

CHAPTER 8.

Industrial Mineral Extraction and Geothermal Exploration

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Introduction

The Valles Caldera is the result of the youngest major volcanic episode in the creation of the central Jémez volcanic field. This geological feature is a diverse suite of basaltic through rhyolitic rocks, which erupted from some time less than 13 million years ago to no later than .13 million years ago. It represents some of the greatest volcanic activity documented in the earth's history.

The vast heat content and the high subsurface temperatures associated with shallow, crystallizing magma cause convection of hot groundwaters in overlying rocks. These hot convecting waters usually form surface hot springs and fumaroles. At the Valles Caldera, a hydrothermal system at temperatures of 428 to 572 °F (220 to 300 °C) exists at depths of 1,968 to 8,200 feet (600 to 2,500 m) in caldera-fill ignimbrites and pre-caldera andesites (**Dondanville 1971**). Acid-sulfate springs, mud pots, and fumaroles at Sulphur Springs issue from the west side of the central resurgent dome of the Valles Caldera. Hot waters leach soluble constituents from fresh volcanic rocks and from older rocks. As temperature, pressure, and chemical environment change, hydrothermal minerals are deposited in favorable structures and horizons within the hydrothermal system. Many of the world's precious and base metal ores are mined from the eroded remnants of ancient calderas. Early Jémez volcanic rocks in the Cochiti Mining District south of the caldera contain gold deposits that were mined at the beginning of the twentieth century.

Two reservoirs have been drilled in the Valles hydrothermal system: the Redondo Creek and the Sulphur Springs reservoirs (**Goff et al. 1988**). The deep reservoir fluids are neutral-chloride; they contain about 16 to 58 ounces per ton (500–1,800 mg/kg) total dissolved solids (TDS) (**Goff et al. 1988**). About 16 miles (10 km) from the Valles Caldera, two sets of neutral-chloride hot springs discharge along the pre-caldera Jémez fault zone at Soda Dam and Jémez Springs. These springs have strong chemical similarities to the deep fluids within the caldera. The conclusion generally drawn from this is that a hydrothermal outflow plume travels out of the caldera in the subsurface along the Jémez fault zone and within adjacent sedimentary rocks toward the springs (**Goff et al. 1988:6041**).

The silver and gold deposits of the formation were exploited, with modest success, about a century ago. The hydrothermal resources of the caldera have been the focus of more recent development.

Historical Overview

Fray Gerónimo de Zárate Salmerón served as the resident missionary at the Jémez Pueblo of Giusewa, between 1618 and 1626. He subsequently prepared a report of his observations in or after 1629. Salmerón emphasizes the mineral wealth of New Mexico and states that he filed on many mineral locations in the Jémez Mountains (**Ayer 1916:217**). None of these filings, however, led to any known mining in the region.

John Wesley Powell first described rocks of the Jémez Mountains region during reconnaissance work performed in the 1880s (**Powell 1961 [1885]**). The region was known at the time as the Tewan Plateau. Powell recognized it as an extensive volcanic field that had erupted many types of volcanic rocks including voluminous deposits of ash. **J. P. Iddings (1890)** presented petrographic and chemical data for some of Powell's samples, including Bandelier Tuff and some quartz-bearing basalts.

About 1881 Miguel Antonio Otero and his nephew, Maríano Sabine Otero, jointly acquired the Jémez Springs. Maríano also pursued development of Sulphur Springs as a second commercial resort. Maríano became "excited about the possibilities of mining sulfur, an idea that he probably borrowed from John W. Walton, a miner who had staked out a claim along the Baca Location's western boundary in 1865" (**Martin 2003:42**). In 1898 Maríano filed a mineral claim for a 19-acre (7.6 ha) parcel next to Walton's tract. According to the 1876 U.S. Government survey, the Sulphur Springs were just outside the west boundary of the Baca Location No. 1 (Baca Location) (**Sawyer and McBroom 1876**). The resurvey of 1911, however, determined that the Sulphur Springs were inside the tract.

The Oteros formed a development company to operate the Jémez Springs resort, with Miguel Otero as president, and Maríano Otero and various officials of the Atchison, Topeka and Santa Fe Railroad serving on the company's board of directors (chapter 3). They began building new bathhouses, a hotel, and other improvements, while the railroad surveyed and graded a branch that would bring tourists from Bernalillo to Jémez Springs. The hotel and bathhouses at Jémez Springs were completed in 1882. The death of Miguel Antonio Otero later that year stopped the development of a spur railroad, but visitors continued to reach the resort by stage. Plans to make Jémez Springs into a major resort were dropped (**Otero 1935:237–238, 241–277**).

Although he gave up the plans that he had shared with his uncle to enlarge the Jémez Springs resort, Marfano did not quit his resort and mineral interests upstream. He established a 10-acre (4 ha) resort at Sulphur Springs in 1901 (**Scurlock 1981:153**). He first built bathhouses over the largest springs. Building through 1902, Marfano added a hotel for the steady stream of visitors who traveled from Jémez Springs to the Sulphurs (**Martin 2003:44**).

In 1900 Otero established an experimental plant for refining sulfur at Sulphur Springs. Pleased with the trial run, Marfano began planning to expand his mining and milling works to achieve production levels of up to 15 tons (1,361 kg) of refined sulphur per day. To get new equipment to the site, Otero began negotiations with influential Santa Feans in June 1902 to improve transportation over the Jemez Mountains between his Sulphur Springs operations and Santa Fe (**Martin 2003:42–43**). He claimed that the capital investment to rebuild the old military road through the Cañon de Valle Pass and several other unimproved trails would benefit both Jemez Spring and Santa Fe. The Territorial government was not interested. Marfano made a deal with entrepreneurs in Santa Fe; he would fund construction of 13 miles (20.8 km) of road himself, and they would pay for the remaining 2 miles (3.2 km) of the project (**Martin 2003:43**).

Otero miscalculated the quantity and availability of the sulphur at his mine. Through 1903, sulphur was abundant near the surface. By 1904, however, the mining operations had exhausted the surface resource and Otero needed to begin tunneling. Poisonous hydrogen sulfide gas rapidly built up in the mineshaft (**Martin 2003:44–45**), and to make matters worse, prevailing sulfur prices dropped so low that the venture was no longer profitable (**Boyd 1938:14–14, 35–39**). G. R. Mansfield notes, “Old sulphur mill at Sulphur Springs hills built 1902. From 1902–1904, 200,000 lbs. [90,718 kg] of sulphur were produced here. Same locality as No. 426” (**U.S. Geological Survey 1918–1925**, G. R. Mansfield, #428). Marfano Otero died in a buggy accident near Jémez Springs in 1904. G. R. Mansfield photographed the resort in April 1918 (**U.S. Geological Survey 1918–1925**); a fire destroyed the buildings, probably in the 1970s. In 1983, Goff and Bolivar mention the destruction of the Sulphur Springs resort by fire as having occurred “several years ago” (**Goff and Bolivar 1983:32**).

Gold and silver were discovered about 5 miles (8 km) south of the Baca Location in 1889. Development of major mines and the founding of the boomtowns of Albemarle, Allerton, and Bland followed circa 1894. The demand for lumber led to the establishment of several sawmills (**Scurlock 1981:140**; see also chapter 6).

Gold claims were first staked in the Cochití Mining District in the southeast Jémez Mountains in 1893. The 2 largest mines, Lone Star and Albemarle, produced ore from quartz veins in altered volcanic rocks from about 1897 to 1903 and from 1914 to 1916 (**Lindgren et al. 1910**). About 185,000 tons (167,829 metric tons) of ore grading about 0.2 ounce per ton (6 mg/kg) gold and 4 ounces per ton (124 mg/kg) silver have been mined from the district, “but only recently [i.e., the late 1980s] have workers realized that the deposit was formed

in an earlier hydrothermal system of the Jémez Mountains volcanic field” (**Goff and Gardner 1988:5997**).

C. S. Ross of the U.S. Geological Survey first began surveys in the Jémez Mountains in the 1920s (**Ross 1931, 1938**; see also **Goff and Gardner 1988:5997**). Ross returned to the area in the mid-1940s to continue geologic mapping and volcanic studies with R. L. Smith, and again in 1954 with R. A. Bailey (**Goff and Gardner 1988:5997**). These investigations resulted in a series of papers on ash flow tuffs, eruption mechanisms, ring dikes, resurgent cauldrons, and ash flow magmatism (**Ross and Smith 1960; Smith 1979; Smith and Bailey 1966, 1968**).

The first geothermal well drilled in the Valles Caldera in 1960 was not meant to be such: it was an oil test well on the west flank of the resurgent dome. The Westates–Bond 1 well struck superheated water about 392 °F (200 °C) at shallow depths, but found no oil (**Dondanville 1971**). Three more wells followed in the 1960s in the same general area.

Union Oil Company of California drilled a well (Baca 4) in the resurgent dome in 1970. In July 1978 the U.S. Department of Energy (DOE), Union Oil Company of California (Unocal), and the Public Service Company of New Mexico (PSCNM) began a jointly sponsored cooperative geothermal demonstration project. The project drilled 20 more wells over the next 4 years. When this project ended by mutual agreement in January 1982, Unocal’s predictions concerning the resource (up to 400 Mwe of electrical capacity) had not been met. To the partnership’s disappointment, only 20 Mwe had been proven. Only 2 of the 13 exploratory wells drilled by Unocal were successful. Although all the wells yield superheated water, most were not sufficiently permeable to be considered production wells (**Goff 2002:9**). Because the DOE provided funding to the project, its results are available to the public and represent “one of the most extensive, publicly available data bases of any drilled caldera system in the world” (**Goff and Gardner 1988:5997**).

In all, about 40 deep exploration and research wells, including those described above, were drilled in the Valles Caldera in the Redondo Creek and Sulphur Springs reservoir during the period between 1959 and 1983, defining a small, but hot (572 °F [300 °C]), neutral-chloride, liquid-dominated geothermal system (**Goff and Janik 2002:300; Goff et al. 1988**). “The system proved to be too small in volume for economic development” (**Goff and Janik 2002:301**).

The Fenton Hill Hot Dry Rock demonstration project, designed and built by Los Alamos National Laboratory, followed in the 1980s (**Goff and Bolivar 1983:39**). The first hot dry rock (HDR) geothermal experiments were performed on the west margin of the Valles Caldera (**Goff and Janik 2002:300**). Four deep wells were drilled to depths as great as 7.2 miles (11.6 km) to determine whether electricity could be generated commercially from a man-made reservoir. High development costs and continuing low prices for fossil fuels finally ended this project in 1998 (**Goff and Janik 2002:300**).

“The HDR concept was developed and tested in Precambrian crystalline rocks beneath the west margin of the

caldera from 1972 to 1998” (Goff and Janik 2002:304). Cold water was pumped down an injection well, forced through artificially fractured reservoir rocks, and extracted from a nearby production well. The cold water dissolved minerals lining the fractured rocks and absorbed CO₂ and other gases while reaching thermal equilibrium ($T \geq 320$ °F [160 °C]). Depth of circulation was greater than 8,200 feet (2.5 km) (Goff and Janik 2002:304–305).

The geothermal and HDR experiments were followed in the 1980s by a broad array of investigations of processes in magmatism, hydrothermal systems, and ore deposit mechanisms. The DOE’s Office of Basic Energy Sciences sponsored investigations, designated as part of the Continental Scientific Drilling Program, that led to papers describing the hydrothermal system; the collapse, resurgence and location of calderas, the evolution of volcanism and tectonics, and the geophysical structure of the caldera. (Goff and Gardner 1988:5997-5998). The first corehole was drilled in August 1984, and a workshop followed that October to organize a scientific drilling program. A second corehole was drilled in September 1986, and a third in 1988 (Goff and Gardner 1988:5998).

The demonstration project led to legal challenges by the All Indian Pueblo Council and the State of New Mexico, which

contended that the project would deplete or dry up the water flow from the hot springs and aquifers in San Diego Canyon. This issue was never resolved in court because the project ended. Goff concludes, however, that this view is correct—a hydrothermal outflow plume from the Valles reservoir feeds the hot springs in San Diego Canyon (Goff et al. 1988; Goff 2002:10).

The exploitation of the mineral resources of the Valles Caldera for profit both precedes and follows scientific and theoretical studies. Nonetheless, after many years of work and considerable expense, only 20 Mwe of geothermal reservoir capacity have been proven in the Valles Caldera. Estimates of undeveloped capacity range as high as 1,000 Mwe but remain unsubstantiated. The shallow heat within the Valles rocks is vast, but extraction of large quantities of hot fluids from these rocks has proven difficult (Goff 2002:10).

Mining of precious metals in the early twentieth century met with modest results and was abandoned. Geothermal exploration with a view to commercial development has shown small capacity. It appears fair to conclude that the acquisition of the Valles Caldera by the Federal Government in the year 2000 as a permanent public resource and park is a mature judgment of the resources and best use of the lands.

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