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LOST HORSE GOLD MILL
Joshua Tree National Monument
Twentynine Palms Vicinity
San Bernardino County
California

HAER No. CA-128

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWINGS

Historic American Engineering Record
National Park Service
Department of the Interior
P.O. Box 37127
Washington, D.C. 20013-7127

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HISTORIC AMERICAN ENGINEERING RECORD

LOST HORSE GOLD MILL
Joshua Tree National Monument

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Note:	For shelving purposes at the Library of Congress, Twentynine Palms Vicinity, San Bernardino County, was selected as the "official" location for the Lost Horse Gold Mill, which is actually located in Indio Vicinity, Riverside County.
Location:	Approximately 15 miles SSW of Twentynine Palms in Joshua Tree National Monument, Indio Vicinity, Riverside County, California. SE1/4, NW1/4, Sec. 3, T.3 S., R.8 E. UTM: 11/579890/3755770 Quad: Key's View, 7.5 min. series Twentynine Palms, 15 min. series
Date of Construction:	1893
Present Owner:	Joshua Tree National Monument National Park Service Department of the Interior
Present Use:	Mine and mill not in use. Site open for walking tours.
Significance:	The Lost Horse Gold Mine and Mill is a prime interpretive exhibit of efficient early western gold-mining practices and compactness of design, whereby the mine's ten-stamp mill was located directly over the shaft being mined, thus negating the need for transporting ore to a central collection point for processing.
Historians:	Richard Vidutis, Summer 1992. Donald Hardesty, Lester Ross: Archeological Inventory Report

INTRODUCTION

The Lost Horse Mine and Mill site is located in Joshua Tree National Monument, Riverside County, California, three miles southeast of Ryan Campground and Lost Horse Well. Situated in the central part of Lost Horse Mountain, which reaches 5,178' above sea level, the mining and milling operation was erected directly over the main vertical shaft at 5,000' on the southwest side of Lost Horse Mountain, which runs northwest to southeast. The mill site complex straddles a shallow valley--the mill on one side and several support and habitation sites on the other side. Several habitation features sit some distance from the milling site along the road to the mill and along a wash connecting the mill site with the access road.

The climate of the area is hot and dry in the summer and may be cold and snowy in the winter. Weather statistics for Twentynine Palms, which is in the low desert, about 20 miles to the north of Lost Horse, show a maximum average temperature ranging from 62° in January to 104.7° in July; average lows are 35.1° in January and 71.5° in July. The number of days of 100° or higher temperatures varies from 62 to 101 per year with an average of 80.7 days per year. Precipitation ranges from a low of .02" in June to a high of .73" in August during the so-called monsoon season; the yearly average is 4.17". The humidity is also very low, averaging 21.9 percent, and in the summer months it may be as low as 10-15 percent. But at the higher altitudes, in the high Mojave Desert where Lost Horse is situated, temperatures are approximately 11° cooler with about 3.5" more of annual precipitation.

GEOLOGY OF LOST HORSE

The Lost Horse Mine gave its name to some of the surrounding areas such as the Lost Horse Valley and Lost Horse Mountains. They are part of the eastern Transverse Ranges that lie between the San Bernardino Mountains to the south and the Pinto Mountains to the north, a region characterized by numerous faults: the Pinto Mountain, Blue Cut, Porcupine Wash-Substation, Smoke Tree Wash-Victory pass, and Chriaco.[1]

The Lost Horse Mountains, extending north from the San Bernardino Mountains, are a topographic expression of gneiss between two bodies of the White Tank quartz monzonite. The area is characterized by the presence of quartz, biotite, andulusite, and/or sillimanite, and cordirite with most mining activity taking place on shear zones with quartz veins containing remobilized gold and silver.[2] Contacts between the area's quartz monzonite and gneiss are either very abrupt or broadly gradational, with rarely complete mineralogical and textural transition between the two types of rocks over a distance greater than a few feet.[3]

The Lost Horse area may lay on top of thrust faults that became slightly domed during the mobilization of ore forming fluids. According to geologist Edward Fife, the Lost Horse Vein,

> apparently a classic auriferous quartz vein filled fault or shear zone, was apparently cut off at depth by a "low angle fault" around 500 to 600 feet below the surface. This is on the correct order of magnitude for a contact, perhaps a "thrust contact," drawn between the Pinto gneiss-White Tank quartz monzonite boundaries on the east and west side of Lost Horse Mountain.[4]

A similar formation is the Skidoo laccolith in Death Valley which is considered to be a spectacular example of an auriferous-siliceous ore body.

The Lost Horse site itself, according to Fife, is:

> underlain by dark well-foliated thin-banded quartz biotite Pinto gniess ranging from dioritic to granitic in composition. The banding strikes generally north to N40°W and is steeply dipping to vertical. About 100 feet north of the main shaft, the foliation strikes N7°W and dips 71° west south. The principal mine workings explore a quartz vein which strikes east, dips 85°N, ranges from 6 inches to 5 feet in width, and is exposed on the surface at several points for about 800 feet. The vein exposed adjacent to the shaft and stamp mill strikes N85°E. About 100 feet eastward along strike, the vein is 1 to 1.5 feet wide on the surface with an attitude of N75°W.82°N. On the ridge west of the main shaft there is a 20 foot wide medium to fine grained diorite dike trending eastward toward the main shaft. East of the shaft about 20 feet, a 4-inch near vertical quartz vein strikes N20°E. Where best defined in the upper shaft the shears strike N15°W, and dip 70°SW. Shallow shafts, 300 and 500 feet to the West on the ridge expose east-striking vertical, thin, iron-stained quartz veins in shear zones in gneiss.[5]

Examining the waste dump material, Fife found it to contain iron-stained vein quartz, gneiss, and black mica schist. Near the main shaft a hornblende pyroxene schist indicates possible xentime mineralization. The plotting lineaments (which may actually be faults) along the east side of the Lost Horse Mountains suggests that the Lost Horse vein may occur at the junction of two local faults, an indication of Mesozoic or later mineralization.[6] The age of the Lost Horse vein may be pre-Mesozoic, even Precambrian, or contemporaneous with post-Mesozoic intrusives. The existence of basalt at Malapai Hill two and a half miles east and along the western part of Lost Horse Mountain suggests hydrothermal mineralizing solutions.

The workings of the mine explore a quartz vein exposed on the surface at several points for about 800'. The vein strikes east, dips 85° N., and ranges from 6" to 5' in width.[7] Approximately 20' east of the main shaft, a 4" vertical quartz vein strikes N. 20° E. East-striking vertical quartz veins in shear zones in gneiss are explored by two shallow shafts on the ridge (300' and 500' to the east) as well as by several pits. The best defined shears in the upper shaft strike N. 15° W., and dip 70° southwest. About 100' west of the main shaft an adit extends N. 80° E. along a 5' wide shear zone. The adit is 80' long with a 50' winze and a 50' drift east driven from the bottom of the winze.[8] The vertical 500' main shaft shows a small amount of drifting of the vein on the 100', 200', 300', and 400' levels.[9] By 1896,[10] the main vertical shaft was already at 235' feet and was being worked with a horse-whim.[11]

Gold production at Lost Horse suggests the richness of the vein. During the period 1895-1901, the company processed just over 10,000 ounces of gold and 16,000 ounces of silver. By the end of the century, note numerous articles, $350,000 had been extracted from the Lost Horse. This six year period produced over 95 percent of the wealth made in the first seventeen years of the mine's recorded production.[12]

Table 1: Gold Production at Lost Horse Mine, 1895-1936

Year	Crude Ore (tons)		Recoverable Metals Gold (ounces)	Silver (ounces)
1895			604.69	3,769
1896			1,209.38	7,353
1897			2,418.75	
1898			2,902.50	1,695
1899			2,418.75	3,333
1900			483.75	
1901			193.50	
1905			169.31	82
1906			38.70	22
1908			113.39	23
1931	100		50.90	18
1932	200		14.31	2
1933	300		15.19	2
1934	120		30.36	4
1935	10		1.43	1
1936	600 (tailings)		86.83	75
		Totals	10,751.74	16,379

The totals appearing at the end of the above table are incomplete. For example, the first year of production (1894) is not included; the amount of alleged skimming of amalgamated ore by John Lang is unknown; and the easily extractable early ore pockets such as float gold could have been used directly to buy supplies. These unknown amounts may have added perhaps another 1,000 ounces to the production totals, Fife surmises.[13] For seventeen years of production at the Lost Horse, the yearly average was 633 ounces of gold and 963 ounces of silver.

Regarding the mineral potential of the Lost Horse vein, Fife concluded:

> The age of auriferous mineralization in the Lost Horse vein is important to potential for additional precious metals in this mine. If the vein is simply a faulted off vein or roof pendant from a pre-Mesozoic episode of mineralization, the opportunity for additional ore in the main vein system is diminished. If the contact is a post intrusive or synchronous thrust fault or Quaternary hydrothermally filled fissure, then the potential for additional precious metals is greatly enhanced. If the latter two are the case, the future potential may be several orders greater than past production.[14]

MINING AND MILLING AT LOST HORSE

Spanish exploration and settlement opened the region to mining activity. First recorded in the 1820s, within thirty years the Spanish had developed a system of roads with a southern route connecting the gold fields of La Paz with San Bernardino. Occasionally, while prospecting for gold bearing sites, they took a northerly cutoff through the area now known as the Monument.[15] Other evidence, such as mine names, smelter types, and old Spanish coins, suggest a Spanish presence in the area.[16]

The Piñon Mining District was organized in 1892. Its boundaries were marked by the Lost Horse Mine on the west, the San Bernardino-Riverside county line on the north, the White Tanks on the east, and the Golden Bee Mine on the southeast. Major mines in the area were: Piñon Mountain, the Homestake, the Dewey, the Hexahedron, an undetermined group of mines close to the Lost Horse Mine in Pleasant Valley, and the Golden Bee and El Dorado mines.

Stories of the discovery of the Lost Horse vein are numerous and often repeated. All start from the same basis in fact: the Mining Claims Book No.1, in Riverside, California, records a Notice of Location at the request of John Lang for four claimants: George W. Lang, John Lang, Ed Holland, and James Fife. Since Lang filed that notice, popular legends have tried to explain how he found the rich Lost Horse vein. The great variability in the basic elements of the discovery tale suggests that the facts have become a local tale or legend meant as much for entertainment as for historic clarification. In most cases, popular articles merely repeat an oral tradition existing in the community about Lost Horse; they often repeat each other.

Major variations of the basic story credit as many as five different people or groups with discovering the vein. John Lang is prominent in three, either as discoverer or as opportunist at the site immediately after it was discovered by someone else.[17] The true version of the discovery likely will never be known. Of the popular versions in print, the most detailed and probable are contained in articles by Lucile Weight and Edward Fife (a descendant of James Fife, one of the original claimants).[18]

Weight argues that Lang discovered the vein while looking for a lost horse. George Washington Lang, the father of Johnny Lang, the hero of so many legends and tales about the Lost Horse Mine, was born in New York State, and John was born in Texas in 1853 when George was 25. The Langs were not miners but cattlemen, herding cattle throughout the West and developing markets in Oregon, Idaho, Montana, Nevada, Kansas, Texas, New Mexico (where they operated a ranch)[19], and Arizona.[20] The Langs kept moving west to satisfy newly opening markets for beef cattle, and by 1890 George Lang was headquartered in Los Angeles, a large growing market. Within three years, George and son John were established in the Indio area with Banning as their post office point.[21] It was during this period that the business pair came into contact with Tingman and Holland who were already established as mine investors in the area of Lost Horse. In 1891 the Colorado spilled over its banks, creating new fertile pasture lands. At this time, the Langs were driving their cattle from New Mexico to Los Angeles, grazing them in the country below Indio in the barren desert. According to Weight, "(i)t was in this period that one or more of the Lang horses got away, and John went into the mountains for them--and found gold."[22]

Edward Fife's version differs from Weight's, and is based on interview with his grandfather, one of the original locators. James Fife came from Illinois to California approximately in 1873, prospecting for gold for about ten years without much success.[23] In Los Angeles he worked as a teamster, a job that took him to outlying towns and mines where he eventually met Alfred G. Tingman, a prominent merchant and citizen of Indio. In time, he moved to Mecca to a desert climate for the benefit of his wife, who suffered from asthma. In Mecca, on Tingman's recommendation and with his assistance, he opened a trading post that served local agricultural and mining operations. Business was insufficient to support his family, so Fife supplemented his income by working at the salt mines at Salton and at other mines in the area. He also drove a 20 mule team monthly to Los Angeles for supplies, which he then traded for crafts, blankets, baskets and firewood stockpiled for him by local Indians.

According to Edward Fife, his grandfather James found the original vein, although he acknowledges that it may have been seen first by a surveyor named Washington who came through the area in the 1850s. He describes the Langs as showing up one cold and stormy night at the Piñon mining camp, where they were given shelter in the bunkhouse. Their horses, spooked during the night by lightning, escaped from the company corral. James Fife and John Lang followed the animals' tracks down Piñon Canyon to the floor of Pleasant Valley, and eventually found themselves in a small valley several hundred feet above the west side of Pleasant Valley. According to Fife,

> (w)hile Johnny Lang stopped to remove a rock from his boot, Jim took his pick and knocked off a sample from a protruding ledge. Close examination of the specimen revealed small specks of yellow metal dispersed throughout; some of the yellow metal appeared to be gold.[24]

George W. Lang offered to bankroll the new discovery if the ore was rich enough to mine. The Langs, James Fife, and his friends Al Tingman and Ed Holland went back to the site to sample the ore.

The discovery tale notwithstanding, on December 29, 1893, George W. Lang, John Lang, Ed Holland, and James J. Fife (Al G. Tingman also may have been a partner on the side) filed a notice of location on a gold bearing lode "adjoining the Peoples Party Mine on the East."[25] County records at the Riverside County Hall of Records reveal thirteen claims filed by the five partners in 1893, while Ed Holland filed a notice of intention on an additional twenty-one. Thus, in 1893 alone, the group of six (including Johnny Lang's wife, Jessie (Green) Lang, filed thirty-four claims. The most important was the Lost Horse.

The partnership between the four primary claimants was one of convenience. According to Fife, since the Langs were wealthy, they would provide the capital; Tingman and Holland were included to balance off the majority interest of the Langs and to gain access to their processing facilities. Perhaps most importantly, Ed Holland, who was the Piñon Mining District Recorder, insured that no one would file conflicting claims over the group's holdings without his signature.[26]

Alfred G. Tingman was known as the "Grand-daddy" of Indio, as well as "Hombre Dolorado" (the Dolor Man). His father was a Sacramento pioneer and one of the early families of merchants there. In 1875, Tingman came to the Coachella Valley as a telegraph operator and construction gang boss for the Southern Pacific Railroad, remaining in Indio as an agent after the tracks were laid. According to Wilhelm, old files and railroad records reveal that Tingman was knowledgeable in geology and particularly interested in gold mining.

> In his free time during the next 12 years, he made forays into bordering desert mountains. His knowledge of geology was put to good use. Several gold claims that he later developed paid off handsomely. From the period beginning in 1880, his name appears on many Riverside County gold mining ventures.[27]

Tingman built the first store in Indio, trading with the early prospectors (and grubstaking them), homesteaders and employees of the Southern Pacific Railroad. His store also contained the valley's first post office. In 1900, Tingman went prospecting in the Chocolate Mountains, where he died.[28] Although Tingman's name does not appear on the mining claim for Lost Horse, he was involved in the Lost Horse and other surrounding claims with the group.

The last of the claimants, Ed Holland, left few traces of his life. It is known that he was a merchant who, along with Tingman, had invested in mines in the Piñon Mine District in the 1880s. As mentioned above, he was also the Piñon Mining District Recorder.

In 1895 the site was surveyed for patent (U.S. Mines Survey No. 3333), and in August, 1897 a patent (No. 28417) was issued for 13.5 acres to Thomas C. Ryan, Jepp D. Ryan, Matthew Ryan, Ethan B. Ryan and Samuel N. Kelsey. The chronology of operators of the Lost Horse is as follows: Thomas C. Ryan, 1896-1898; Lost Horse Mining and Milling Company, 1899-1900; Samuel M. Kelsey, 1901-1905; and the Lost Horse Mining and Milling Company, 1906-1908.[29] Between 1908 and 1931, the mine was leased to a succession of people who realized little profit but, apparently, had high hopes that the vein could be recovered. The property lay idle from 1923 until 1931, when the General Mining and Development Company mined the upper ore pillars; and the last work to be done at the mill was by J.D. Ryan in 1936 when he cyanided 1,330 tons of tailings.[30]

The early period of mining was continuous from 1893 to 1908. Work proceeded steadily and the partnership formed the Lost Horse Mining Company.[31] Throughout most of 1894, regular grade ore was hauled eight miles to the Pinyon Well Mill (perhaps also known as the Piñon[32] Mountain Mill and later the El Dorado patented mill site).[33] Results were very encouraging, with the ore producing up to 25 ounces of gold per ton. Two tons of hand cobbed ore brought $7,000.[34] Moreover, the discovery of rich ore-shoots, float and outcroppings, brought the mine immediate prosperity. Ore of this grade, at about 4,000 ounces to the ton, was considered "jewelry gold" and was sold directly to dealers as specimens. It would have paid the investors approximately $80,000 per ton.[35]

The mill was in full operation by November, 1894,[36] when Johnny Lang and J.J. Fife constructed a larger two-stamp mill at Lost Horse Spring[37] on the southwestern slope of Ryan Mountain.[38] The stamp battery was made by Baker Iron Works in Los Angeles. Possibly an earlier arrastra (a crude machine for grinding ore and amalgamating gold) was used at the site before the introduction of the two-stamp mill. By the summer of 1895, a six horse power gasoline engine[39] manufactured by the Los Angeles Windmill Company[40] powered a two-stamp mill with two 850-pound stamps with a capacity of four tons every twenty-four hours.

In 1895, the partners began to sell their interests in the mine and company. According to Fife, doubts about John Lang's handling of the ore resulted in accusations that he was skimming the profits while transporting the gold-mercury amalgam to a refiner in Los Angeles. George Lang offered to buy out the partners. James Fife sold his interest in the Lost Horse for $10,000, and he and his wife sold their interest in the Lost Horse Company for $2,000 in silver.[41] Tingman and Holland also sold their interests to George Lang. But John Lang continued to skim the amalgam, even from his father. Unable to trust his own son, George Lang finally sold his share to James and Thomas Ryan for $76,000 sometime around 1896. John Lang continued to work for the Ryans with a fourth interest in the Lost Horse claim and a fifth interest in the Lost Horse Mining Company.[42]

Apparently, the Ryans were long time partners and friends of the Langs. Specific information on their earlier activities is not available, although they were known to have been partners with the Langs in slaughtering and meat packing interests in the 1880s. In 1897, Thomas C. Ryan, Jepp (D.D.) Ryan, Matthew Ryan, Jr., Ethan B. Ryan, and Samuel N. Kelsey patented the mine as the Lost Horse Mining and Milling Company. The group established its company with capital of $500,000.

Although John Lang remained part owner, the problems of shortcomings in the amalgamated ore remained. Lang ran the night shift and the Ryans the day shift. There soon developed a noticeable difference in the sizes of the gold-quicksilver amalgam balls. The Ryans hired a detective to watch Lang and he was finally confronted with the fact that he had been taking about half the amalgam from the night shift for himself. The Ryans offered him a choice: buy, sell, or go to a penitentiary. Lang sold his share for $12,000 and the whole mine enterprise now was in the hands of the Ryans.[43] During the period 1917-1926 Johnny Lang sold Bill Keyes nearly $18,000 worth of gold supposedly from amalgams stolen and buried by him around the mill site.[44]

When the Ryans acquired control of the mine, they made numerous improvements. Hauling Lost Horse ore by mule to the Piñon Well mill quickly proved unproductive. The amounts of ore taken from the mine may have overwhelmed the capacity of the small two-stamp mill, and the amount of water available at Langville proved too little. According to a contemporary source, "(a)fter going down 100 feet below the first ore pocket they discovered the main ledge, and built a 10-stamp mill in addition to their 2-stamp mill."[45] The new mill, with a thirty tons-per-day capacity, was disassembled and moved from the Sterling Mine[46] in the Chuckawalla Mining District (at the Colorado River) to the Lost

Horse mine during in April.[47] A two-inch pipeline was laid 3.5 miles from Lost Horse Spring (later to become Ryan Wells)[48] and steam engines raised water 750 vertical feet to an earth and stone reservoir 16' x 12' at the mill site. A steam engine operated a hoist, skip, and the new ten-stamp.[49] A shipment of ore was made every week from Lost Horse to Banning; the trip took five days and required two wagons, a water tank, and a feed rack.[50] Ryan also improved the access road and rerouted it from the older, shorter route followed by Lang. The present entrance trail, taking off from the Salton View Road, approximates the Ryan road route.[51]

From 1908 to 1931 no production figures were reported to the United States Bureau of Mines; nonetheless, a variety of activities took place at the mine. In 1900, the property was bonded to U.S.G. Todd of Los Angeles for $200,000 from the current owners, Ryan and Kelsey,[52] and in 1904 the mine was reopened after having been closed for several years.[53] Eight years later, a notice appeared in the paper that Lost Horse Mine would be sold to satisfy a judgement in the amount of several thousand dollars for Addie B. Ryan (wife of Jeptha DeGarret) who apparently had loaned the mining company large sums for development work.[54] In 1915 minor, but unspecified, alterations were made to the stamp blocks.[55]

Lost Horse lay idle for about 20 years, but was reopened by Daniel Stafford and Sam Ryan of the General Mining and Development Company in 1931 under lease from J. D. Ryan to process upper level support pillars and ore in the ten-stamp mill. The renewed interest in mining the Lost Horse grew out of the rise in gold prices in 1931.[56] Theirs was probably the last work to be done in the mine itself.

Saul reports that the yields during the 1930s amounted to only a few hundred ounces of gold. Furthermore, he notes that local residents reported the vein was faulted off at depth, and that drifting failed to rediscover the vein.[57] Fife concluded that

> the vein was still in paying ore in the bottom of the workings but encountered a low angle (thrust?) fault and little effort or expense was made in an attempt to find the faulted vein. Unfortunately, no professional expertise was applied to find the faulted extensions of the vein.[58]

In 1966 the National Park Service acquired title to the Lost Horse Mine from the Ryan descendants,[59] and the following year the property was acquired by the government for the National Park Service.[60] By 1970, the condition of the mill had deteriorated to the point that the headframe over the vertical shaft attached on the uphill end of the structure collapsed.[61] The Lost Horse mine site continued to be a popular tourist attraction. With concern for the safety of exploring tourists new wooden steps and a safety rail were added to the eastern side of the structure, and concrete foundations were inserted under part of structure in 1973.

ENGINEERING FEATURES OF THE LOST HORSE GOLD MINE AND MILL

Types of Ores

Low-grade ore containing gold was rarely visible to the naked eye. In high grade ore gold occurs in lamellae along the division in the quartz ("ribbon rock"), often assumes the form of wire ("wire gold"), and occasionally looks arborescent or tree-like. Ores containing free gold ("specimen gold") were often sold to jewelers for $20 to $27 per ounce (1888 prices).[62] Most of the quartz veins worked by the old prospectors were either the exposed and decomposed surface ores or clean quartz bodies containing bright yellow gold. Underground, surface ores changed into sulphuret compounds of iron and copper, with galena, blende, and other minerals.[63] Ore at depth did not yield as much gold as surface ore. Examination of tailings revealed a percentage of unrecovered gold, and it was the interest in saving fine particle gold ore in the sulphurets that spurred, in part, the development of amalgamation or concentrating tables.

The Stamp Mill

In the 1850s, methods for concentrating gold in California consisted mainly of saving the placer gold and processing it with rocker and sluice mixed from various grades of ore.[64] Many types of sluice bottoms were tried in attempts to catch the gold: plain riffle bars; blocks of wood sawed across the grain; boards filled with holes, and the like. Mercury was used to concentrate the gold as often as it was not.[65]

During the early periods of gold discovery in California, efficient methods appropriate to local conditions were yet to be developed for extracting and concentrating gold. At first, the old square wood-stem Cornish stamp was used, as well as various arrastras. With time, improvements were made to the old stamp by replacing it with round iron stems rotated slightly when lifted by the cam. The cam, tappets, shoes, and dies were made of die-cast steel reducing wear to a minimum.[66]

Depending on the type of gold ore found at the mine - that is, high grade ores (free gold and silver) versus low grade ores (often as invisible particles and even in compounds with other minerals) - amalgamation tables were used to recover the free gold by running a "pulp" of crushed ore mixed with water over copper plates covered with a thin film of mercury. Amalgamation was an early technique for the treatment of free-milling ore and often was used in combination with the cyanide process.

Turn-of-the-century technology to reduce gold ores in California was summarized by John Hammond in 1888. Coarse ore retained by the grizzly in the upper ore bin

> is passed through the rock breaker, by which it is reduced to the proper size for stamping, thence it passes through the battery, where part of the free gold is extracted by amalgamation. The pulp, from which part of the free gold has been eliminated, passes from the mortars on to the copper plates, and thence to the concentrators. The concentrators effect the concentration of the auriferous sulphurets, the residual pulp passing off into the sluices below the mill, where a portion of the sulphurets and other valuable contents, which have escaped from the concentrators and preceding appliances, is saved by various contrivances. From sluices the pulp passes away as tailings, or, comparatively speaking, worthless gangue.[67]

<u>The Mill Site</u>

The choice of the mill site was of paramount importance, since its location in large part determined the cost of milling ore. In 1895 Preston listed five major economic considerations in selecting a site for a mill: 1) the proximity of the mined ore; 2) quick transport of the ore to the mill, as well as carrying it directly to the highest point of the mill for gravity decent through all the different points of operation required in the process of ore reduction; 3) ability to house large ore storage bins necessary to prevent stoppage of mill work through a lack of ore due to delays in the mine, along the roads, or lack of water; 4) accessibility of the mill to fuel, water, wood, and other supplies throughout the year; and 5) solid placement of the mill, if possible, on rock foundations, since the stability of the mill is essential for successful milling.[68] He further presented the ideal site, one very reminiscent of the Lost Horse:

> The ideal site would be to have the mill in close proximity to, but below the level of the collar of the shaft or the mouth of the tunnel; on sloping ground, where the ore can be delivered directly from the mine to a "grizzly" on the upper level floor of the mill, to be passed later, without rehandling, through the crushers, ore-bins, self-feeders, mortars, etc., while leaving sufficient space for a waste dump. For a mill arranged in this manner, including concentrators and canvas platforms, 40' of fall should be available.[69]

Mill Construction

Once selected, the surface of the mill site was removed to bedrock for the different floors of the mill, and the bedrock used for buttresses. Particular attention was paid to the foundation for the mortars and erection of the battery frames. For the mortar block, a trench had to be prepared proportional to the height of the block and wide enough to leave about 2' of free space around it to be filled later with concrete or tailings from the battery. In California the mortar blocks were usually cut from a solid piece of pine. Once set into the ground, the top was planed perfectly true and leveled. Before setting the mortar on the block, a 1/4" thick rubber cloth or two or three folds of mill blankets, well tarred, were placed on the block.[70]

The battery frame was supported in a number of ways: with diagonal braces and hog chains at front and back, or with knee-frames as at Lost Horse; at larger mills with stamps exceeding 750 lbs., knee-frames were preferred. The battery posts generally were 24" deep and from 12" to 20" wide. The center post of a ten-stamp mill was made the heaviest since it had to absorb the greatest strain.[71]

Parts of the Mill Involving Dry Reduction of Ore

The grizzly was a coarse screen attached to parallel bars set on an angle from 45° to 55° over the ore bin. The grizzly separated ore into two classes, allowing smaller ore pieces to drop through to the ore bin before reaching the crusher floor, and retaining the coarse ore that passed into the ore bin on its way to the rock-crusher. Grizzlies were made in a variety of shapes and materials: round, rectangular, v-shaped; of iron or wood faced with iron; all resting on cross-rods. Distance between the bars equalled the opening of the rock-crusher jaws, which were set between 2" and 3". No set dimensions were required for the grizzly. Usually the size varied from 3'-6' in width and 12'-15' in length.[72]

The grizzly was always placed at the highest point in the mill, over the ore bin where the ore car entered and dumped its materials. There were two major reasons for this: to quickly separate the fine ores from the coarse; and to recover tools which may have come from the mine, such as hammers and drills, before they reached the rock crusher or mortar. The lower end of the grizzly rested in front of the rock-crusher with a chute having an adjustable end-gate.[73]

Below the grizzly, and above the ore bin, were the rock crushers or breakers. The crushed rock from the rock breakers fell into the ore bin together with the fine materials falling from the grizzly. The rock breaker was placed directly below and in front of the coarse ore bin, with a chute leading from the gate of the bin into the jaws of the rock breaker. Ore breakers had to be heavy enough to resist movement and strain. One rock crusher provided ore to twenty stamps, and usually was driven independently.[74]

Rock crushers were adjusted to crush rock smaller than the throat of the mortar (less than 3"). Crushing rocks with the crusher was considered to be cheaper than with stamps. Some mills had two crushers, one beneath the other, to greatly reduce the size of the ore processed by the stamp and increase its efficiency.[75] Rock breaker shoes and dies lasted six to eight months, and twice as long if made of steel.[76]

The function of the ore bins was to amass ore in quantities sufficient to run the mill for about twenty-four hours, supplying each stamp with about 65 cu. ft. of ore. In general, ore bins were built with a slanting floor and covered with iron plates, especially in those places where ore was dropped. The front of the bin was parallel to the mortars. Discharge was regulated through chutes by means of rack and pinion gates. The discharge fell into the self-feeders below, next to the stamps and mortars.[77]

Self-feeders guaranteed regular and even feeding of crushed ore to the stamps, increasing their efficiency. According to Hammond,

> (t)he use of these feeders has increased the capacity of the battery from 15 to 20 per cent, besides effecting a very considerable reduction in the wearing of screens, dies, shoes, etc. The maximum capacity,

> other things being equal, of the battery is attained by "low feeding." Low feeding is denoted the feeding of small quantities of ore upon the die. The ore should be fed steadily and in small quantities. When fed in the mortar with more or less irregularity and in large charges, the ore is piled up to a height that reduces the fall of the stamp and also forms a cushion of ore on the dies that impairs the efficiency of the impact of the shoe."[78]

Self feeders were made to run on a track, be suspended from tracks supported by the battery posts, or run on wheels, as at Lost Horse. In general, the feeders consisted of a hopper with a movable circular plate beneath set slightly inclined toward the mortar. At Lost Horse, each five-stamp battery had its own feeder and was very similar to the Tulloch feeder described by Preston in 1895:

> The Tulloch feeder consists of a square frame, into which a hopper fits, having below a tray suspended from the frame at any desired angle, and in such a manner as to have a forward and backward swinging motion inside the frame, which can be arrested on the forward motion at a certain point by lugs, underneath the tray, striking a bar. The back of the hopper is supplied with an adjustable scraper, and at each motion of the tray a certain amount of the ore is scraped forward and falls into the battery. The machine is operated by the descent of the stamp.[79]

<u>Metal Parts of the Stamp Batteries (of Cast Iron or Steel)</u>

<u>Mortars</u> for stamp batteries in California were usually cast in single solid pieces. If shipped to places inaccessible by wagon, they were cast in pieces to be bolted together later. Design differences grew out of differences of opinion over whether or not to amalgamate inside the battery.

> Their interior form depends on the nature of the ore, and the procedure to be applied; thus we find them made with narrow or flaring, deep or shallow troughs, and with or without inside plates. Mortars with narrow troughs are made for greater output, while a wide trough assists battery amalgamation, and gives opportunity for placing inside copper plates. In the some of the newest styles of mortars a series of grooves are furnished in the lining plates, to contain quicksilver.[80]

The weight of mortars varied from 4,000 to 6,500 lbs. Mortars at Lost Horse were probably 6,500 lbs., of the Hayward type with a full-lined mortar, flaring trough, and without any special arrangements for inside amalgamation. Dimensions were such that the outside width corresponded to that of the foot-plate of the dies.

The stamps of a battery were constructed of the metal parts described below. As a unit it dropped and struck the ore in the mortar. The number of tons of ore crushed per stamp depended on: the weight of the stamp, the number of drops per minute, the height of the drop, the height of discharge through the screens, the size of the screens, the width of the mortar, and the characteristics of the ore. Hard ores or ores heavy with clay decreased the output of the stamp batteries. The average output in the State of California in 1888 was about 2-1/4 tons per stamp per 24 hours.[81]

The shoe consisted of a cylindrical body having the same diameter as the stamp-head and was about 5" long. The weight of the shoe was about 1/6 of the total weight of the stamp; because of its greater wear, the shoe was somewhat longer than its corresponding die, which was protected by a cushion of quartz. Both shoe and die parts were worn as thin as possible--the shoe to 1/2" and the die to the foot-plate. Stamps weighing about 900 lbs. had shoes of about 150 lbs. According to Preston,

> (t)he life of the shoes depends on the nature of the quartz and the height and speed of the drop, but as a general rule shoes and dies of steel last as long as two and a half sets of iron ones, and cost twice as much. In the matter of choice between steel and iron, the vicinity of the mill to foundries is of consequence. Steel shoes and good iron dies usually work very smooth, but where the waste iron can be disposed of at a foundry, this metal is preferred for both.[82]

Dies consisted of a cylindrical body the same diameter as the shoe with a square foot plate with squared corners fitting loosely against the front and back plates of the mortar.[83]

The early versions of stamps and dies met with little enthusiasm, for they tended to chip and cup. Mill operators preferred steel versions introduced later, especially in places remote from foundries where transportation was an important cost factor. Later still, chrome steel shoes and dies proved their superiority over other kinds of steel used. Some mills used a combination of steel shoes and iron dies, producing more even wear on the dies and considerably longer life for shoes. Iron shoes and dies of good quality lasted approximately 30-50 days. Dies wore less rapidly than shoes because they were protected by the thickness of the wet pulp, which could be from 1" to 3" above the surface of the dies. Nevertheless, the actual life of shoes was longer, primarily because the wearing part of the shoes was several inches longer than that of the dies. Die surfaces had to be on the same level: if a die sat above the pulp surface, the shoe would drop on naked iron.[84]

Stamp heads, bosses or sockets had the same diameter as the cylindrical part of the shoes and dies containing the neck or shank of the shoe.[85]

Stems were turned perfectly true and tapered at the ends for a distance of 6"-8". The rods were from 11'-14' in length and the diameter varied with the stamp from 2-7/8" to 3-1/2". Rods were reversible in case one end broke. The stem carried the greatest weight of any part in the stamp.[86]

Tappets were bored through the center with flanges on both ends; they were fitted onto the stem containing the shoe and fastened with keys. Tappets weighed from 100-120 lbs.[87] The revolving cam, in lifting the tappet, also imparted a rotary motion to the stem and shoe that produced a slight grinding effect on the ore in the mortar. This also had a beneficial effect of equalizing and diminishing wear on the shoes and dies.[88]

Cams were made of tough cast iron or steel, double armed, strengthened by a hub, and were 2"-3" wide. The cam was fastened to the cam-shaft by steel, hand fitted keys.[89]

Cam-shafts were made of wrought iron or soft steel. Cams were placed on the cam-shaft with the hub side away from the stem, such that when the cams raised the stamps, the weight was distributed over the shaft as evenly as possible. As Preston noted,

> (f)or this reason proper attention must be given to the sequence in which the stamps are to drop in the battery. Where the shaft is for ten cams, the following order or sequence of drops is recommended, viz.: 1, 5, 9, 3, 7--10, 6, 2, 8, 4, and would give a drop in each battery as follows: 2, 4, 1, 3, 5.[90]

Stamps were dropped in these numbered rotations to insure even distribution of the pulp on the row of dies; otherwise; it accumulated at one end of the mortar, reducing the efficiency of the stamps at that end by decreasing the height of drop and retarding the pulverization of the ore.[91] When the cam raised the stem from the underside of the tappet, it imparted a revolving motion to tappet and stem. Four to six strokes of the cam were required to complete one entire revolution. Revolving cams insured even wear on the faces of both the shoes and dies, but did not impart any grinding action to the stamp.[92]

The height of the drop was regulated by the cam raising or lowering the tappet on the stem, and depended primarily on the hardness of the rock. That in turn determined the speed with which the blows in the stamp battery were repeated. In California, the usual combination was a low drop and rapid motion, or about 100 drops per minute from a height of 4" to 10", with the mean drop height about 6".[93] Sufficient drop was necessary to produce a good splash; soft and highly sulphuretted ores required a low drop.[94]

Parts of the Mill Involving Wet Reduction of Ore

Apart from the stamps mentioned above, the parts and processes described below took place in the mortar basin and constituted the final reduction of ores before amalgamation and concentration.

The final forceful reduction in rock size occurred at the stamping mill and involved the use of water for the first time in the process. Care was taken not to carry on the stamping process too long when attempting to liberate gold and sulphurets in low grade ores. As Hammond noted,

> (i)t is desirable to crush as coarse as possible when the sulphurets constitute an important part of the value of the ore, since too fine stamping produces an excessive quantity of pyritous slimes, thereby increasing the loss of the sulphurets. Furthermore, when stamping is carried out too far, there is the danger of hammering the gold particles so as to render them less sensitive to amalgamation, and also to make them liable to escape as "float" gold."[95]

Screens and frames were made from different materials: wire cloth of brass or steel, tough Russian sheet iron, English tinned plate, slot, needle-punched sheet-iron, and aluminum bronze. Depending on the materials making up the different types of screen, they might last from ten days to over one month. The life of a screen depended on the width of the mortar, the height of discharge, and the hardness of the rock. "Wide mortar and high discharge," Preston noted, "are favorable to the preservation of a screen; the form of the perforations--round holes, or slots, etc.--influences the discharge area of the screen."[96] The frame was made from pine and was meant to close the entire discharge opening; the mortar was groovee to accept the frames.[97]

Water Supply to the Site

There is strong indication that mill operators attempted to exploit a water source close to the Lost Horse. Visible to this day from the mine site, about one-half mile away, is an area of extensive disturbance around a spring. Stephen Bowers noted in his article in 1904 that "the great drawback has been want of water which I learn is now overcome, and the future of the mine is promising."[98] Most likely he was referring to the source of water provided by the 3-1/2 mile pipeline from the spring. In 1905, a 75' deep well was sunk by the Lost Horse Mining Company after it erected the mill. A three-cylinder high-pressure Gould pump driven by a twenty-five-horsepower gasoline engine replaced steam pumps.[99] That same year, James D. Ryan filed a mill site notice under the name of Lost Horse Wells on the land that contained two other wells (40' and 45' deep) and the spring.[100] The reason for drilling extra wells may have been shortage of water at the Lost Horse mine site. The Citrograph referred to well-drilling work close to Lost Horse in 1895: "The Fife and Howard Co. is down 139 feet with its well in the Pleasant Valley, near the Lost Horse mine. There is good prospect for a bountiful supply of water, which will open up another large mining region."[101] Whether the well produced water and how long drilling attempts took place at this spot is not known.

Since the Lost Horse provided one of the few ore processing mills in the area, it had a major incentive to have a water source close at hand. During the early period of the area's mining history, many of the district's claims were mined by parties without sufficient finances to erect large and efficient reduction works. Some used arrastras to extract gold; the other alternative was to haul ore to sites which had arrastras, or to stamp mills such as Lost Horse. Many miners in the district hauled their ore 12 to 15 miles to an arrastra in Twentynine Palms. As Bowers observed, "(s)ome ore has been hauled a dozen miles to Lost Horse mill, but owing to the scarcity of water this mill could do but little custom work."[102] This statement in 1904 suggests that, although the pipeline to Lost Horse Well had been in place for eight to nine years, water capacity was insufficient for ore processing assignments from other mines.

Water Supply to the Stamp Battery

The amount of water needed by the battery depended on the type of ore being processed and the size of the screen. Clay and highly sulphuretted ores required the maximum amount of water. In general, one ton of ore stamped required from 1,000 to 2,400 gallons of water, with the mean amount about 1,800 gallons.[103] Three inch diameter pipes along the front of the mortar and branch pipes 1" in diameter supplied water to the feed side of the mortar or through the plan-covering on the top. A second pipe was placed in front to the lower lip of the mortar, where a perforated branch discharged along the entire line of the lip and the front of the screen. As Preston explained,

> The battery water should enter both sides of the mortar in an even quantity, and the total amount must be sufficient to keep a fairly thick pulp that discharges freely through the screen. About 120 cu.ft. of water per ton of crushed ore may be considered an average, or 8 to 10 cu.ft. per stamp per hour.[104]

The amount of water used per ton of ore varied greatly, from 1,000 to 2,400 gallons per ton of rock crushed, or about one miner's inch[105] of water per twenty-four hours per five-stamp battery.[106]

The Amalgamation Process

Amalgamation is the process of using mercury to extract gold from ores. When gold comes into contact with mercury it is extracted and forms an amalgam. The amalgam is then separated into mercury and gold. The process of amalgamation was very common in small mills such as the Lost Horse because of its simplicity and low cost.

Amalgamation could be carried out in the mortar where the stamps crushed the small ore and on amalgamation tables extending from the lower lip of the mortar. It is not known if amalgamation took place in the mortar at Lost Horse, but we do know it was performed on amalgamation tables.

Amalgamation tables extended from the lower lip of the mortar and slanted down in a stair step fashion. First, mercury was coated onto silver-plated copper plates. The flowing pulp from the mortar, which came in waves from the stamping action, was turned over to expose it to more mercury. Mercury-gold amalgam would accumulate at the drop from the lip of the mortar, further down at the bottom of the step and, finally, at the very end of the table in the amalgam trap. The amalgam trap caught any loose mercury or amalgam. Unfortunately, no information was uncovered describing the amalgamation tables at Lost Horse.

The Concentration Process

In the recovery of small particles of gold and silver, concentrating tables separated the metals from the gangue, settling the heavier metals at the bottom while the lighter gangue remained on top to be washed away. Concentrators transformed lower grade ore into higher grade concentrate by mechanically removing most of the worthless gangue.[107] The resulting pulp had a higher percentage of valuable metals remaining. This concentrate was then melted in a smelter that separated individual metals. There is no evidence that concentrating tables were used at Lost Horse.

The Cyaniding Process

The cyanide process of recovering precious metal from ores dissolves gold and silver in fine particles in a diluted solution of sodium or potassium cyanide. Cyanidation requires finely ground mill products to accomplish maximum extraction. The process allows the solution to percolate through the ore or agitates a mixture of ore and solution. The solution is then separated from the solid material and the gold and silver are precipitated in metallic form.[108] Writing about the process in California in 1894, Scheidel explains that

> (t)his process for extraction of gold and silver is comparatively old in its principle, but modern in it s technical application. During the last four years it has been introduced into almost every gold field, and upwards of $14,000,000 in gold and silver have been recovered by the process, which demonstrates beyond doubt that it is one of the most important additions to the wet methods of gold and silver metallurgy.[109]

Although cyanidation gradually supplanted amalgamation late in the nineteenth century, many mills amalgamated ores but applied the cyanide process to the tailings. The respective ages of the tailings piles - the one still extant from the early period of milling and those produced in the 1930s by Meyer and Phelps - suggests that this likely happened at Lost Horse.

In 1935, John W. Meyer and Charles Phelps, an insurance agent from Los Angeles, visited old mines such as the Brooklyn and the

Los Angeles, looking for tailings piles to cyanide profitably. Travelling with a small plant, they actually ran a sample of ore to calculate percentage of recovery possibilities. Those that appeared promising - the Wall Street Mill, the Desert Queen and the Lost Horse - they leased from the owners. Phelps and Meyer invested a sizeable sum of money into the old site at Lost Horse: they repaired the original 3.5 mile pipeline from Lost Horse Well and built the cyanide tanks - three adjacent vats - in front of the Lost Horse mill. Expecting mining and milling operations at Lost Horse to start up again someday, they located the vats close to the mill as a logical extension of ore processing leading from the stamp batteries to the cyanidation tanks.

By placing the leaching tanks farther from the tailings and closer to the mill, they had to build an extensive aerial cable system that reached from the cyanide tanks down and across the tailing piles. With the cables old tailings could be pulled into the tanks and precipitate emptied from the tanks with a bucket most likely powered by the Hoyt diesel engine still at the site.[110] It is also conceivable that the old winch uphill from the mill was used for the cable. This would have required a large amount of cable but may not have been too expensive.[111] As at Wall Street, the bucket was probably filled by shovel and the tanks shoveled empty by hand as well. But the Lost Horse mine never reopened and Phelps and Meyer went bankrupt.

Initial investments made in equipment, the cost of leasing mines, the costs of supplies, and the wages paid help, all combined to force Phelps and Meyer into bankruptcy. At one point, Phelps and Meyer spent five months unable to mine because of bureaucratic haggling over a date on a gold permit allowing them to mine tailings.[112] During this time they were paying for salaries and supplies. In the meantime, they also leased the Lost Horse from Bill Keys. Expenses at Lost Horse included the rebuilding of the 3.5 mile pipeline, the building of the cyanide tanks, and the aerial cable system. From the Lost Horse, Phelps and Meyer moved to the Desert Queen. There they had to grind the overburden to 200 fine in order to cyanide the ore. For this they set in the foundation for the mill and a motor, set in water and sump tanks, but then ran out of money. At that point Meyer moved to Los Angeles while Phelps remained to cyanide the fines from the overburden.[113] Meyer says that they cyanided between 3 and 5 thousand tons, but production figures from the U.S. Bureau of Mines reported only 600 tons of tailings processed.

ENDNOTES

1. E. J. Fife, D.L. Fife, and J. A. Minch, "Geology and History of Lost Horse Gold Mine, Lost Horse Quadrangle, Riverside County, California," in Geology and Mineral Wealth of the California Transverse Ranges; Mason Hill volume, 1982, 461.

2. Fife, 461.

3. Fife, 461, quoting J.W. Rogers in "Igneous and Metamorphic Rocks of the Western Portion of Joshua Tree National Monument, Riverside and San Bernardino Counties," California Division Mines Special Report No.68.

4. Fife, 461.

5. Fife, 461.

6. Fife, 461.

7. Frederick Merrill, "Lost Horse Mine." Report of the State Mineralogist XV(1917):536.

8. Richard B. Saul, Clifton Gray, and James R. Evans, Mines and Mineral Resources of Riverside County, California, an unpublished report, California Division of Mines and Geology, 1968.

9. W.B. Tucker, and R.J. Sampson, "Los Angeles Field District, Mineral Resources of Riverside County," California Journal of Mining and Geology 41/3(1945), 137.

10. As reported by J.J. Crawford, "Lost Horse Mine," Report of the State Mineralogist XIII(1896):312.

11. A large capstan that is made with one or more radiating arms to which a horse is yoked and that is used in mines for raising ore or water.

12. Linda Greene, Historic Resource Study: A History of Land Use in Joshua Tree National Monument, Branch of Cultural Resources, Alaska/Pacific Northwest/Western Team, U.S. Department of the Interior, National Park Service, Denver Service Center, 1983. 256.

13. Fife, 455.

14. Fife, 462.