In spite of the many adverse conditions cited hydraulicking has an important place in Alaska placer mining. At most mines where this method is used it can generally be applied better than any other method. However, numerous creek placers being hydrau- licked or worked by other methods make a production each season that is ridiculously small, especially when the investment in a water supply and equipment is considered. Conditions at some such properties favored dredging, by which method the ground could have been worked out in easily one-fifth the time at a much lower cost and no doubt with better recovery of gold.

DUTY OF WATER

DEFINITION

The duty of water in hydraulic mining is usually stated as the number of cubic yards of material which can be broken down and put through the sluices by 1 miner's inch (1½ cubic feet per minute) in 24 hours. It varies with the depth and character of the material, the character and grade of bedrock, the size and grade of the sluices, the type of riffles, the quantity and pressure of the water, the facilities for disposal of iling, and the skill of the operator. The duty of water must be least approximately known before estimates can be made as to the possible scale of operation, and a properly balanced plant can be installed. It is also a most im- portant factor in determining the efficiency of the operation. Un- fortunately very few Alaska operators measure the amount of water used or keep account of the time during which the water is turned on, consequently complete or accurate data are seldom available.

DATA ON DUTY OF MINER'S INCH

The table on the duty of the miner's inch in Alaska includes data from engineers whose aid is acknowledged and estimates based on the data obtained from the operators. As stated, some of this latter information was incomplete, but where possible the missing data were closely calculated and the approximate duty of the water de- rived. These estimates are given mainly to show the generally low duty obtained.

Duty of miner's inch

Locality	Height of bank, feet	Sluices: Width, inches	Sluices: Depth, inches	Sluices: Grade, inches	Riffle	Head on field giants, feet	Water, miner's inches	Duty, cubic yards in 24 hours	Remarks
Seward Peninsula: Anvil Creek [a]	30	33	18	4½	Angle iron		500	1.4	Heavy, partly frozen gravel, much flat schist.
	4½						100	3.0	Frozen-muck stripping; 3-inch grade; ditch head water.
	20						400	10.0	Frozen-muck stripping; 4½-inch grade.
	30	30	24	3-5	Blocks	150	543	2.63	Unfrozen, coarse, subangular gravel; hydraulic elevator.
Boulder Creek	15	30	30	4	Mn grate	90	[b] 700	1.00	Unfrozen medium gravel, much flat schist.[a]
Big Hurrah Creek	6	36	18	5	Rails		[b] 900	1.20	Unfrozen medium gravel, much flat slate.[a]
Little Creek	15-35	48	24	5-7	Angle iron and rails.	300		1.25-1.5	Partly frozen medium gravel; hydraulic elevator.
Osborne Creek	9	36	24	7	Blocks, rails.	170	750	1.2	Partly frozen heavy gravel; hydraulic elevator.
	2½					160	600	3.4	Stripping moss and muck with giant.
Ophir Creek	9			5	Blocks, rails.			1.1-1.35	Partly frozen medium gravel; hydraulic elevator.
Mount McKinley district: Moore Creek.	10	24	20	6	([d]) and ([e])		[b] 300	1.6	Unfrozen medium round gravel; tailing stacked two hours a day.
Fairbanks district: Pedro Creek	15	36	30	11	Blocks		[b] 350	1.2	Partly frozen, heavy gravel.[a]
	6	36	30	5	Rails	130	[b] 400	.8	Partly frozen medium gravel.[a]
Goldsteam Creek	8						200	3.5	Stripping muck with pumped water, 3 per cent grade.
Circle district: Mastodon Creek	10	30	24	8	Blocks	100	[b] 500	.7	Partly frozen round medium gravel.[a]
([c])	12	30			do	100	240	2.5	Partly frozen gravel; 20-hour inch.[a]
Seventymile district: Crooked Creek.	7	30	24	8	do	60	[b] 460	1.2	Partly frozen light gravel.[a]
Yentna district: Falls Creek	9	36	30	8	([e])	100	[b] 500	.9	Unfrozen medium gravel; bowlders.[a]
Nugget Creek	6	28	24	7	([e])	200	[b] 450	.8	Do.
Peters Creek	9	30	24	6	Rails[e]	185	[b] 800	.8	Do.
Kenai region: Crow Creek.	10	52	36	6	Rails	145	[b] 2,600	.5	Very coarse wash; many large bowlders; much ground-sluice water used.[a]
Nizina district: Dan Creek	10-18	48	44	5	do	275		.25-.4	Unusually coarse wash and many bowlders; much ground-sluice water.[a]
Chititu Creek	10	40	36	5½-6	do	250	[b] 2,200	.35-.5	Heavy gravel, many bowlders; much ground-sluice water.[a]

[a] Purington, C. W.
[b] Includes ground-sluice water.
[c] Stack tailing with a giant.
[d] Punched plate over matting.
[e] Longitudinal steel-shod riffles.
[f] Ellis, H. L.

They can, however, be considered as being close approximations, although the duty at each operation is subject to variation, and many of the examples are based on data covering short periods only. As given in the table, the number of miner's inches of water used includes the average amount used by the field giants, the stacker giant, or the elevator, as the case may be, and where so noted includes ground-sluice water, which is the most variable in quantity. At most operations the water pressure decreases rapidly as the work proceeds upstream.

REASONS FOR LOW DUTY

The generally low duty is accounted for mainly by the low bedrock and sluice-box grades, by the general low water pressures, and by the large amount of water used by the elevator, or that used by the stacker giant, or the large amount of ground-sluice water, as the case may be. At some Nome operations much of the material is flat, while in the southern Alaska districts the gravels are unusually heavy, and large amounts of ground-sluice water are generally required. Frozen ground at some mines may lower the duty materially, whereas at others the giants can pipe down the material as fast as it can be transported to and through the sluice boxes. Data are unfortunately meager on operations where it is unnecessary either to elevate the material or to stack the tailings. Under such conditions a duty of 3 to 4 cubic yards should not be uncommon. Tables on giants, published by manufacturers, usually show that the duty of a giant under average conditions is taken as approximately 3 cubic yards. In hydraulicking the small rounded gravels of the "White Channel" bench in the Dawson country the water duty ranged from 2 to 10 cubic yards, with sluice grades of 12 to 14 inches.[41] The duty at the Yukon Gold Co.'s operations on Bonanza Creek ranged from 4.50 to 6.60 cubic yards.

Water under high pressure is more effective than under low pressure, and the duty of the water is apt to be low when the head is less than 200 feet. Purington[42] contends that an increase in head will not increase the amount of gravel which can be moved to the sluices, for the force of the stream from the giant is entirely expended in piping (that is, directing the stream from the nozzle) against the face, while the grade of the sluice is the governing factor in moving the gravel after it leaves the face. Although it is true that a given quantity of such spent water will only move a certain amount of gravel to and through the sluices, being dependent on the grade over which it runs, a high head delivers more water and

[41] Purington, C. W., Methods and Costs of Gravel and Placer Mining in Alaska: U. S. Geol. Survey Bull. 263, 1905, p. 130.
[42] Purington, C. W., Work cited, p. 134.

will more readily disintegrate the material than a lower one if other conditions are equal. It is also standard Alaska practice to get behind the material and drive it into the cut and to the sluices, where a high head will move it more readily and farther, thereby permitting the working of larger pits and requiring less frequent moves of the giants.

HYDRAULIC MINING METHODS FOR BENCH AND CREEK DEPOSITS

The various conditions that govern hydraulic mining have brought about the development and adoption of different methods. Although these may follow the same general principles, there are different ways of piping down the material, of delivering it to the sluices, and of disposing of bowlders and tailing. The methods used for removing moss, muck, and in some places barren sand, gravel, and other overburden before the hydraulicking of pay gravel have been described under "Stripping overburden."

The hydraulicking of bench deposits at elevations well above stream level is comparatively simple when a fair water supply is available, as the grade for sluicing and room for gravity stacking of tailing are usually adequate. If the deposit is thick, hydraulicking may be started at the rim or the exposed face, or a deep cut may be sluiced out until pay gravel is exposed. An adit may be driven in the bedrock and a raise extended to the surface, to be enlarged by piping the surrounding material into it, thus opening a pit. This practice was followed in opening a lake-bed deposit in the Silver Bow Basin near Juneau (fig. 1, *55*), where a long tunnel was driven through solid rock to the deposit. Similar means have been used in opening some of the high-bench gravels in California and elsewhere.

The sluice boxes are placed in the tunnel or in the cut, as the case may be. The giants are set up at a safe distance from the bank, which is then undercut and broken down by the stream from the giants. The loosened material is transported through short sluices in the bedrock to the main sluice or sluice boxes. These bedrock sluices are kept close to the face, and if the ground is hard or irregular may be an item of considerable expense. Steel flumes or chutes are sometimes laid on bedrock to assist in moving the loose material to the sluices, but the usual procedure is to carry the nozzles behind the broken-down material and drive it into the head of the boxes. To permit continuous operation two or more working faces should be carried. An oblique stream from the nozzle will break down more gravel than one pounding directly against the face.

For undercutting, small nozzles are generally more efficient than large ones. In frozen ground undercutting is slow and unsatisfactory, as a frozen bank is not only difficult to cave but the caved material usually breaks off in large masses. Constant playing of water under pressure against a frozen face is poor practice. Better results can generally be obtained by letting bank head water aided by the giants cut deep vertical channels in the bank, thus exposing a large area to thawing, and then piping off the thawed material from time to time.

Where shallower placers are hydraulicked, the giants are generally set on top of the bank. By this method advantage is taken of the grade, and the material as loosened is driven ahead into the pit and the sluices. Moreover, in frozen ground a large surface can be exposed for thawing.

Before a creek deposit is mined ample provision must be made for diverting the creek water and all excess water around the workings, as stated under "Water supply," and special provision made for safeguarding the mine from flood water.

GENERAL HYDRAULIC MINING METHODS

Hydraulic mining as practiced in Alaska, excluding the bench methods mentioned or the use of hydraulic elevators, can be divided into three general methods: (1) Piping the material into the head of the boxes; (2) piping the material over the side of the boxes; and (3) a combination of 1 and 2.

Methods 2 and 3 are special methods that have been developed to meet certain adverse and limiting conditions encountered in mining the creek placers and are also applicable to some bench placers. Method 2 can be divided into three general classes based on the position of the sluice boxes in relation to the surface of the bedrock, as follows: (*a*) The sluice boxes are all set in bedrock, with the tops below the surface; (*b*) the lower boxes are in or on bedrock and the upper ones on or above bedrock surface; (*c*) some or all of the boxes are on or elevated above bedrock.

The best method for any mine depends on many limiting factors, and each method has certain advantages.

PIPING INTO THE HEAD OF THE BOXES

The method of piping into the head of the boxes is the one most generally used at hydraulic mines in Alaska. It is best adapted for hydraulicking shallow benches and comparatively narrow creek deposits where the bedrock gradient is 6 or more inches in 12 feet. Its application in connection with mining deep benches has already been mentioned. One major advantage of this method is that all of the water used is devoted to sluicing, so that a comparatively small flow will often suffice. Mines having small or intermittent water supplies therefore find the method practical. The relatively short string of sluice boxes can usually be set at a steeper grade

than that of the bedrock by taking advantage of irregularities in the bedrock surface or by cutting to the required grade. The light sluice boxes used can generally be installed quickly, which is a big advantage where small pits not over 6 or 8 feet deep necessitate frequent moving and setting up.

SLUICE BOXES

The sluice boxes are first placed on or in bedrock at about the middle of the lower end of the proposed pit, with the head box low enough in bedrock to permit proper entry. Where the bedrock is hard and the natural gradient is low, three or four boxes are generally used, but under favorable conditions there may be 12 or more. Timber or board wings at the head of the boxes, one on each side, direct the water and material into the head of the boxes. As a rule,

FIGURE 38.—Hydraulic mining. Piping into the head; sluice-box extension. Note the hose and nozzles

the field giants are set on top of the bank at a distance upstream from the wings that depends on the pressure. If only one giant is used, it is placed at the upper end in line with the sluices or shifted about as required; if two are used, one is placed near each upper corner of the proposed pit. The material is then piped into the head of the boxes.

Where the water pressure and other conditions are favorable, pits 300 to 450 feet long have been mined by the above method. However, in pits of this size intermediate or "booster" giants are used, and the material is moved in stages. Where the slope is satisfactory, a number of short pits can be mined by extending the sluices upstream after each pit has been piped in; but the advantage of this practice may be small if tailing must be stacked. Figure 38 illustrates such an operation on a shallow bench in the Hot Springs district (fig. 1, *30*).

As much more material can be moved through a sluice box than through the ground sluice or bedrock sluice, the giants should not be placed too far from the head of the boxes or the duty of the water will be greatly reduced. At those mines where the head of the boxes is placed above bedrock the material must be piped up a slope before entering the boxes, and the water backs up in the pit. With average bedrock conditions, a sump or pothole is almost certain to develop ahead of the boxes. This impedes the flow of water and material, and requires additional piping to move them into the boxes.

PLACER ON FALLS CREEK

A typical placer of this kind is on Falls Creek in the Yentna district (fig. 1, *26*). The creek deposit averages 8 feet in depth and

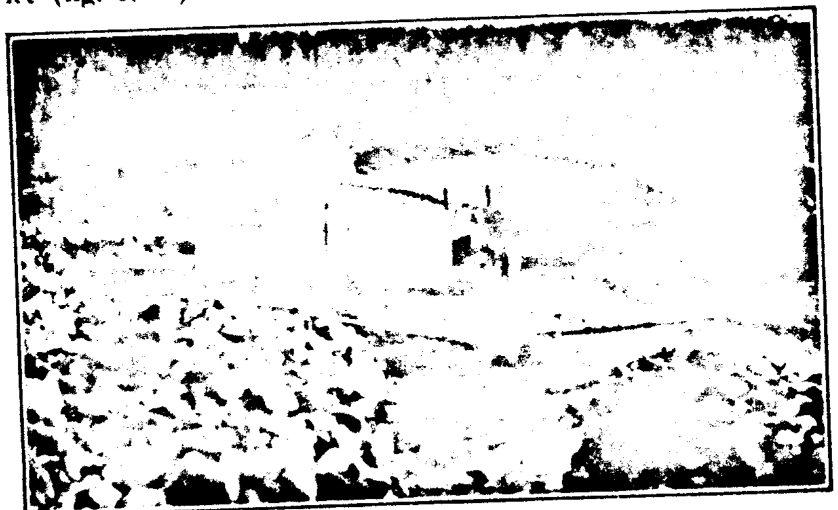

FIGURE 39.—Hydraulic mining in Yentna district. Piping into the head

is unfrozen rounded gravel with 10 to 15 per cent of bowlders, the largest being about 3 feet in maximum dimension. The bedrock formation is clay, shale, and sandstone, easily cleaned with the giants. The average pit mined is 80 feet wide and 125 feet long. Two field giants with 3-inch nozzles, working under a 100-foot head, are set on top of the bank, so that while one giant is piping gravel into the head of the boxes on one side of the pit the bowlders are being removed from the other side and piled by hand on cleaned bedrock. On account of the grade of bedrock 42 to 54 feet of boxes are all that can generally be installed. The sluice boxes are 36 inches wide and 30 inches deep, set on an 8-inch grade, and provided with steel-shod, 2 by 4 inch riffles placed lengthwise. The tailing requires constant stacking by a giant with 3-inch nozzle.

Figure 39 shows the general arrangement of the pit and the sluices, the method of removing bowlders, and the stacker giant at work. The water supply, including ground-sluice water, varies from 300 to 700 miner's inches. The average crew of eight men is divided into two 10-hour shifts. During periods of maximum water supply an area of about 1,000 square feet can be mined in two shifts or an average pit completed in eight to nine days. A set-up for a new pit is made in one day.

During one of the most favorable seasons 70,000 square feet of ground averaging 9 feet in depth (including 1 foot of bedrock) were mined in 73 days at a cost of 7½ cents per square foot, or 23 cents per cubic yard. Average costs are 30 to 35 cents per cubic yard. About $5,000 is invested in the 1,600-foot ditch and the hydraulic equipment.

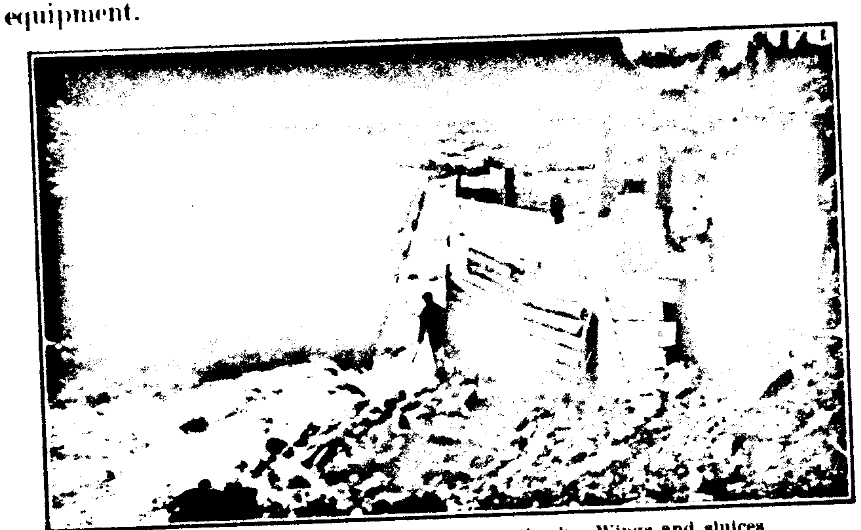

FIGURE 40.—Hydraulic mining at Crow Creek. Wings and sluices

HYDRAULIC MINE AT CROW CREEK

A large hydraulic mine on Crow Creek in the Girdwood district (fig. 1, *49*) is working an unfrozen creek deposit 6 to 25 feet deep, averaging 12 feet. The gravel is unusually coarse, about 50 per cent being bowlders 6 inches or more in diameter, many of them large. Mining is usually carried to a false bedrock of tough clay; the true bedrock is slate and graywacke, all readily cleaned with the giants.

The usual practice here has been to mine simultaneously two parallel adjoining pits. Each pit is 100 to 150 feet wide and 400 to 450 feet long, is worked separately, and has its own sluice boxes. The pits are kept abreast of each other and are alternately used as a by-pass for the creek water, the giants being at work in one pit while the bowlders are being handled in the other, so that mining is virtually continuous.

A No. 7 giant with 6-inch nozzle, working under a 145-foot head, is set on top of the bank of each pit, and sometimes another giant of similar size is set midway between them. The gravel from each pit is then piped into the head of the boxes, which are provided with heavy timber wings (see fig. 40). As the giants are moved upstream and the distance to the head of the sluices exceeds their working range, a smaller "booster" giant is set on bedrock at one side of the pit and about halfway down and drives the gravel into the head box. After the gravel in both pits has been piped in, the bank between the pits is removed and the bedrock is cleaned with the giants. The bowlders are drilled with air drills and blasted and put through the sluices with the rest of the material. A No. 7 giant with 5-inch nozzle under 170-foot head stacks the tailings from both sluices. The disposal of bowlders and tailing will be more fully described under those headings.

The sluice boxes are 5 feet wide and 3 feet deep and are set on a 6-inch grade: 8 to 10 lengths of boxes are generally provided for each line. Riffles of 40-pound rails set transversely are used in the first two boxes: the rest are 25-pound rails set lengthwise. In addition to the giant water, 1,000 to 1,400 miner's inches of ground-sluice water pass through the boxes. Including water for stacking the tailing, about 2,600 miner's inches are normally used, giving a water duty of about ½ cubic yard. In 1923, 66,000 cubic yards were mined, and the crew numbered 12 to 18 men. The cost of mining, exclusive of royalty paid for the use of the equipment and for the claims, was 43 cents per cubic yard. This property was equipped and opened over 15 years ago at an expense of about $250,000. Present equipment in use and the 1¼-mile ditch line would cost about $30,000 to replace.

PIPING OVER SIDE OF SLUICE BOXES WHEN BOXES ARE SET IN BEDROCK WITH TOPS BELOW SURFACE

The method of piping material over the side of sluices boxes set below bedrock surface is used in the Nizina district (fig. 1, 47) for the hydraulic mining of creek deposits and is especially well adapted for the conditions encountered there. The gravel is piped over the side in two ways—by starting at the upper end of the new pit and working downstream or by starting at the lower end and working upstream. Each has its merits, which can best be shown in the description of the operations where they are employed.

HYDRAULIC MINING ON DAN CREEK

The Dan Creek Mining Co. on Dan Creek has one of the largest hydraulic mines in Alaska. The creek deposit mined is 6 to 18 feet in depth. The gravel is rounded but unusually coarse, containing up to 75 per cent of material over 8 inches in diameter, some bowlders being 6 to 10 feet in maximum dimension. The bedrock is slate of varying character and hardness, cut by occasional hard porphyry dikes which form high ridges, but in general is not hard and the average contour is quite regular. The gold is coarse and mostly nuggets of the "pumpkin-seed" variety; from 40 to 60 per cent will remain on a ¼-inch screen. Large quantities of copper nuggets and some native silver are also present.

Arrangement of sluices.—The pits mined usually range from 500 to 700 feet in length and 175 to 300 feet in width. After a pit has been completed a line of sluice boxes 4 feet wide and paved with longitudinal rail riffles is set in the upper end of the old rock sluice, just at the lower end of the projected pit. Usually 16 to 20 boxes are installed, but never less than 8, depending on tailing requirements. Short wings are constructed at the head of the boxes, and as soon as the water begins to run in the spring a central sluice running the full length of the proposed pit is cut through the gravel and into bedrock by means of a giant with a 4-inch nozzle. The bedrock sluice is made about 6 feet wide and 5 to 6 feet deep, or so deep that the tops of the boxes will be 1 or 2 feet below the surface of bedrock. The bottom is leveled with picks, with as little blasting as possible. The maximum grade obtainable ranges from 5 to 5½ inches, although grades as low as 3½ inches have been used.

Sluice boxes 48 inches wide and 46½ inches deep, inside dimensions, are then installed for the entire length of the bedrock sluice, connecting with the lower boxes. They are equipped with 20-pound rail riffles spaced at 4-inch centers, placed lengthwise, and spiked to 6 by 6 inch ties. The sides of the boxes are lined with 1½-inch boards, and the outside is protected by nailing heavy slabs or old boards along the upper parts.

Mining method.—The general set-up and arrangement of the workings are shown in Figure 41. A large amount of ground-sluice water is turned into the head of the sluices, generally about twice as much as that supplied by a field giant, so that the boxes run virtually full when a field giant is operating. The initial cut is first made to bedrock at the upper end of the pit, then two No. 4 giants with 5-inch nozzles worked with a head of 275 feet are placed on bedrock, one on either side of the sluice and well to the outer edge, as shown in the figure. While the giant on one side is piping the material along the diagonal face and over the side into the sluices the bowlder crew is working on the other side. The method of bowlder disposal is described later. (See "Bowlder disposal.") Thus sluicing and bowlder work alternate from one side of the sluice to the other. As a rule, two to three periods of each are required before bedrock is reached.

All the material except the largest bowlders goes through the boxes. These are undercut, rolled over, and left there on cleaned bedrock. A slice or cut 35 to 50 feet deep is made along the diagonal face to bedrock and 1 to 2 feet of bedrock are piped off, then the giant is moved ahead (downstream) to its next position. Two outfits of 2½-inch hose equipped with fire nozzles are used for the final cleaning of bedrock. Deep holes are cleaned with a siphon. The method involves piping over the side a series of diagonal cuts until the pit is completed. Continuous stacking of the tailing is done by a No. 4 giant with a 4-inch nozzle under a 310-foot head.

Clean-up.—The upper boxes and rock sluice are sometimes "cleaned up" as the work advances in order to safeguard against theft or flood, but generally the entire pit is completed before the clean-up starts. The clean-up is made only on day shift by a well-

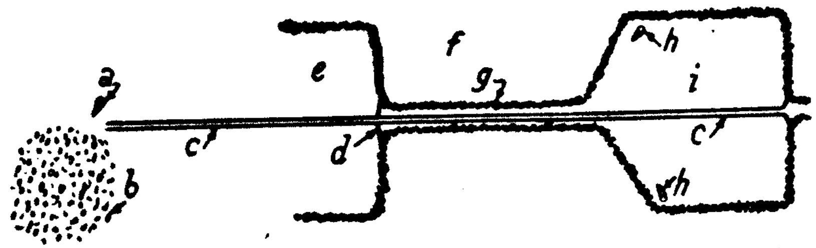

FIGURE 41.—Plan showing method of piping over the side of boxes, advancing downstream: *a*, Stacker giant; *b*, tailing pile; *c*, sluice boxes; *d*, wings; *e*, worked ground; *f*, unworked ground; *g*, bedrock cut; *h*, giant; *i*, pit about 200 feet wide

organized crew of 10 men. Ten boxes are generally cleaned and removed at a time. With the water cut down to the proper point, the rails from the upper or first 10 boxes are removed, the heavier material and the coarse copper nuggets are forked out, and the balance is worked down the sluice and cleaned up. The timber guards and the sides of the boxes, except the lower board, are then removed and with the canvas-hose outfits, one on each side of the sluice, the material alongside is piped in and another clean-up made. The remaining parts of the boxes are then removed and the material in the sluice is hosed down as clean as possible to the boxes below. The next 10 boxes are similarly handled, and after the entire sluice has been cleaned (75 to 80 feet are usually finished in a day) a final clean-up of the rock sluice is made by the foreman and four men who pick out the crevices and with a water siphon put all the

material through two lengths of 12-inch riffled boxes which are placed across the rock sluice and moved along as the work proceeds. This final clean-up requires five to six days under average conditions.

FIGURE 42.—Hydraulic mining on Dan Creek. Completed pit showing bedrock sluice and removal of the boxes

Figures 42 and 43 show the completed pit with the clean-up under way.

Labor.—About 18 men are generally employed, the regular pit crew for each shift of 10 hours consisting of a foreman, nozzle man,

FIGURE 43.—Removing and cleaning up the sluices, Dan Creek

stacker man, sluice tender, powder man, powder man's helper, and two or three extra helpers, with the shifts so arranged that hydraulicking is practically continuous.

Water duty.—According to the manager, G. Howard Birch, the water duty per miner's inch averages 0.25 cubic yard and depends more on the volume of water used than on the pressure. This low duty is accounted for mainly by the unusually heavy material and the low gradient requiring large quantities of ground-sluice water.

Work accomplished.—Two pits were completed in 1923, which was an exceptionally favorable season for hydraulicking. No. 1 pit was 528 feet long and averaged 165 feet wide; No. 2 pit was 480 feet long and averaged 170 feet wide. The No. 2 pit, which averaged only 6 feet in depth, required 9 days for making the set-up, 17½ days for hydraulicking, and 10 days for the clean-up. For both pits 22 days were taken to make the set-ups, forty-two 24-hour days for hydraulicking, and twenty-six 10-hour shifts for the clean-up. The expenses for the season were $34,124. About $100,000 has been invested in the water supply and equipment.

Costs.—The entire operation is conducted in a most systematic and businesslike manner, and the mine is one of the few hydraulic mines where accurate, detailed accounts are kept of the operating data and the costs. These are summarized in the following table:

Hydraulic mining costs, Dan Creek Mining Co.

	1916–1920 average [a]	1921	1922
Costs per cubic yard:			
Operation	$0.091	$0.141	$0.081
Deadwork	.087	.159	.104
Explosives only	.054	.108	.046
	.232	.408	.231
Overhead, etc.	.103	.242	.102
Total	.335	.650	.333
Operating data:			
Average depth ... feet	23.4	12	18
Bedrock mined ... square feet	131,294	140,218	154,786
Material mined ... cubic yards	113,843	62,318	108,190
Actual 24-hour days operated	94.2	64	77.1
Average number of men employed	18.4	17.5	16.8
Average wage per shift, mess included	$6.04	$6.57	$6.39
Mess cost per man-day	$1.43	$1.68	$1.62

[a] Average per season over a period of five years, during which time 569,214 cubic yards of material were mined, at a total cost of 19 to 60 cents per cubic yard.

NOTE.—The above data include a small yardage mined on the benches.

HYDRAULIC MINING ON CHITITU CREEK

A similar method that differs in the disposal of bowlders and the construction of the sluice boxes is used at the No. 1 mine of John E. Andrus on Chititu Creek in the Nizina district (fig. 1, *47*), shown in Figure 44.

Set-up at No. 9 mine.—At the No. 9 mine on this creek the set-up is very similar to that on Dan Creek, but the piping starts at the lower end of the pit and advances upstream (see fig. 45). By alternating from one side of the sluices to the other the material is piped along a face which is at about right angles to the sluices or

FIGURE 44.—Piping over the side on Chititu Creek

points slightly upstream. A shoulder next to the sluice is often left to the last as a protection to men clearing bowlders on the opposite side. In other respects the methods used at No. 1 and No. 9 Chititu mines are very much the same. The bowlders are

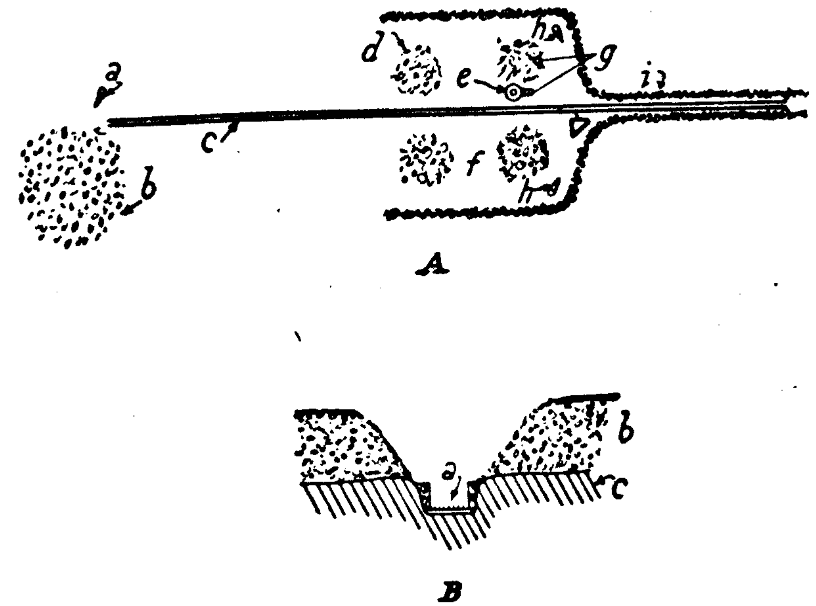

FIGURE 45.—Method of piping over the side, advancing upstream. *A*, Plan: *a*, Stacker giant; *b*, tailing pile; *c*, sluice boxes; *d*, bowlder piles; *e*, donkey hoist; *f*, pit; *g*, unworked ground; *h*, giant; *i*, bedrock cut. *B*, Section across bedrock cut, showing position of sluice boxes in relation to bedrock: *a*, Sluice box; *b*, gravel; *c*, bedrock

loaded onto a steel stone boat operated by a donkey hoist and are piled on cleaned bedrock. The tailings are stacked by giant.

A special type of sluice box is used. Ties are placed crosswise in the bedrock sluice and to these are spiked 20-pound rails, placed lengthwise and spaced at 4-inch centers. The rails form the bottom of the sluice, the sides being boarded up as at Dan Creek. Caps are, however, used to keep the tops of the boxes from collapsing. The grade of the sluices at No. 1 mine is 5½ inches; at No. 9 mine it is 6 inches. The boxes are 3 feet in cross section, and those below the pit are constructed with the regular bottoms. The clean-up is conducted in much the same manner as at Dan Creek, but more easily, as the bedrock is generally softer and permits the cutting of a smoother sluice.

Operations in 1923.—In 1923 the No. 1 mine started a pit 900 feet long and averaging 150 feet in width, but about 150 feet at the lower end remained unfinished at the close of the season. The average depth of the deposit was 10 feet. There were 39,326 cubic yards hydraulicked in sixty-four 20-hour days. The cost of labor and board only for making the set-up, hydraulicking, and cleaning up is reported as 22 cents per cubic yard. At the No. 9 operation a pit 460 feet long, averaging 140 feet in width and 11 feet in depth, was hydraulicked in forty-four 20-hour days, the total yardage handled being 23,323 cubic yards. The cost of labor and board was 21 cents per cubic yard. In 1924 the two operations mined 99,180 cubic yards, the average depth being 9 feet, at a total operating cost of 51 cents per cubic yard. Thirty-five men were employed.

DISCUSSION OF METHOD

The method of piping over the side with the sluice boxes all set below bedrock as described is particularly adapted to the mining of creek placers that are comparatively wide and not too shallow, that contain unusually coarse wash and have low stream gradients. An ample, steady supply of water under high pressure for the giants and a large quantity of ground-sluice water are required. To insure a good recovery, the gold should be coarse and heavy. The placer deposit should be at least 10 feet deep, providing a large enough volume of gravel to justify making the extensive and costly set-up. The bedrock should be fairly regular and not too hard. With this method, the set-up for an entire working season can be made at one time; furthermore, virtually continuous use of the water is possible. No backstops are required, as the gravel faces serve for this purpose. The dip, strike, and contour of the bedrock largely determine the relative advantages of working up or down stream. Working downstream from the head of the pit permits taking advantage of the grade, the material moves in the general direction of the flow in the sluices, and hence on reaching them can be more readily transported than when the work is upstream. In the latter method the gravel is piped straight across or at an angle upstream, and on encountering the sluice flow may come practically to a dead stop and must again be put in motion. This has a tendency to block the sluices. However, where much fine material is present, the boxes can be easily overloaded by either system. The downstream system permits at any time a clean-up of the sluices as far as work has advanced, which is a valuable safeguard against theft and floods. However, with this system, when a pit is not completed by the end of the season the following season's work is handicapped, whereas with the system of working upstream it is a simple matter to extend the pit from where work was left off the season before.

PIPING OVER SIDE WITH LOWER SLUICE BOXES SET IN OR ON BEDROCK AND UPPER ONES ON OR ABOVE BEDROCK SURFACE

The chief benefit of raising the boxes is to obtain a steeper grade than the natural conditions afford. In order to pass through enough boxes to insure good gold recovery, the material from the lower part of the pit must be piped upstream to a certain point before it is piped over the side of the boxes. The tops of the boxes are usually above bedrock at and beyond this point, hence most of the material must be piped up the low incline of gravel alongside the boxes. Some of the pressure water does not reach the boxes, so more ground-sluice water must be turned in at the head.

The height to which the boxes are raised above bedrock is governed chiefly by the size of the gravel and the hydraulic pressure. When the heads of the boxes must be raised 8 to 10 feet above bedrock to obtain enough slope, it is generally better practice to drive the material from the upper part of the pit along to a point where it can be more easily washed over the side of the boxes. The pressure water should be under high head, so that most of the material can be readily piped up over the side and the pit made large enough to justify the set-up. The gravel should not be too coarse, otherwise unusual quantities of the larger stones may have to be handled and piled out of the way.

The method is used principally in the Fortymile, Circle, and Seventymile districts (fig. 1, *37*, *39*, and *41*), and to a small extent in some of the other interior districts where the creek placers are 8 to 12 feet deep after stripping.

PLACER ON EAGLE CREEK

On Eagle Creek, in the Circle district (fig. 1, *37*), a frozen creek deposit that averages 18 feet in depth and 150 feet in width is being hydraulicked; the central 60 feet have been mined by drift workings. In order to aid thawing and help sluicing, 6 to 8 feet of sandy overburden are stripped with the giants, usually a season in advance of actual hydraulicking. About 6 feet of medium-size pay gravel, 4 feet of sandy clay which pinches out at the edges of the channel, and 1 foot of schist bedrock are piped to the boxes. The gold is coarse. Most of the bowlders encountered are the remains of old rock piles

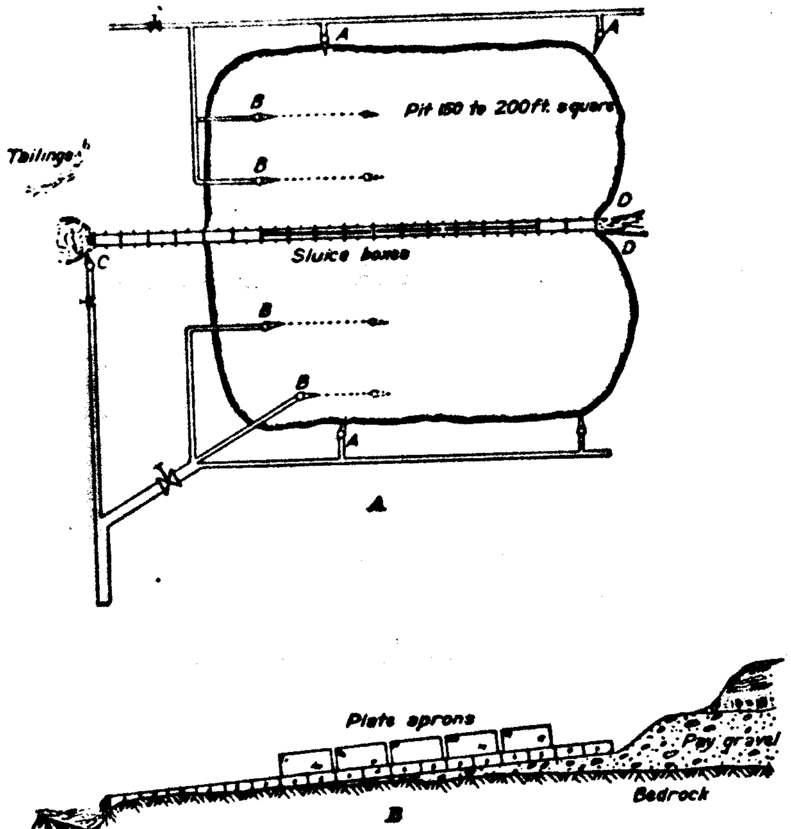

FIGURE 46.—Method of piping over the side as used on Eagle Creek, Circle district. A, Plan: A, B, and C, Giants; D, Unworked ground. B, Longitudinal section

from former drift mining. Many old drift timbers are also present. The average grade of the creek is 125 feet to the mile.

Equipment.—The general pit arrangement and sluice-box set-up are shown in Figure 46. A trench is first piped into bedrock and into the bank ahead, and three or four boxes are set on a 9-inch grade and light wings erected at the head. A head giant then pipes out to grade a cut down the center of the proposed pit connecting with these boxes. Ten or twelve more boxes are then installed on a 7-inch grade. Steel standards, fastened to each side of the boxes

and meeting 4 feet above over the center of the boxes, support steel plates 1/4 inch thick, 5 feet high, and 8 feet long, which hang from a 3/4-inch pipe running from one standard to the other. Although it is the aim to pipe the gravel so it will just roll over the top of the boxes and into them, these plates are necessary to stop flying material and water from going beyond. During piping, the bottoms of these plates are fastened to the opposite side of the boxes, as the piping is generally done from only one side at a time.

The boxes are 36 inches wide (excluding the 1½-inch liners) and are 24 inches deep. The bottom and sides are made of 1¼-inch material. A heavy timber with a quarter section cut out so as to fit over the top and upper outer side of the boxes is nailed along each edge as a protection from the piping.

The upper 10 boxes or those on 7-inch grade are paved with high-carbon steel plates ½ inch thick and cut square so they can be turned as they become worn. These plates are laid on 2 by 4's running crosswise of the boxes, with a special spacing block placed to leave a 2-inch space, which acts as a riffle, between plates. These plates are used to save grade. The lower boxes are paved with 12-pound rail riffles set lengthwise, spaced at 2¾-inch centers with cast-iron spacers, and bolted together in sets 4 feet long.

Depending on conditions, the lower end of the boxes may be resting on bedrock, or a foot or so below, while the head of the boxes may be 6 to 10 feet above bedrock, so that the tops at this point are generally but a few feet below the surface of the gravel. Small wings are erected at the head to guide the ground-sluice water.

The average pit mined from a set-up is about 150 feet square. Eight field giants, four on each side of the boxes, are placed about as shown in Figure 46. These are equipped with 3¼-inch nozzles and use water under a 120-foot head. The stacker has a 3½-inch nozzle operating under a 135-foot head. Normal water conditions permit the use of only one field giant and the stacker at a time, so the field giants not in use are "plugged." During low-water periods water is impounded in a ditch reservoir, necessitating intermittent operation or splashing for periods of about one hour; 8 to 10 of these splashes are necessary per 24 hours.

Explanation of diagram.—Giants *B*, which are first set on bedrock below the pit, pipe the material upstream into the field of giants *A* and also drive some of it over the sides. The giants *A* do most of the piping over the side. The upper giant *A* drives the material over the side at a point usually below the first or second upper boxes and also drives it into the field of the others. Giants *B* are, however, used mainly for taking up the lower gravel, clay, and bedrock and for final cleaning, and are advanced upstream in stages.

Giant C does the stacking, and along with the inner giant B drives the material lying alongside the boxes to points upstream for piping over. The boxes are last cleaned up and removed, then giants B and C drive ahead the remaining material which was left alongside and under the boxes and at points D onto unworked ground, to be recovered in the next pit. Giant B finally pipes the short trench for the lower three or four boxes to start the next pit.

Operating data.—The average crew consists of six men, and two 12-hour shifts are worked when water is available. A complete set-up for a pit, exclusive of moving the pipe lines, can be made in 24 hours. One set-up of the main pipe lines serves for two pits. During an average season two or three pits are mined. In 1921, 20,740 cubic yards were handled at an operating cost of 36.1 cents per cubic yard and in 1922, 49,860 cubic yards at a cost of 19.96 cents per cubic yard. During exceptionally dry periods only stripping ahead can be done, as the water supply is then too low to permit the regular hydraulicking. About $50,000 is invested in equipment and the 3 miles of ditch lines.

PLACER ON CROOKED CREEK

On Crooked Creek, in the Seventymile district (fig. 1, *39*), the creek deposit mined is 6 to 12 feet in depth, and the gravel is of medium size, with but few bowlders. Bedrock formation is com-posed of alternating beds of sandstone, shale, and conglomerate, some beds being harder and more resistant and forming occasional high ribs or reefs. A sticky clay sediment overlies all but the con-glomerate formation. The average grade of the stream is 100 feet to the mile.

The deposit is stripped with giants well ahead of mining, leaving 5 to 6 feet of gravel and 1 to 2 feet of bedrock to be mined. The average pit mined is generally 125 feet long and 80 to 150 feet wide, depending on water pressure and the width of the pay. The trench is piped out and the sluice boxes are placed in much the same manner as at Eagle Creek.

Sluice boxes.—Ten to fourteen boxes are generally set on a grade of 8 inches to 12 feet. The lower end of the boxes is usually set just below bedrock, while the head is 1 to 3 feet above bedrock; in one set-up the head was 12 feet above, which was found to be much too high for good work. The boxes are 30 inches wide and 24 inches high, constructed according to a regular design of 1-inch sides and bottom, and paved with block riffles made up in sets and held in place by special lining boards bolted to the sides of the boxes. These liners are made up in sets 12 feet long, 2-inch boards being bolted together, making them high enough to come flush with the tops of the boxes.

Old boards or slabs are nailed lengthwise to the side braces of the boxes, and a 1½-inch board strip is nailed lengthwise along the top edge, so that the boxes are fully protected from the force of the piping. Board aprons or backstops are hung centrally along the boxes from standards of 2-inch pipe and are similar in principle and purpose to those used at Eagle Creek (see fig. 24). At some other operations board backstops are erected along one side of the boxes opposite to the piping instead of being hung from standards.

Operation of giants.—Four field giants are set—two on the bank near each upper corner of the pit (*a*) and two at the lower edge of the pit on bedrock (*b*). The field giants use 2½ or 3 inch nozzles, depending on the water supply. These now operate under only a 60-foot head, although 150 feet was available at earlier work farther down the creek. This low head is handicapping the operation and a higher ditch is being constructed. The stacker giant *c* with 3-inch nozzle operates under a 70-foot head. The set-up is very similar to that at Eagle Creek, and the piping is done in much the same way.

During low times of water the water is stored in the ditch reservoir and used intermittently for short periods. The average water supply permits the use of but one field giant and the stacker giant at a time; then the practice is to complete one side of the pit before the other side is piped. When a full head of water is available, piping is sometimes done from both sides at once. The lower giant *b* pipes the material diagonally upstream and as far to the head of the boxes as practical before it is put over the side by this giant and giant *a*, and the pit is piped well into bedrock. The material alongside the boxes at the lower end is then piped to the upper end by giant *b* and the stacker giant *c* and piped over the side. Bedrock is then given final cleaning with a hose and nozzle outfit. From 6 inches to 3 or 4 feet of bedrock are piped up. Boxes are then cleaned and removed and material remaining alongside and underneath is piped ahead on virgin ground for the next pit. Under normal operation the flow of material through the sluice boxes is about 6 inches deep. The bowlders are removed and piled by hand on cleaned bedrock, the larger ones being broken with a sledge. Six men are employed, and shifts of 12 hours are worked.

Operating data.—One pit of 18,750 square feet (about 4,170 cubic yards) was piped over the side in eight days with a full head of water available. About 220 inches of ground-sluice water were used, or about twice as much as the one field giant with 3-inch nozzle used under a 60-foot head. The total water used, including that for the stacker giant, was 455 miner's inches, giving an approximate water duty of 1.2 cubic yards. Twelve boxes can be installed, the giants set, the bedrock drain prepared, and everything made ready for a new pit 125 feet long by three men in eight shifts. Four men usually clean up the boxes in one shift. In 1922, with a steady water supply under a head of 120 feet, 34,000 square feet of ground 6 feet deep (7,555 cubic yards) were piped over the side in 10½ days of steady piping. Including the set-up and clean-up, 15 days were required. This record is the best that has been made here. Where the water is used intermittently, it generally requires 25 to 27 days to pipe over a pit 125 by 150 feet and 6 feet deep (4,180 cubic yards). During an average season, May 10 to September 15, about five pits, or 75,000 to 80,000 square feet, are completed, and the operating cost ranges from 5 to 7 cents per square foot, or 23 to 32 cents per cubic yard. About $5,000 is invested in the equipment and $5,000 in the ditch line.

PIPING OVER SIDE WHEN BOXES ARE ON OR ABOVE BEDROCK

A method of piping over only one side of the boxes, which were all elevated above bedrock and ran across or at angles with the channel, was used for a time on Moose Creek in the Kantishna district (fig. 1, *27*). The creek deposit averages 10 feet in depth and contains unfrozen medium-size round gravel. The bedrock is a tough clay. A trench is first piped to grade in the gravel, crosswise or at an angle with the channel. Nine or ten lengths of sluice boxes 40 inches wide are then installed in this cut on a grade of 9 inches, which usually brings the top of the head box about 2 feet below the surface of the ground and the bottom of the last box a foot or so above bedrock. These boxes are heavily constructed and have timber guards on the lower side as a protection from the battering of the gravel. A heavy board apron or side about 8 feet high is erected along the upper side of the boxes.

Two giants with 3½-inch nozzles, under a 250-foot head, are set up about 200 feet or so downstream from the sluices, so that each can cover its field to the best advantage, and a third giant is placed so that it can pipe the material into the field of the central giant and also stack the tailing. A large quantity of water is turned into the head of the boxes, as much of the giant water does not enter them. The material is then piped upstream against the slight grade and toward the upper half of the sluice, then up the incline of gravel lying alongside the boxes and over their side, striking the apron and falling into them. As piping advances upstream bowlders are piled behind or at one side on cleaned bedrock. When all the material has been put through the boxes, except that directly alongside and under them, which is later driven on to the next set-up, the boxes are cleaned up and removed. While this hydraulicking has been under way another line of boxes has been installed about 200 feet

farther upstream. Giants are then reset and the next pit mined. Very little time is lost between pits.

At a mine in the Yentna district (fig. 1, *26*) the boxes were elevated above the ground but placed lengthwise with the channel and the material was piped over the side, alternating from one side to the other. No hanging plates or backstops were used. The method as applied there did not prove advantageous.

COMBINATION OF PIPING OVER SIDE AND INTO HEAD OF BOXES

A combination of piping over the side and into the head of the boxes, often termed the "circle" system of hydraulic mining, affords some of the advantages of both methods. The combination method is particularly applicable to hydraulicking gravel of average size and medium depth where the grade is too flat for piping into the head, or where the bedrock and other conditions are unfavorable for piping over the side a pit of practical size. A longer pit can generally be mined than would be practical by some of the other hydraulic methods.

PLACER ON MASTODON CREEK

On Mastodon Creek in the Circle district (fig. 1, *37*) a frozen creek deposit which ranges from 15 to 20 feet in depth is being hydraulicked after being partly drift mined. The overburden is stripped with the giants well ahead of actual mining to aid thawing and reduce the depth to about 10 or 12 feet of gravel. The gravel is mostly of medium size and contains an average number of medium-size bowlders. Much of the schist bedrock is slabby, but most of it can be cleaned with a giant, although the crevices require hand cleaning. The average stream grade at the lower ground is 5 inches to 12 feet, increasing to 6 inches at the present workings farther up the creek.

Water supply.—The water supply is erratic, but under full head will supply one field giant and the stacker. During periods of low water about eight to twelve 10-minute periods, called "splashes," are used in 12 hours, the field giant alternating with the stacker giant. The pressure water is obtained from two ditch lines at different elevations, the average head being about 100 feet. The size of the crew varies according to the volume of water available. In a favorable season 10 to 12 men, working two 12-hour shifts, may be employed, whereas in an unfavorable season only one shift may be worked with two to four men.

Pits and sluice boxes.—Figure 47 shows the general set-up. At the lower workings the pits are usually about 200 feet long and 150 to 200 feet wide, but on the upper ground the pits are only 80 to 100 feet wide, mainly because of the narrower channel. When a pit is opened, three or four boxes are first installed on grade below the proposed pit, as deep in bedrock as conditions will permit, and small wings are erected at the head. The trench down the center is then piped out, the material going through these boxes. Then more boxes, usually 8 to 10, are placed in this trench, and heavier wings

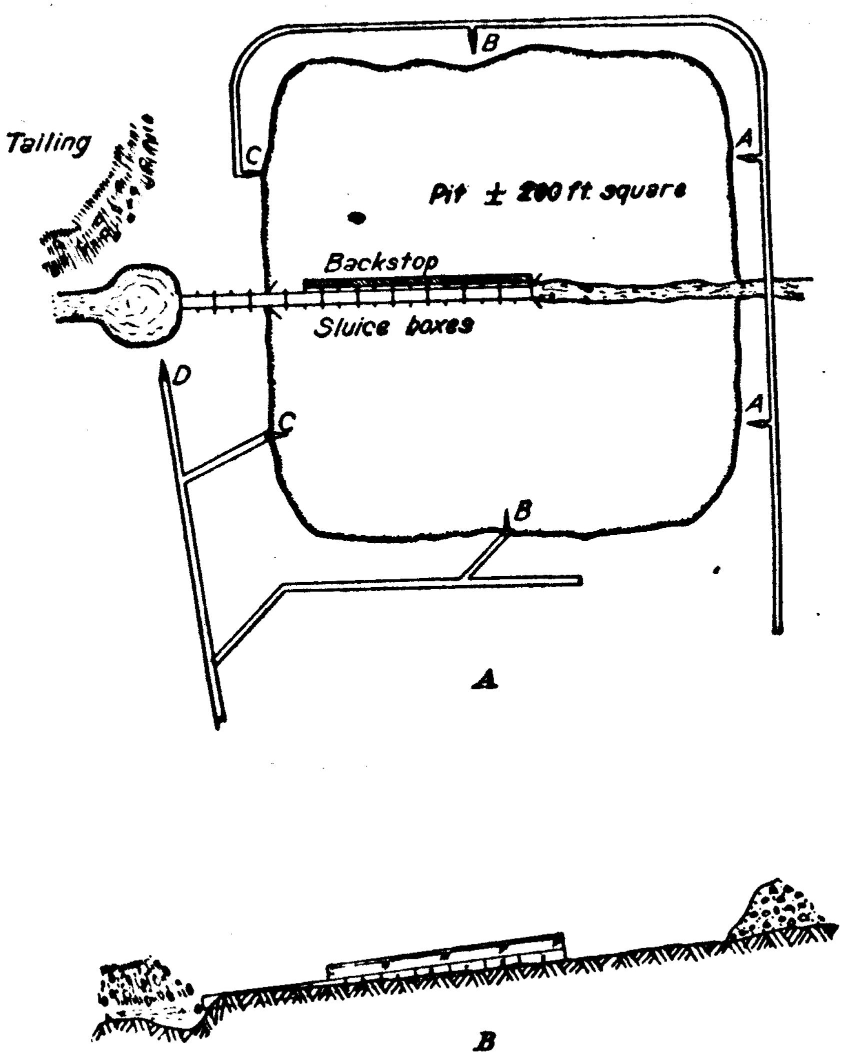

FIGURE 47.—Combination method of hydraulic mining (circle system) as used on Mastodon Creek. *A*, Plan: *A*, *B*, *C*, and *D*, Giants. *B*, Longitudinal section

erected at the head. These boxes are 32 inches wide and 24 inches deep, set on a grade of 7 to 8 inches. Block riffles (see fig. 24) are used. The head box is usually placed about the center of the pit and rests on bedrock; sometimes it is a foot or more above bedrock, but this should be avoided, for reasons stated under "Piping into the head." After the bank has been piped down level with the

tops of the boxes a board backstop about 6 feet high is built along the side of the boxes, opposite the side being piped.

Giants.—The field giants are first placed on top of the bank as shown. In shorter pits the giants *B* may be omitted. When the water supply permits, 3¼-inch nozzles are used on all of the giants, and the amount from the ground sluices is about twice that provided by one field giant. The giants *C* pipe the material upstream, and with the aid of giants *B* drive it over the side of the boxes. The giants *A* drive some material into the field of *B* and also drive a little over the side, but they are used mainly for piping the material within their field into the head of the boxes. Giants *A* and *B* may later be moved down into the pit, especially if the bank is too high for efficient hydraulicking. In finishing the cut the material alongside the boxes is driven by *C* and *D* over the side or into the field of *A* and through the head box. The upper boxes are removed, and any remaining material is piped ahead to the next cut.

Operating data.—When this method is used on some creeks where grades are lower, and especially during a period of low water supply, the greater part of the pit is piped into the head of the boxes. With a full head of water supplying one field giant and the stacker steadily, one pit on the upper ground—100 feet wide, 200 feet long, and averaging 10 feet deep—was piped to the boxes in 21 days, four men working per 12-hour shift, at a cost of 10 cents per square foot, or about 27 cents per cubic yard. This area was stripped of 6 to 8 feet of overburden for 5 cents per square foot. With average "splash-water" conditions, it would have required about 50 days to pipe in the 10 feet of gravel and bedrock this pit contained. The average time required for installing 12 to 14 boxes, setting up the giants, and other preparatory work is three 8-man shifts. The average clean-up takes one shift. With an exceptionally good water supply, the operating cost for hydraulicking some pits by this method, exclusive of stripping, has been as low as 15 cents per cubic yard, but usually ranges from 25 to 50 cents per cubic yard.

DISPOSAL OF BOWLDERS

The generally low gradients and meager water supplies at most hydraulicking operations materially increase the amount of heavy material which can not be passed through the sluices, and its disposal decidedly increases the cost of mining. All of the material can rarely be passed through the sluice boxes, even after the larger bowlders have been broken. All rocks too heavy for sluicing are therefore piled to one side on cleaned bedrock or entirely removed from the pit. At small mines this is generally done by manual labor. Stiff-leg derricks, usually operated by hand, have proved very useful where there are many large bowlders and the pit is small (fig.

48). The bowlders may be loaded on a stone boat drawn by horse or mechanical power. The use of a steel stone boat operated by cables from a donkey hoist, as practiced on Chititu Creek, is shown in Figure 49.

FIGURE 48.—Difficult hydraulic mining in Iditarod district. Derrick for handling bowlders

Some mines are equipped with overhead cables stretched across the pit, along which traveling carriers are pulled by steam or water power. Wire nets or stone boats are loaded with bowlders, the trac-

FIGURE 49.—Bowlder disposal. Loading the steel stone boat

tion cable is tightened, and the load of bowlders is hoisted to the carrier, hauled over the traction cable, and automatically dumped at the desired place. Large derrick-and-cable outfits, especially when operated by steam, have a very restricted field in Alaska.

The larger bowlders are generally broken to facilitate handling. The flat, soft, or friable ones can be readily broken by sledging. The more rounded, hard, tough bowlders are blasted, generally by "bulldozing" or "mud capping." However, at several of the larger hydraulic mines, such bowlders are drilled before being blasted (fig. 50), which makes a great saving in the amount of explosive required.

A deposit is being mined (fig. 1, *47*) on Dan Creek in the Nizina district, where an unusually large number of rounded bowlders, chiefly of greenstone, limestone, and slate, are encountered. All bowlders over 15 inches are broken by sledging and bulldozing and put through the sluice, except those 6 to 10 feet in size, which are undercut with the giants, rolled over, and left.

FIGURE 50.—Drilling a bowlder before blasting it, Crow Creek

At this property a total of 27,415 shots was fired during the season of 1922, or 357 per day. There were 14,075 pounds of 60 per cent straight dynamite used, costing 20.3 cents per pound. Including No. 8 detonators at $1.88 per box and triple-taped waterproof fuse at 92 cents per 100 feet, the total cost for explosives was $4,812, or 4.6 cents per cubic yard of ground mined. There was 0.59 pound of dynamite used per shot, or 0.13 pound per cubic yard mined; 0.26 shot was fired per cubic yard mined, or 3.8 cubic yards of ground mined per shot fired. Two men per shift are employed for this work.

On Crow Creek in the Girdwood district (fig. 1, *49*) about one-fifth of the material mined is hard, round bowlders of granite and graywacke. Some are sledged or "bulldozed" but most of them are drilled before blasting (fig. 50). All the material is put through