Min. Br. Perm. File Copy

I. C. 7085

August 1939

UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

SAVING GOLD BY MEANS OF CORDUROY

BY

M. W. VON BERNEWITZ

I.C. 7085,
August 1939.

INFORMATION CIRCULAR

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SAVING GOLD BY MEANS OF CORDUROY[1]

By M. W. von Bernewitz[2]

PURPOSE OF THIS REPORT

Corduroy is used for saving gold in small and large milling plants throughout the world. Investigations by the Metallurgical Division of the Bureau of Mines indicate that corduroy blankets, used with or without a trap or jig in the mill classifier circuit, often are effective in concentrating gold and sulfides, especially if the gold does not amalgamate readily and if not enough sulfides are present to warrant the use of a shaking table, flotation cells, or cyanide plant.

Most gold-mining countries include several or many small mines that produce siliceous ores low in sulfides and gold, which can easily be amalgamated or caught in traps or jigs or on corduroy and shaking tables. At these mines the ore is crushed by stamps or ball mills, and the flow sheets include plates, flotation cells, and cyanide treatment, yet probably nearly as much of the pay minerals may be recovered by the less expensive plant. A well-known western maker of mine and mill equipment asserts, as the result of considerable observation of installed plants, that gold and other valuable minerals should be caught as soon as they have been released by a mill, and recommends jigs to do this. A supplier of corduroy has informed us that at some mines this material is being replaced by jigs that catch gold as fine as 400-mesh. But for the small operator, inexpensive equipment such as a corduroy table may be better adapted and give a good recovery of gold and associated minerals.

CORDUROY

The corduroy from which wearing apparel is made is unsuitable for gold-saving; that weave has narrow, closely spaced ribs and the fibers or threads are not cut or free, as they are in milling corduroy. Figure 1 shows the material commonly used for milling. Another milling weave has a slightly wider rib and space between ribs. The high side of the rib should be laid toward the pulp flow.

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Inf. Circ. 7085."

2/ Assistant mining and metallurgical engineer, Metallurgical Division, Bureau of Mines.

In the United States the American Cyanamid Co., New York City, sells corduroy direct and through supply firms to mining companies. Only one width (28 inches) is handled. For quantities up to 5 yards the price is $2 a yard; for more it is $1.50. In Canada, f.o.b. Montreal or Vancouver, sales tax paid, Peacock Brothers, Ltd., of Montreal, quote $1.10 per yard for 28-inch and $1.35 for 36-inch narrow-ribbed corduroy.

As corduroy is probably the most efficient blanketing for catching gold, other blanketing, canvas, burlap, sacking, cocomat, skins with hair, and sponge rubber will be discussed only briefly, although these have been more or less satisfactory and are inexpensive.

CORDUROY TABLES

For the average run of siliceous gold ores containing up to, say, 5 percent of sulfides, corduroy tables are set at a slope of 1-1/2 inches per foot; the range is 1-3/8 to 1-7/8 inches. Tables may be built so that the slope can be altered easily, or they may be hinged for adjustment by means of a handwheel and worm gear to accommodate pulp flow and permit washing into a special launder. If copper plates were used at a mine, these may be removed and the corduroy laid on the tables, which should have the proper slope.

In amalgamating practice the pulp flows over the copper plates as a series of gentle, shallow waves to enable the gold to have contact with the mercury-coated surface; but a heavy flow does not prevent corduroy from catching the gold and sulfides. (See fig. 2.) It is necessary, however, that corduroy be washed frequently so that gold and sulfides do not accumulate to such depth that the ribs are buried and the riffling action stops.

Ores containing arsenic, antimony, lead, bismuth, talc, clay, or graphite, or acid mine water (all of which more or less foul mercury-coated copper plates and prevent amalgamation of gold) need not be considered when corduroy is used. Even if gold be coated it will be caught.

Unclassified and fairly coarse pulp may be run over corduroy.

Although gold and rich sulfides caught on corduroy are bulkier than gold amalgam from copper plates, and therefore not so easy to handle, a strip of corduroy may easily be folded and stolen. To prevent theft, some plants enclose their corduroy tables and clean-up equipment with heavy wire netting with a locked door. The tubs or tanks in which the corduroy is washed also should have hinged lids of similar construction.

ORE-TESTING WITH CORDUROY

The Metallurgical Division of the Bureau of Mines introduced the use of corduroy in ore testing in 1936 as part of its regular procedure in determining preferred treatment methods for ores from various districts.3/

3/Davis, C. W., and Staff of the Ore Testing Section, Progress Reports 16, Metallurgical Division, Ore Testing Studies: Bureau of Mines Rept. of Invest. 3328, 1937, p. 68.

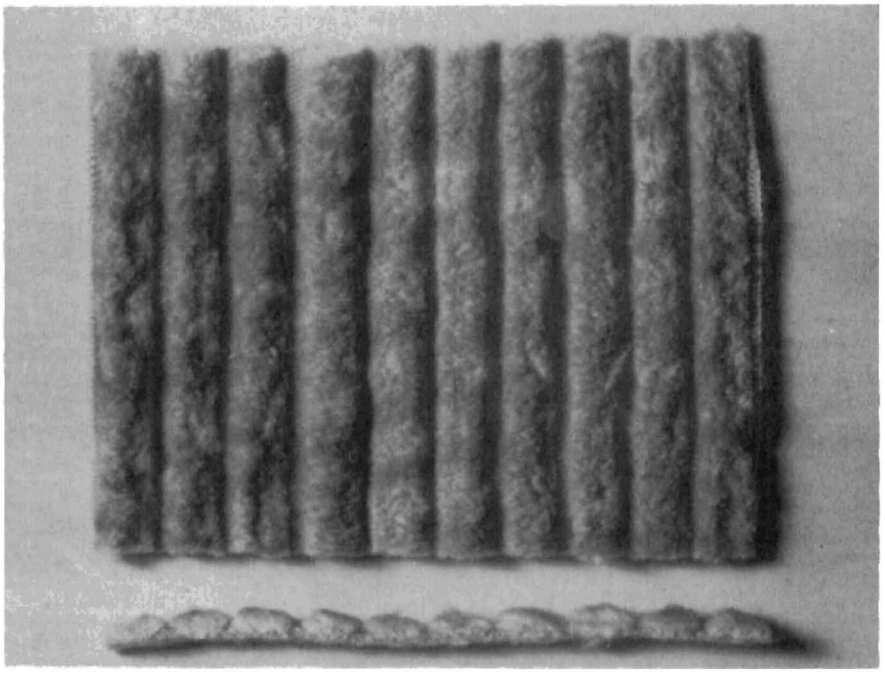

Figure 1.- Natural size of corduroy, end and top views.

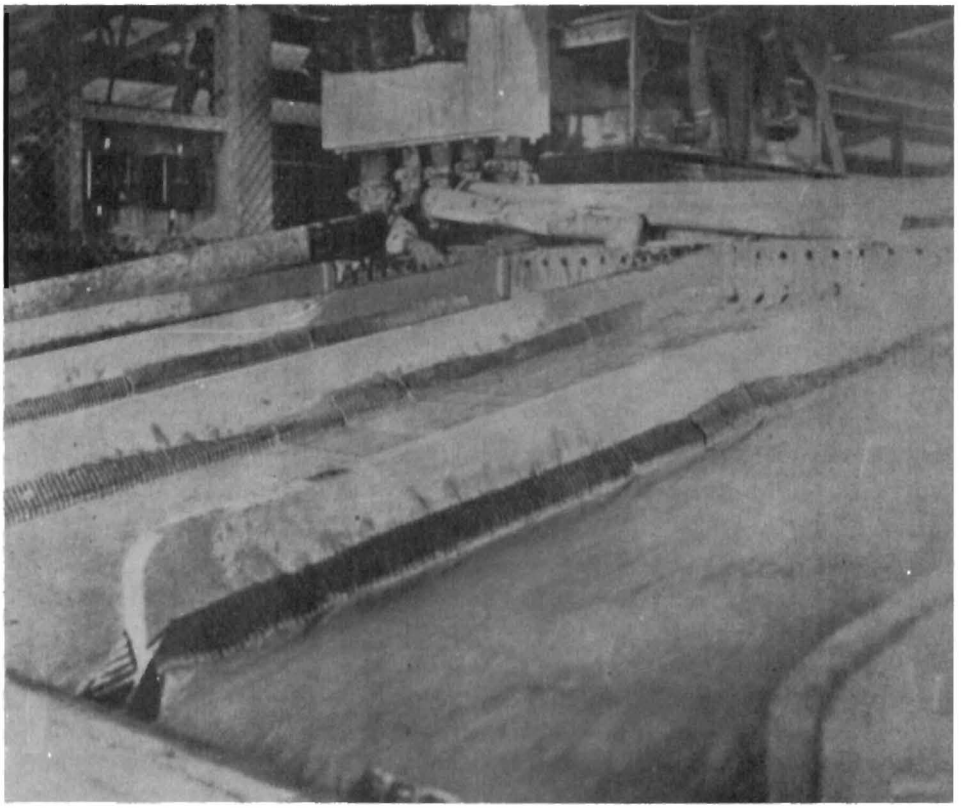

Figure 2.- Corduroy tables in the Paringa plant, Kalgoorlie, Western Australia.

According to their annual reports, the Ore-Dressing and Metallurgical Laboratories of the Bureau of Mines, of the Mines and Geology Branch, Department of Mines and Resources, Ottawa, Canada, make blanket (corduroy) concentration tests on many gold ores received for investigation. These tests are part of the standard testing program, which also includes amalgamation, classification, flotation, and cyanidation. If corduroy recovery is satisfactory, it is so reported. It is also recommended that removal of free gold by jigs, traps, blankets, and copper plates be done in the grinding-classifier circuit; also, that such concentrates be barrel-amalgamated and reground prior to being returned to the mill circuit. Corduroy has been tested also to determine whether free gold escapes from flotation cells, and, as this has been found to occur, the use of blankets or shaking tables is recommended for catching any elusive gold.

In reply to an inquiry as to how the corduroy is cleaned thoroughly after each test so that any gold or sulfide entrapped in it will not salt the test to follow, C. S. Parsons, chief of the Division of Metallic Minerals, in Ottawa, replied:

> When we are using the blankets, we depend entirely on the tailing assays and calculate from them and the head samples the amount of gold retained on the blankets. We have never been able to obtain proper checks by washing, weighing, and assaying the product caught on the blankets.
>
> We do not believe that there is much danger of salting the tailings obtained from running different ores over the same blanket, as any material that is held in the blankets after being thoroughly washed is not likely to pass over into the tailings when the blanket is used the second time. However, if we have to be very particular, we simply use a new piece of corduroy.
>
> We do not think that it is possible to wash the blankets entirely free of gold or gold-bearing sulfides, no matter how carefully the operation is carried out; and then, again, if you destroy the blanket and try to weigh all the material that has been caught on it, it is very difficult to sample this product, as it carries so much free gold.

Tests on the suitability of corduroy are also made at the school of mines, Kalgoorlie, Western Australia, where considerable work on mineral dressing is done for the public.

LITERATURE ON CORDUROY

The use of corduroy is mentioned rather casually in descriptions of milling plants, but it has received fairly extensive attention in a few papers.4/

In chapter 9, Gravity Concentration in Gold Mills, Rose and Newman5/ give flow sheets and discuss the use of blanketing, which includes blankets, canvas, and corduroy. They show tables at Morro Velho, Brazil, where the ore contains arsenopyrite, pyrrhotite, and other sulfides with rusty gold; the tables may be tilted sideways for washing by an overhead traveling frame for this operation; they show also a continuous canvas table and an adjustable rubber blanket strake.

PLANT PRACTICE

The following information has been procured direct and culled from published articles. Plant practice is described well enough to guide anyone who purposes to use corduroy.

United States

In his review of milling during 1938, Engelmann6/ says:

> In treating gold and silver ores, increasing use is being made of combination processes. Installation of traps, riffles, blankets, jigs, unit flotation cells, tables, and other equipment in the ball-mill classifier circuit to recover gold at as early a stage as possible continues to replace the old-style plate amalgamation, whether grinding is carried out in cyanide solution or in water preparatory to concentration by flotation.

A reading of several valuable reports on gold mining in the United States based upon recent visits to mines by engineers of the Mining Division of the Bureau does not reveal many mills that are using corduroy or any type of cloth. Those mentioned and whose flow sheets are given, are discussed hereafter. Apparently none were seen in Arizona, Nevada, and New Mexico.

The firm that handles most of the corduroy in this country states that it does not know how much is used each year; some is sold direct and some to dealers in mining supplies who probably have stocks of the material.

4/ von Bernewitz, M. W., Corduroy as a Gold-Saver: Eng. and Min. Jour., vol. 136, February 1935, pp. 63-67.
American Cyanamid Co., The Use of Corduroy in Gold Ore Treatment: Ore-dressing Notes 3, March 1935, pp. 1-4.
Chicanot, E. L., The Use of Corduroy in Gold Milling: Canadian Min. Jour., vol. 56, May 1935, pp. 179-182.

5/ Rose, T. K., and Newman, W. A. C., The Metallurgy of Gold: Griffin's Metallurgical Series, J. B. Lippincott Co., Philadelphia, 7th ed., 1937, pp. 233-241.

6/ Engelmann, E. W., Ore Concentration and Gold Milling: Min. and Met., vol. 20, January 1939, pp. 13-16.

Gayford[7] states that blanket strakes, one of the oldest methods for recovering free gold, are again being used extensively; but whereas previously they generally supplanted amalgamation plates, they now often replace them. Gayford briefly explains the use of corduroy, shows a self-washing blanket table, and gives the cost of labor involved in washing and changing blankets as 3 to 5 cents per ton of ore milled.

Jackson and Knaebel[8] said the following in their report on milling:

> Blanket tables, consisting of flat, sloping surfaces covered with strips of corduroy, blanket cloth, coco matting, or coarse woven canvas, are used in many plants. ***. The heavy minerals including gold, sink to the bottom and are caught in the riffles of the corduroy or between the fibers of the matting or other material that may be used. ***. Concentrates are washed from the blankets at short intervals.
>
> Blankets, matting, and riffles have two rather distinct fields of use: In the earlier practice, blankets were employed chiefly as scavengers or guards to catch any gold not retained on the plates [copper] or saved on shaking tables, and they are still recognized as excellent devices for this purpose. Later, they became competitors of plate amalgamation and have directly replaced the plates in some mills, notably on the Rand. Although they [blankets] usually do not save as much free gold as plates, they cost considerably less to operate, and where the pulp is subjected to further treatment, they frequently yield improved economic results.

California

Probably a considerable amount of blanketing was used in California in the past, but it is reported by engineers who have spent months in the State during the past 2 years that little corduroy is to be seen. One dealer in the cloth informs us that it supplies six gold producers.

In Mariposa County, the Oaks and Reese mine has a 40-ton Marcy ball mill with a jig in the circuit with a classifier. The pulp then flows over a copper plate, a shaking table, and a corduroy table 18 inches by 14 feet. The corduroy washings are panned. The ore is siliceous, according to F. W. Horton of the Bureau of Mines.

7/ Gayford, Ernest, Ore Treatment as a Factor in Small Gold-Mining Enterprises: Trans. Am. Inst. Min. and Met. Eng., vol. 112, 1934, pp. 561-563.

8/ Jackson, C. F., and Knaebel, J. B., Gold Mining and Milling in the United States and Canada: Bureau of Mines Bull. 363, 1932, p. 109.

Logan's general report[9] on mining and metallurgy of the Mother Lode, California, contains little on the use of corduroy.

At the Montezuma-Apex, Eldorado County, the ore consists of quartz and Mariposa slate. Coarse gold occurs in places. The plant handles 240 tons per day. About 70 percent of the gold is saved by amalgamation (presumably from trap and corduroy concentrates ground with mercury) and 30 percent in sulfides, which comprise 3 percent of the ore. Following each of two Marcy ball-mills are six hydraulic traps and then 4-1/2 square feet of corduroy. The overflow from these tables runs to two Dorr classifiers whose overflow goes over two lots of 30 square feet of corduroy. For periodic clean-up of classifier free gold is another lot of 30 square feet of corduroy. Concentrates from the traps and corduroy are tabled, barrel-amalgamated, and the amalgam retorted. Flotation recovers the rest of the sulfides.

Idaho

Lorain's[10] description of Idaho County, Idaho, includes the following as to the use of corduroy:

Shamrock or New York mine. - The quartz vein contained free gold, pyrite, arsenopyrite, and galena. The ore was broken by a jawcrusher and 5 stamps, which reduced 8 to 10 tons per day through 35-mesh. The pulp flowed over two 4- by 5-foot copper plates and one 4- by 6-foot corduroy table, all set at a slope of 1-1/2 inches per foot. The corduroy saved 10 pounds of concentrates per ton of ore.

Robinson or Dixie Dike mine. - In a sampling of this property at the rate of 40 tons per day the plant had a 2- by 4-foot blanket table below the ball mill and another of similar area for the Dorr classifier overflow. Flotation cells followed. All concentrates were lightly roasted and cyanided.

Montana

In summarizing milling practice in the Tobacco Root Mountains region, Montana, Lorain[11] said:

9/ Logan, Clarence A., Mother Lode Gold Belt of California: State Division of Mines Bull. 108, 1934, 240 pp. and maps in pocket. (A flow sheet similar to that shown is to be found in Ernest Gayford's Ore Treatment as a Factor in Small Gold-Mining Enterprises, Trans. Am. Inst. Min. and Met. Eng., vol. 112, 1935, pp. 549-569.)

10/ Lorain, S. H., Gold Mining and Milling in Idaho County, Idaho: Bureau of Mines Inf. Circ. 7039, 1938, pp. 36 and 54.

11/ Lorain, S. H., Gold Lode Mining in the Tobacco Root Mountains, Madison County, Mont. Bureau of Mines Inf. Circ. 6972, 1937, 74 pp.

Milling practice is simple and generally uniform. All plants operating in 1936 were using bulk flotation, supplemented in some instances by plates, blankets, traps, or unit flotation cells for the recovery of coarse free gold or partly oxidized sulphides. The only cyanide plant in the region was idle.

One mine in the Virginia City district is making a high recovery on partly oxidized ore by interposing a hydraulic trap in the ball mill-classifier circuit. In other gold-mining regions an excellent recovery has been obtained on partly oxidized ore by the use of plates or corduroy blankets in the ball mill-classifier circuit, and additional plates or blankets to treat the classifier overflow; the sulphides are then recovered by flotation.

Two examples of the use of blanketing in this region will be given:

Goldschmidt. - The ore consists of oxidized quartz lenses and stringers along a bedding-plane fault in limestone. Ore of lower than shipping grade, also dump ore, was crushed and milled in a 10-stamp Straub mill. The pulp flowed over a 35- by 90-inch copper plate in two sections followed by two 33- by 54-inch blanket tables used alternately. The recovery was 83 percent on $10 to $12 ore when 12 to 15 tons daily was being milled.

Marietta. - Mineralization of the quartz lenses is principally free gold and auriferous pyrite, with some arsenopyrite and galena. About 1,000 tons per month was milled and floated. Tailings from the eight cells passed over a 24-inch by 10-foot blanket table, thence to waste. The pulp is low-grade, so the blankets catch little gold. (These blankets would act somewhat as a pilot shaking table to determine the loss from flotation.)

Oregon

The White Swan plant, Virtue district, Oregon, according to Lorain[12/], has a box distributor in circuit with a Dorr simplex classifier and a Marcy ball mill. It feeds a blanket table of six 2-foot-square sections, and there is an auxiliary blanket table of four 2-foot sections in reserve. Concentrates from the blankets were washed and passed over a Wilfley table whose concentrate was ground and amalgamated in a barrel 8 hours with lye and 6 hours with mercury.

This plant handled about 40 tons per day and saved 80 percent from $10 ore.

Canada

According to a list of sales of corduroy prepared by Peacock Brothers, Limited, Montreal, distributors of the material, about 140 individuals and companies in Canada have used or are using it.

12/ Lorain, S. H., Gold Mining and Milling in Northeastern Oregon: Bureau of Mines Inf. Circ. 7015, 1938, pp. 26-28.

Several of the descriptions of the use of corduroy in the Dominion are taken from a pamphlet giving representative flow sheets of Canadian mills published by the Canadian Mining Manual.

British Columbia

Considerable interest and space are being given to the Zeballos area, 180 miles north of Victoria, Vancouver Island, British Columbia. Native gold appears to be consistently associated with pyrite, arsenopyrite, galena, and sphalerite, yet it occurs largely in the quartz and calcite gangue in close proximity to them rather than within them. At the Privateer mine, which is in rugged country and has rich pockets of gold-silver ore, according to MacDonnell[13], careful sampling and testing showed that the flow sheet should embody washing, sorting, single-stage crushing, milling in cyanide solution with jig and classifier in closed circuit to 80 percent through 200 mesh, blanketing of classifier overflow as a safety factor, and cyanidation. Jig and blanket concentrates are ground and amalgamated in a barrel.

Nova Scotia Ores

The gold in Nova Scotia ores occurs both free and intimately associated with sulfides, chiefly arsenopyrite. Much of the gold is fairly coarse and crystalline, especially when in white quartz, but when in slate it is generally in thin plates and scales, frequently coated and discolored. For this type of ore, Roach[14] suggests the flow sheet of figure 3. It is designed to recover, cheaply and effectively, the free gold in a form readily sold to the Ottawa Mint and the auriferous sulfides in a concentrate acceptable to a custom treatment plant. As shown by the flow sheet, which is suitable for any mine producing such ore, concentrates are caught by trap, jig, and blankets of corduroy. The third process would catch fine gold and sulfides that escape the jig and should have a surface of at least 1/4 square foot per ton of ore. Corduroy should be washed frequently to prevent undue loss. All the concentrated material, including heavy stuff in the boot of the classifier, should be ground in a barrel with water, lime, and mercury and the pulp therefrom flowed through an amalgam trap and then over a small copper plate. The pulp may then be collected, drained, dried, and sold if assays show it to be worth shipping.

During 1936, the ore-dressing laboratory of the Mines and Geology Branch, Department of Mines and Resources, Ottawa, Canada, made some blanket (corduroy) tests on ore from the Blockhouse area, Nova Scotia. This consisted of white quartz with free gold, iron pyrite, arsenopyrite, and chalcopyrite assaying 0.90 ounce of gold and 0.18 ounce of silver per ton. Test 18 included grinding the ore so that 96-1/2 percent passed 200 mesh, the pulp was run over corduroy, and the tailing was floated. The flotation concentrate assayed

---

13/ MacDonnell, G. F., The Privateer Mine, Zeballos: Paper presented at annual western meeting, Canadian Inst. Min. and Met., Vancouver, November 9-11, 1938; The Miner, vol. 11, December 1938, pp. 29-36.

14/ Roach, A. G., A Flow-Sheet for Nova Scotia Gold Ores: Canadian Min. and Met. Bull. 314, June 1938, pp. 228-231.

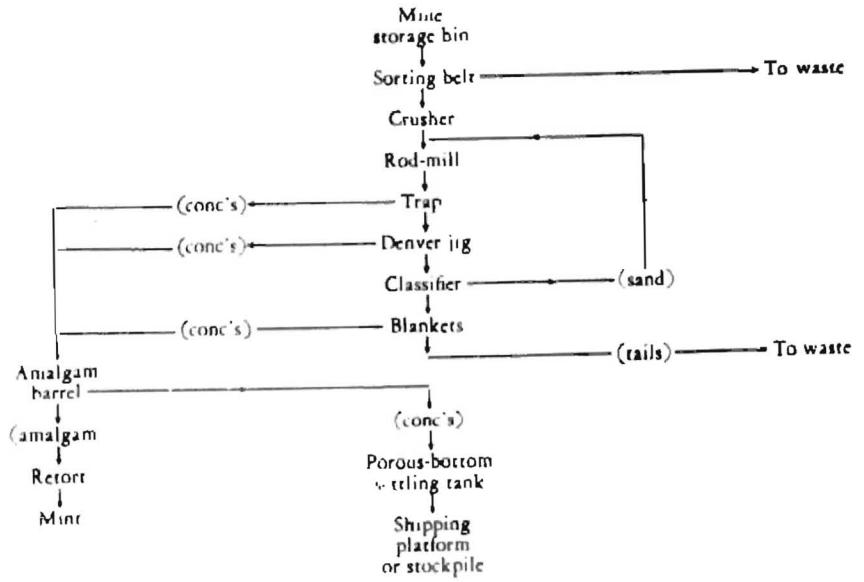

Figure 3.- Flow sheet suggested for Nova Scotia gold ores, as described.

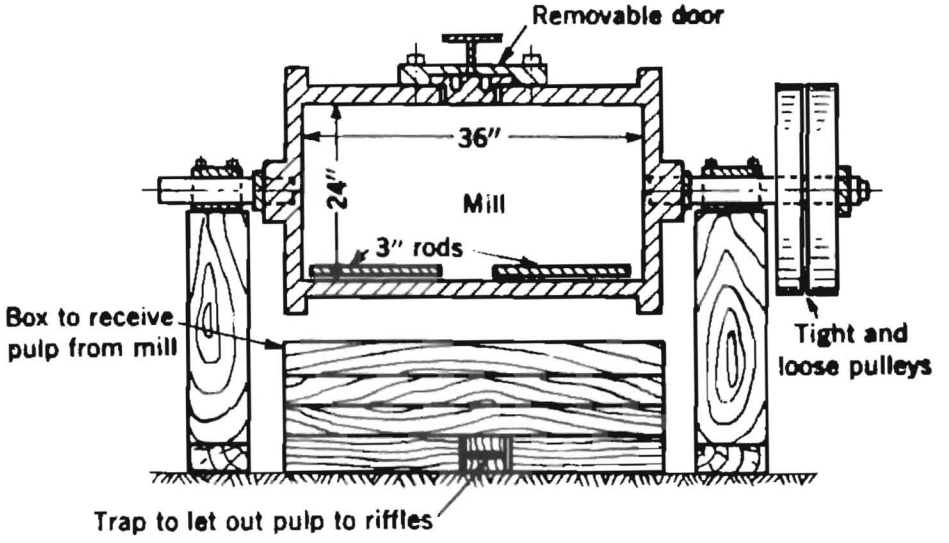

Figure 4.- Ball mill suitable for grinding and amalgamating rich material from corduroy or other cloth, jigs, traps, copper plates, and tables.

3.68 ounces per ton and the tailing 0.04 ounce, and the calculated gold content of the blanket concentrate was 117.4 ounces and it contained 69.13 percent of the gold.

Ontario

Porcupine United mine. - At the lower end of each 4- by 8-foot copper plate at the Porcupine United mine was attached a 42- by 48-inch sheet of 1/8-inch iron upon which corduroy was laid, according to Vary.[15] This was held down by an iron bar 1/8-inch thick and 2 inches wide resting in notches cut in the table frame. The slope was 1-5/8 inches per foot. Forty percent of the total gold recovery was made on the plates and 35 percent on the corduroy, which caught fine gold, pyrite, and mercury that escaped the plates. The corduroy was washed each time the plates were dressed.

The plant handled 20 to 39 tons per day of ore consisting of quartz with mineralized schist, or banded quartz-schist, or stringers of quartz in schist accompanied by pyrite and visible gold, of which 75 percent is free and mostly fairly coarse.

Dome mine. - Gold in the ore of the Dome mine, Porcupine district, Ontario, is so free that 70 percent or more is caught on corduroy tables. The writer saw these tables in 1935 and noted the gold and sulfides on the cloth that was being washed, their grinding in barrels, and the squeezing and retorting of the amalgam. When the former mill was burned 10 years ago copper plates were used. Hall[16] describes the present practice as follows in part:

Each of the 28 tables has an area of 27 square feet and a slope of 1-3/8 inches per foot. The corduroy blankets are backed with cheesecloth and reinforced at the ends with canvas. They are 28 inches wide and 5 feet long, three to a table, and overlap 3 inches. The rough edge of the material faces the flow of pulp. A blanket lasts about 90 days and is soaked in cyanide solution before being discarded. Two men change all the corduroys every 1-1/2 hours, and a third man washes them in a tub. When ready to be removed, they are rolled to prevent the loss of rich material. There are two 31- by 60-inch amalgamating barrels for the washings. They hold 1 ton of concentrates and 500 pounds of 1-1/2-inch balls and are run 18 hours. Then mercury is added, and the barrels are run another 1-1/2 hours. They are then emptied and the amalgam is cleaned with hot water, squeezed to about 50 percent mercury, and finally retorted. The mill pulp eventually is cyanided.

15/ Vary, Ronald A., Amalgamation Practice at Porcupine United Gold Mines, Ltd., Timmins, Ontario: Bureau of Mines Inf. Circ. 6433, 1931, 5 pp. and 1 flow sheet.

16/ Hall, James D., Mining and Milling at Dome, Hollinger, and McIntyre: Canadian Min. and Met. Bull. 318, October 1938, pp. 481-488.

Little Long Lac mine. - The flow sheet of the Little Long Lac plant shows blanket tables receiving overflow pulp from the ball-mill classifier and pulp from the tube mill. The table concentrate is treated as usual, and the table tailing goes from a cone to the mill classifier and to the classifier that follows the tube mill.

Pickel Crow Mine. - The Pickle Crow flow sheet shows gold traps in the two ball-mill classifier circuits and six blanket tables for each preceding the primary pulp thickeners. Cyanidation is by countercurrent treatment.

Quebec

Siscoe mine. - The flow sheet of the Siscoe plant shows the ball-mill classifier overflow passing to a cone and then to three blanket tables 48 feet long with a fall of 1-3/8 inches in 12 inches. The concentrates are barrel-amalgamated, run over a copper plate, milled and classified, and the pulp returned to the main mill circuit.

Sullivan Consolidated mine. - The flow sheet of the Sullivan Consolidated shows four corduroy tables in parallel, with an area of 240 square feet, being fed from the mill-classifier overflow. These concentrates, with those from hydraulic traps, are ground and amalgamated.

The Philippines

Demonstration mine. - Bell's concise description[17] of the Demonstration plant near Baguio, Philippine Islands, includes a few lines on corduroy, and the flow sheets show where it is placed.

There are two circuits, connected at two points, one (250 tons daily) for oxide ore and one (150 tons daily) for sulfide ore. The former is cyanided and the latter floated, and the concentrates are shipped to Tacoma, Wash.

The ores assay 0.28 ounce and 0.354 ounce gold per ton and contain a little silver, copper, lead, zinc, and other minerals.

In the oxide grinding-classifying circuit is a jig followed by two 5- by 12-foot tilting corduroy tables. In the sulfide circuit are two unit flotation cells followed by three 3- by 19-foot tilting corduroy tables.

In the oxide ore are a little refractory sulfide and coated gold, which are transferred from the jig and corduroy to the sulfide circuit, and from the sulfide ore most of the free gold is recovered by the unit cells and corduroy before flotation.

17/ Bell, George A., Milling Practice at Demonstration Gold Mines, Ltd., Philippine Islands: Am. Inst. Min. and Met. Eng., Mining Technol., Tech. Pub. 1017, January 1939, 7 pp.

Milling and cyanidation cost $1.42 per ton to extract 88 percent of the gold; milling, flotation, and marketing cost $2.71 per ton to extract 90 percent; and corduroy operation costs 1.05 cents per ton of ore milled.

Replying to a request for further information, Bell stated that the corduroy tables were built by the mill carpenter at a cost of $25 each. They are lined with zinc-coated iron to prevent leaking. A wide-wale corduroy, which has a life of 12 to 18 months, is cut into strips and wedged down by 1/2- by 2-inch cleats, which act as riffles and aid in collecting gold. Washing is done on the tables themselves. Every 2 hours the feed is cut off a table and the slime hosed off, leaving a clean concentrate. The table is then tilted back and the corduroy taken up and washed down the table into a screened launder, which leads to the concentrate thickener. The tilting feature is important because the grade of concentrate and recovery of gold is greatly affected by the slope, dilution, and volume passing over a table. The average slope is 1 inch per foot and there are 1.1 square feet per ton of solids per 24 hours. The corduroy tables save 70 percent of the fine free gold and the concentrates average 4 ounces per ton. Occasionally, the corduroy is acid-treated to remove lime and slime, and worn-out material is burned to ash and melted in the clean-up. The cost of operating corduroy tables is 1.05 cents per ton of ore, 1 cent of which is for labor.

Additional information on the Demonstration plant is given by Bell in the Philippine Mining Year Book, 1939, published by the Chamber of Mines of the Philippine Islands, prepared by Ralph Keeler and others. Two flow sheets show where the blanket tables receive and discharge the pulp. Final concentrates from the corduroy tables and unit flotation cells are thickened, filtered, partly dried, sacked, pipe-sampled, and shipped to a smelter.

Suyoc Consolidated mine. - According to Weekley and Iverson[18], ore of the Suyoc Consolidated, 60 miles north of Baguio, Philippine Islands, assays 0.29 ounce of gold, also some copper pyrite, iron pyrite, sphalerite, and galena. The plant capacity is 250 tons per day. Free gold is caught on three 30-inch by 20-foot corduroy tables in the circuit between the ball mills and classifiers. The pulp is 1/4-inch trommel undersize. The corduroy concentrate is tabled and the concentrate is ground and amalgamated while the table tailing is returned to the general circuit. In the circuit for the combined flotation concentrates, two 18-inch by 8-foot corduroy tables follow a small ball mill. The concentrate is ground and amalgamated and the table tailing is reground.

Replying to a request for further information, Weekley stated that the slope of the tables that treat the minus 6-mesh pulp from the ball-mill discharge is set at 1-1/2 inches per foot. These tables are pivoted at the upper end so that by means of wedges the slope can be varied from 1 inch to 2-1/2 inches. Other tables fed with 95 minus 200-mesh pulp are set at 1 inch per foot.

18/ Weekley, C. A., and Iverson, H. G., Suyoc Mill Treats Complex Ores: Eng. and Min. Jour., vol. 138, August 1937, pp. 415-417.

The corduroy is washed off into a steel tank every 2 hours. Considerable pyrite is collected with the gold, but it is passed over a half-size Wilfley table before amalgamation. Table tailings return to the mill circuit and gold concentrates are ground in a pan amalgamator of local and satisfactory design. It is 3 feet in diameter and is loaded with about a dozen 4-inch steel balls. An eccentric on the shafting gives the pan a motion similar to that of hand panning. A little caustic soda is used during amalgamation. In 1938, 33 percent of the total gold in the ore was caught by corduroy.

Costa Rica

Individual mining operations in Costa Rica, Central America, are small, according to Bennett[19], but the total gold output is considerable. Along the Cordillera Central the vein filling in general is soft quartz in the upper levels and sometimes a tough, sticky gray clay with quartz stringers. Milling methods are simple, with more or less handwork. Soft ores are washed in a trommel ahead of the crusher and milled to 40-mesh. Plate amalgamation is common, followed by corduroy or flotation. Concentrates often are low in grade, and shipping and smelting costs are high.

Africa

Rand, Transvaal

Plate amalgamation on the Rand has given way to corduroy, and Prentice[20] has the following to say:

> Corduroy concentration, followed by barrel amalgamation of the re-dressed concentrate, effects an average recovery of 50 percent of the gold in Rand ores at a cost of 1.4 pence (2.8 cents) per ton milled, and mercury consumption is now only one-tenth of what it was when plate amalgamation was in general use.

On the Rand, more than 54 million tons of 4-1/2-pennyweight ore is treated annually. This ore contains some iron pyrite, with which the gold is associated.

A quartz vein in granite is being mined at the Reitfontein mine, and 30 percent of the gold has been caught on corduroy, according to Boxall.[21]

19/ Bennett, Evan, Gold Mining in Costa Rica: Eng. and Min. Jour., vol. 140, January 1939, pp. 56-58.

20/ Prentice, T. K., The Witwatersrand Gold Mining Industry and its Metallurgical Development: Jour. Chem., Met., and Min. Soc. South Africa, vol. 37, August 1936, p. 30.

21/ Boxall, W. P., The Reitfontein (T.C.L.) Mine, Sabie: Jour. Chem., Met., and Min. Soc. South Africa, vol. 39, October 1938, p. 96.

The oxidized ore contains 78 percent silica and the pyritic ore 25 percent. Between the Dominion ball mill and Dorr classifier, whose product is 60 to 70 percent through 200 mesh, are three corduroy tables. The washings therefrom are barreled for 17 hours, when mercury is added; loss is 0.37 ounce per ton crushed. Barrel tailings pass through a trap and then mix with the concentrate from the Geco flotation cells. Concentrates are sold.

Plate amalgamation was unsatisfactory for this ore because of the action of arsenopyrite. There is no cyanidation at this mine.

West Africa

According to Hastings,[22] in an address on February 22, 1939, to the Chemical, Metallurgical, and Mining Society of South Africa, in Johannesburg, the metallurgy of the auriferous conglomerate of West Africa is simple. This "banket" is similar in appearance to that of the Rand, South Africa, but it has no sulfides and the pebbles are cemented by sand and granular hematite. The gold content is extremely fine. In one of the newer plants, ball mills are in closed circuit with corduroy tables. At a reduction treating quartz ore in which are carbonaceous minerals and sulfides, the ore is milled by stamps followed by corduroy and the pulp is reduced further in ball mills followed by corduroy. The corduroy strakes save 85 percent of the gold in the ore, which is higher than the recovery at the Dome mine, Ontario.

Australia and New Zealand

Considerable corduroy is used in Australia and ordinary blanketing has long been employed in New Zealand.

Western Australia

Corduroy is to be found at mines where oxidized and sufide ores are milled, also where roasted concentrates are treated.

Lake View & Star. - According to the last annual report of the Lake View & Star Co., Kalgoorlie, which floated 619,919 tons of sulfotelluride ore during the year, the onion-sack strakes collected free gold worth £102,000 (say, $400,000 at current exchange), from the pulped roasted concentrates. This represented 12.4 percent of the total mill heads. A total of 52,675 tons of concentrates was handled last year.

In the milling plant are corduroy tables in the ball mill-classifier circuit and in the classifier-overflow and bowl-classifier circuit. These are known as primary corduroy and secondary corduroy and are 3 feet wide. The former has a grade of 1 in 8 and a pulp flow of about 8 tons per square foot per day, and the others are 1 in 10 with 15 tons per day. A comparison with the tables for calcine, on which onion sacking was used, shows 1-1/3 tons per foot per day. The wide-ribbed material was favored when the writer visited the plant in 1933.

22/ Hastings, B. J., West African Mining Conditions: South African Min. and Eng. Jour., vol. 50, Mar. 4, 1939, pp. 11-13.

Hannan's North. - At this mine the ore is washed, sorted, screened, crushed, stamped, classified, and tube-milled. The stamp and tube-mill pulp flows over two groups of five 3- by 6-foot corduroy tables having a slope of 1-1/4 inches per foot. The concentrate is ground and amalgamated, and the ore slime is cyanided by counter current decantation. The plant treats 3,000 tons a month.

Kalgurli ore treatment. - This plant treats ores from the Boulder Perseverance, North Kalgurli (1912) and Enterprise mines. The 3- by 5-foot corduroy tables are set at 1 in 8 and save gold from the ball mill-classifier circuit. The flow is gentle and wavelike, similar to pulp from stamps going over copper plates. This mill treats over 20,000 tons per month.

LAUNDERS LINED WITH CORDUROY

Launders lined with corduroy and other fibrous material are used more or less on dredges and in copper plants to save as much as possible of the gold discharged in the tailings.

At the Johnson mine, near Octave, southern Yavapai County, Arizona, the ore consists of quartz and gold-bearing sulfides. The 50-ton plant includes gold traps, shaking tables, and flotation cells. In the circuit where a trap receives the undersize from the ball-mill screen, the tailing from the trap goes to a corduroy launder. Its tailing is tabled and the concentrates are ground and amalgamated with material from the traps.[23]

TREATMENT OF CORDUROY CONCENTRATES

As the foregoing descriptions of the use of corduroy give details of the procedure in the clean-up and production of gold, little need be added here.

Several methods are employed in the handling of corduroy concentrates:

First, these are washed off the cloth at intervals by rinsing them in a tight box, tub, or tank with or without a filter bottom. The concentrates soon settle and the water may be siphoned or filtered off.

If they are to be sold, the concentrates should be sun-dried or dried by artificial heat, a little moisture being left to prevent dustiness. This material should be mixed, coned, and quartered on a clean floor or cloth to get a representative sample for assay. The coarse gold is likely to make check assays difficult.

Arrangements should then be made to send the carefully bagged material by express or parcel post to some smelter.

23/ Metzger, O. H., Gold Mining and Milling in the Wickenburg Area, Maricopa and Yavapai Counties, Arizona: Bureau of Mines Inf. Circ. 6991, 1938, pp. 31-32.

Unless conditions favor shipping concentrates to a custom plant, it is better not to do so but to treat them at the mine, as is commonly done. They may be ground and amalgamated in a barrel (fig. 4) or Berdan pan, as made by equipment manufacturers, or in any available grinding machine. The barrel is partly filled with washings and water, with a little lime or lye and a few grinding rods or balls. After several hours the barrel is opened, mercury is added, the door is closed, and amalgamation proceeds for an hour or more. Then the barrel is re-opened and the pulp is thinned with water and flowed over riffles, which catch the amalgam and surplus mercury. The amalgam is cleaned and either squeezed through a cloth and retorted, or the whole is retorted. The sponge gold may be melted into bars or sent direct to the mint.

Because the pulp or tailing from an amalgamating barrel contains small globules of amalgam and more or less rich particles, it should not be run to waste; the material may be settled and dried in a tank or dam and then sold or fed to the mill or run or pumped to mix with the main flow of mill pulp for re-treatment. Eventually, everything of value is recovered by such means.

CORDUROY FOR PLATINUM ORES

In the section on Ore Dressing and Metallurgy of the platinum ores of Transvaal, Wagner[24] mentions and shows the use of corduroy. In the oxidized zone of the dunite deposits the platinum exists in the metallic state. After much experimentation the flow sheet at the Onverwacht mine had a trap for metallics below the stamps and one below the tube mills. Pulp from the mill passed over Wilfley tables and the tailings therefrom over James tables and corduroy. Metallics from the traps were tabled and the heads hand-panned and acid-treated successively with 10 percent of sulfuric acid and 10 percent nitric acid; the product assayed 82 percent platinum-group metals. The other table and corduroy concentrates were treated in lots of 1,000 pounds for 2 hours in a barrel with mercury, zinc amalgam, copper sulfate, and sulfuric acid. The dirty amalgam was reamalgamated for 1/2 hour with similar activating agents and then treated in earthenware jars with dilute sulfuric acid to remove iron and zinc. The amalgam was retorted and the sponge panned, sorted, and acid-treated, giving a product of 70 percent platinum-group metals. This amalgamation recovered 98 percent and the whole plant 82 to 86 percent.

Corduroy was used in the Maandagshoek plant between the Dorr thickeners and flotation cells. The corduroy concentrates were tabled and acid-treated, and the final product assayed 60 percent platinum-group metals, but mostly platinum.

At the Potgietersrust plant, a mixture of oxidized and sulfide ores was concentrated by flotation, tabling, and corduroy. Shaking corduroy

---

24/ Wagner, Percy A., The Platinum Deposits and Mines of South Africa: Oliver & Boyd, Edinburgh, Scotland, 1929, pp. 272-284.

tables followed the tube-mill and stationary corduroy tables for the tailing therefrom, and corduroy for the middlings from the recleaner cells for the Minerals Separation rougher cells. Corduroy metallics were tabled and the heads treated with a magnet and acid. The final product assayed 60 percent platinum-group metals.

RUBBER MATTING FOR SAVING GOLD

Rubber matting or sponge rubber is used at some mines for saving gold. We have a sample of the material but have never seen it in use. It is about 1/8 inch thick, has a rough surface and many pinholes, and looks as though it might catch gold; the Denver Equipment Co. and others recommend its use.

One example of its use is in the 50-ton plant of the Golden Anchor mine, Idaho[25]. The ore carries free gold and silver and in sulfides. The tailing from a Denver jig passes to an Akins classifier, whose overflow goes over three 11-inch by 12-foot parallel tables covered with rubber matting, and the tailing from the sixth flotation cell is passed over one rubber-matting table of similar size. These tables slope 1-1/4 inches per foot, they are cleaned up every two days, and the concentrates are barrel-amalgamated with those from the jig. These account for 76 percent of the gold recovered.

Another example of the use of sponge rubber is the Mossback mine, near Oatman, Ariz. The ore consists of brecciated andesite and calcite with some quartz; the gold is in fractured parts of the veins. The small mill of 1934 had a sponge-rubber mat between the Harding mill and Dorr simplex classifier, whose overflow passed through a 6-inch launder lined with that material. The mat was washed every 2 hours and the launder once a day. The concentrates were ground in a 3-foot pan and amalgamated, and accounted for half of the gold in the ore[26]. Rubber was not used in the reconstructed plant.

RECOVERY OF GOLD IN TAILINGS FROM COPPER ORES

Accompanying Engelmann's review of ore concentration and gold milling, cited, is a picture of some of the launders for saving gold from flotation tailings at the Arthur plant of the Utah Copper Co. The recovery plant at the Magna mill, as in 1935, has been described by Engelmann[27]. Ten-ounce burlap was found to be the most economical material to use. There are two

25/ Lorain, S. H., and Davis, W. B., Mining and Milling Methods and Costs of the Golden Anchor Mining Co., Burgdorf, Idaho: Bureau of Mines Inf. Circ. 7024, June 1938, p. 8.

26/ Gardner, E. D., Gold Mining and Milling in the Black Mountains, Western Mohave County, Arizona: Bureau of Mines Inf. Circ. 6901, September 1936, p. 35.

27/ Engelmann, E. W., Recovery of Gold from Copper Mill Tailing: Min. and Met., vol. 16, August 1935, pp. 331-332.

banks of launders set at 3/16 inch per foot. The fabric, which is slightly wider than the launder bottom, is held down at each side by blocks and wedges. About 2 square feet of burlap is used per ton treated per 24 hours. Pulp is fed to the launders from a concrete distributing tank arranged so that any one launder may be cut out of service for cleaning or other reason.

As to the gold, most of it is coated so that it does not respond to flotation or to cyanidation, and 75 percent of it is caught in the first set of launders in the first 500 feet. The clean-up cycle is 40 days. When the flow of pulp is stopped, the burlap is washed carefully with clear water to remove some sand and slime, and before it is dry it is cut into 8-foot lengths. These strips are hung on racks in a drying house and are then burned in a stove, as much as 250 yards in a day. After being screened, weighed, and sampled, the concentrate and ash are sent to a smelter.

The saving of gold in copper-mill tailings by corduroy is practiced at a number of large mines and has been found profitable, especially in Canada.

AFTER THIS REPORT HAS SERVED YOUR PURPOSE AND IF YOU HAVE NO FURTHER NEED FOR IT, PLEASE RETURN IT TO THE BUREAU OF MINES. THE USE OF THIS MAILING LABEL TO DO SO WILL BE OFFICIAL BUSINESS AND NO POSTAGE STAMPS WILL BE REQUIRED.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

OFFICIAL BUSINESS

RETURN PENALTY LABEL

THIS LABEL MAY BE USED ONLY FOR RETURNING OFFICIAL PUBLICATIONS. THE ADDRESS MUST NOT BE CHANGED

PENALTY FOR PRIVATE USE TO AVOID PAYMENT OF POSTAGE, $300

BUREAU OF MINES,

WASHINGTON, D. C.