History of the San Manuel-Kalamazoo Mine, Pinal County, Arizona

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Early Years (1879-1942)

A green copper stained outcrop on the south slope of Red Hill attracted the attention of prospectors at the time of the discovery of the nearby Mammoth mine in July 1879. Some of the oldest test pits excavated at this site probably date from the early 1880s. However, prospecting efforts over the next four decades failed to locate any ore grade mineralization and the claims were allowed to lapse.

In July 1925, the original San Manuel Claims No. 1 to No. 5 (inclusive) were staked at Red Hill by Anselmo Laguna. James Douglas, a saloon owner in Superior, purchased a third interest in the San Manuel claim group in June 1926 and subsequently acquired another third interest in August 1939. The remaining third interest in the claim group was acquired by James Douglas and Burns Giffin in October 1939. They deeded a quarter interest in the property to Victor Erickson in March 1940 in return for performing assessment work on their claims and building a small camp at Red Hill. By the summer of 1942, they realized they needed assistance from someone, who had mining experience. In August 1942, they enlisted the support of Henry Nichols, an assayer at Magma Copper, who agreed to assist them in return for an interest in the property. Over the years, the number of claims had also been expanded from five to twenty-one.

Discovery and Development (1942-1956)

By the late 1930s, disturbing news from Europe and Asia suggested the world was rapidly approaching the onset of war. In an effort to prepare America for this possibility, U. S. Congress passed the Strategic Materials Act in June 1939. Provisions contained within this legislation, required the U. S. Geological Survey (USGS) and the U. S. Bureau of Mines (USBM) to explore for new domestic sources of strategic metals. However, copper was not initially included on the list of metals covered by this act. Upon the entry of the United States into World War II in December 1941, Washington D.C. became very concerned about impending copper shortages and added copper to the list of strategic metals in July 1942.

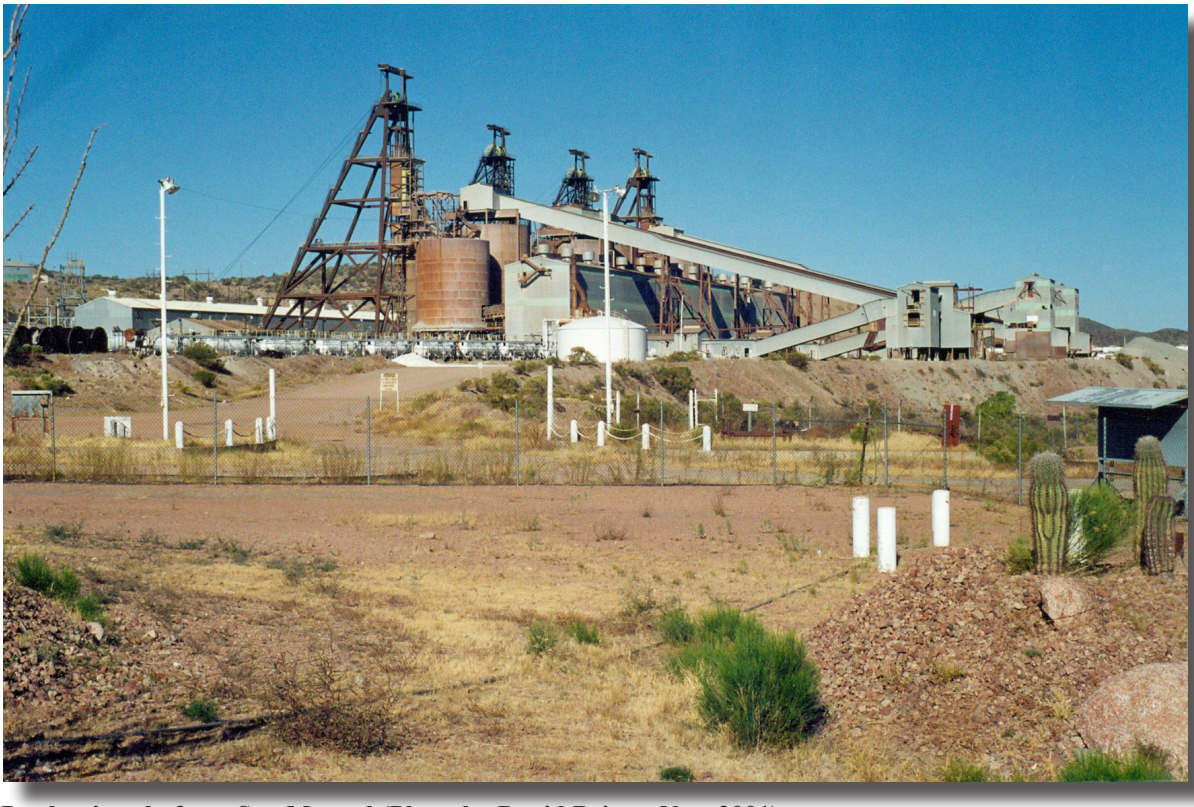
Despite Henry Nichols' early efforts to interest Magma Copper or ASARCO in the San Manuel property, both decided it did not warrant further examination. In October 1942, Henry Nichols decided to apply for a $20,000 loan from the U. S. Reconstruction Finance Corporation (RFC) in order to finance an exploration drilling program, that might prove enough ore to justify construction of a mill. In support of this application, he also submitted a technical report on the property. Their loan application was ultimately rejected in March 1943, although an RFC engineer, who visited the property, seemed interested in their proposal.

Although the RFC rejected the loan application from the San Manuel partnership, they did forward a copy of the Nichols' technical report to the USGS. In response to this report, two USGS geologists briefly examined the property during March of 1943. Their findings resulted in a favorable report recommending the USBM explore the property's copper potential. An exploration agreement between the San Manuel partnership and the USBM was reached in August 1943. Their exploration program began in November 1943 and by mid-January 1944, five shallow churn drill holes, totaling 1,480 feet, had encountered significant, but uneconomic oxide mineralization over drill intercepts of 75 to 300 feet. Later drilling activities encountered the sulfide ore body in May 1944. At that time, reserve estimates for sulfide and oxide ores totaled approximately 30 million tons, averaging 0.80% Cu.

The results of this limited churn drilling program provided enough interest for the Magma Copper Company to obtain an option to purchase the property in August 1944. Magma Copper began its own drill exploration program at the site in December 1944. Results of this study were positive and Magma Copper exercised its option to purchase the property in September 1945. The San Manuel Copper Corporation was formed to carry on future exploration and development activities at the site. Their surface drilling program continued until February 1948.

The No. 1 shaft was collared in March 1948, well north of the ore zone, to serve as a ventilation and supply shaft and for possible future use in hoisting the ore. The No. 2 shaft was collared in October 1948, over the southern limb of the ore body in order to expedite exploration and underground development of the deposit. The RFC approved Magma Copper's application for a $94 million loan to finance the development of its San Manuel project in July 1952. The first two 2,950-foot production shafts, No. 3A and No. 3B, were collared southwest of the San Manuel deposit in September 1953. Pre-production processing of ore derived from the development of this deposit began at a newly constructed 30,000 short ton/day concentrator at the end of September 1955.

Like many mines throughout the west, the Magma Copper Company established a company-owned town for its employees. However, unlike other mining communities, which were established in a piecemeal fashion, Magma Copper Company enlisted the assistance of the Del E. Webb Construction Company and M.O.W. Homes Inc. to plan and build the entire community. The site selected for this community was located in the San Pedro Valley, approximately seven miles southeast of the mine site. Completed in 1954, the town of San Manuel was Del Webb's first master planned community in Arizona with homes for Magma Copper employees, stores, schools and parks.



Production shafts at San Manuel (Photo by David Briggs, Nov. 2001)

Block caving operations commenced on November 24, 1955 and ore from the first panel dropped into the chutes shortly thereafter. Commercial mining and milling operations were achieved on January 1, 1956 at a total cost of $98.2 million. The San Manuel smelter was brought on line on January 8, 1956.

Discovery of Kalamazoo (1944-1968)

From the time of its discovery, geologists recognized that the San Manuel copper deposit was situated in the foot wall of a major low angle fault zone and the portion of the deposit located in its adjacent hanging wall was missing. Although initial efforts to find the other half of the deposit failed to encounter ore grade mineralization, seven drill holes completed between 1947 and 1958 did encounter the alteration halo in the hanging wall of the fault that surrounded the other half of the deposit. The Quintana Minerals Corporation began exploration in the area under the direction of J. David Lowell in August 1965 and discovered the Kalamazoo ore body in 1967. The Magma Copper Company purchased the Kalamazoo property from Quintana Minerals in March 1968, for cash and stock valued at $31.8 million.

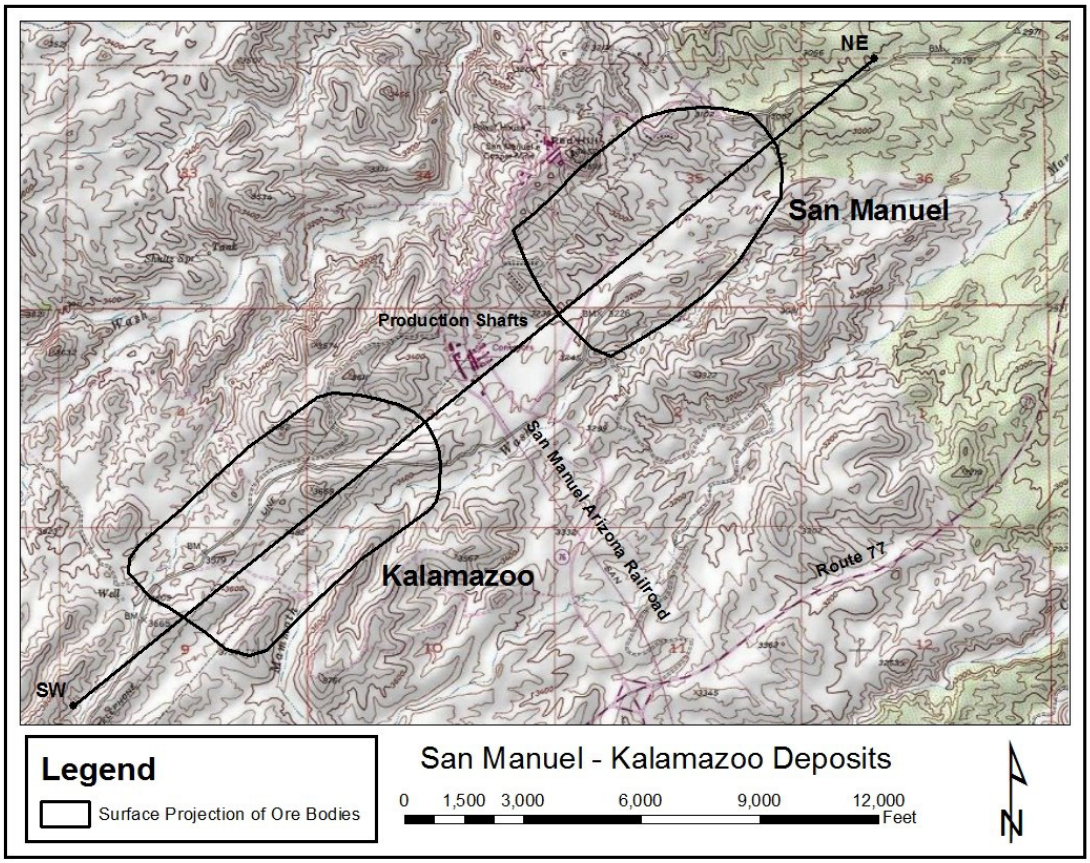
The analysis of scientific data gathered from San Manuel and Kalamazoo lead to the development of a geological model for porphyry copper deposits by J. David Lowell and Dr. Charles Guilbert, which is still used by geologists to evaluate these large mineralized systems.

Production Years (1956-1999)

Located at a depth ranging from 0 to 2,700 feet, the San Manuel deposit measured approximately 7,700 feet long by 3,500 feet wide. Shaped like an upright canoe that was tilted 45 degrees to the northwest, the long axis of this deposit plunged to the southwest at approximately 20 degrees. This mine employed a block-caving mining method, which entailed the removal of a horizontal slice of ore so the ore above caves naturally and flows by gravity into a system of transfer raises into draw points where it could be recovered and hauled by a underground ore train to the production shafts and hoisted to the surface. At the surface the ore was crushed and transported 6.8 miles via rail to the concentrator, which was located adjacent to the town of San Manuel.

In May 1962, Newmont Mining Corporation increased its equity interest in the Magma Copper Company from 21.5% to 80.6% and acquired the remaining stock it did not already own in May 1969, making Magma Copper a wholly-owned subsidiary of Newmont.

San Manuel concentrator with smelter stacks in background (Photo by David Briggs, Nov. 2001)



Schematic sketch showing surface projection of underground ore bodies (Topographic Base from USGS, Mammoth 7.5 Minute Quadrangle Map)

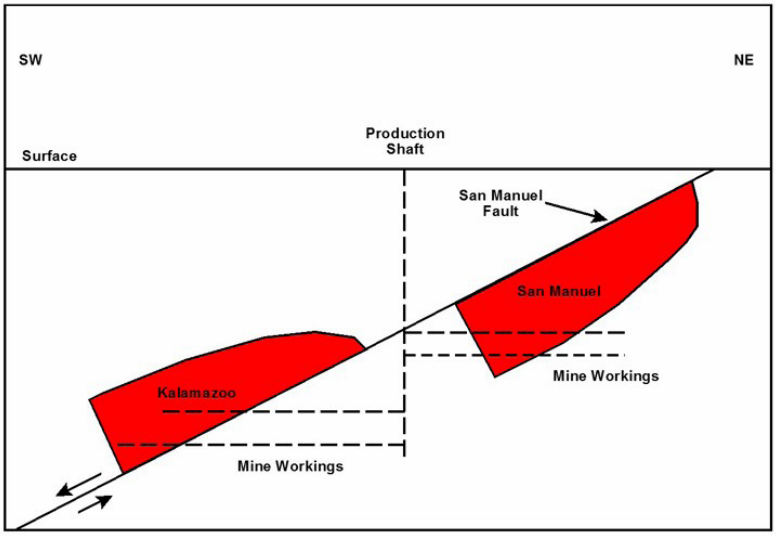
The capacity of the concentrator was subsequently increased to 36,000 short tons/day in 1963, 40,000 short tons/day in 1965 and finally 62,500 short tons/day in 1971. An electrolytic refinery designed to produce refined copper from copper anodes and continuous casting rod plant were completed in December 1971 at a total cost of $31 million. A sulfuric acid plant was added to the plant facility in 1974 to convert sulfur dioxide gas from the smelter's converter into sulfuric acid, which could be sold as a by-product.

Magma Copper sank the 4,123-foot #5 shaft to provide access to the Kalamazoo ore body and commenced underground development of the upper levels of the Kalamazoo deposit during 1977. However, these development activities were suspended in December 1981 due to adverse market conditions.

During 1983, Magma Copper commenced work on a feasibility study that examined the economic potential of mining the shallower, oxide copper ores located in the caved zone above the San Manuel underground mining operations by open pit mining methods. Magma Copper initiated this $70 million project in February 1985. Over the ten year life of this project approximately 93 million tons of oxide ore, averaging approximately 0.61% copper was stacked on a lined heap facility located north of the open pit and leached with a weak sulfuric acid solution. Copper cathodes (99.999% pure) were produced from the copper-bearing solutions at a solvent extraction-electrowinning (SX-EW) plant that was commissioned in May 1986.

Beginning in 1986, Magma Copper began a pilot in-situ leach program within the San Manuel open pit and portions of the San Manuel block caved underground unit to determine the practicality of using this method to recover copper from the oxidized mineralization located in this area. Although these efforts were negatively impacted by ground movement attributed to underground mining activities and logistical problems with on-going open pit operations, production of

copper using in-situ methods gradually increased from 614 short tons in 1986 to 12,500 short tons in 1990. Two types of in-situ mining methods were employed at San Manuel. Surface "well to well" in-situ



Simplified schematic northeast-southwest cross section through San Manuel and Kalamazoo deposits. (See map for location of cross section, not to scale.)

mining consisted of closely spaced injection and recovery wells that allowed for copper recovery in the remaining widths of the mined open pit benches. Many of these wells were subsequently mined out as the phases of the open pit advanced. A more limited and deeper set of injection wells were drilled to target material that had been caved and broken on the eastern side of the San Manuel underground operation, but not extracted by underground methods. Dilute sulfuric solutions were directed to trickle downward by gravity from the "well to underground" system through the caved zone. The copper-bearing solutions were then collected from sumps and dams located on the two lowest underground levels and pumped to the surface to be processed in the SX-EW plant.

In 1987, the Newmont Mining Corporation divested itself of its copper holdings, to form a new public company, also named the Magma Copper Company.

With the end of the mine life of the San Manuel ore body in sight, Magma Copper resumed limited development of the upper levels of the Kalamazoo deposit in 1986 and achieved limited production in August 1990. Centered approximately 5,000 feet southwest of the production shafts, the Kalamazoo ore body is located at a depth of 2,500 feet to 4,600 feet, measures approximately 6,700 feet long by 3,000 feet wide and ranges up to 1,000 feet in thickness. It has the shape of an overturned canoe, whose keel plunges to the southwest at approximately 20 degrees.

During the period, 1986-1988, Magma Copper modernized its smelting facility, replacing its existing reverberatory-converter smelter with an Outokumpu flash smelter at a total cost of $149.6 million. Commissioned in July 1988, this flash smelter was the largest of its type in the world.

Open pit at San Manuel, looking south toward Santa Catalina Mountains on skyline. Broken ground in the far wall resulted from the collapse of surface exposures above the underground block caving operation (Photo by David Briggs, early 1990s).

During the early 1990s, both the labor unions and management of Magma Copper realized that impressive gains could be enjoyed by all through employment of problem-solving techniques, working together and negotiating in a spirit of joint cooperation. Magma Copper introduced a gains-sharing program in July 1991, where pre-set targets, agreed to by all were established for productivity, costs and safety. If these targets were surpassed, the gains would be shared by all. In October 1991, Magma Copper and the labor unions successfully negotiated an unprecedented 15-year labor agreement, eight months before the current labor contract expired. Another approach employed to increase productivity involved the establishment of "high performance teams." These teams provided the vehicle that enabled employees to work with management to find more cost effective ways to perform their jobs.

In March 1993, Magma Copper's Board of Directors approved the development of the lower levels of the Kalamazoo ore body at a total estimated cost of $150 million. This was only possible after the joint union-management agreements that took place in 1991.

Open pit operations were suspended in January 1995 after depleting its mineable ore reserves. Broken Hill Proprietary Company Ltd. acquired the San Manuel-Kalamazoo property through its merger with the Magma Copper Company in January 1996. Sulfide ore production from the lower levels of the Kalamazoo ore body was achieved in January 1997. Although most of the underground reserves remaining within the San Manuel ore body had been mined by early 1999, mining continued at the deeper Kalamazoo ore body until June 1999, when BHP Copper placed all mining, milling, smelting and refining operations on care and maintenance status due declining copper prices, which had fallen from a high of $1.395 in July 1995 to $0.645 in June 1999. However, production from the existing heap leach and in-situ leach operations continued to produce limited amounts of cathode copper from the San Manuel ore body.

San Manuel Smelter (Photo by D. Briggs, Nov. 2001)

Final Closure and Reclamation (1999-Present)

From 1999 onward, BHP Copper engaged in extensive communications with state and federal environmental regulatory agencies and the local communities (Mammoth, San Manuel and Oracle) to discuss the closure approach and timeline. BHP initiated site closure evaluations and applied for comprehensive amendments to their existing Aquifer Protection Permits to include the closure designs and post-closure monitoring program at both the mine and plant sites. The applications and permit process required BHP to document the current site conditions after 50 years of mining and processing and develop closure systems that would reduce post-closure impacts to the environment. Community input indicated the desire to see a more natural shape to the benched heap leach facility so the heap was contoured with gentler slopes and an undulating crest line that included highs and lows.

In January 2002, all underground operations were permanently suspended after a detailed analysis determined it would be unprofitable to resume production in the foreseeable future. Following the salvaging of the remaining underground equipment and removal of any hazardous fluids or materials, the pumps were turned off in mid-February 2002, allowing the underground workings to flood. Cathode copper production from the heap leach operation was halted in March 2002.

The concentrator, smelter, refinery and rod plant remained on care and maintenance status until October 2003, when a decision was made to permanently close these facilities. The plant facilities were subsequently demolished and the 4,600-acre site was reclaimed, including 3,600 acres of tailings impoundments and 625 acres of industrial plant facilities. The San Manuel community was divided on whether to take down the two iconic smelter stacks, but the 500-foot high stacks were demolished on January 18, 2007.

Epilogue

Over its 44 year life, the San Manuel-Kalamazoo mining operation produced approximately 703,686,000 short tons of sulfide ore, averaging 0.66% copper from its underground operation and 92,969,000 short tons of oxide ore, and averaging 0.61% copper from an open pit. Copper and molybdenum production totaled 4,651,600 short tons and 73,200 short tons, respectively.

In terms of total ore production, San Manuel-Kalamazoo was the largest underground mining operation in North America and one of the largest operations of its type in the world. It was an important contributor to the economy of both Pinal and Pima Counties. Its rail operation and transloading facility remains in operation - now used by Capstone's Pinto Valley operation to ship concentrates for smelting and refining.

The San Manuel reclamation program was one of the largest owner-funded mine and plant site closure projects in the world. Successfully completed during 2007, it demonstrates full reclamation of large copper projects is possible once mining operations have been completed.

References

Anonymous, 1990, World's Largest Flash Smelter: E&MJ, v. 1991, n. 1, p. C37-39.

Anonymous, 1999, BHP Will Close Two U. S. Copper Operations: Mining Record, v. 110, n. 28, p. 1.

Beal, J. V., 1965, Southwest Copper: Mining Engineering, v. 17, n. 10, p. 77-92.

Chadwick, J., 1992, Magma from the Ashes: Mining Magazine, v. 167, n. 10, p. 221-237.

Creasy, S. C., and Pelletier, J. D., 1965, Geology of the San Manuel Area, Pinal County, Arizona: U. S. Geological Survey Professional Paper, no. 471, 64.

Jenkins, J. G., 1994, Copper Heap Leaching at San Manuel: Mining Engineering, v. 46, n. 9, p. 1094-1098.

Knoerr, A. W., 1956, San Manuel - America's Newest Large Copper Producer: E&MJ, v. 157, n. 4, p. 75-100.

Lowell, J. D., 1968, Geology of the Kalamazoo Orebody, San Manuel District, Arizona: Economic Geology, v. 63, p. 645-654.

Lowell, J. D., and Guilbert, J. M., 1970, Lateral and Vertical Alteration-Mineralization Zoning in Porphyry Ore Deposits: Economic Geology, v. 65, n. 4, p. 373-408.

Magma Copper Company, 1993, Company Brochure.

Sandbak, L. A., and Alexander, G. H., 1995, Geology and Rock Mechanics of the Kalamazoo Orebody, San Manuel, Arizona; in Porphyry Copper Deposits of the American Cordillera: F. W. Pierce adn J. G. Bolm (eds.), Arizona Geological Society Digest 20, p. 396-423.

Schwartz, G. M., 1953, Geology of the San Manuel Deposit, Arizona: U. S. Geological Survey Professional Paper, 256, 56 p.

Thomas, L. A., 1968, Geology of the San Manuel Ore Body; in Geology of the Porphyry Copper Deposits, Southwestern North America: S. R. Titley and C. L. Hicks (eds.), The University of Arizona Press, Tucson, Arizona, p. 133-142.

Wiley, K. L., Ramey, D. S., and Rex, M.J., 1994, In-Situ Leaching Wellfield Design at San Manuel: Mining Engineering, v. 46, n. 8, p. 991-994.

Zaburunov, S. A., 1990, Magma Independence: E&MJ, n. 191, n. 1, p. C30-C35.