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LA BAJADA URANIUM-BASE-METAL DEPOSIT, SANTA FE COUNTY, NEW MEXICO

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Abstract—The La Bajada (Lone Star) deposit is an unusual, low-temperature, uranium-base-metal vein deposit in Santa Fe County that formed during the Oligocene or Miocene. Haji-Vassiliou and Kerr (1972) proposed a two-stage process of formation after faulting and fracturing of the host rocks. During faulting, they suggest that petroleum derivatives migrated along the fault, possibly even forming an oil seep on the surface. Then, rising hydrothermal solutions carrying uranium and base metals moved through the fault and mixed with the older petroleum derivatives. Alternatively, the mineralization at the La Bajada may have formed by dewatering of rift basins. During the Miocene, meteoric waters within the Tertiary and older sediments of the rift evolved chemically as they became warmer with depth due to burial and/or basin compaction, by dissolving rock constituents to produce waters of varying salinities and metal concentrations. As the rift developed, favorable discharge zones such as the La Bajada fault allowed the mineralizing fluids to migrate up along fractures and faults. The organic material could have been deposited prior to or during deposition of the metals. Once the deposit was emplaced, oxidation, dissolution, and downward reprecipitation and enrichment of the deposit occurred as the groundwater level dropped in the area.

INTRODUCTION

The La Bajada (Lone Star) deposit is an unusual, low-temperature, uranium-base-metal vein deposit that formed during the Oligocene or Miocene (Hilpert, 1969; Haji-Vassiliou and Kerr, 1972). The uniqueness of this deposit is due to the presence of ore-controlling carbonaceous material (Haji-Vassiliou and Kerr, 1972) in volcanic rocks intruding the intensely hydrothermally altered limburgite. It is located in the Santa Fe River canyon in NW¼ sec. 9, T15N, R 7E (projected) (Fig. 1). This mine produced copper and silver in 1923–1929, then uranium in 1956–1966 (Table 1), and is currently being evaluated for remediation.

The purpose of this report is to summarize published and unpublished data and present a revised theory on the origin of this deposit. Lustig (1957) and Haji-Vassiliou and Kerr (1972) described the mineralogy of the deposit. Hilpert (1969) and Chenoweth (1979) described the uranium potential. Various unpublished company and government reports described the geology and drilling results and are on file at the New Mexico Bureau of Mines and Mineral Resources archives. I examined the area on several occasions beginning in 1981.

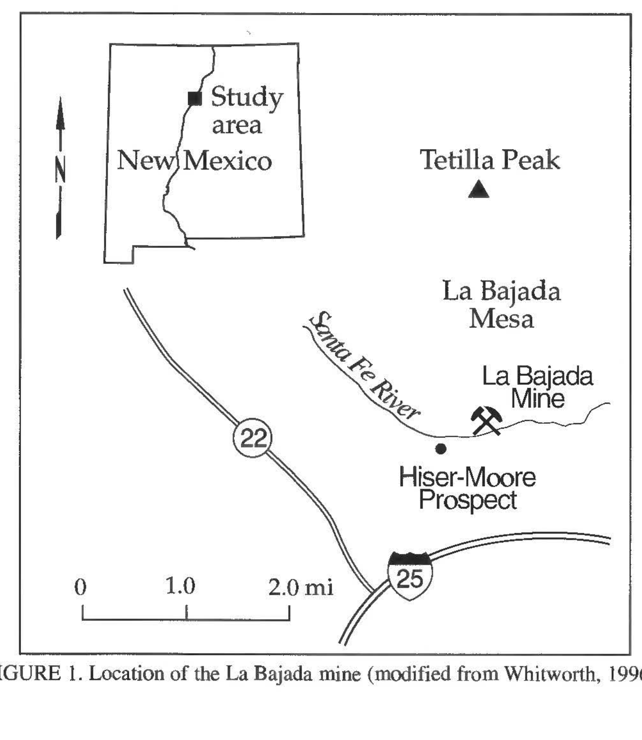

FIGURE 1. Location of the La Bajada mine (modified from Whitworth, 1996).

MINING HISTORY

In 1915 or 1916, George Rinaldi discovered copper in the Santa Fe River canyon at the La Bajada and began development of the deposit with William Kolman. In 1923, the La Bajada Mining Co. was formed and bought the property. Development and minor production began. Kolman became president of La Bajada Mining Co., and Rinaldi was the mine owner. Reportedly, the company sold $2 million worth of stock, but only 8.8 metric tons of ore were produced. The American Smelting and Refining Co. acquired the mine in 1926 and produced copper-silver ore through two shafts in 1928–1929. The ore was shipped to El Paso, Texas (Chenoweth, 1979). The La Bajada Mining Co. was dissolved in 1929.

In 1950, O. T. Gay discovered uranium in the dump at the La Bajada, and in 1955, Lone Star Mining and Development Co. leased the property. Uranium production began in 1956, and continued sporadically until 1966. In 1957, the mine consisted of two shafts with drifts on three levels. However, the underground workings were found to be unsafe, and further development was by open-pit. The ore was shipped to the Homestake-Sapin Partners uranium mill at Grants, and penalties were assessed because of the unrecoverable base-metal content (W. Lambert, unpublished report, August 25, 1978). The ore material was difficult to mill because of the high sulfide and clay content (Chenoweth, 1979). Production ceased in 1966, and by late 1967, nearly all of the equipment had been removed. Total production amounted to 27,111 lbs U_3O_8, 5345 lbs Cu, and some silver and vanadium (Table 1).

The pit has since filled with water because the rim is only a few meters below the river level. A dirt berm made of mine waste material separates the pit from the river, but sporadic storms have allowed the river to flood the mine area periodically. Exploration drilling resumed in the area until 1977, but no additional reserves were located. In the late 1970s, Bokum Resources and Union Carbide Corp. Metals Division drilled exploratory holes in the vicinity of the La Bajada mine without encountering significant uranium deposits in the Jurassic sedimentary rocks. In 1979, Lone Star Mining Co. lost the La Bajada lease for failure to submit an approved mining plan to the Bureau of Land Management. The pit is approximately 61 m long, 15 m wide, and 181 m deep and has filled with water. The site is being evaluated for reclamation. Whitworth (1995, 1996) summarized the environmental geochemistry of the area.

TABLE 1. Reported production from the La Bajada mine, Santa Fe County (from McLemore and North, 1984 and U. S. Atomic Energy Commission, ore production records).

YEAR	TONS ORE	Ag OUNCES	Cu POUNDS	U_3O_8 POUNDS	V_2O_5 POUNDS	MINING COMPANY
1923	15	?	?	–	–	La Bajada Mining Co.
1928	8	24	2423	–	–	American Smelting and Refining Co.
1929	9	28	2922	–	–	American Smelting and Refining Co.
1956	45.82	–	–	162.56	21	Lone Star Mining Co.
1957	51.25	–	–	202.17	21	Lone Star Mining Co.
1962	1616.88	–		5276.63	–	Lone Star Mining Co.
1963	5465.03	–	–	14,482.06	–	Lone Star Mining Co.
964	2105.99		–	5882.02	–	Lone Star Mining Co.
1966	363.69	–	–	1105.60	–	Lone Star Mining Co.
TOTAL	**9680.66**	**52**	**5345**	**27,111.04**	**42**	–

DESCRIPTION OF THE DEPOSIT

The deposit is located within the La Bajada fault zone and is bounded by the north-trending Rosario fault to the east and the San Francisco fault to the west (Fig. 2). The oldest formation exposed in the area is the Cretaceous Mancos Shale of marine origin. The Mancos Shale crops out on the upthrown side of the Rosario fault, east of the mine. An altered monzonite plug has intruded along the Rosario fault. The Rosario fault strikes north-northwest and continues southward to the Ortiz Mountains (Disbrow and Stoll, 1957; Kelley, 1978). The San Francisco fault, west of the mine, cuts the poorly consolidated gravels of the Miocene–Pliocene Tesuque Formation of the Santa Fe Group; it strikes N30°E. Younger Santa Fe Group alluvial deposits overlies the Tesuque Formation along the La Bajada fault. The Tesuque Formation consists of interbedded conglomerates, sandstones, and shales. The Pleistocene Cuerbio Basalt forms the caprock at La Bajada Mesa. The faults do not cut the overlying Cuerbio Basalt. The La Bajada deposit lies in the bottom of the Santa Fe River canyon, and part of the deposit was eroded by the river prior to discovery.

The La Bajada fault zone lies in between the San Francisco and Rosario faults. This zone strikes N15°W to N15°E, dips 75° to the east, and is characterized by as much as 11 m of fault breccia (W. Lambert, unpublished report, August 25, 1978). The zone is displaced by at least three, east–west post-mineral faults. Mafic dikes have intruded the fault zones and subsequently hosted uranium-base-metal mineralization. These dikes are related to the Cieneguilla Limburgite. The mineral deposits consist of discontinuous and spotty disseminations and veinlets (less than 1 cm wide) within the fault-breccia zone and in the mafic dike. Drilling and mining of the deposit suggest that the deposit was wedge shaped and decreased in thickness with depth (Fig. 2).

Chalcopyrite and marcasite are the most abundant sulfide minerals reported: bornite, chalcocite, colusite, bravoite, pyrite, and sphalerite are present in minor amounts (Lustig, 1957; Haji-Vassiliou and Kerr, 1972). The sulfide minerals occur as massive colloform habits that indicate a low temperature of formation (Haji-Vassiliou and Kerr, 1972). The sulfides are also associated with small blebs of organic material (R. G. Anderson, unpublished report, October 31, 1956). Marcasite and pyrite typically coat chalcopyrite. Most of the uranium occurs in small blebs of urano-organic material, although brannerite and tyuyamunite are present in small quantities (Lustig, 1957; Haji-Vassiliou and Kerr, 1972). These uraniferous organic blebs occur as spherical inclusions and as void, cavity, and fracture fillings in masses as large as 20 mm in diameter (Chenoweth, 1979). Quartz, ankerite, dolomite, calcite, sericite, kaolinite, and iron oxides also occur in the fault breccia.

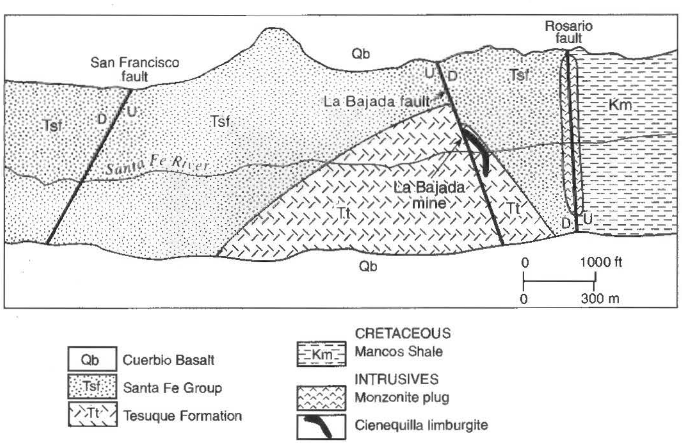

FIGURE 2. Geologic sketch map of the La Bajada mine area (modified from Disbrow and Stoll, 1957; E. V. Reinhardt, unpublished report, July 1958; Haji-Vassiliou and Kerr, 1972; Kelley, 1978).

Assays of composite samples collected about 1958 contained 0.196% U_3O_8, 2.07% Cu, 0.047% Ni, and 0.028% Co. Another sample contained 5.18% Cu, 0.009% Ge, 0.07% Au, 0.21% Ag, 0.08% Cd, and 0.13% U_3O_8. Hilpert (1969) reported an assay of a pulp sample from one lot of ore of 1.5% Cu, 0.03% Ni, 0.13% As, and 18.4% S. A sample from the mine waste pile contained 0.09% U_3O_8, 1.51% Cu, and 19 ppm Th (McLemore, 1983). Small amounts of lead, zinc, selenium, and molybdenum are also present in places (Chapman, Wood, and Griswold, unpublished report, December 1958). Overall, metal values are erratic. This metal assemblage is unusual for hydrothermal vein deposits in New Mexico (McLemore, 1996a, in press).

The entire Tesuque Formation exposed at the mine is altered; the most intense alteration is along the La Bajada fault. Many boulders and pebbles within the Tesuque Formation are altered to kaolinite, chlorite, and sericite, and iron oxide staining is prevalent. The overlying Cuerbio Basalt appears unaltered and unconformably overlies the altered zone along the La Bajada fault.

At the Hiser-Moore prospect southwest of the La Bajada mine (sec. 8, T15N, R7E; Fig. 1), yellow uranium minerals occurs along fractures within the Cieneguilla Limburgite (Chenoweth, 1979; McLemore, 1983). Not enough uranium was found to be economic.

ORIGIN

The geologic data summarized in this paper and published accounts (Lustig, 1957; Hilpert, 1969; Haji-Vassiliou and Kerr, 1972; Chenoweth, 1979; Kelley, 1978) provide evidence that mineralization at the La Bajada occurred during the early to middle Miocene or Pliocene. The host rock, the Cieneguilla Limburgite, has been dated as 25.1 ± 0.07 Ma (Baldridge et al., 1980). The altered Tesque Formation is Miocene–Pliocene (Kelley, 1978) and indicates a maximum age of mineralization. The unaltered Cuerbio Basalt of Pleistocene age (Disbrow and Stoll, 1957) unconformably overlies the altered zone and the La Bajada fault and provides a minimum age of mineralization.

Haji-Vassiliou and Kerr (1972) proposed a two-stage process of formation after faulting and fracturing of the host rocks. During faulting, they suggest that, first, petroleum derivatives migrated along the fault, possibly even forming an oil seep on the surface. Then, rising hydrothermal solutions carrying uranium and base metals moved through the fault and mixed with the older petroleum derivatives.

I propose some modifications and refinement to the theory proposed by Haji-Vassiliou and Kerr (1972). The mineralization at the La Bajada may have formed by dewatering of rift basins, similar to the process that formed Rio Grande rift barite-fluorite-galena deposits elsewhere along the rift (McLemore et al., 1998). During the Miocene–Pliocene, meteoric waters within the Tertiary and older sediments of the rift evolved chemically as they became warmer with depth due to burial and/or basin compaction, by dissolving rock constituents to produce waters of varying salinities and metal concentrations. As these warm brines interacted with Precambrian basement rocks, Jurassic and Cretaceous sediments, Tertiary volcanic rocks, and sediments derived from these sources, the fluids mobilized uranium, copper, silver, and other metals. Even the organic material could become suspended in these warm circulating waters as colloids, typically absorbed to clay colloids. The organic material then would collect at the La Bajada fault, perhaps due to a filtering effect within the low permeability fault zone. As the rift developed, favorable discharge zones such as the La Bajada fault allowed the mineralizing fluids to migrate up along fractures and faults. The organic material could have been deposited prior to or during deposition of the metals. Circulation of these warm waters would be along faults, fractures, contact zones, and other permeable zones within the basin. Once the deposit was emplaced, oxidation, dissolution, and downward reprecipitation and enrichment of the deposit occurred as the groundwater level dropped in the area.

Potential source rocks are abundant in the subsurface. The organic material may have been derived from carbonaceous material in Cretaceous or older sediments. Sulfur may have been derived from lacustrine evaporite deposits, pyrite-rich black shales, or other sulfur-bearing units in the subsurface. Uranium may have been derived from uranium-bearing Cretaceous and Jurassic sedimentary rocks. Copper, silver, and other metals may have been derived from sedimentary copper deposits, Proterozoic metal deposits, or Paleozoic, Jurassic, Cretaceous, or Proterozoic crystalline rocks enriched in these metals.

Probably, the most controversial aspect regarding the origin of the La Bajada deposit is the nature of the plumbing system responsible for mobilization, transport, and deposition of ore constituents. It is likely that mineralizing fluids began as meteoric water, although fluid inclusion studies at the La Bajada are lacking. Two general hypotheses have been proposed for Rio Grande rift barite-fluorite-galena deposits that are applicable to the origin of the La Bajada deposit: (a) basin dewatering by compaction (McLemore and Barker, 1985; Norman et al., 1985; Lueth and Goodell, 1996; McLemore et al., 1998) and (b) topography-driven (gravity) flow (Morgan et al., 1985; Witcher, 1988; McMahon, 1989; McLemore et al., 1998). In the basin-dewatering model, basinal brines accumulated in rift and older sediments and were subsequently heated in part as a result of burial and compaction within the high heat-flow environment of the rift. These warm fluids, after leaching mineral constituents from sediments and crystalline rocks, were ejected along faults and fractures, and unconformities during early diagenesis, later compaction, or uplift of sedimentary basins during extension (Hanor, 1979; McLemore and Barker, 1985; Norman et al., 1985). The second model uses presentday rift geothermal systems as an analog model. Erosion and tectonic stripping of older aquitards over structural highs created geohydrologic windows for discharge of deeply circulating, forced convective (gravity-driven) regional hydrothermal systems (Witcher, 1988). The circulation framework for these systems utilizes fracture permeability with greater potential for vertical flow in Pre-Tertiary rocks, especially in the upflow or discharge zones. Flow in these systems is topographically controlled, with recharge in highlands and discharge in structurally high, pre-Tertiary bedrock or highly fractured Tertiary volcanic rocks in the lowlands.

The La Bajada fault zone lies in between two major fault zones, the Rosario and San Francisco fault zones. These fault zones extend into the Hagan basin and Ortiz Mountains, where they may also have channeled mineralizing fluids that formed the uranium-selenium deposits in the Hagan basin (Moore, 1979; McLemore, the volume) and alkaline-related gold deposits in the Old Placers district (Great Plain Margin deposits of North and McLemore, 1986, 1988, and McLemore, 1996b, in press).

Additional copper-uranium vein deposits of probable Miocene age that are similar in composition and alteration to the La Bajada exits (McLemore, in press). Similar deposits occur at the Jeter mine in the Ladron Mountains and other small prospects in the Socorro area (Lucky Don, Little Davie, Aqua Torres, Marie: Chamberlin et al., 1982; McLemore, 1983; McLemore and Chenoweth, 1989). Copper-silver veins, but without uranium minerals, are also found at the Virginia mine in the Sacramento Mountains (Bent district), Marian and Oohoo mines in the Caballo Mountains, and Mockingbird Gap mine in the northern San Andres Mountains; a similar origin for these deposits is proposed (McLemore, in press). Finally, Rio Grande rift barite-fluorite-galena deposits occur throughout central and southern New Mexico and were probably formed by similar de-watering of the rift basins (North and McLemore, 1986; McLemore and Barker, 1985; McLemore et al., 1998). The Rio Grande rift barite-fluorite-galena deposits also contain a variety of trace metals (McLemore et al., 1998; McLemore, in press).

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ALBUQUERQUE GEOLOGY-CENOZOIC STRATIGRAPHY

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