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PROCESSES OF GOLD RECOVERY IN VIRGINIA

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About 98,600 troy ounces of gold were produced in Virginia from 1804 through 1947, when gold was last mined in the State (Sweet, 1980). During this 144-year-long period, processes of recovering gold changed in response to the need to use leaner and deeper ores and to the progress of technology. Early mining was in placers or in oxidized, near surface, lode deposits. As these reserves were exhausted, deeper lode or vein deposits were mined. It was estimated that in 1837 a profit-making gold mine had to yield a dollar for every bushel (about 100 lbs., 45.0 kg) of rock processed; the cost of mining 100 pounds of rock in 1837 was about 30 to 35 cents (Silliman, 1837, p. 106, 123). Gold that must be mined by underground methods is costly to produce because shafts and drifts must be constructed, the ore is generally in hard rock, and the rock commonly must be pulverized before recovery processing begins. By contrast, placer deposits can be worked by hand-shoveling, sluicing, or dredging the ore materials, which are then ready for processing without further treatment.

RECOVERY METHODS USED IN PLACER DEPOSITS

Much of the early recovery from placer deposits was by pan, but the success of this process was limited in two ways. First, gold recovered with the pan was chiefly only the coarser fraction of the gold particles; much fine and float-gold was carried off along with the gravel and water. Second, the amount of gravel that could be processed was small—even by those who mastered the art of panning. Only the richest deposits were profitable to work by this simple, direct method. Placers were mined in Virginia around 1832 at the Belzoro and Collins mines in Goochland County, the Whitehall mine in Spotsylvania County and the Grasty tract and Vaucluse areas in Orange County and placers were mined as late as 1935 in Prince William County.

Two types of pans (Figure 1) were commonly used in placer mining, the standard metal pan and the batea. The standard pan has a varied diameter, with the maximum being about 16 inches (41 cm), and is about 2 inches (5.1 cm) deep; and "sides" slope at about 45 degrees. These pans are generally made of

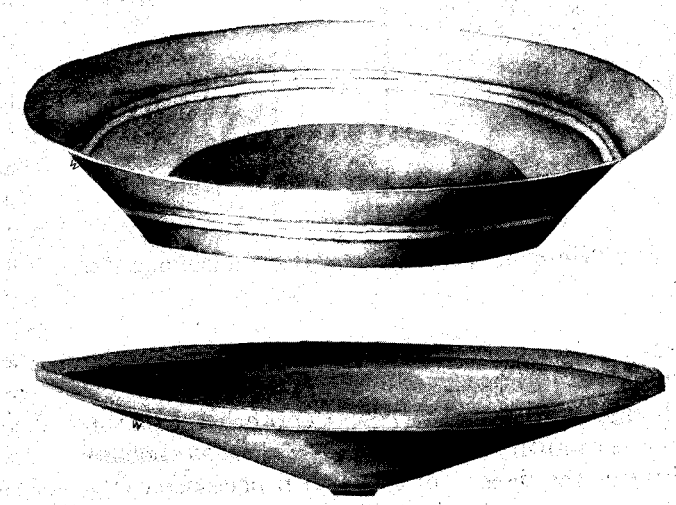

Figure 1. Two types of gold pans commonly used in placer mining, standard metal pan (top) and the batea (bottom).

sheet steel and the rim is crimped over a heavy iron wire for stiffness (Taggart, 1945, sect. 11, p. 56). The batea has a greater diameter than the standard pan and the sides slope at a lower angle giving the pan the shape of a flattened coolie hat. Heavy minerals are concentrated at the narrow center of the pan. Initially, the batea was early made of wood, but later steel was used.

Pans were better used for prospecting than for mining and recovery. When the richer placers were depleted, these crude implements were discarded in favor of mechanical devices capable of processing greater amounts of gravel.

The "cradle" or "rocker" (Figure 2) was one of the first devices used instead of the pan. Rocker-washing devices of varied designs had screens or grates for sorting the material. The screen in the hopper was commonly about 20 inches (50.8 cm) on each side with ½ inch (1.3 cm) openings. The finer materials, which contained the gold, were washed by water onto an inclined apron. The apron was

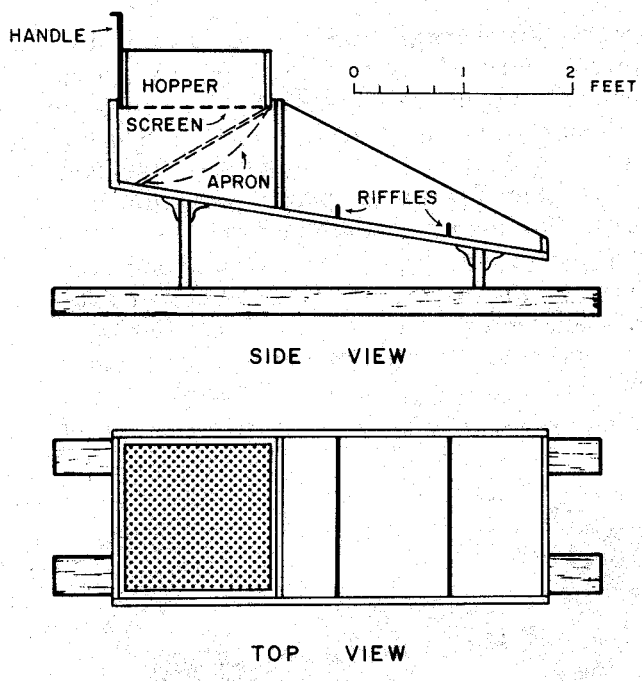

Figure 2. "Cradle" or "rocker" (after von Bernewitz, 1943).

commonly covered by canvas, blanket or corduroy to catch the gold; riffles below the apron also helped to catch the gold before it reached the head of the rocker. A quantity of water equal in weight to about four times the weight of the gravel processed was needed to separate the gold. The output of the cradle was small because the hopper had to be emptied each time the finer material was washed through the screen; the cradle was an inefficient machine.

Cradles, and also sluices, were utilized at the Belzoro, Bertha and Edith, and Collins mines in Goochland County and probably at many other placer deposits in Virginia in the 19th century (Taber, 1913, p. 141, 143).

The "tom" or "long tom" (Figure 3), another early device, was a more productive machine. It was made of two screened boxes and an inclined channel or flume, which sloped about one inch/foot (one cm/12 cm). The lower end of the upper box was at a 45

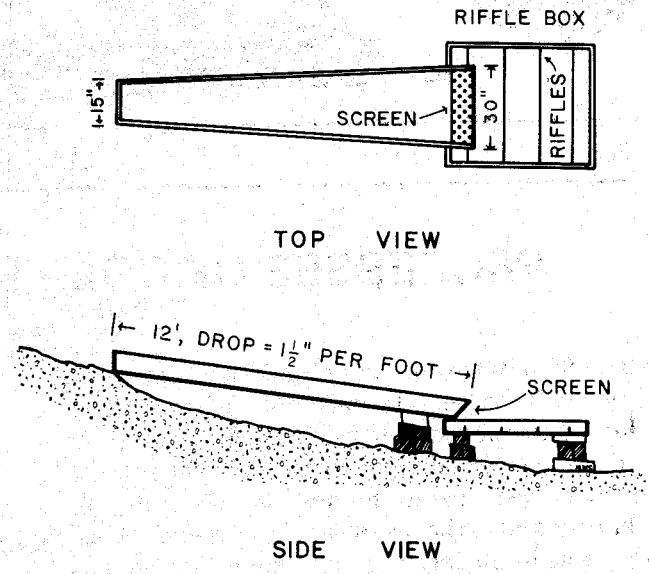

Figure 3. "Tom" or "long tom" (after von Bernewitz, 1943).

degree angle and was covered with a grating that retained the larger particles (mesh size was between ¼ and ¾ inches, 0.6 and 1.9 cm). Below the grating was a second box whose bottom surface contained riffles. The device could be operated continuously and production achieved by its use was relatively high. One or more men fed gravel into the upper box of the tom, and another stirred the gravel, broke up any clay, and discarded the particles that collected at the grating. Two men could wash five times as much gravel with a tom as with a cradle (Christiansen, 1974, p. 88-89), but the tom, like the cradle, was useful only where the gold was fairly coarse because in processing most of the fine gold was lost. After the particles were thoroughly sorted and washed, mercury sometimes was poured along the riffles to trap the gold by amalgamation (see later section for discussion on processes of amalgamation). Sometimes, pieces of blankets were laid between the riffles to trap the finer gold.

Sulfide minerals, which commonly occur with gold in placer deposits, must be removed before amalgamation processing. An early method used to

separate sulfides and gold in placer deposits was gravity concentration. This technique was used on coarse ores that contained too much sulfide gangue for immediate mercury amalgamation. One type of gravity concentration used was "corduroy tabling." In this process a mixture of gold ore and water was washed over a sloping surface covered with corduroy cloth, which retained the gold. This technique was effective in concentrating sand-size or larger gold particles, but a large fraction of the fine materials was lost. Corduroy tabling was utilized around 1913 at the Young American mine in Goochland County, (Taber, 1913, p. 119).

Another method of gravity concentration used was jigging, a process which utilizes the pulsating motion of water to separate ore from the larger, but lighter, grains of gangue. The gold itself is stratified by grain size during the process; coarser gold is at the bottom and finer is at the top. One type of jig, the Denver mineral jig, is a box with a screened bottom. A diaphragm is used to send pulses of water through the box; a series of pulsations separates the ore according to grain size and weight. A Denver mineral jig was used by the Moss Mining Company in Goochland County (Sweet, 1971, p. 27). As late at 1937 two jigs were utilized in the concentrating mill at the Bull Neck (Kirk) mine in Fairfax County (Ulke, 1937, p. 373).

Still another method of gravity concentration is sluicing, which uses water flow through a box (or trough) with riffles to separate the gold. Sluices were operated at most of the earlier placer gold deposits in Virginia, especially in Goochland, Orange and Spotsylvania counties.

RECOVERY METHODS USED IN LODE DEPOSITS

Crushing techniques: The majority of the ore recovered from veins must be crushed before any further refinement or recovery can be accomplished. The crushing has been done in a variety of ways, all based on the hand-held mortar and pestle. An early method employed a large rock tied firmly to a pole which was supported by a crutch made from a forked tree. One man raised the heavy rock while another kept the ore under it so that the rock could be dropped time after time to complete the crushing process. Crushing of ore at the Tellurium mine in Goochland County in 1834 was accomplished with heavy, hand-operated pestles and wooden mortars lined with iron (Taber, 1913, p. 153). This crude hit and miss method gave way to the arrastra.

Basically, an arrastra was a circular pit or container about 2 feet (0.6 m) deep, and 10 to 20 feet (3.0 to 6.1 m) or more in diameter. The sides and bottom were grinding surfaces made of crude, cut or dressed stone, or, uncommonly, of fitted wood, Grinding was accomplished by causing a 400 to 500 pounds (180 to 225 kg) rock to pass over the ore. The machinery consisted of a boom attached to a revolving pole set in the center of the arrastra. A mule at one end of the boom walked around the outside of the arrastra and the rock at the other end was dragged across the ore and the grinding surface. To "charge" the arrastra, ore was crushed by hand to the size of pigeon eggs (about 1 inch (2.5 cm) long dimension) and placed in the pit. Such an arrastra was utilized at the Tellurium mine in the late 1830's (Taber, 1913, p. 153).

The Chilean mill developed from the arrastra and differed from it by having grinding wheels, made of stone or iron, in the place of the heavy stone. More a grinding than a crushing machine, the Chilean mill was commonly used to pre-grind ores for the arrastra (Christiansen, 1974, p. 91). In 1847, 6 large Chilean mills were in operation at the Vaucluse mine (Lonsdale, 1927, p. 81).

The next later development for crushing was the stamp mill. In this device heavy wooden stamp stems with iron shoes were used to crush gold ore placed on a cast iron die seated at the top of a concrete mortar. Most stamps were driven by a steam-powered pulley and belt. In some stamps the mortar was mounted on a heavy, metal anvil, which in turn rested on a large block of concrete. The weight of the shoes and of the stamps varied. The average cost of crushing by stream stamps was 15 to 30 cents per ton in 1907 (Taggart, 1947, Sect. 4, p. 87-89). A total of ten stamp mills were operated at the Belzoro, Grannison and Morgan mines in Goochland County in the middle 1800's, and other stamp mills were probably in operation in the County at that time (Taber, 1913, p. 140-142). Several individual units were sometimes incorporated into a battery of stamps; two abandoned batteries of five stamps each are present today at the Red Bank mine in Halifax County (Sweet, 1971, p. 31). The crushed ore was commonly further separated from gangue by amalgamation.

At the Vaucluse mine in Orange County, three stamps weighing between 350 and 380 pounds (157.5 and 171.0 kg) each were used. After each blow of the stamp, a mixture of finely stamped gold ore and water passed through horizontally moving runners, and through a small mercury-coated eye opening. Contact of the gold ore and water mixture with mercury produced amalgam from which the gold was subsequently recovered (Lonsdale, 1927, p. 81-82).

Chemical and floatational processing: Amalgamation, the process in which mercury or "quicksilver" alloys with gold, permits recovery of much

gold missed by physical methods. The process commonly is used in mines that are small and which extract a fine, high-grade ore. The ore must be free of sulfides and sufficiently coarse to allow it it settle in a flowing stream of water. The surface tension of the gold ore and water mixture must be low enough to allow mercury to wet and engulf it; some types of impurities can preclude the process. The gold ore must also be free of such contaminants as oil or grease because the oil may collect sulfides, clays, calcite, etc., which would prevent the gold from being captured by the mercury. Gold from oxidized areas, tarnished gold, will not amalgamate readily and gold coated with iron oxides will not amalgamate at all. Thus mercury is not generally useful in amalgamating placer deposits of gold, but copper-plate amalgamation was used at the Crawford placers in Prince William County around 1935 (Pardee and Park, 1948, p. 60).

Once the amalgam is formed, it is commonly thinned by the addition of more mercury in order to separate insoluble material by causing it to overflow its container. The amalgam is then filtered, either by squeezing it by hand through canvas or by a mechanical or hydraulic press. The gold-concentrating process is completed when the filtered amalgam is heated in a furnace or over an open fire. The much more volatile mercury is vaporized and the gold is left behind (Taggart, 1927, Sect. 14, p. 10-24). (Some gold miners placed the amalgam in a hole in a potato so that when the potato was heated above an open fire the mercury was burned off and a lump of gold was left in the potato. This process can be dangerous because the potato may explode and because mercury vapors are poisonous.)

Amalgamation was used in 1836 at the Busby mine in Goochland County and processing included straining amalgamated gold through silk to separate excess mercury before the amalgam was heated to drive off the mercury (Sillman, 1837, p. 103). Gold was also recovered by amalgamation in the 1830's from the Moss (Goochland County), Walton (Louisa County), Culpeper (Culpeper County), and many other mines in Virginia (Sillman, 1837, p. 105, 111, 118).

In a more advanced process of amalgamation than the ones described for the Vaucluse mine, copper plates generally ⅛ to ⅜ inch (0.32 to 0.95 cm) in thickness are used instead of bowls and runners. A film of mercury is attached to the copper plates over which the gold ore and water mixture is passed. A processing plant at the Red Bank mine in Halifax County utilized amalgamation plates in the early 1900's (Sweet, 1971, p. 31), but in this process some gold was lost in the slime, (the suspension of finely powdered ore in water that is too fine to settle out).

Figure 4. Roasting stack at the Grasty tract in Orange County.

The loss of gold in slime at many mines throughout the country led to the development of cyanidation in the 1890's.

Cyanidation is a leaching process in which gold and silver are taken into solution in potassium or sodium cyanide and then precipitated with zinc (Salisbury, 1964, p. 58). This process is widely used at mines that produce sizeable quantities of relatively low-grade gold ore. The gold should be clean and free of base-metal sulfides. Cyanidation is sometimes used as a secondary-recovery process after the coarser gold has been treated by gravity concentration and amalgamation. A cyanidation plant was in use at the Bertha and Edith mine in Goochland County in 1897 (Taber, 1913, p. 143). Cyanidation equipment was purchased by the Red Bank mine but was never used (Laney, 1917, p. 161). The process was used on about 1,000 tons of tailings with little success at the Franklin mine in Fauquier County in 1901 (Lonsdale, 1927, p. 79).

A different process is used on gold ores having a large amount of pyrite, but a small amount of base-metals. In such ores the gold may be combined in the crystal structure of pyrite or other sulfides. For

these impure ores, a flotation process, which is based on the unequal affinities of gold and sulfides for air or water, can be used. In this process, air is injected into a tank of water (flotation cell) to form bubbles and then the ore-water mixture is added. Non-wettable particles, including gold, have a greater affinity for bubbles of air then wettable ones, including sulfides. The bubbles, strengthened by a frothing agent and containing non-wettable particles, can then be skimmed off. By changing the reagents of the flotation process, the surface characteristics of the particles can be altered, which allows a variety of minerals to be collected (Salisbury, 1964, p. 57). A small flotation-cell was used at the Melville mine in Orange County in 1935 (Pardee and Park, 1948, p. 57). A concentrating (oil-flotation) mill having three flotation-cells was in operation at the Bull Neck (Kirk) mine in Fairfax County in November, 1937 where jig concentrations were put into the flotation-cells with an emulsifying dope of pine oil, copper sulfate and xanthate (Ulke, 1937, p. 371). In such operations wettable minerals collect in the bottom of the flotation-cell. The gold-sulfide concentrate, along with the inevitable minor amounts of gangue material, either is roasted and treated by cyanidation or is smelted. Either process eliminates the residual sulfides. Three of these old roasting stacks are still standing in Virginia; one is at the old Grasty tract in Orange County (Sweet, 1975, p. 2) (Figure 4), one is at the Melville (Rapidan) mine, Orange County (Sweet, 1971, p. 29-30) and the third is located on Wilderness Run in Orange County. The old Wilderness Run Chimney (brick roasting-stack) was operated by Colonel Stockton probably in the 1830's and 1840's (Figure 5).

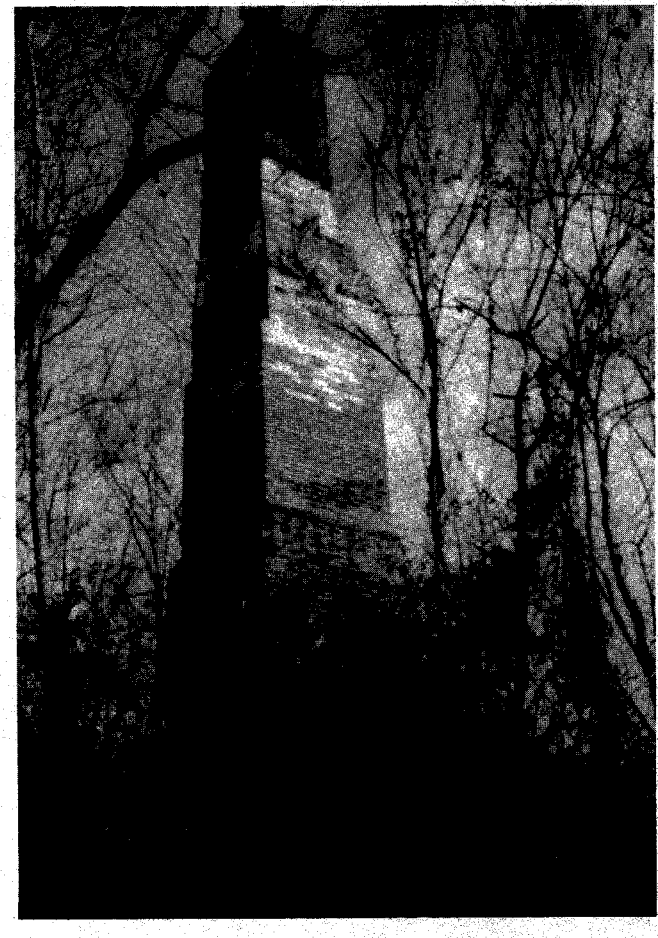

Figure 5. Roasting stack at the Wilderness Run tract in Orange County.

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