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by Ted Konigsmark

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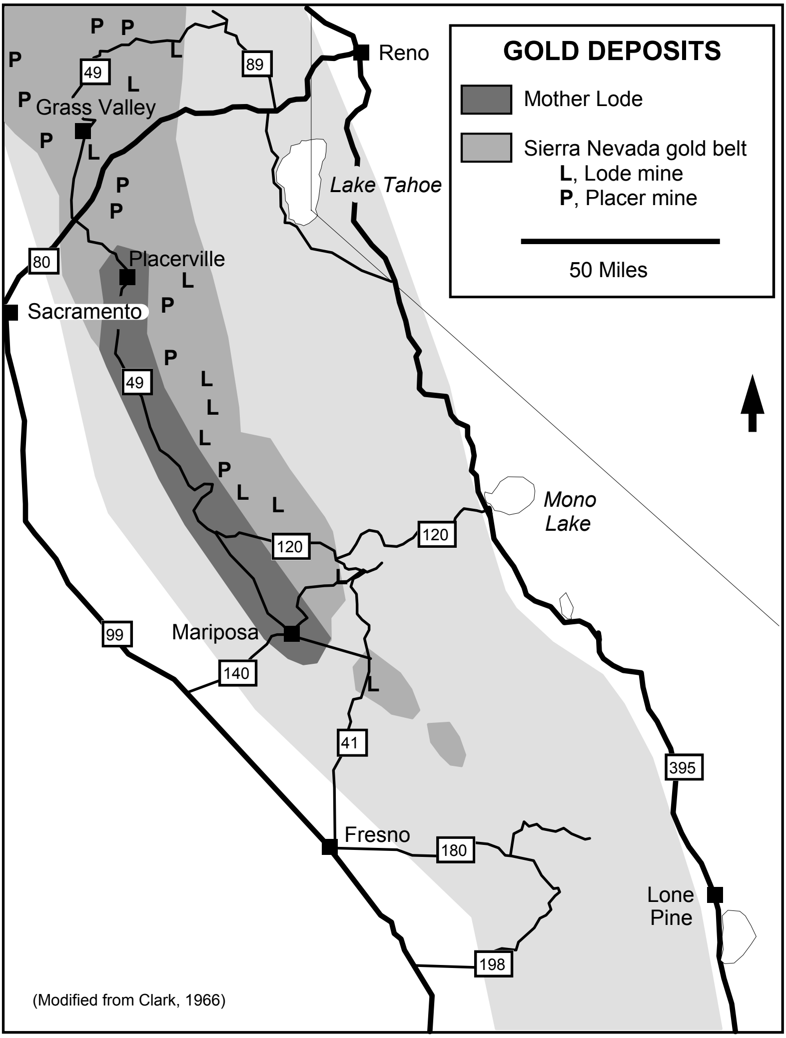

GOLD DEPOSITS
Mother Lode
Sierra Nevada gold belt
L, Lode mine
P, Placer mine
50 Miles
Reno
Lake Tahoe
Grass Valley
Placerville
Sacramento
Mono Lake
Mariposa
Fresno
Lone Pine
49
89
80
120
99
140
41
395
180
198
(Modified from Clark, 1966)

THE SIERRA NEVADA GOLD BELT

When gold was discovered at Sutter's mill in Coloma on January 24, 1848, there were less than 15,000 people in California, not counting Native Americans. The gold rush began shortly after this discovery. Gold mining at that time was not particularly high-tech. Because gold is heavy and commonly occurs in the native form, it is easily separated from sand, gravel, and other host rock using various agitating and collecting devices, usually with water. At the beginning of the gold rush, all that was needed was a gold pan and a good eye to pick up the gold—or so it was thought. Four months after the gold discovery, there were 800 miners working in the vicinity of Coloma. A month later, there were 2,000 miners in the Sierra foothills, including almost the entire population of San Francisco. During the next year, 1849, thousands of prospectors headed for California by ship and wagon train from all parts of the United States and many other countries as well. By the end of the gold rush, in 1852, the population of California had swelled to 225,000.

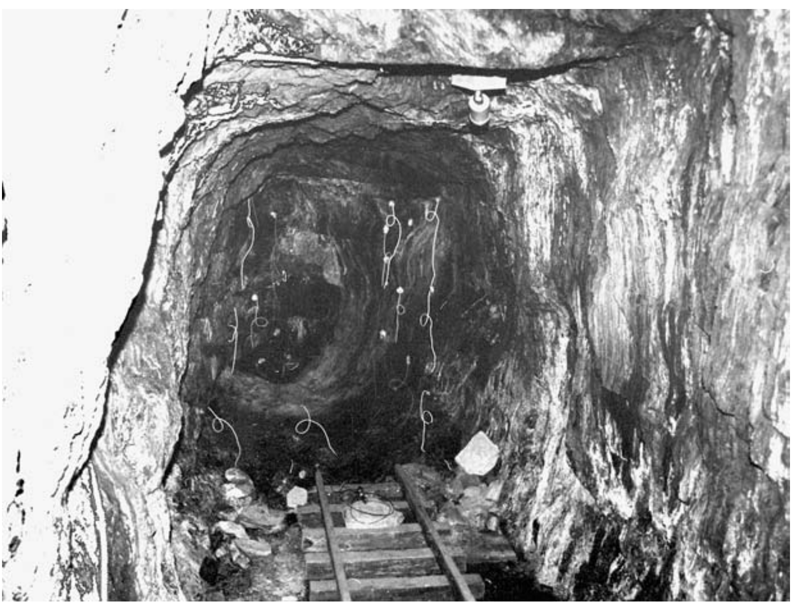
Thousands of gold discoveries were made in the foothills of the Sierra Nevada during and after the gold rush. Hundreds of these discoveries were developed into commercial gold mines, and a few dozen of these mines produced large quantities of gold. Most of this gold was found in a belt of gold deposits about 30 to 50 miles wide that extended from Mariposa to Sierra City. This trend of gold deposits is generally referred to as the Sierra Nevada gold belt. The richest part of the gold belt was within a mile or so of the Melones fault between Mariposa and Placerville. This string of rich gold mines is known as the Mother Lode.

No one knows how much gold was produced from these mines. Production figures in the early years of the gold rush were in dollars rather than ounces, and many of the early production figures are missing or incomplete. Nonetheless, if you value gold at $300/oz., the total production from California mines from 1848 to present is estimated at approximately thirty billion dollars. The periods of greatest production were from 1850-65, from 1879-84, and from 1936-1941. Most of the mines closed during World War II. A few mines were able to open after the war, but operations were expensive and difficult. Only a few mines are operating at present.

Origin of the Gold

Gold is ubiquitous in nature, and small quantities occur in many different rocks. The average igneous rock contains 0.0000005 percent gold. The main problem for the prospector is to find gold in concentrations that are profitable to mine, in the range of 1/3 ounce/ton. Mother Nature, using several different chemical and physical processes, did a remarkable job in concentrating gold in the Sierra Nevada gold belt.

Most of the Sierra gold occurs in the rocks of the Western Metamorphic Belt. These rocks accumulated in a series of subduction zones that were present in this area from early Paleozoic to Jurassic time. During this period, thousands of miles of oceanic crust were swept into these subduction zones. Although most of this oceanic crust was carried under the North American plate and returned to the mantle, some of the oceanic crust remained in the subduction zone, and some of these rocks contained small amounts of gold. However, this gold still needed to be concentrated. The Nevadan orogeny would help in this process.



This mine tunnel in the Gold Bug Mine near Placerville is open to the public. White veins of quartz cut through the dark metamorphic rock on the walls of the tunnel. When the mine was operating, the fuses at the end of the tunnel would have set off dynamite that was packed into holes drilled into the hard rock.

During the late Jurassic Nevadan orogeny, the rocks in the subduction zone were subjected to intense heat and pressure. As the rocks were heated, the gold was removed from the rocks and concentrated in CO_2-rich solutions. During early Cretaceous time, at the beginning of the Franciscan subduction, these gold-bearing solutions were forced upward by the heat in the subduction zone and injected into the overlying rocks. The gold-bearing solutions mainly followed the weak and shattered rocks along the major fault zones of the Western Metamorphic Belt, since this was the easiest route to the surface. During this upward trip, gold and other minerals were precipitated along the fracture zones wherever the solutions reached sympathetic conditions of temperature, pressure, and local chemistry.

Most of the gold was precipitated in fractured rocks near the fault zones. The rocks consisted of schist, greenstones, slate, granite, or any other rock that was fractured. The gold was often deposited with quartz in veins that filled fractures in the rock. Some gold was also deposited in open fractures, where gold crystals had space to grow into their delicate shapes. Other minerals often accompanied the gold and were deposited along with the gold. These minerals include copper, zinc, lead, iron, silver, and mercury. In some places, gold was chemically combined to form gold compounds. After the gold and other minerals were deposited, the solutions continued to the surface and were expelled in hot springs. By early Cretaceous time, most of the gold had been deposited in the veins and shear zones in the metamorphic rocks of the gold belt. The gold was ready to begin the next stage of concentration.

PROPERTIES OF GOLD	
Chemical symbol	Au
Atomic number	79
Atomic weight	169.9665
Density	18.88 at 68°F
Boiling point	5,576°F
Melting point	1,948°F
Crystal habit	Cubic, octahedral, dodecahedral Commonly dendritic, reticulated or spongy Also occurs as nuggets, flattened grains, or scales
Hardness	2.5-3
Color	Yellow, silver white; opaque

As the gold was being deposited in the veins along the gold belt, the ancestral Sierra began to be uplifted, and the gold veins in the Western Metamorphic Belt were exposed to weathering and erosion. Uplift and erosion continued through Cretaceous and Paleocene time, and by Eocene time the ancestral Sierra had been eroded to a low range of hills that was drained by large rivers. During this long period of uplift and erosion, large quantities of gold were removed from the gold veins and concentrated on the Eocene erosion surface. Since the gold was heavy, most of it remained in the vicinity of the weathered veins.

Some of the gold on the Eocene erosion surface was swept into the Eocene rivers and deposited with the gravel in the deep river channels. Large quantities of gold eventually accumulated in these Eocene river gravels, and these gravels have been extensively mined in the northern Sierra. Some of the gold also remained in the gold veins of the Western Metamorphic Belt. Most of the large gold mines along the Mother Lode extracted ore from these veins. Some of the gold also accumulated in the channels of the present-day Sierra rivers. This placer gold was washed into the rivers where the rivers had cut through gold veins and through gold-bearing Eocene river gravels.

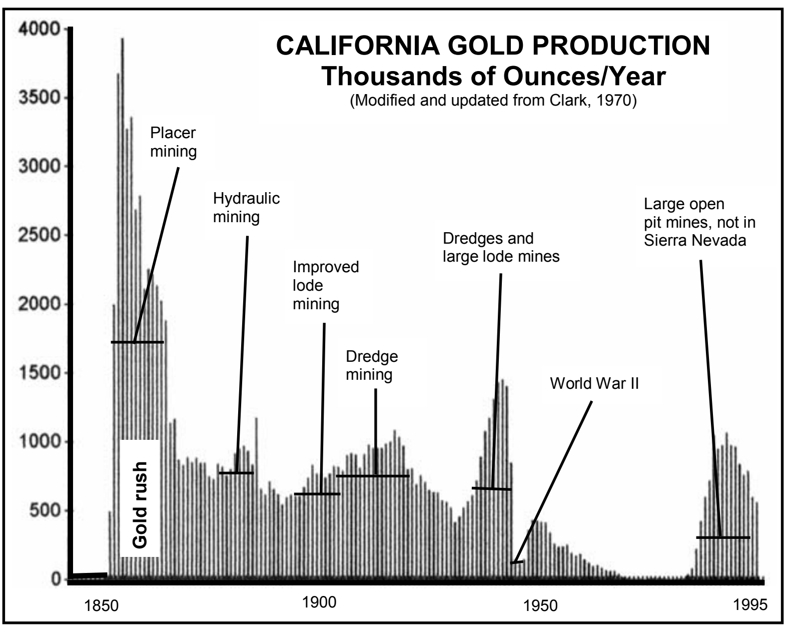
The placer gold was easily and quickly extracted during the early days of the gold rush. However, more creative and effective methods would be needed to mine the low-grade gold deposits, the gold deposits in hard rock, and the gold that lay deep underground.

PRINCIPAL GOLD DISTRICTS OF THE SIERRA NEVADA
(Based on Clark, 1970)

District	Type	Production ($MM)
Grass Valley	Lode	300
Jackson-Plymouth	Lode	180
Hammonton	Dredge field	130
Folsom	Dredge field	125
Columbia	Placer	87
Oroville	Dredge field	55
Nevada City	Lode and placer	50
Allegheny	Lode and placer	50
Sierra City	Lode	30
Angels Camp	Lode, some placer	30
Jamestown	Lode	30
Placerville	Placer and lode	27
Carson Hill	Lode	27

Gold Mining

Although gold had been found and used by local Native Americans in the Sierra foothills for many years prior to the gold rush, it was not considered valuable and was of no particular significance. All of that changed rapidly with the 1848 gold discovery at Coloma. With that discovery, the gold rush began. Although the first discoveries were in the channels of the present-day Sierra rivers, gold was soon found in the Eocene and Oligocene river gravels and in the quartz veins and sheared metamorphic rocks of the Western Metamorphic Belt. Some of these gold deposits were rich and others were low grade. Some of the deposits were at or near the surface of the ground. Others extended hundreds or thousands of feet underground. Some of the gold ore was hard and difficult to process. Other gold ore was soft and easy to mine. Since the gold occurred in a wide variety of conditions, many different methods were used to mine the gold. The most common mining methods were placer, hydraulic, dredge, lode, drift, and open pit.



Placer Mining: Most of the gold found at the beginning of the gold rush was extracted from rich placer deposits in the present-day rivers. In the first few months, all that a prospector had to do was pick up the gold nuggets from the stream channels. Sometimes a knife or pick was helpful in prying out the nuggets. Needless to say, this didn't last long, and other devices were soon used to separate the gold from the river gravel. Most of these devices separated the heavy gold from the lighter rock fragments by washing the gold-bearing alluvium with water. The lighter rock fragments would be washed away and the heavy gold would remain.

Gold pans were used by many early miners to extract the gold from the alluvial deposits. The pans were inexpensive and easily portable. However, panning was slow and labor intensive. It worked for very rich gold deposits, but was not practical for recovering large quantities of gold from medium- and low-grade deposits. Rapidly, other methods were found to separate the gold.

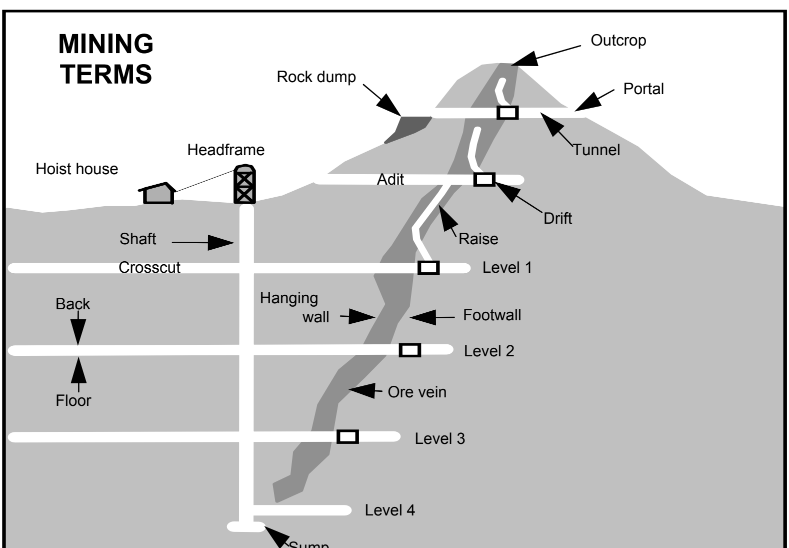
One of the favorite methods of the Chinese miners was the rocker. This consisted of a small box with a screen on top. River gravel was shoveled into the box and the box was rocked using a handle. The screen kept the larger rock fragments out of the box and let the smaller fragments pass into the lower part of the box. Water flowed through the lower part of the box across a series of slanted riffles, which separated the gold from the alluvium.

Long toms were even more efficient. A typical long tom was a wooden trough about 12 feet long and eight inches deep. The upper end of the trough was a foot or so wide, and the trough widened to about twice that distance at the lower end. The bottom of the box was a perforated sheet of iron. Below that, there was a riffle box. The gold-bearing alluvium was shoveled into the upper part of the box and washed through with water. The gold accumulated along the riffles.

Sluice boxes were used to handle even larger volumes of alluvium. The sluice box was a wooden trough, usually about 12 feet long. Alluvium was shoveled into the box and washed through with large amounts of water. The gold was caught in riffles at the end of the sluice. Often, many sluice boxes were strung together to make a sluice up to several hundred feet long. Sometimes a ditch in the ground would be used as a sluice rather than a wooded box. The gold would be trapped in a riffle box placed at the end of the ditch. This was called ground sluicing. Long toms and sluices required lots of water, a problem in many areas.

Lode Mining: In most areas where placer mining was in progress, miners quickly traced the gold upslope to its source. The source was often a gold-bearing quartz vein, referred to as a *lode* by the early prospectors. Soon they would be mining the vein with pick and shovel. At first, the gold vein was rich and easy to work. The gold had been concentrated in the weathered rocks near the surface. In a short time, however, the rich gold in the weathered rocks was gone and further mining required hard work. The unweathered rock was usually hard, and the ore in the fresh vein was not as rich as the surface ore. The vein would be followed into the ground with a tunnel or shaft, and this would come to be known as lode mining.

In general, lode mining required more work, more capital, more expertise, and larger operations than placer mining. Large lode mines also required experienced labor willing to work for minimal wages under extremely difficult and dangerous conditions. Many foreigners were imported to handle this work. When successful, the lode mines were major sustained operations. More gold was recovered from lode mines than from placers. During the late 1800's, there were hundreds of lode mines all along Sierra foothills. The largest operations were along the Mother Lode between Jackson and Plymouth and in the northern Sierra near Grass Valley. Some of these mines would eventually follow the gold ore to depths of over a mile and have up to 200 miles of tunnels and other workings. At present, there is very little lode mining in the Sierra



(Modified from Kortick et al., 1985)

foothills. Most of the lode mines were closed during World War II. Although gold is still present in many of these mines, the mine workings have deteriorated and it would be very costly to reopen the mines.

Drift Mining: Drift mining is similar to lode mining, except the mining is done horizontally. Most of the drift mines in the Sierra Nevada gold belt were in rich gold-bearing Eocene river channels. The miners dug into hillsides and followed the river channels into the hill, twisting and turning with every whim of the channel. They followed the deepest part of the channel, which contained the richest gold, and thus neatly defined the direction and extent of the old river channels. Some drift mines extended as much as a mile or so into the hillside. However, the rich gold-bearing gravels were usually only a few feet thick and were often discontinuous. Drift mining was thus difficult and risky in most areas. There were many drift mines near Placerville and Nevada City, but none are now operational or accessible.

Hydraulic Mining: Many Eocene river channel deposits were mined hydraulically. The gold-bearing gravel in these channels was from a few feet to 600 feet thick. Most of the gold was in the lowest part of the gravel, and there was little, if any, gold in the upper part. To get at the rich gold in the lower part of the channel it was necessary to remove the overlying gravel. However, removing this overburden was difficult and expensive if the gravel was thick—until someone found that you could simply wash down the entire bank of gravel with a hose and recover the gold as the gravel was washed through a sluice. With the discovery of this hydraulic mining method, large deposits of Eocene river gravel could be mined that could not be economically mined any other way. Hydraulic mining grew rapidly and was used in many major mining operations in the northern Sierra. The largest of these hydraulic mines was the Malakoff Diggins near North Bloomfield.

Dredge Mining: Most of the gold nuggets and flakes in the Sierra rivers were not carried far beyond their source in the Gold Belt, and most of this gold was recovered during the early placer mining operations. However, large quantities of very fine flakes of gold were carried many miles downstream from the gold belt and were deposited in the gravel along lower courses of most of the major Sierra rivers. The concentration of the very fine gold in these gravels was usually quite low, a few cents worth of gold per cubic yard of gravel. However, there was a lot of gravel, and the gravel could be profitably mined by large dredges. The dredges scooped up the gravel in huge buckets, recovered the gold, and redeposited the tailings back into the river channel. The dredges floated in a pond that moved along with the dredge as it consumed the river gravel. The Feather, Yuba, American, and Merced rivers all had large dredge mining operations at the base of the foothills. One of the largest of these operations, at Hammonton on the lower Yuba River, operated from 1903 to 1968. Large amounts of gold were recovered from these operations. There is no dredge mining at present.

Open Pit Mining: A few gold mines in the Sierra foothills have been mined by open pit mining, where large quantities of low-grade ore are excavated from the surface using large trucks and other surface equipment. Two of the largest of these mines were the Harvard Mine and Carson Hill Mine, both near Sonora. Some leaching operations were also carried out where gold was leached from mine tailing by cyanide solutions and then recovered from the cyanide solution.

This model stamp mill at the California State Mining Museum shows how gold was recovered from gold ore. The ore entered the mill at the upper right where it was crushed into bite-sized pieces. The crushed ore was then powdered in the stamp mill in the center of the model. The powder was next washed across the sloping copper plate and the gold was recovered as an amalgam ready for refining.

Milling and Refining

During the first days of the gold rush, the recovery of the gold was easy, as long as an abundant supply of water was available. The gold nuggets and gold dust were heavy and easily separated from the sand and gravel placer deposits. However, most of this easy-to-recover gold was mined out within a year or two. Much of the remaining gold occurred as very fine particles that were dispersed in a variety of hard rocks, including quartz veins, schist, slate, phyllite, and granodiorite. Most of this gold ore was low grade. Recovering gold from this ore required a large milling and refining operation.

Most of the gold mills were built on a slope below the mine portal. Ore that was removed from the mine was dumped into large jaw crushers at the top of the mill. The crushers, like a giant human jaw, broke the rock into two-inch or smaller pieces. The rock was then fed into a stamp mill, where the rock was crushed into powder by large iron stamps. A small mill commonly had five stamps, and larger mills could have 100 or more stamps. Each stamp consisted of a vertical iron rod, about 14 feet high, with a large iron cylinder on the lower end. The rod and cylinder were lifted on a cam, and then dropped so that the cylinder struck an iron mortar that was in place below the cylinder. Water was fed into the mortar during the stamping. The slurry from the stamp was washed over a sloping apron plate made of copper that was coated with mercury. The finely divided gold combined with the mercury to form an amalgam, and the tailings were passed on to a tailings pile. Once a day or so the stamping would be halted and the gold-bearing amalgam would be recovered from the copper plate.

The amalgam was sent to a refinery for processing. There, the amalgam was placed in a retorting furnace, where the mercury was vaporized, leaving a porous mass of gold sponge. The mercury was condensed, recovered, and used again. The spongy mass of gold was then heated in a crucible, the impurities were skimmed from the molten gold, and the gold was poured into a cast-iron mold.

A stamp mill was not a pleasant place to work. The mill operated continuously. The roar of the stamp mill could be heard for miles. The noise of the stamps often caused hearing loss for the mill workers within weeks. Pieces of breaking rock from the stamp were like bullets, another hazard to mill workers. The mercury, if not handled properly, was still another health hazard. Nonetheless, jobs in the mill were preferable to the underground jobs in the mines.

The large open pit mine at Carson Hill has removed much of the original Carson Hill. The Carson Hill Gold Mine is no longer in operation, but the pit is being mined for gravel.

This ten-stamp mill at the Empire Mine near Grass Valley was used to crush gold ore into powder during the milling process. At its peak, the mill at the Empire Mine had 80 stamps that operated 24 hours a day and could be heard for miles.