant supervision because if the temperature dropped below 700 degrees, the entire batch had to be thrown out as insoluble. USV chose a rotary kiln because it was a continuous feed apparatus. Crushed ore entered the top end, tumbled and roasted, and trickled out the bottom end. While still superheated, the material was quenched in a basic solution that dissolved most of the vanadium. Like the early processes, the liquor was then tapped into precipitation tanks and the redcake recovered, while the solid compounds were leached in agitation tanks filled with hot acid to dissolve the uranium. Workers then precipitated out the uranium by adding agents.[217]

While highly simplified above, the process was complex and temperamental, it required vigilance, and it offered numerous opportunities for error. Hence, Union Carbide, which

[216] Kithil and Davis, 1917:62.
[217] Clark and Kerr, 1974:41; Gittus, 1963:28; Gupta and Krishnamurthy, 1992:211; Merritt, 1971:50; *Mesa Miracle*, 1952:23; Metal Mining, 1961:93.

absorbed USV, took an interest in the revolutionary, new ion exchange process shortly after its development in South Africa in 1952. Ion exchange was an efficient alternative to the touchy stage of precipitation, and it relied on columns of resin to strip the uranium molecules dissolved in the acid solution. VCA was the first company in North America to try ion exchange at its Shop Rock mill in 1954, and Union Carbide installed the process in the Uravan Mill the following year. Union Carbide continued to precipitate out the vanadium with the traditional method into the 1960s, when it used ion exchange for that metal, as well.[218]

[218] Chenoweth, 1993:50; Merritt, 1971:138, 470; McGinley, 1958:218.