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INFORMATION CIRCULAR

PLACER MINING IN THE WESTERN UNITED STATES

PART II. HYDRAULICKING, TREATMENT OF PLACER  
CONCENTRATES, AND MARKETING OF GOLD

Sluice Box and Riffle section Only.



BY

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### Sluice Boxes

#### Construction

Sluice boxes are rectangular in section and are nearly always built of lumber; steel or iron sluices, however, were used at a few washing plants operated in 1932.

The construction of a wooden sluice box depends somewhat upon the size and service expected of the box; a number of types, however, may be used satisfactorily. Common types of construction for large and small boxes are illustrated in figure 13.

The important features in design are sturdiness and simplicity of construction. Large flumes may have to withstand severe battering and vibration from the passage of heavy boulders, hence they must be strongly constructed and well braced. In small flumes this feature is less important, but the use of lighter lumber increases the difficulties of maintenance and prevention of leaks.

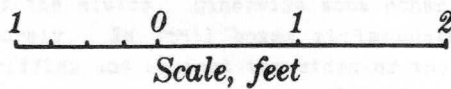
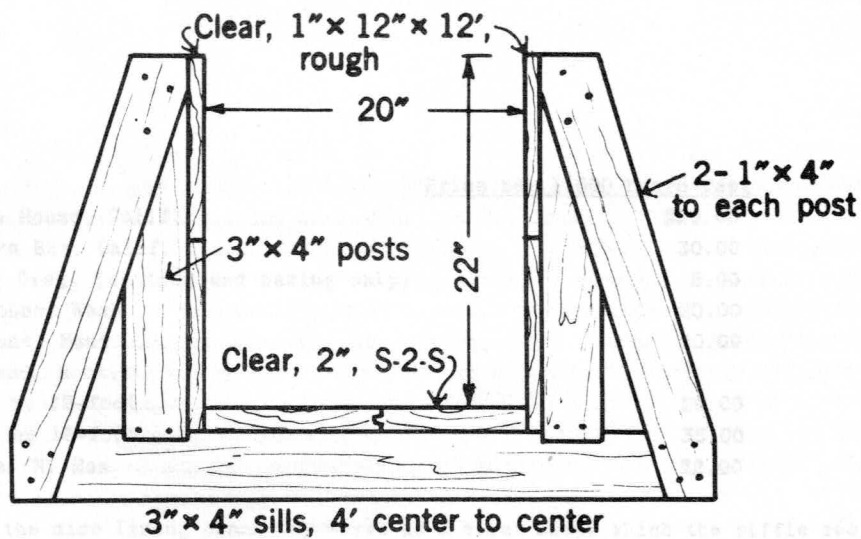
The bottom of a narrow sluice should be a single plank if lumber of the desired width is obtainable; for wider boxes two or more bottom planks must be used. The bottom joints may be made tight by the use of soft-pine splines, by batten strips nailed on the outside, or by caulking with oakum or other material. Bowie<sup>30</sup> recommends half-seasoned lumber as most suitable for the construction of boxes. Where local timber is used it is common practice to cut the plank during the dry season or before snow is off the ground. It is not customary to use surfaced lumber for boxes, although a smooth bottom facilitates the clean-up. The lumber should be clear and of uniform size.

For any but small, temporary installations the sides of sluice boxes should be lined with a wearing surface of rough lumber or sheet iron. Otherwise the entire box must be replaced when the sides are worn out. Board lining is easier to place and replace than sheet iron. In early Californian practice some of the side linings were made of wide, thin blocks nailed on so as to present the endgrain to the wear. Worn iron or steel riffles are used for side lining at some places. Usually only the lower half or third of the side of the box needs this protection, and a single 2-inch board may serve not only for lining but as a cleat to hold down the riffles. False bottoms of planed or rough boards may be used to save wear on the box proper.

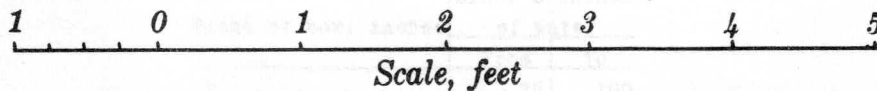
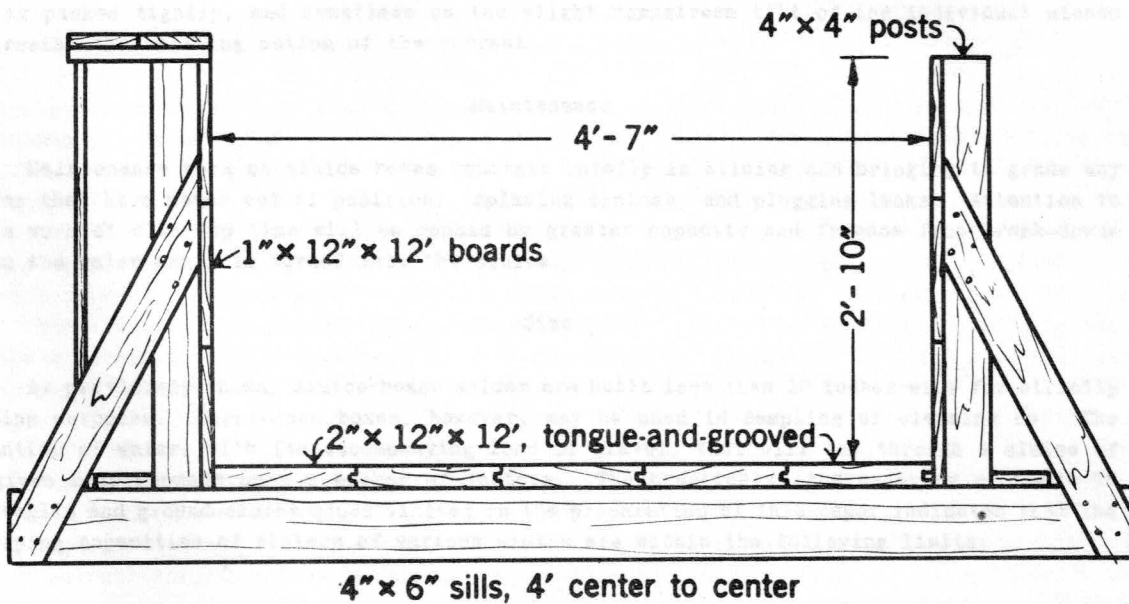
Each box should rest on three or four sills, equally spaced. The sills and upright members at the ends of the box serve as battens to prevent leakage at joints. The practice of tapering the box enough to permit a telescope joint is very convenient in small sluices, especially if the boxes must be moved occasionally. Small, three-board boxes may be braced with ties across the top, although this hampers shoveling and clean-up operations. Larger boxes should be braced externally from the ends of the sills, as illustrated in figure 13, A and B. Sills should be weighted with rocks to check any tendency of the sluice to rise. If the sluice is placed in a bedrock or other cut, water under it or at the sides has a strong lifting effect. Moreover, the vibration caused by boulders rolling through the sluice permits fine gravel to be washed under the sills placed on the ground.

The following table shows the price of lumber suitable for building sluices at various places in the summer of 1932:

30 Bowie, A. J., Hydraulic Mining in California: Van Nostrand Co., New York, 3d ed., 1889, p. 220.



A



B

Figure 13.—Sluice-box construction: A, Twenty-inch box at Henderson mine, Gold Creek, Mont.; B, five-foot sluice box.

	<u>Price per 1,000 board-feet</u>
Oregon House, Calif. ....	\$25.00
Sawyers Bar, Calif. ....	30.00
Waldo, Oreg. (cutting and sawing only) .....	8.00
Wenatchee, Wash. ....	20.00
Emigrant, Mont. ....	20.00
Townsend, Mont.: .....	
1- by 12-foot.....	28.00
2- by 16-foot.....	35.00
Therma, N. Mex. ....	22.00

As mentioned, the side lining plank may serve as a cleat under which the riffle sections can be wedged to the bottom of the sluice. Otherwise some other provision must be made as the riffles must be held securely. In small boxes it is customary to lay long, narrow boards on edge on top of the riffles and against the sides of the sluice. These boards are wedged down tightly under cleats nailed permanently to the sides of the box. The practice of nailing riffles to the bottom of the box, or using any device that requires driving nails in the bottom or sides, should be avoided as it results in leaks and eventually damages both sluice and riffles. Wooden blocks are the most difficult to secure in place but can be held by the method described in the following section. Rock pavement depends on its weight, on being packed tightly, and sometimes on the slight downstream tilt of the individual stones to resist the shifting action of the current.

#### Maintenance

Maintenance work on sluice boxes consists chiefly in alining and bringing to grade any boxes that have moved out of position, replacing linings, and plugging leaks. Attention to this work at clean-up time will be repaid by greater capacity and freedom from break-downs when the water again is turned into the sluice.

#### Size

As previously shown, sluice boxes seldom are built less than 10 inches wide for strictly mining purposes. Eight-inch boxes, however, may be used in sampling or cleaning up. The quantity of water, with its accompanying load of gravel, that will run through a sluice of a given size depends upon a number of factors. The practice at the majority of about 75 hydraulic and ground-sluice mines visited in the preparation of this paper indicates that the carrying capacities of sluices of various widths are within the following limits:

Width of box, inches	Miner's inches of water	
	From	To
12.....	25	100
18.....	100	300
24.....	200	600
36.....	500	1,300
48 to 60.....	1,000	3,000

These limits probably represent good practice.



More trouble is experienced from clogging of boxes that are too wide, because the depth and velocity of water are insufficient, than from failure of boxes to carry their load because they are too narrow.

The current velocities required to transport different sizes of material have been studied; works of various authorities are cited by Gilbert.<sup>31</sup> The following table is based chiefly on Dubuat's figures for competent velocity; the figures are adjusted to approximate mean velocity instead of bed velocity. The last three figures are taken from Van Wagenen.<sup>32</sup>

Size of material moved approximate feet	Mean velocity per second
Sand:	
Fine.....	0.5
Coarse.....	1.0
Gravel:	
Fine.....	1.5
1-inch.....	2.5
Egg-size.....	4.0
Boulders:	
3- and 4-inch.....	5.3
6- to 8-inch.....	6.7
12- to 18-inch.....	10.0

Well-rounded pebbles are easier to move than angular ones, and rock of low specific gravity is appreciably easier to wash than heavy, dense rock such as greenstone or basalt. Gold has a better opportunity to settle and be caught in riffles in a wide, shallow stream than in a deeper and narrower stream of the same volume; the wider sluice, however, usually must be set on a steeper grade.

Small- or medium-size boxes generally are roughly square in cross-section; large boxes usually are one half to two thirds as deep as they are wide. The water in a sluice should always be more than deep enough to cover the largest boulder that may be sent through. In practice, the depth of the stream in the main sluice at hydraulic mines usually is a fifth to a half the width of the box so as to prevent spills if the box is temporarily plugged by boulders or sand. Where screened gravel is being washed, as in undercurrents or on dredges, wide and shallow streams are necessary for the recovery of fine gold. In "booming" operations the boxes usually are run full in order to handle the relatively large volumes of water that flow for short periods only, and the sluices commonly are about as deep as they are wide. It would be desirable but impracticable to decrease the depth of water by using wider sluices, as flows of 5,000 to 10,000 miner's inches are not unusual when the gate of the reservoir suddenly is opened wide.

Miner's inches	Grade
1000	1/200
500	1/100
250	1/50

Usually the grade of the sluice depends upon the slope and contour of the bedrock. If the gradient of bedrock, however, is too low to permit sufficient fall for the sluice, cuts or tunnels may be run in the bedrock to overcome this difficulty. Very short sluices of only

31 Gilbert, G. K., The Transportation of Debris by Running Water: U.S. Geol. Survey, Prof. Paper 86, 1914, p. 216.

32 Van Wagenen, T. F., Manual of Hydraulic Mining: Van Nostrand Co., New York, 1880, p. 88.

1 or 2 boxes sometimes are set nearly flat where there is a drop at the end of the box, the gravel being forced through the sluice by the initial velocity and the head of water in the pit.

The opinion of most operators is that about 6 inches in 12 feet is the best grade for average conditions. As shown, grades as flat as 3 inches in 16 feet can be used but only at great loss of capacity. At the Depot Hill mine, where a grade of 3 inches in 14 feet is used, all rocks over 5 or 6 inches in diameter must be left in the pit. Because of the greater friction and the consequent lowering of velocity, steeper grades are needed for small sluices than for large ones; some operators favor grades of 12 inches to a 12-foot box. For maximum gold-saving efficiency, as well as for economy in dump room, grades should be as flat as possible without lowering the velocity to such an extent that the riffles pack with sand. Any increase in slope from that adjustment will increase the capacity of the sluice, increase the wear on the sluice, and decrease the efficiency of the riffles, resulting in gold losses if carried to extremes or if the gold is very fine. If water is scarce, gold recovery may well be sacrificed to capacity. Bowie<sup>33</sup> states that grades of 10 to 24 inches were used in some Forest Hill Divide (Calif.) mines for this reason. Increasing the proportion of water to solids decreases the tendency of riffles to pack with sand.

Sluice capacity increases with grade but more rapidly; that is, doubling the grade of sluice boxes will more than double the quantity of gravel that can be put through the boxes by a given flow of water. The absolute increase cannot be predicted closely as coarseness of gravel, velocity, and shape of the box appear to have some bearing on the relation of capacity to slope. For instance, Bowie<sup>34</sup> cites a mine at which changing the grade from 3 to 3 1/2 inches in 16 feet increased the quantity of gravel sluiced through the same boxes with the same flow of water by about one third.

The established grade should not be decreased anywhere along a sluice, otherwise gravel may accumulate where the current loses velocity. If the water and gravel, however, enter the first box with considerable speed, say, from the discharge of a hydraulic elevator, the first boxes may be placed on less than the regular grade. Bends or curves are undesirable as they complicate construction and induce clogging and running over. When a curve is unavoidable it should be as gradual as possible, the outside of the sluice should be elevated a fraction of an inch, and the grade should be increased perhaps an inch per box at and immediately below the curve. Similar rules apply to turn-outs or branches, and drops of 3 or 4 inches should be provided at junctions to check the deposition of gravel at these points. Such drops occasionally are inserted in straight sluices if the grade is available, particularly if the gravel is a difficult one to wash or if heavy sand tends to settle to the bottom. A drop of even a few inches from one box to the next has a disintegrating effect and mixes the material passing through the sluice, thus assisting gold recovery. At one place where drops were provided at intervals between different types of riffles, 25 percent of the gold recovered in the sluice was found at the drops.<sup>35</sup>

#### Riffles

##### Theory of gold-saving by riffles

The function of riffles is to hold back the gold particles that have settled to the bottom of a flowing stream of water and gravel. Any "dead" space in the bottom of a sluice

33 Bowie, A. J., A Practical Treatise on Hydraulic Mining in California: Van Nostrand Co., New York, 3d ed., 1889, p. 220.

34 Bowie, A. J., work cited, p. 266.

35 Theller, J. H., *Hydraulicking on the Klamath River*: Min. and Sci. Press, vol. 108, Mar. 28, 1914, pp. 523-526.

box, where there is no current, fills quickly with sand and thereupon loses most of its value as a gold saver, unless the sand remains loose enough to permit gold to settle into it; therefore, the shape of riffles is important, regardless of the fact that under some conditions, as with coarse gold and free-washing gravel, all forms of riffles are almost equally efficient. The riffle should be shaped so as to agitate the passing current and produce a moderately strong eddy or "boil" in the space behind or below it, thus preventing sand from settling there and at the same time holding the gold from sliding farther down the sluice. In other words, riffles, for maximum efficiency, should provide a rough bottom that will disturb the even flow of sand and gravel, will retain the gold, and will not become packed with sand. Where grade is lacking the riffles must be relatively smooth, so as not to retard the current unduly; under these conditions the sluice must be long enough to compensate for the loss in gold-saving efficiency of the individual riffles.

Natural stream beds act as gold-saving sluices, not because they are particularly efficient as such but because most gold is "hard to lose" and the streams are long.

#### Types of riffles

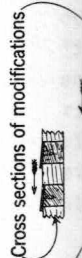
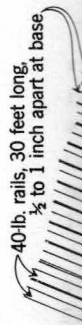
Riffles, of course, should be designed so as to save the gold under the existing conditions. They should also be cheap, durable, and easy to place and remove. Not all these qualities are found in any one type.

Sluice-box riffles may be classified roughly as transverse, longitudinal, block, blanket, and miscellaneous roughly surfaced ones, or, according to material, as wood block, pole, stone, cast iron, rail, angle iron, fabric, and miscellaneous. Usually more than one type of riffle is used, although in California very long sluices have been paved entirely with wood-block riffles, and on dredges the type illustrated in figure 14, A, is used almost exclusively.

Of about 80 hydraulic, ground-sluice, and mechanically worked placer mines visited in 1932 by the authors, approximately 25 percent used riffles of the transverse variety, loosely termed "Hungarian", consisting generally of wooden crossbars fixed in a frame and sometimes capped with iron straps. About 20 percent used the longitudinal pole type, 15 percent wooden blocks, and 15 percent rails, the last being placed crosswise or lengthwise. Angle-iron riffles, wire-mesh screen or expanded metal on carpet, blankets, or burlap, rock paving, and cast-iron sections together made up the remaining 25 percent. The only general rule observed was that the size of the riffles was roughly proportional to the size of the material to be handled and that for fine material, particularly the screened gravel washed in most of the mechanically operated plants, the dredge-type riffle found most favor.

For a small or medium-size sluice (if lumber is costly and a plentiful supply of small timber, such as the lodge-pole pine so common in many Western States, is available) peeled pole riffles (fig. 14 B and C) are perhaps the most economical and satisfactory of the various types. Their construction is evident from the drawing. Those of transverse variety may have a somewhat higher gold-saving efficiency, but undoubtedly they retard the current more and wear out faster. Poles 2 to 6 inches in diameter may be used, spaced 1 or 2 inches apart. Such riffles are cheap but wear out rapidly. The sections should be a third or half the box length for convenience and 1 or 2 inches narrower than the sluice. At the Golden Rule mine 6-inch pole riffles had to be replaced every 10 days or after each 1,200 cubic yards had been sluiced. The sluice was 30 inches wide and had a grade of 8 inches in 12 feet. At other mines poles last several times as long.

If sawed lumber can be obtained cheaply, riffles similar to the one described may be made of 1- by 2-, 2- by 2-, or 2- by 4-inch material, as shown in figure 14, D and E. The top surfaces of the riffles may be plated with strap iron (fig. 14, F and G). Transverse





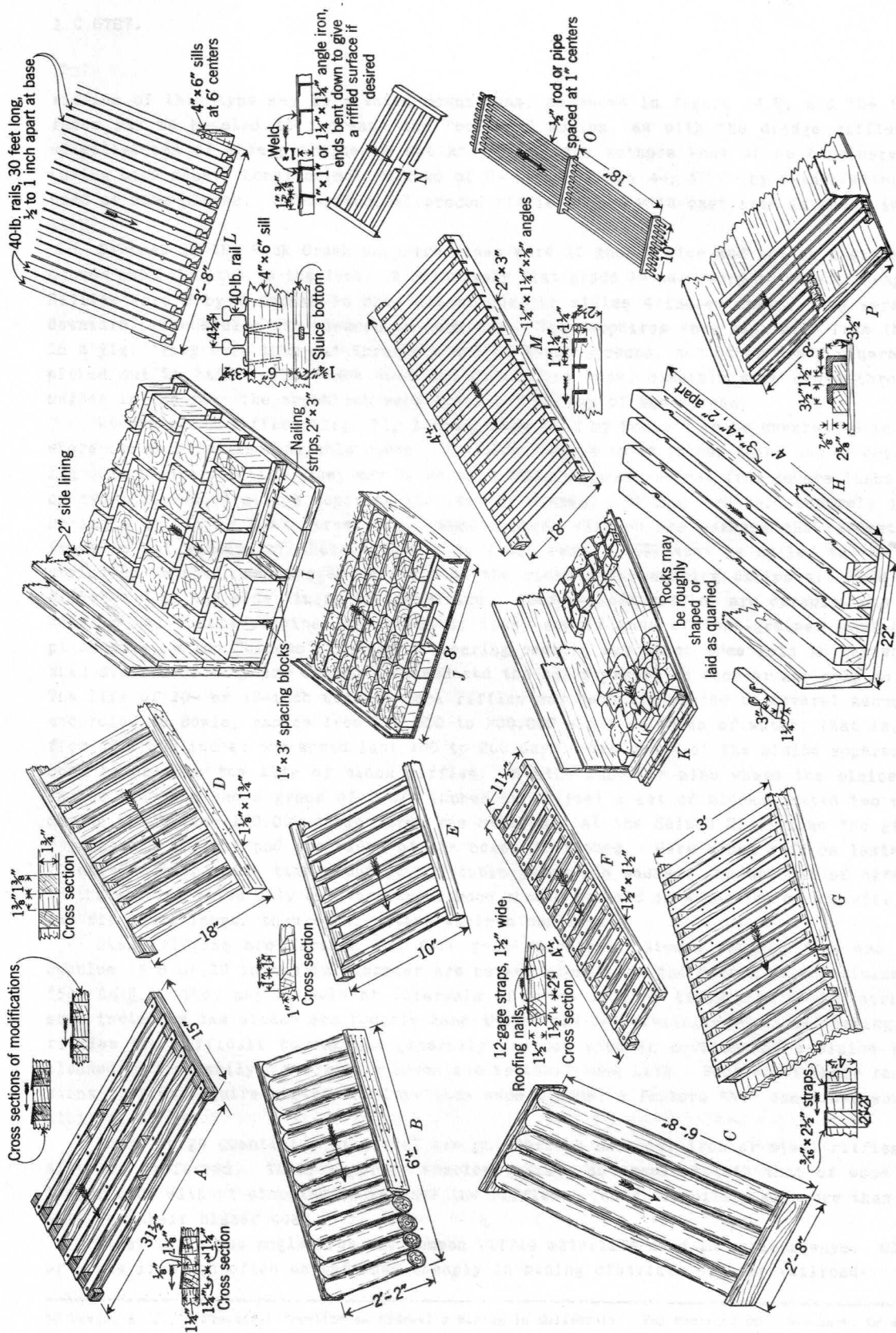


Figure 14.—Types of riffles: A, Transverse wooden, steel-capped riffles used on dredges; B, transverse pole riffles; C, longitudinal pole riffles; D, transverse wooden riffles, square section; E, transverse wooden riffles, beveled section; F, Transverse wooden riffles, steel-capped, inclined section; G, transverse wooden riffles, steel-capped, with binding; longitudinal wooden riffles capped with cast-iron plates; I, wooden-block riffles; J, wooden-block riffles for undercurrents; K, stone riffles; L, longitudinal rail riffles on wooden sills; M, Transverse angle-iron riffles; N, Transverse angle-iron riffles with top tilted upward; O, longitudinal riffles made of iron pipe; P, Transverse cast-iron riffles used in undercurrents.



riffles of this type may be slanted downstream, as shown in figure 14,F, and the top surfaces may be beveled to increase the "boiling" action, as with the dredge riffles. The effectiveness of this practice is not known, and the authors know of no conclusive tests having been made. Longitudinal riffles of 2- by 4-, 3- by 4-, or 2- by 6-inch material are used at some places. A longitudinal wooden riffle capped with cast iron is shown in figure 14,H.

Sluices in the Rock Creek sapphire mines were 12 inches wide and set on a grade not to exceed one half inch to the foot. A relatively flat grade is necessary to save the sapphires. Riffles were 2 by 4 inches in size set across the sluice 4 inches apart; they were tilted downward. The sluice was cleaned up each day. The sapphires were separated from the sands in a jig. They were then put through a set of seven screens, and other heavy minerals were picked out by hand. The black sand and other fine heavy minerals were drawn through the screen in the jig; the sapphires were taken off on top of the screen.

Wooden-block riffles (fig. 14, I and J) are held by Bowie<sup>36</sup> to be unexcelled in regions where the material is available cheap. The blocks are 4 to 12 inches thick and of corresponding diameters or widths. They may be round, partly squared, or cut from square timber. One- or two-inch wooden strips separate the rows of blocks, and they are held securely in place by nails driven in both directions. Wooden-block riffles are perhaps the hardest of all types to set because of their tendency to float away. They must be nailed to the spacing strips, as stated, and wedged securely at the sides. The spacing strips are held down at either end by the side lining of the sluice. Wooden-block riffles are durable, can be worn down to half their original thickness or less, and if made of long-grained wood (such as pitch pine, which "brooms" instead of wearing smooth) may catch some gold in the endgrain. When discarded, they are commonly burned and the ashes panned to recover any gold so caught. The life of 10- or 12-inch wooden-block riffles may be a few months to several seasons and, according to Bowie, ranges from 100,000 to 200,000 miner's inches of water; that is, with a flow of 1,000 inches one would last 100 to 200 days. The grade of the sluice apparently has much to do with the life of block riffles. At the Superior mine where the sluice was 48 inches wide and had a grade of 2 3/4 inches in 12 feet a set of blocks lasted two seasons, during which time 140,000 cubic yards was sluiced. At the Salmon River mine the grade was 7 inches in 12 feet and the width of the boxes 30 inches. Here block riffles lasted 60 to 70 days, during which time about 18,000 cubic yards was washed. On account of differences in the wearing rates only one variety of wood should be used in a section of a sluice. Douglas fir wears longer than other native western conifers.

Stone riffles are durable and fair gold catchers. Stones ranging from the size of cobbles to 8 or 10 inches in diameter are packed closely on the bottom of the sluice. (See fig. 14,K.) They may be held at intervals of a few feet by transverse wooden strips. In some instances the stones are roughly hand-shaped and set similarly to street paving. Stone riffles are difficult to set and generally are not used in portions of a sluice that are cleaned up frequently. Their main advantage is their long life. Because of their roughness, stone riffles require a steeper slope than wood blocks, a feature that sometimes would prohibit their use.

Where large quantities of gravel are put through sluices, iron or steel riffles generally are preferred. Their superior wearing quality as compared with that of wood permits longer runs without stopping to replace the riffles. Their durability may more than compensate for their higher cost.

Steel rails and angle iron are common riffle materials used in various ways. Old rails or angle iron can often be obtained cheaply in mining districts or near railroads. Various

36 Bowie, A. J., A Practical Treatise on Hydraulic Mining in California: Van Nostrand Co., New York, 3d ed., 1889, p. 225.

other steel products such as pipe and channels have been utilized for riffles. Cast iron is also used and has the advantage of a lower first cost than steel rail or angle iron. Iron or steel riffles should not be used in units too long to be handled readily. Rope blocks on movable tripods have found favor at some places for lifting heavy riffle sections. When used as transverse riffles lengths of steel rail usually are set upright, the flanges almost touching or not more than 1 or 2 inches apart. Where grade is lacking and gold saving is not particularly difficult, longitudinal rail riffles make excellent paving for a sluice as they provide a smooth-sliding bottom for the gravel and boulders. The rails ordinarily are bolted together by tierods passing through wood, pipe, or cast-iron spacing blocks, forming riffle sections the width of the sluice and any convenient length. At the La Grange mine in Trinity County, Calif., 40-pound rails costing about \$125 per ton proved more satisfactory than wood riffles.<sup>37</sup> When 16- by 16- by 13-inch wood blocks were used the riffles tended to "sand up." Moreover, the blocks had to be replaced every 2 or 3 weeks. Lengthwise rails 8 inches apart lasted 2 months and rails 5 inches apart, 4 months. Strangely enough, transverse rails 5 inches apart lasted 6 months. The rails were spaced by cast-iron lugs and set right side up on timber sills. When the head of the rail was worn off the remainder was used for side lining. This sluice was handling a flow of about 4,000 inches of water and 1,000 cubic yards of material per hour, boulders as large as 7 tons being washed through. The eddies behind the rails were believed to be the cause of the improved recovery as compared with that using block riffles. The lower part of the branching sluice line was cleaned up every other season only.

The combination of steel rails and wooden sills used at the La Grange mine appears to make an excellent gold saver, and modifications have been used at many large mines. Figure 14, L, illustrates a combination of longitudinal rails and transverse timber sills.

At the Round Mountain mine 25-pound rails were placed longitudinally in a 36-inch sluice with a grade of 4 inches in 12 feet. After about 150,000 cubic yards had been run through the sluice the center rails showed considerable wear and were removed to the outside. At the Lewis mine on Rogue River a set of riffles made of 40-pound rails lasted 15 seasons. The sluice was 30 inches wide and had a grade of 8 inches in 12 feet. About 7,000 cubic yards was washed yearly. Only material under 5 inches in diameter was run through the sluices.

Angle iron is commonly used for making riffles, as illustrated in figure 14, M and N. Many methods of assembling the lengths of angle iron into riffle sections are in use, and no one method can be said to excel. The irons may be set with flat upper surfaces or inclined slightly to increase the riffling action. Usually the gap between the riffle bars is 1/2 to 1 inch. The effectiveness of this type of riffle is believed by some operators to depend largely on the vibration of the riffles under the impact of boulders which keeps the sand trapped under the angles in a loose condition favorable to gold saving.

Figure 14, Q, illustrates an unusual all-metal riffle used at a Colorado drift mine, which was said to be giving satisfaction and appears to be simple to construct and convenient to use. The riffling effect could be increased, with some loss of velocity, by spacing the transverse bars closer.

Cast-iron riffles of all shapes and sizes have been used. If available at low cost they are very economical, as they wear slowly, can be quickly and securely placed, and are efficient gold savers if designed so as not to pack with sand. In an undercurrent at the Indian Hill mine, Calif., cast-iron riffles were in use that were 4 feet long, shaped like angle irons, and had equal 3 1/2-inch legs 7/8 inch thick. (See fig. 14, P.)

37 MacDonal, O. F., The Weaverville-Trinity Center Gold Gravels, Trinity County, Calif., U.S. Geol. Survey Bull. 430, 1910, pp. 48-58.

One property in California was reported to be using old car wheels for sluice paving. They were laid close together, flange side up, in a box just wide enough to hold one row of wheels. The riffling action caused by the hubs, webbing, and spaces between adjacent wheels and under the flanges was said to have resulted in a satisfactory gold recovery. A gravel-washing plant in Arizona was provided with riffles made of standard 2-inch pipe and 2 1/2-inch angle iron welded into riffle sections resembling pole riffles. This riffle should be fast-running and as efficient as any longitudinal type of riffle, relatively light, and easy to handle. It would not be durable enough for very heavy gravel and would be relatively expensive unless salvaged material and welding equipment were available.

For shallow sluice streams carrying only fine material various gold-saving materials are used, including brussels carpet, coco matting, corduroy, and burlap. These may be held down by cleats or by wire screen. Fabrics often are used in combination with riffles to catch fine gold and hinder its being washed out of the riffles by eddies. A corduroy woven specially for a riffle surface is used by some large Canadian lode-gold mines to catch their "coarse" gold before flotation or cyanidation. As such gold would be considered fine by most placer miners it seems probable that such a fabric would be useful for treating finely screened placer sands. The corduroy in question has piles about 1/4 inch wide and 1/8 inch high, spaced about 1/4 inch apart. The piles are beveled slightly on one side. The cost in Canada is about \$1.00 per square yard.

Heavy wire screen such as that used for screening gravel makes an excellent riffle for fine or medium-size gravel in fairly shallow sluice streams, and generally it is used with burlap or other fabric underneath.

Expanded metal lathing and woven metal matting are common types of riffles for fine material and are used with carpet or burlap. If the thin strands of metal slant considerably in one direction, the material should be placed with this direction downstream. Eddies in back of the strands will then form gold catchers, whereas if the recesses face upstream they will at once fill with a tight bed of sand and lose their effectiveness.

A matting woven of twigs or cane is recommended by Idriess<sup>38</sup> as an efficient gold catcher for a small, portable sluice box for shoveling-in operations or prospecting. Turf, as used at the Hockensmith placer in Idaho, is said to make an efficient trap for fine gold.

Solid-rubber riffles were noted at one washing plant. Sponge-rubber riffle material is on the market, but it was not observed in use and nothing is known by the authors of its merits or cost.

Another form of riffle often used as an auxiliary to other types is a mercury trap, consisting of a board the full width of the sluice with 1- or 1 1/2-inch auger holes in which mercury is placed. Instead of round holes, transverse grooves or half-moon-shaped depressions, 2 to 4 inches wide and with the rounded, deep side downstream, may be cut in a wide board and partly filled with mercury. These riffles have no apparent advantage over the ordinary transverse-bar type and are suitable only for fine gravel, as large pebbles would splash the mercury out of the traps.

Many ingenious and odd kinds of riffles are encountered in the field, some of which have been patented. It is very unlikely, however, that the advantage of any unusual or freakish design of riffle is sufficient to offset the cost of royalties on patented inventions.

#### Undercurrents

An undercurrent, as defined before, is a device for sluicing separately a finer part of the gravel passing through the main sluice. The fine material and a regulated quantity of

38 Idriess, I. L., *Prospecting for Gold*: Angus & Robertson, Sydney, 3d ed., 1932, pp. 64-65.



water pass through a stationary grizzly in the bottom and usually near the end of the sluice to one or more wide sluice boxes, commonly called tables, paved with suitable riffles. If the main sluice is in sections, with drops between, the water and sand may be returned from the undercurrent tables to the main stream, and several undercurrents may be installed at convenient points along a sluice.

The screen or grizzly in the main sluice may present the most difficult problem in building a satisfactory undercurrent. The screen should divert all the undersize yet not take so much water that it causes plugging of the main sluice below the undercurrent. The proper size of opening can be determined only by experiment. A screened or barred opening, the full width of the main sluice and a few inches to a foot or more long, will usually draw off as much water as can be spared. New water may be added to either the undercurrent or main sluice if the screen opening does not take out the right quantity for successful operation. Usually minus 1/4- to 1/2-inch material is desired for the undercurrent, and either punched-plate screen or iron-bar grizzlies may be used to make the separation. Grizzlies should be made of tapered bars or screens punched with tapered holes with the largest openings downward, otherwise they will plug and render the undercurrent ineffective.

Because undercurrents need a wide, shallow stream, grades of 12 to 18 inches per 12 feet must be used, depending largely on the type of riffle. Cobblestone, block, transverse or longitudinal wooden strips, rails, screens, or fabrics may be used for riffles. Often several types of riffles are used on successive parts of one undercurrent. Undercurrents may be a few to 25 or 30 feet wide and 10 to 50 feet long.

Most of the gold recovered by undercurrents is so fine that it does not settle in the relatively swift, deep current of the main sluice, but part consists of gold that is freed from its matrix of clay by dropping through the grizzly and rolling over the undercurrent riffles. All coarse gold is saved in the first few boxes of the main sluice unless conditions are radically wrong. Unless the undercurrent is installed at the end of the sluice, or at least below where gold is recovered, not all the saving in the undercurrent should be credited to its installation. In the early days when hydraulicking was at its height undercurrents were much favored, sometimes 5,000 to 10,000 square feet of undercurrent being used along a single sluice line. The gold saved in them occasionally exceeded 10 percent of the total clean-up but more often was less than 5 percent. As this recovery usually was effected by 5 or 10 large tables and as considerable would have been saved by the main sluice without the undercurrents, the economy resulting from their use was perhaps doubtful. Bowie<sup>39</sup> presents details of the use of undercurrents in early Californian practice and indicates that their particular field lay in the treatment of cement gravels. Of the several undercurrents observed by the authors in use in 1932 it is doubtful, as shown before, if many were justifying their installation. Table 13 gives data on undercurrents in use at mines operating in 1932.

#### Operation of Sluice Boxes

Under favorable conditions a properly designed and constructed sluice box requires little attention other than periodic clean-ups and minor repairs which are made at the same time. Unfortunately, such a combination rarely occurs, and an appreciable part of the miner's operating expense is chargeable to work along the sluice lines.

39 Bowie, A. J., A Practical Treatise on Hydraulic Mining in California: Van Nostrand Co., New York, 3d ed., 1889, pp. 252-262.



The best results are obtained when a steady flow of water and gravel passes through the sluice. An excessive flow of clear water through the sluice will bare the riffles, causing some gold to be lost. On the other hand, a continued overload of gravel will plug the sluice at some point so that sluicing must be stopped for the time needed to clear the obstruction; this time lost may be appreciable. If plugging cannot be prevented by increasing the grade or the flow of water or reducing the feed, one or more sluice tenders must work along the sluice with forks or shovels to keep it open. This added cost may be serious at small mines. All effort should be directed toward getting the gravel into the box and letting the water do the rest.

Large boulders are another cause of expense and lost time. When the maximum size of boulder that the sluice will carry is known, all boulders larger than this should be prevented from entering the boxes. Relatively little work directed to this end will save hours of delay in clearing plugged sluices and unnecessary wear and tear on the boxes and riffles.

An exception is found in the operation of "booming." A necessary condition of this work is a heavy head of water which usually fills the sluice to the brim. Sometimes little or no work can be done in the pit while the water is on, and the entire crew may profitably patrol the sluice with long-handled shovels to guard against stoppages which might be disastrous because of the large flow of water and gravel. Before each "boom" all oversize boulders should be moved out of the course of the water.

#### Cleaning Up

Clean-up time should be kept to a minimum. This can be done by cleaning up as seldom as practicable and by using efficient methods. Large hydraulic mines, particularly if the water season is short, clean up only once a season except perhaps the upper one or two boxes. Dredges clean up every 10 days or 2 weeks, because large amounts of gold are recovered in relatively short sluices with attendant possible loss when the upper riffles become heavily charged. This necessary delay is used for routine repairs on the dredge. In ground-sluicing the clean-up period ranges from weeks to months, while in shoveling-in operations the sluice may be partially cleaned up daily. The danger of theft from the upper, richer boxes can be lessened by filling them with gravel at the end of each day's work.

The general principle is the same in all clean-up operations, but practice differs widely. Clear water is run through the sluice until the riffles are bare, the stream being reduced enough to prevent washing out the gold. Then the water is turned off or reduced to a very small flow, and the riffles of the first box are lifted, washed carefully into the box, and set aside. Any burlap or other fabric used under the riffles likewise is taken up, rinsed into the box, or placed in a tub of water where it can be thoroughly scrubbed. Then the contents of the sluice are shoveled to the head of the box and "streamed down" with a light flow of water. The light sand is washed away, and rocks and pebbles are forked out by hand. This operation is repeated until the concentrates are reduced to the desired degree of richness. Gold or amalgam may be scooped up, as it lags behind the lightest material at this stage, or all the black sand with the gold, mercury, and amalgam may be removed and set aside for further treatment. Successive boxes are treated similarly, until the sluice is bare. The last step is to work over the whole sluice with brushes and scrapers to recover gold and amalgam caught in cracks, nail holes, or corners. At the Wisconsin mine a small box was set up in the main sluice and the concentrate from the riffles shoveled into it to reduce the bulk. At the Round Mountain mine the concentrate from the lower section of the sluice was treated in a quartz mill.