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PLACER MINING IN THE WESTERN UNITED STATES

PART III. DREDGING AND OTHER FORMS OF MECHANICAL HANDLING OF GRAVEL, AND DRIFT MINING

E. D. GARDNER AND C. H. JOHNSON

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By E. D. Gardner[2] and C. H. Johnson[3]

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1 The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U.S. Bureau of Mines Information Circular 6788."

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INTRODUCTION

This paper is the third of a series of three on placer mining in the western United States. The first paper[4] discusses the history of placer mining in the Western States and the production of placer gold, geology of placer deposits, location of placer claims on public lands, sampling and estimation of gold placers, and classification of placer-mining methods, together with hand-shoveling and ground-sluicing.

The second paper[5] deals with hydraulicking, sluice boxes and riffles, recovery of gold and platinum from placer concentrates, treatment of amalgam, and marketing of placer gold. The discussion of sluice boxes and subsequent subjects in the second paper applies to all forms of placer mining.

The present paper treats of dredging and other forms of mechanical handling of placer gravels, and drift mining.

ACKNOWLEDGMENTS

The authors wish to acknowledge their indebtedness to the operators of placers in the Western States who generously supplied information without which this paper could not have been written.

Descriptions of placer operations in Nevada were supplied by Alfred M. Smith of the Nevada State Bureau of Mines and Wm. O. Vanderburg of the United States Bureau of Mines, both of Reno, Nev., Francis C. Lincoln of the South Dakota School of Mines at Rapid City, S. Dak., supplied the description of placer operations in South Dakota.

The account of the dredging operations of the Fairbanks Exploration Co. at Fairbanks, Alaska, was prepared by C. G. Rice, vice president of the United States Smelting, Refining, & Mining Co., Boston, Mass.

Available literature upon placer mining, engineering, and allied subjects has been consulted; the authors have endeavored to make suitable reference throughout the text.

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4 Gardner, E. D., and Johnson, C. H., Placer Mining in the Western United States: Part I. - General Information, Hand-Shoveling, and Ground-Sluicing: Inf. Circ. 6786, Bureau of Mines, 1934, 73 pp.

5 Gardner, E. D., and Johnson, C. H., Placer Mining in the Western United States: Part II. - Hydraulicking, Treatment of Placer Concentrates and Marketing of Gold: Inf. Circ. 6787, Bureau of Mines, 1934, 89 pp.

EXCAVATING BY TEAMS OR POWER EQUIPMENT

General Statement

Numerous gold-bearing deposits occur throughout the western placer districts that cannot be mined by the usual methods. Often there is insufficient water for hydraulicking or ground sluicing, or the deposits are too small to justify the building of ditches or pipe lines. Such deposits may not be amenable to dredging owing to lack of water or small size; also, the depth or character of the gravel or the topography and condition of the bedrock may make dredging impracticable. A large number of operations were begun in 1931 and 1932 in which mechanical equipment was used as the principal means of excavating the gravel prior to washing. This activity was due to two principal causes: (1) The increased general interest in placer mining and (2) the desire of excavating contractors and sand and gravel operators to use otherwise idle equipment and to keep organizations together. A third but less important cause was the endeavors of inventors and manufacturers of "trick" gold-saving machines to find placers in which to install and test their equipment.

Although the early placer miners were as adept as the present generation and power shovels, scrapers, and other mechanical excavators have been tried for placer mining at many places during the last 40 years, the modern operator has at his command greatly superior excavating units and more efficient pumps and other mechanical equipment. Most of the present mechanical installations, however, have been built as cheaply as possible, using second-hand or homemade equipment. Often the equipment used was not the best for the purpose but was employed because it was handy or cheap. For example, old automobile engines were used largely as power plants. At many mines much better fuel economy could have been obtained with a different type of engine of a horsepower more nearly corresponding to the work to be done.

In opencut copper and iron mining, as well as in large coal-stripping and quarrying operations, it is an axiom that all operations should be planned to serve the digging units and keep them working steadily and at full capacity. It is equally true in mechanical placer mining that both the excavator and washing plant must operate at capacity if the mine is to be worked at a profit. In the present stage of development of this form of placer mining the plants seldom work steadily at capacity. Standard power shovels or other forms of excavators can be obtained for digging the gravel. Standard set-ups, however, for washing the gravel and saving the gold have not been developed in this type of placer mining; nearly every plant has been built in accordance with a new design. Standard trommels of proved design are used for screening and washing gravels in the sand-and-gravel industry and on dredges; such equipment, however, seldom is purchased for the type of mining under discussion. Delays due to breakdowns and remodeling are to be expected with newly designed or homemade equipment; this has been a contributing cause of failure at nearly all of the unsuccessful placer operations where mechanical excavating and washing equipment have been used. It is probable that eventually washing equipment like that for dredging will be perfected so that it can be operated steadily without breaking down.

Nearly all the excursions of excavating contractors and sand-and-gravel men into placer mining have proved unsuccessful. They failed principally because the gravel did not contain the expected amount of gold and because they did not consider the necessity of handling tailings. Sometimes, both of the foregoing reasons applied. In nearly all unsuccessful plants some innovation was tried.

During June and July 1932 the authors visited about 40 properties in the Western States at which teams or mechanical excavators were used. In addition, data were obtained by correspondence on 1 plant in Montana, 5 in North Dakota, and 3 in Nevada. Operations had progressed far enough so that approximate operating costs could be calculated at only 18 mines. These costs and other data on the mines are given in tables 1 to 5, inclusive. The other plants under consideration were being built, had not been run long enough, were run in such a manner that reliable cost figures could not be obtained, or had been shut down before enough data were available to calculate costs. With 4 or 5 possible exceptions, the gold recovered was not sufficient to meet the operating expenses if the workmen had been paid the prevailing wage in the district; at the majority of mines the labor was performed by men interested in the enterprise.

This method of mining has, for convenience, been divided into three classes, according to the method of excavating the gravel: (1) By teams or tractors, (2) by drag scrapers pulled by hoists, and (3) by power shovels or draglines. Teams and tractors are best adapted to relatively small-scale operations where the gravel is shallow and flexible operation is desired. Moreover, the first cost of the equipment is relatively low. The main disadvantage is the high labor cost per cubic yard handled. Lower operating costs may be attained by using scrapers and hoists, but there is less opportunity for selective mining. Under some conditions the scrapers may have advantages over power shovels or draglines for mining deposits within 400 or 500 feet of a stationary washing plant or where the shovel or dragline could not discharge directly into the plant. Scrapers on headlines have an advantage in that the material can be elevated to any desired height; moreover, they can be used for transporting gravel over rivers or other obstacles where other means of transportation would not be practicable.

Power shovels or draglines are adaptable to a wide range of conditions, but they have a high first cost and must be kept busy to be economical in use.

A large majority of the mines in this general group that were visited used power shovels or drag lines. Such mines are further subdivided into those (1) where stationary washing and gold-saving plants are used, (2) where movable washing plants on land are used, and (3) where floating washing plants are used. Operations of the last class are comparable to regular dredging operations except that separate excavators are used.

The great advantage of a movable washing plant is the elimination of trucking charges. Contract rates for trucking gravel at the properties visited in 1932 where movable plants were used ranged from 6 cents per yard for a haul of a few hundred feet to 16 cents for a haul of one half mile. Often the movable plant has the added advantage of easy disposal of tailings on the cleaned bedrock. Against these advantages are a number of disadvantages, which at times may be unimportant but have caused the failure of many projects.

Because the size and weight of movable washing plants must be held to a minimum most of them have been built either too cramped or too weak structurally to function well. Even if these faults are avoided the cost of designing and building such a plant is much higher than that for a similar permanent plant. Moreover, a wider range in design is possible in stationary plants.

Another result of the limited space in a mobile plant is lack of storage, which means that the feed to the gold saver may be very irregular even if an automatic feeder is used, as the plant must shut down whenever the shovel stops or a move is necessary. At a permanent plant, on the contrary, storage sufficient for several hours of operation may be provided if desired. Sluices that are too short are another result of striving for compactness in movable plants. The sluices, moreover, often are operated at a disadvantage because of the nuisance and delay in leveling the plant properly after each move. Most of the above disadvantages can be overcome, however, by building a constantly lengthening line of sluice boxes on trestles behind the plant as it moves upgrade, or by providing powerful jacks for leveling the plant. Water connections to a movable washer must be flexible, and they constitute a minor source of delay.

TABLE 1.- General data on placer mines where gravel is excavated by teams or power equipment, 1932

Mine			Gravel				Bedrock					
Name	Location	Operator	Depth, feet	Physical condition	Boulders over 8 inches in diameter, percent in gravel	Clay, percent	Kind	Physical condition	Kind of excavator used	Method of transportation	Kind of washing and gold-saving plant	Nominal daily capacity, cubic yards
Robbins	Vernal, Utah	F. W. Robbins	4	Easy digging	0	0	Clay	Soft	Team and slip	Team and slip	Screen and sluice.	6 1/2
Scott and Case	Douglas County, Nev.	Scott and Case	4	do.				do.	do.	Truck	Shaking box and sluice.	16
Roberts	Folsom, Calif.	W. H. Roberts	(1/)	Loose	0	3	None		Tractor and scraper.	Tractor and scraper	Grizzly and sluice.	20
Delaney	Wenatche, Wash.	Delaney Bros.	6	Easy digging	5	0	Not reached		Slip and hoist	Slip and hoist	do.	30
McElroy	Princeton, Br. Columbia.	T. E. McElroy	6	Medium	10	0	do.		Scraper and hoist.	Scraper and hoist	do.	60
Mammoth Bar	Auburn, Calif.	F. W. Roumage	30	Easy digging	3	0		Hard	Scraper on headline.	Headline and hoist	do.	200
Yellow Nugget	Hereford, Oreg.	S. A. Wells, et al.	8	Tight	5	0	Clay	Soft	Power shovel	Trucks	do.	160
Heine	Centerville, Idaho.	A. U. Heine, et al.	6	Medium	0		Granite	Easy	do.	do.	Sluice	1,000
Grant Rock Service 2/.	Fresno, Calif.	Grant Rock Service Co.	30	Easy digging	5	0	Volcanic ash	Soft, even.	Dragline	Locomotive and dump cars	Trommel and sluice.	3,000
Skull Valley	Kirkland, Ariz.	Skull Valley Corporation.	8	Medium	1/2		Clay	Soft	Power shovel	Trucks	Trommel and Wilfley tables	90
Forbach and Easton.	do.	Forbach and Easton.	3	do.	0	15	do.	do.	do.	do.	Trommel and Deister tables	120
Mysto	Mystic, S. Dak.	Mineral leasing Co.	30				Slate		do.	do.	Shaking sluice	3/300
Haag	Randsburg, Calif.	Haag Mining Co.		Very tight	15	10	Clay	Soft	do.	None	Movable plant with trommel and sluice.	100
La Cholla	Quartzsite, Ariz.	La Cholla Mining Co.	11	Tight	1		do.	do.	Dragline	do.	do.	400

1 Tailings pile.

2 Sand-and-gravel pit, gold a byproduct.

3 Reported.

TABLE 1.- General data on placer mines where gravel is excavated by teams or power equipment, 1932 - Continued

Mine			Gravel				Bedrock					
Name	Location	Operator	Depth, feet	Physical condition	Boulders over 8 inches in diameter, percent in gravel	Clay, per-cent	Kind	Physical condi-tion	Kind of excavator used	Method of transportation	Kind of washing and gold-saving plant	Nominal daily capacity, cubic yards
Benrose	Breckinridge, Colo.	Buffalo Exploration Co.	15	Easy digging	5	0		soft	Power shovel	Elevator	Movable plant with trommel and centrifugal bowl.	200
Grand Hills	Custer, S. Dak.	Grand Hills Mining Co.	13	do.	1/2	0		do.	do.	None	do.	400
Kumle	Oregon House, Calif.	H. T. Kumle	15	do.	5	0	Porphyry	do.	Steam shovel	do.	Floating plant with grizzly and sluice.	250
Sumpter	Sumpter, Oreg.	Hofford and Johnson.	13	Tight	10	3	Volcanic ash	do.	Dragline	do.	Floating plant with trommel and sluice.	640

TABLE 2.- Excavators and methods of transportation at placer mines where gravel is excavated by teams or power equipment, 1932

Mine	Excavator					Transportation		
	Type	Capacity of dipper, bucket, or scraper, cubic yards	Length of boom on shovel or drag line, feet	Diameter of drums on hoists, inches	Horsepower of engines	Kind of power or fuel	Method	Length of haul, feet
Robbins	Team and slip	1/7	0	0	0	Burros	Team and slip	25
Scott and Case	do.		0	0	0	Horses	One 1-cu.yd. truck	[1]3 1/2
Roberts	Tractor and scraper	1/4	0	0	0	Gasoline	Tractor and scraper	300
DeLaney	[2] Slip	1/5	0	10		do.	Slip scraper	20
McElroy	Scraper from hoist	1/4	0	14		do.	Bottomless arc scraper	50
Mammoth Bar	Bucket on headline	1	0	24	95	do.	Headline	300
Yellow Nugget	Power shovel	5/8	15			do.	Two 4-cu.yd. trucks	2,000
Heine	do.	1 1/4				do.	Three 4-cu.yd. trucks	400
Grant Rock Service	Full-revolving dragline	5	100			Electric	20-cu.yd. dump cars and steam locomotive.	2,000
Skull Valley	Power shovel	3/8			18	Gasoline	Two 2-cu.yd. trucks	2,500
Forbach and Easton	do.	3/8				do.	One 2 3/4-cu.yd. and one 1 3/4-cu.yd. truck.	2,600
Mystic	do.	1/3				do.	Trucks	
Haag	do.	7/8	18			do.	Dumped directly into hopper of washing plant.	
La Cholla	Full-revolving dragline	2 1/2	85			do.	do.	
Bemrose	Power shovel	5/8			60	do.	do.	
Grand Hills	do.	1 1/4			110	do.	do.	
Kumle	do.	3/4				Steam, coal	do.	
Sumpter	Full revolving dragline	1			75	Gasoline	do.	

[1]Miles.
[2]Pulled from drum on transmission of old truck.

TABLE 3.- Washing and gold-saving plants at placer mines where gravel is excavated by teams or power equipment, 1932

Mine	Washing or disintegrating plant							
	Type	Spacing of grizzly bars, inches	Trommels				Kind of power or fuel	Disposal of oversize
			Length, feet	Diameter, feet	Diameter of holes, inches	R.p.m.		
Robbins	Screen and sluice	1/16 by 1/4	None				None	Shoveled away by hand.
Scott and Case	Shaking box		None				Gasoline	Car to dump.
Roberts	Grizzly, bucket elevator, and sluice.	2	None				None	Pulled away by tractor.
DeLaney	Grizzly and sluice	3 by 3	None				None	Pulled away by scraper.
McElroy	do.	3 1/2	None				None	do.
Mammoth Bar	do.	4	None				None	Scraper from hoist.
Yellow Nugget	do.	6 1/2	None				Nne	Slide to dump.
Heine	Hopper and sluice	None	None				None	By hand.
Grant Rock Service	Sand and gravel plant	None			3/16		Electric	Elevator to cruher.
Skull Valley	Trommels and elevators.	None	4 3	9 8	1/4 1/8	24	Gasoline	Boulders by hand; trommel oversize by belt stacker.
Forbach and Easton	do.	6	9 6	4 3 1/6	1/4 1/8	21	do.	do.
Mystic	Shaking sluice	7 by 7	6	3 1/2	1/8by5/8	21	do.	Trucks to dump.
Haag	Movable plant with trommels and riffle tables.	8	22	4	5/16 and 3/4		do.	Boulders by hand; trommel oversize by belt stacker.
La Cholla	do.	9 by 9 3	8	5 1/2	3/4		do.	Belt stackers.
Bemrose	Movable plant with elevator and trommels	None	14	3 4	1 1/4 1/8	9	do.	Boulders by hand; trommel oversize by belt stacker.
Grand Hills	do.	None	21	5	1/4 and 3/8	11	do.	do.
Kumle	Floating plant with grizzly and riffle tables.	1/2	None				do.	Belt stackers.
Sumpter	Floating plant, standard dredge equipment.	None	24	4	1/2		Electric	do.

TABLE 3.- Washing and gold-saving plants at placer mines where gravel is excavated by teams or power equipment, 1932 - Continued

Mine	Gold-saving plant: Sluice boxes: Type	Width, inches	Length, feet	Grade, in. per ft.	Riffles: Type	Size, inches	Center to center, inches
Robbins	Sluice	14	10	1 1/4	Wire screen over burlap		
		8	10	1 1/4			
Scott and Case	do.	10	48		Wire screen		
Roberts	do.	12	110	1 3/8	Hungarian over wire screen and burlap.	1 by 1	2 3/4
DeLaney	do.	20	128	1/2	Longitudinal wooden strips over screen and burlap.	1 1/4 by 2	2 1/2
McElroy	do.	18	48	1	Pole	3	4
					Hungarian	1 1/4 by 1	2 1/4
					Screen over cloth		
Mammoth Bar	do.	18	36	3/4	Angle iron	1 1/4 by 1 1/4	2 1/4
Yellow Nugget	do.	18	40	1	12-pound rails lengthwise	1 by 2	3
Heine	do.	32	125	3/4	20-pound rails	1 3/4 by 2 5/8	4 1/4
Grant Rock Service	do.	30	50	2/3	Dredge	1 1/4 by 1	2 1/2
Skull Valley	4 Wilfley tables	None			None		
Forbach and Easton	3 Deister and 1 Wilfley tables.	None			None		
Mystic	Shaking sluice	48	4 1/3	1 1/2	Transverse	2 by 2	6
	Sluice	25	9	1	do.	2 by 2	6
Haag	do.	[4]30	40		Rubber	3/8 by 1/2	7/8
		30	8				
La Cholla	do.	[6]14	40	5/6	Transverse pipe	2	3
Bemrose	4 centrifugal bowls	None			None		
Grand Hills	do.	None			None		
Kumle	Sluice	[6]27	30	1 1/2	Dredge	1 1/4 by 1	2 1/4
Sumpter	do.	30	(7/)		do.	1 1/4 by 1	2 1/4

[4]In parallel.
[6]Two sluices in parallel.
[7]Sluices in parallel, 900 square feet.

TABLE 3.- Washing and gold-saving plants at placer mines where gravel is excavated by teams or power equipment, 1932 - Continued

Mine	Water: Type and size of pumps	Water: Vertical height pumped, feet	Water: Pipe line: Length, feet	Water: Pipe line: Diameter, inches	Water: Pressure discharge, lb. per sq. in.	Water: Miner's inches used
Robbins	3-inch centrifugal	12	25	3	...	...
Scott and Case	...	...	...	...	...	...
Roberts	3-inch centrifugal	20	20	4	...	...
DeLaney	None	...	...	...	...	...
McElroy	One 6-inch and one 3-inch centrifugal	6	20	7	...	...
		10	25	7	5	...
Mammoth Bar	6-inch centrifugal	35	...	8	5	82
Yellow Nugget	5-inch centrifugal	44	350	7	18	80
Heine	One 12-inch and one 7-inch centrifugal	37	700	14	5	350
		37	700	7	[1]20	30
Grant Rock Service	...	...	...	...	...	...
Skull Valley	One 5 1/2-inch triplex and one 2 1/2-inch centrifugal.	240	7,800	...	...	[2]10
Forbach and Easton	One 5- by 6-inch triplex and one 2-inch centrifugal.	170	8,000	4	...	[3]22
Mystic	...	...	...	...	...	...
Haag	(5/)	1,800	6,000	4	...	[2]16
La Cholla	Trucked 5 miles	...	...	...	100	[2]9
Bemrose	None	Hydraulic head	...	...	150	17
Grand Hills	4-inch centrifugal	...	...	...	...	22
Kumle	7-inch centrifugal	15	...	...	15	...
Sumpter	One 8-inch and two 5-inch centrifugals	...	...	...	...	2,000

[1]2-inch nozzle on pipe.
[2]New water.
[3]7 miner's inches of new water.
[5]Water purchased at $1 per 1,000 gallons.

TABLE 4.- Operating data at placer mines where gravel is excavated by teams or power equipment, 1932

Mine	Cubic yards treated per hour average	Power and fuel												
		Excavator		Transport		Washing and gold-saving plants				Pumps				Cost per gallon of fuel
		Fuel consumed		Fuel consumed		Motors		Fuel consumed		Motors		Fuel consumed		
		Per hour, gal.	Per cubic yard, gal.	Per hour, gal.	Per cubic yard, gal.	No.	Hp.	Per hour, gal.	Per cubic yard, gal.	No.	Hp.	Per hour, gal.	Per cubic yard, gal.	
Robbins	0.8	0	0	0	0	0	0	...	...	1	1.5	0.2	0.2	$0.22
Scott and Case	2	0	0	0	0	1	...	...	...	...	...	...	...	...
Roberts	2.5	[1]2.5	[1]1.0	(2)	...	1	3	...	...	1	6	...	...	.15
DeLaney	3.8	1.25	.35	(2)	...	0	0	...	...	0	0	...	...	.20
McElroy	7.5	[3].8	.12	(2)	...	0	0	...	...	2	...	.3	.05	[3].33
Mammoth Bar	12	5	.6	(2)	...	0	0	...	...	1	20	1	.01	.15
Yellow Nugget	16	...	...	2.7	0.17	0	0	...	...	1	...	3	.19	.19
Heine	50	...	...	...	...	0	0	...	...	1	100	...	...	...
										1	10			
Grant Rock Service	370	...	...	...	...	...	...	...	...	...	...	...	...	...
Skull Valley	11	1.3	.12	2.0	.18	2	36	1.6	0.14	1	18	1.3	.11	[4].14
														[5].19
Forbach and Easton	15	1.9	.12	1.25	.083	1	50	3.7	[6].25	1	25	2	.13	[4].14
						1	9			1	...	2	.13	[5].19
														[6].17
Mystic	[7]30	...	...	...	...	...	...	...	...	...	...	...	...	...
Haag	6	3	.5	0	0	1	...	2	.3	...	...	...	...	.20
La Cholla	50	7	.14	0	0	1	6.5	7.5	.15	(8)	...	...	...	.17
Bemrose	20	1.5	.07	0	0	1	20	1.5	.07	0	0	...	...	.22
						1	8							
						1	4							
Grand Hills	40	6	.15	0	0	1	30	3	.08	1	12	1	.02	.16
						1	14							
						1	12							
Kunle	28	[10]18	[10].6	0	0	1	36	1	.04	1	35	(11)	(11)	.20
Sumpter	40	5	.12	0	0	1	25	[12]60	[12]1.5	1	25	(11)	(11)	[13].24
						1	10			1	30			

[1]Total for plant. [2] Same motor as used for digging. [3]Imperial. [4]Gasoline for washingplant. [5]Gasoline for trucks. [6]Distillate. [7]Reported. [8]Water trucked. [10]Pounds coal at $14 per ton. [11]Included with washing plant. [12]Kilowatt-hours. [13]Power, $0.03 per kilowatt-hour.

TABLE 4.- Operating data at placer mines where gravel is excavated by teams or power equipment, 1932 - Continued

Mine	Labor											
	Shifts		Excavator		Transport		Washing and gold-saving plant		Pumps		Total	
	Number per 24 hours	Length, hours	Men employed	Wages per hour	Men employed	Wages per hour	Men employed	Wages per hour	Men employed	Wages per hour	Per shift	Per 24 hours
Robbins	1	8	1	$0.37	0	0	1	$0.37	0	0	2	2
Scott and Case	1	8	...	...	...	...	...	...	...	...	...	...
Roberts	1	8	1	.40	...	...	1	.40	0	0	2	2
DeLaney	1	8	2	.50	0	0	1	.50	0	0	3	3
McElroy	1	8	3	.28	0	0	2	.28	0	0	5	5
Mammoth Bar	2	8	1	.60	1	$0.60	1	.50	0	0	3	6
Yellow Nugget	1	10	2	.55	2	.50	2	.50	0	0	6	6
Heine	2	10	4	...	3	...	2	.40	1	$0.40	10	20
Grant Rock Service	...	...	...	1.00	...	.75	...	.50	...	...	...	...
Skull Valley	1	8	1	.75	2	.40	2	.40	1	.40	6	6
Forbach and Easton	1	8	1	.75	2	.40	3	.40	1	.40	7	7
Mystic	1	10	...	...	...	...	...	...	...	...	...	...
Haag	2	8	2	.75	0	0	4	.50	0	0	5	10
La Cholla	1	8	2	.60	0	0	3	.45	[8]1	...	6	6
Bemrose	1	10	1	.50	0	0	2	.50	0	0	3	3
Grand Hills	1	10	1	.60	0	0	3	.70	0	0	4	[9]4
Kumle	1	9	2	.50	0	0	1	.45	0	0	3	3
Sumpter	2	8	2	.50	0	0	2	.40	0	0	4	8

[8]Water trucked.
[9]Part-time superintendent at $0.60 per hour also employed.

TABLE 5.- Operating costs per cubic yard at placer mines where gravel is excavated by teams or power equipment, 1932

Mine	Excavation			Transportation			Washing and gold saving			Pumping			Miscellaneous			Supervision	Total operating costs
	Labor	Supplies	Total	Labor	Supplies	Total	Labor	Supplies	Total	Labor	Supplies	Total	Labor	Supplies	Total		
Robbins	$0.46	[1]$0.02	$0.48	(2)	...	...	$0.46	$0.00	$0.46	(3)	$0.05	$0.05	$0.00	...	...	$0.00	$0.99
Scott and Case	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1.50
Roberts	.16	.24	.40	(2)	...	...	.16	.01	.17	(3)	(3)	...	...	$0.05	$0.05	0	.62
DeLaney	.27	.12	.39	(2)	...	...	.13	.04	.17	$0.00	...	...	0	...	...	0	.56
McElroy	.11	.05	.16	(2)	...	...	.08	.03	.11	...	...	(3)	...	...	.03	0	.30
Mammoth Bar	.05	.11	.16	[4]$0.05	...	$0.05	.04	.005	.045	(3)	.015	.015	[5].015	.03	.045	.05	[6].365
Yellow Nugget	.07	.05	.12	...	...	[7].09	.06	.01	.07	...	.04	.04	...	...	.05	.02	.39
Heine	...	...	[7].20	...	...	(2)	.016	.004	.02	.008	[8].017	.025	.015	.02	.035	.01	.29
Grant Rock Service	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	[9].18
Skull Valley	.07	.03	.10	.07	$0.06	.13	.07	.04	.11	.04	.02	.06	...	.03	.03	.11	.54
Forbach and Easton	.05	.03	.08	.06	.06	.12	.08	.04	.12	.03	.05	.08	.03	.03	.06	.08	.54
Mystic	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	[10].25
Haag	.12	...	[11].55	0	...	...	.32	.10	.42	...	...	[12].18	...	...	.10	.05	1.30
La Cholla	.023	.044	.067	0	...	...	.027	.05	.077	...	...	[13].024	...	...	.05	.025	[14].243
Bemrose	.025	.03	.055	0	...	...	.05	.03	.08	0	...	...	...	...	.04	...	.175
Grand Hills	.015	.029	.044	0	...	...	.023	.037	.060	(3)	.004	.004	.002	[15].035	.037	.015	.16
Kumle	.03	.05	.08	0	...	...	.02	.01	.03	...	...	(2)	...	...	.05	.02	.18
Sumpter	.025	.04	.065	0	...	...	.02	.065	.085	...	...	(2)	...	...	.025	...	.175

[1]Burro feed.
[2]Included with excavation.
[3]Included with washing.
[4]General mechanic.
[5]Workman's compensation.
[6]Grand total, $0.455, including amortization.
[7]Contract price.
[8]Daily cost of electric power $17.00.
[9]Grand total, $0.20.
[10]Reported.
[11]Shovel rental including operator and supplies, $55 per two 8-hour shifts.
[12]New water purchased.
[13]Water trucked at cost of 0.1 cent per gallon at plant.
[14]Indicated from calculations.
[15]Includes workman's compensation, insurance, and miscellaneous expense.

Some physical characteristics of the deposit, often not considered beforehand, may alone be enough to cause failure. In very shallow ground moves will be so frequent as to reduce both digging and washing time to a point where profitable work may be impossible. In very deep ground, on the other hand, the stacker may not be long enough to dispose of the tailings. If the deposit is spotty, selective mining may be necessary, which is not practicable with most portable plants. If the gradient of bedrock is not favorable, provision must be made for drainage of the tailings water which otherwise may flood the pit or at least seriously hamper operations. Finally, steep or rolling bedrock may stop the advance of a heavy plant. One plant weighing nearly 100 tons, mounted on skids, was erected at a point where bedrock directly ahead of it rose on a grade of about 15 percent under a deceptively smooth cover of gravel.

At two properties visited the washing plants were floated. This arrangement eliminates most of the disadvantages of a movable plant but introduces another complication as the gravel must be excavated under water.

There is no apparent relation between the manner of excavating the gravel and the kind of washing plant used. The types of washing and disintegrating devices and the kind of gold savers selected should depend upon the quantity of water available and the physical characteristics of the gravel and contained gold.

Owing to lack of water or the cost of pumping the coarse material usually is screened out of the gravel before sending it through the gold saver. Moreover, some agitating or spraying device usually is needed to free the gravel of clay and thoroughly disintegrate it before extracting the gold. In some plants, however, only a grizzly is used ahead of a sluice box.

The revolving screen or trommel developed in gold-dredging and sand-and-gravel plants is an efficient and economical device for disintegrating and washing gravel. If the gravel is partly cemented and contains much clay, longer trommels are required than if the gravel is free-washing, and the first few feet of a trommel may be left blank; this permits full advantage to be taken of the disintegrating influence of the coarse material in a relatively large quantity of water. As an alternative to this method a disintegrator may be used ahead of the trommel; concrete mixers have been used for the purpose. A single trommel is preferable to one with concentric screens for treating clayey or cemented material; where only one screen is used a better opportunity is afforded for the coarse material to break up small lumps of cemented material than where the oversize is screened out in stages.

Riffled sluice boxes generally are used to save the gold. They are simple to build and operate and efficient if properly used. Many forms of riffles are employed. The design and operation of sluices is discussed in a previous paper[6]. The common practice of treating a screened product permits economy in the use of water and eliminates wear on the riffles from coarse material. Shaking or rocking sluices are used at a few places. This practice apparently increases the capacity of the sluice per unit of water used and may prevent sand from packing in the riffles.

Standard concentrating tables were used at a few plants visited and appear to have an advantage in treating screened gravel that contains a large proportion of black sand. In July 1932 a patented centrifugal gold washer was being used at three mines and had been or was to be used at a number of others. This machine was easy to clean and was said by its operators to save the gold satisfactorily. Its disadvantages were that it was costly and heavy and required power to operate. A carefully washed and screened product consisting of only a small part of the gravel excavated was treated in the machine. Apparently, an equally

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6 Gardner, E. D., and Johnson, C. H., Placer Mining in the Western United States: Part II. - Hydraulicking, Treatment of Placer Concentrates, and Marketing of Gold: Inf. Circ. 6787, Bureau of Mines, 1934, 89 pp.

good recovery of gold could have been made with this prepared product in a properly designed sluice box with a corresponding quantity of water. Possibly under some conditions, however, a greater capacity per unit of water could be obtained with the machine than with a stationary sluice box. Because small machines of this type can be cleaned up quickly they appear to have merit for sampling and prospecting work. Other types of gold savers were seen but not in operation, and no operating data concerning them were obtained.

The descriptions of individual properties in the following sections illustrate practices in the Western States in 1932. A few references are made to plants that were operating in 1931; practices in Alaska, described in other publications, are cited to illustrate some conditions not met in western plants.

Teams or Tractors

Teams

Teams have an advantage in very small-scale work in that they represent a relatively small capital investment. They may have an operating advantage in very selective mining in shallow gravels and may be worked in water where a tractor could not run.

Robbins.- J. W. Robbins, with two young boys, was mining at Horseshoe Bend on Green River, below Vernal, Utah, during the summer of 1932. The gravel was loosened by hand picking and pulled about 25 feet to a sluice box by a span of burros hitched to a 1/7-cubic-yard slip scraper. A very small quantity of water was pumped from the nearby river by a 3-inch centrifugal pump run by a 1 1/2-hp. gasoline engine. The gravel was dumped through a trap into a small hopper, from whence it was drawn by a hoe to a screen with 1/16- by 1/4-inch holes. The water from the pump was discharged on the screen and together with the undersize dropped into the head of a sluice. The oversize was raked off the screen by a hoe and thrown to one side by hand shoveling. Because of insufficient water more ground could be excavated in a shift than could be washed. The sluice consisted of two 10-foot boxes set on a grade of 1 1/4 inches to the foot. The first box was 14 inches wide and discharged into the second, which was 8 inches wide. Riffles consisted of burlap held down by wire screen. The gravel contained a high percentage of black sand, and the gold was extremely fine; however, a satisfactory saving of the gold apparently was made. Most of the black sand went through the sluice, but the tailing showed very little gold. Quicksilver was used in cleaning up. About 6 1/2 cubic yards was washed per day. The current daily cost of supplies was 33 cents for 1 1/2 gallons of gasoline and 10 cents for grain for the burros, which otherwise foraged for themselves, or less than 7 cents per cubic yard. Wages in the district were $3.00 for 8 hours. Allowing one man's wage for the two boys the labor cost per cubic yard would be 92 cents, or a total of 99 cents per cubic yard. (See table 5.) Amortization or rental for the complete outfit for the summer's work would be about $37.50, or 5 cents per cubic yard on 100 days' work, making a grand total of $1.04 per cubic yard.

Scott and Case.- C. F. Scott and S. C. Case were mining placer gravel with teams and scrapers in the Buckskin district in Douglas County, Nev., in the summer of 1932.[7] The gravel was 3 to 5 feet deep and lay on a decomposed bedrock. The soil and gravel were first plowed and scraped to one side by the team and scraper. Although it was reported that this material contained considerable gold it could not be treated at a profit. The bedrock was then plowed to a depth of 10 inches and scraped up a slide to a trap through which it was loaded into a small truck for transportation to the treatment plant 3 1/2 miles away at a

7 Smith, A. M., and Vanderburg, W. O., Placer Mining in Nevada: Univ. of Nevada Bull., vol. 26, no. 8, Dec. 15, 1932, pp. 39-40.

farm where water was available. The treatment plant consisted of a shoveling platform on which the gravel was unloaded from the truck, a shaking washing box to disintegrate the clayey material handled, and a sluice. The shaking box was 18 inches deep, 30 inches wide, and 5 feet long; it was made of sheet iron and was suspended from a rod by two strap-iron hangers. A screen consisting of 8-mesh woven-wire screen cloth on sheet iron with 3/4-inch holes was placed 6 inches above the bottom of the box. A horizontal shaking motion was imparted to the box by iron rods connected to 6-inch eccentrics. The eccentric shaft was belt-driven at 60 r.p.m. by a 60-hp. automobile engine.

Water was run onto the gravel as it was shoveled by hand into the box. Stones 5 and 6 inches in diameter were used to assist in the disintegration. The oversize from the screen was discharged into a 1-ton mine car and pushed to a dump. The minus 8-mesh product which contained the gold was run through a 10-inch sluice 48 feet long. Riffles were made of coarse-woven wire screen. The capacity of the plant was 16 cubic yards per day; operating costs were said to be $1.50 per cubic yard.

Arrowhead.- K. C. Nelson was operating the Arrowhead placer in the Lynn district, Eureka County, Nev., in the summer of 1932.[8] The gravel in the creek bed was loosened by a horse-drawn, spring-tooth harrow while water was flowing over it. A large part of the soil and clay was carried away by the water. The partly washed gravel was moved into a pile by a scraper drawn by a team. It was then shoveled by hand into a 12-inch rocking sluice, 10 inches high and 16 feet long, operated by a 1 1/2-hp. gasoline engine. Riffles consisted of a 6-foot plank with holes 1 inch in diameter drilled into it at the head of the box and 1- by 2-inch wooden cross-strips placed 2 inches apart in the lower 10 feet. About two thirds of the gold was recovered in the plank riffles. About 2 1/2 miner's inches of water was available; this was stored in a reservoir and an augmented flow used when sluicing. The sluice had a capacity of 4 cubic yards per hour. Early in the season when more water was available ordinary sluice boxes were used. When the water supply failed entirely dry-washing machines were used until autumn.

Horseshoe Bar.- The Utah Mining Co. was starting operations on the Horseshoe Bar on Green River near Vernal, Utah, in July 1932. The gravel was excavated by teams; after being plowed it was pulled in slip scrapers over a trap through which it went into the boot of a bucket elevator. The elevator discharged into a trommel with 18-mesh screen. The undersize was pulled out of a settling tank by a rake classifier and treated on Wilfley tables. The gold in the table concentrate was amalgamated in an ordinary copper-bottomed pan treated with quicksilver. Water was pumped from the river and settled before being used. The plant was homemade, second-hand materials being used. It was apparent that considerable remodeling would be necessary.

A crew of 20 men with three teams was employed. Five more teams were on their way to the mine. It was expected that 240 cubic yards of material could be handled per day. Not enough work, however, had been done to estimate the capacity of the plant or the costs per cubic yard.

Tractors

Roberts.- During 1931 and 1932 W. H. Roberts reworked the tailings from the Blue Channel drift mine near Folsom, Calif. The gravel as originally mined underground was tight, contained clay, and was partly cemented; apparently it did not disintegrate entirely during the first washing. In standing exposed to the rain and weather for a number of years, lumps of

8 Smith, A. M., and Vanderburg, W. O., Placer Mining in Nevada: Univ. of Nevada Bull., vol. 26, no. 8, Dec. 15, 1932, p. 50.

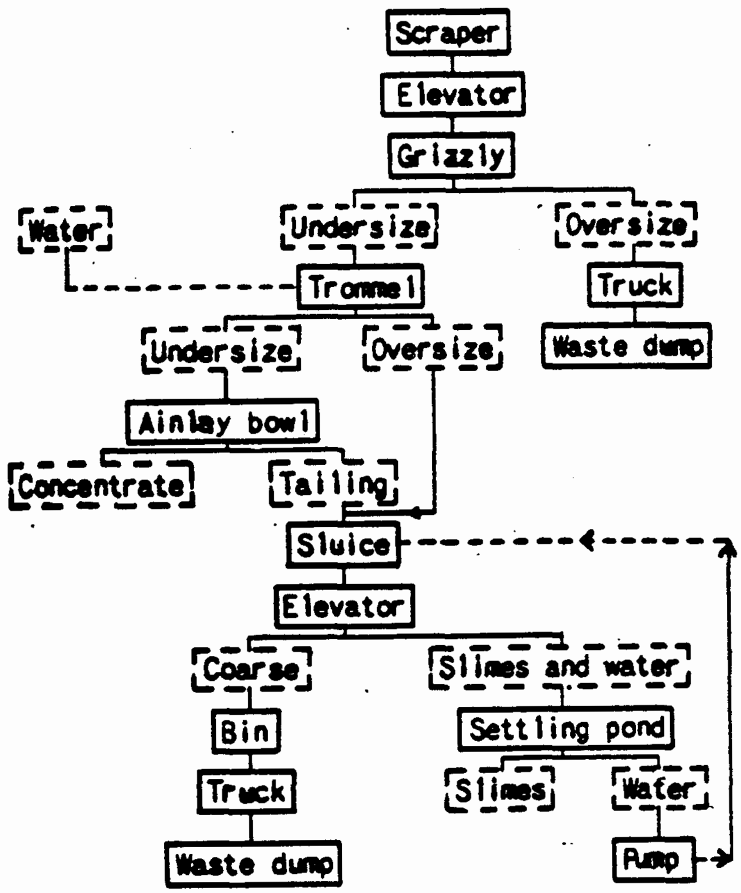

Figure 1.— Flow sheet of Queen placer, Manhattan, Nev.

3- and 2-inch pipe line 2 miles long to a 23,000-gallon storage tank at the treatment plant. The capacity of the plant was about 16 cubic yards per hour. A total of 20 hp. was required to operate the plant.

Burnt River.- Two material-handling contractors had just discontinued placer operations on Burnt River, Oreg., at the end of June 1932. Both used tractors and large Fresno slips. The operations of one had been unsuccessful because the mining costs were higher than the gold content of the gravel. At the other property the gravel was loose, and the permanent water level was near the surface. Neither the type of Fresno used nor the tractor operated satisfactorily in the water. Operations had been discontinued, and new plans were being formulated.

Scrapers and Hoists

Scrapers and hoists have been used for excavating and pulling placer gravels to washing plants. A scraper set-up with ground lines only consists of a hoist, usually with two drums, a scraper, and a cable. The scraper is pulled forward by the hoist over the gravel and picks up a load which is then pulled to the washing plant. The cable for pulling back the scraper goes through a sheave on the far side of the pit. To allow latitude of operation the sheave usually is attached to another cable stretched at right angles to the line of pull. The sheave sometimes can be shifted at right angles to the pull by means of a third drum on the hoist. The scraper is pulled on the ground both ways.

The set-up with an overhead cable is more elaborate; additional equipment consists principally of the overhead cable and a mast. After being filled the scraper is run to the plant and back on the cableway. The scraper or bucket is elevated by tightening the headline. Both bottomless and closed-bottom scrapers are used with ground lines, and only closed buckets, usually of the Page type, are used with cableways.

Boulders in the gravel and points of bedrock projecting up into the gravel cause the scrapers to jump. A bottomless scraper will loose its load on hitting a boulder, and a scraper of the closed type is difficult to fill in bouldery gravel. In easily dug gravel the bottomless scraper usually delivers a full load and can push considerable loose material ahead of it. The load is dropped by simply pulling the scraper backward, an advantage that scrapers with bottoms do not have. A closed-type bucket operating on a headline overcomes some of the difficulties of excavating with a drag; furthermore, it can be run at a greater speed once it is filled and the headline tightened. For long hauls the headline or cableway excavator has a further advantage in lower power and labor costs; moreover, the excavated ground can be elevated to the plant at any desired height with less trouble. However, this type lacks the mobility of the straight drag scraper, is more difficult to install, and because of the additional and heavier equipment has a higher first cost.

A scraper is not suitable for digging placer gravels under water. It follows the line of least resistance and leaves islands of bedrock untouched even where other conditions are favorable. The water is roiled by the digging, and the scraper works out of sight. Moreover, the stirring permits the gold to settle in the gravel being moved, and considerable gold may be left behind unless the pit can be pumped out for cleaning up.

For many years scrapers have been used successfully at sand and gravel pits. They have been tried at a number of placer mines in the Western States but generally have failed, usually because boulders were encountered in the gravel. In Alaska, however, scrapers have proved successful under favorable conditions and have been preferred to other types of excavators.[10]

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10 Wimmler, Norman L., Placer-Mining Methods and Costs in Alaska: Bull. 259, Bureau of Mines, 1927, p. 94.

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10 Wimmler, Norman L., Placer-Mining Methods and Costs in Alaska: Bull. 259, Bureau of Mines, 1927, p. 94.

Scraper installations are less costly than power shovels or drag lines, but they have much lower capacities in most placer gravels so that the initial cost per cubic yard of daily output is roughly the same. The cost depends chiefly upon the type and size of power unit. Steam, electric, gasoline, and Diesel hoists are available. The usual installation ranges from 25 to 60 hp. Table 6 shows the approximate prices of several sizes of gasoline hoists as quoted by one manufacturer.[11]

TABLE 6.- Dimensions, capacities, speeds, and costs of hoists for scraping

Number of drums	Drum dimensions, inches			Number of brakes	Rope capacities of drums, feet		
	Length	Diameter	Flange diameter		3/8-inch rope	1/2-inch rope	5/8-inch rope
1..........	14 1/4	11 1/2	17 3/4	None	850	500	....
1..........	16 1/2	16 1/4	26	None	2,200	1,300	850
1..........	16 1/2	16 1/4	26	None	2,200	1,300	850
2..........	6 5/8	11 1/2	18 1/2	None	480	275	....
2..........	5 3/4	11 1/2	17 1/2	1	350	200	....
2..........	4 3/8	16 1/4	24	2	550	325	215
2..........	7 1/2	16 1/4	26	None	1,100	650	425
2..........	4 3/8	16 1/4	24	2	550	325	215
2..........	7 1/2	16 1/4	26	None	1,100	650	425

TABLE 6.- Dimensions, capacities, speeds, and costs of hoists for scraping - Continued

Number of drums	Speed and pull of pull rope, (drum half full of rope)						Over-all dimensions						Engine hp.	Weight pounds	Price, f.o.b. Chicago
	3/8-inch rope		1/2-inch rope		5/8-inch rope		Length		Width		Height				
	Speed, f.p.m.	Pull, pounds	Speed, f.p.m.	Pull, pounds	Speed, f.p.m.	Pull, pounds	Ft.	In.	Ft.	In.	Ft.	In.			
1..........	200	2,475	240	2,060	280	1,768	6	4	1	11	3	8	25	1,400	$1,100
1..........	230	3,600	315	2,600	400	2,000	8	6	2	3	4	1	35	3,300	1,570
1..........	230	5,000	315	3,700	400	2,850	9	4	2	3	5	2	45	3,600	1,885
2..........	200	2,475	240	2,060	280	1,768	6	4	2	1	3	8	25	1,560	1,275
2..........	200	2,475	240	2,060	....	....	6	4	2	1	3	8	25	1,585	1,275
2..........	230	3,600	315	2,600	400	2,000	8	6	2	3	4	1	35	3,380	1,850
2..........	230	3,600	315	2,600	400	2,000	8	6	2	3	4	1	35	3,330	1,765
2..........	230	5,000	315	3,700	400	2,850	9	4	2	3	5	2	45	3,690	2,160
2..........	230	5,000	315	3,700	400	2,850	9	4	2	3	5	2	45	3,640	2,080

The hoists listed are powered by well-known makes 4-cylinder engines, connected by housed-in reduction gearing to the hoist drums, which are mounted in line with the engine center line. The drums are provided with external hand clutches and in some models with brakes. The drums of the 2-drum hoists are on a single shaft. Engine and drums are mounted on a channel-iron bedframe.

11 Sullivan Machinery Co., Chicago, Ill., February 1933.

Correctly designed head sheaves are important factors in the life of hoist ropes, which constitute the chief item of supply cost in scraper operation. The same manufacturer lists the following roller sheaves:

Size of rope sheave (outside diameter)........inches	8	10	12
Inside diameter of rope sheave........do.	6 1/4	8	9 3/4
Maximum size of rope to be used........do.	7/16	5/8	7/8
Maximum capacity........pounds	6,000	10,000	14,000
Weight........do.	30	50	85
List prices........	$37.50	$45.50	$57.50

These sheaves are of the snatch-block type and are provided with swivel hooks. The sheave wheels turn on roller bearings.

The following table concerning two sizes of gasoline-engine-powered scraper outfits was supplied by a maker of excavating equipment (Sauerman Bros., Inc., Chicago, Ill., Dec. 1932). The hoists comprise two tandem drums, connected by chain drive and reduction gears to a gasoline engine, all mounted on a channel-iron bed frame. The scraper is of the open-bottom type, crescent-shaped, and provided with digging teeth. The prices quoted include all accessory equipment needed for a set-up besides that listed, such as rope sockets, clips, and lashings. Larger and smaller sizes also are available. Both outfits are designed and furnished with sufficient rope for 300-foot spans but can be used for spans as long as 500 feet.

	Outfit A	Outfit B
Hoist:		
Horsepower of engine........	48	66
Inhaul speed........feet per minute	200	200
Backhaul speed........do.	400	400
Weight........pounds	5,415	5,830
Scraper:		
Capacity........cubic feet	20	26
Weight........pounds	420	685
Guide blocks: Number and size........inches	2 - 12, 1 - 14	2 - 14, 1 - 16
Cables:		
Load cable:		
Size........inches	5/8	5/8
Length........feet	350	350
Backhaul cable:		
Size........inches	1/2	1/2
Length........feet	675	675
Bridle cable:		
Size........inches	5/8	5/8
Length........feet	150	150
Tail guy cable:		
Size........inches	5/8	5/8
Length........feet	30	30

	Outfit A	Outfit B
Total weight, including accessory equipment........pounds	6,665	7,630
Cost, f.o.b. Chicago, Ill., February 1933........	$2,400	$2,935
Rated capacity, for continuous operation in easy-digging material, with 300-foot haul....cubic yards per hour	17	23

The following table from Bureau of Mines Bulletin 357[12] gives the strength, weight, and costs of nonrotating plow-steel hoisting rope of 18 strands with a hemp center and 7 wires to the strand.

Diameter of cable, inch	Breaking strength, short tons	Safe load, factor of safety of 8 short tons	Weight per foot, pounds	Cost per foot (December 1930 - Arizona)
1........	33.8	4.25	1.73	$0.28
7/8........	25.9	3.25	1.32	.225
3/4........	19.0	2.50	.97	.18
5/8........	13.3	1.75	.68	.135
9/16........	10.8	1.50	.55	.120
1/2........	8.7	1.00	.43	.105
7/16........	6.7	.80	.33	.090
3/8........	5.1	.60	.24	.085

The following table gives the weight and cost at Marion, Ohio, December 1932, of one type of Page bucket used on draglines or overhead cableways.[13] Lighter and heavier Page buckets are available as well as other types of dragline buckets.

Capacity, cubic yards	Shipping weight, pounds	Price
1/2........	1,650	$285
3/4........	2,425	370
1........	3,460	522
1 1/2........	4,540	698
2........	5,630	868
2 1/2........	7,430	1,315
3........	8,200	1,475
4........	10,000	1,765
5........	11,775	2,160

Scrapers for drag-scraper service, whether of the Bagley or hoe type, are of lighter construction and cost less than corresponding sizes of drag-line buckets.

The following mines at which scrapers were used were operating in June or July 1932. The practices depicted are representative of this type of mining.

12 Gardner, E. D., and Johnson, J. Fred, Shaft-Sinking Practices and Costs: Bull 357, Bureau of Mines, 1932, p. 6.

13 Quotation by Marion Steam Shovel Co., Marion, Ohio

Drag scrapers

DeLaney.- The mine of the three DeLaney brothers on Peshastin Creek near Wenatchee, Wash., is an example of a small placer mine operated mechanically with the minimum of equipment. The gravel was excavated at the side of a sluice box by a 1/5-cubic-yard slip scraper pulled by a drum fastened to the transmission on an old truck. The gravel was dumped through a 3- by 3-inch grizzly made of flat iron rods, placed crisscross, into a sluice box. The oversize was dragged over the sluice box to one side by the slip. The slip was pulled back and held by hand while being loaded. The truck engine was run in low speed while the slip was dragged forward and in reverse while the slip was pulled back. The gravel was dug readily by the slip, although in places some loosening of the material by hand picks was necessary. The average length of haul was 20 feet. The man who guided the scraper alternated with the one at the hoist controls. The third man tended the boxes and prevented the gravel being dumped from damming up the sluice.

The boxes were made of full 1-inch lumber and were 14 inches high and 20 inches wide at the upper end, the lower end being narrowed sufficiently for one box to telescope 8 inches into the next one below. Lumber cost $20 per thousand board-feet. Riffles consisted of 1 1/4- by 2-inch wooden strips 5 1/3 feet long, held 1 1/4 inches apart, by crosspieces at either end. Three sections of riffles were used to a box. Burlap held in place by wire screening was used on the bottom of the boxes under the wooden riffles. A piece of carpet fastened to a wooden frame, such as is used in hand rockers, was placed ahead of the riffles and caught about one-half of the gold. This device could be removed quickly, the contents dumped into a pan, and the quantity of the gold caught determined readily. It was used to check continuously the value of the gravel being washed. Water was brought in a flume from a small diversion dam in the creek to the head of the sluice under the grizzly. As much water as could be used was available.

Under the best running conditions 30 cubic yards could be moved per 8-hour shift by three men. At 50 cents per hour the labor cost of excavation and transportation would be 40 cents per cubic yard. About 2 1/4 gallons of gasoline was used per hour by the truck engine. The cost per yard of the gasoline at 20 cents per gallon would be 12 cents and that of other supplies 4 cents, making a total operating cost of 56 cents per cubic yard of gravel removed.

McElroy.- An attempt was made by T. E. McElroy in June 1932 to mine a bar at the water's edge on the Similkameen River near Princeton, British Columbia, by means of a scraper and hoist. The gravel was fairly easy to dig but contained many boulders which seriously reduced the capacity of the scraper. The gravel was pulled up a steep slide onto a pole grizzly with 3 1/2-inch spacing. The oversize was pulled by the scraper over the grizzly and down another pole slide to a dump. (See fig. 2,A.) The undersize dropped through the grizzly into a flat-bottomed hopper from which it was fed by means of a regulating gate into a sluice box. The tailing from the sluice ran into the river. The scraper was operated by a 2-drum logging hoist run by a gasoline engine. The engine was set well back of the grizzly. The cables ran through snatch blocks set on a headframe at the proper height to pull the scraper up the slide and onto the grizzly which was about 10 feet above the surface of the ground. An arc-shaped bottomless scraper was used; when boulders were encountered it was replaced by a 3-pronged plow. The scraper was weighted on the rear to make it dig. Most of the digging was under water. When the gravel was dragged out of the pit by a bottomless scraper under water it was considered that an appreciable part of the gold had an opportunity to drop downward and be lost. Water for washing was pumped from the river. The stream from a 6-inch centrifugal pump emptied directly into the sluice box, and that from a 3-inch pump under a pressure corresponding to about a 10-foot head was used for washing the gravel from

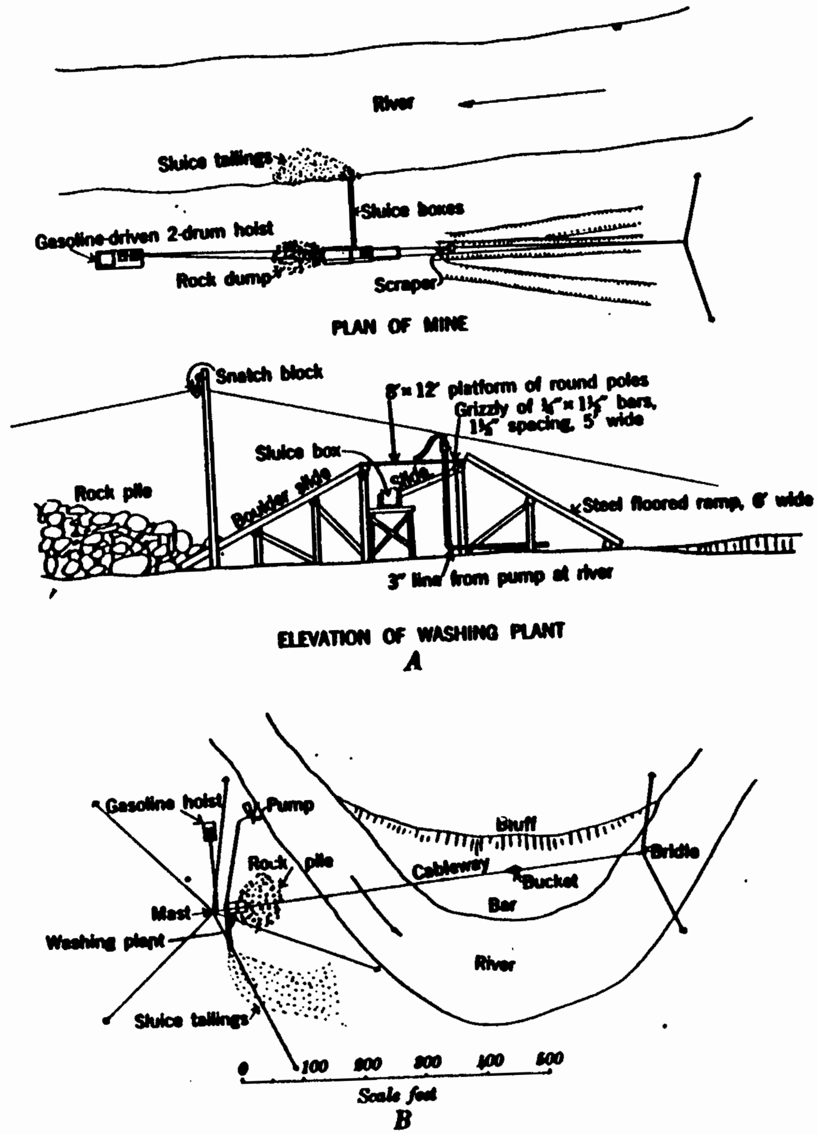

Figure 2.—Lay-outs of mines using scrapers: *A*, Drag scraper at McElroy mine, Princeton, B. C.; *B*, scraper on cableway, Mammoth Bar mine, Auburn, Calif.

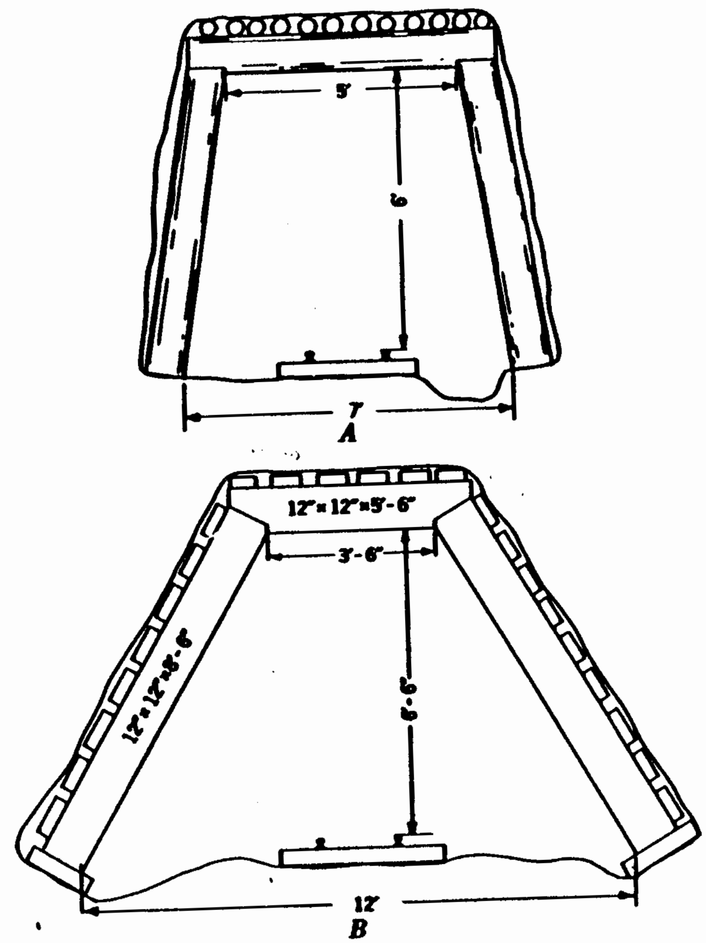

Figure 3.—Methods of timbering drifts: *A*, Drift set for normal ground; *B*, tunnel set used at Hidden Treasure mine, Placer County, Calif.

the hopper into the sluice. The sluice was 18 inches wide and set on a grade of 1 inch to the foot. The first 10 feet was lined with pole riffles in 5-foot sections; the next 5 feet had 1- by 1 1/2-inch Hungarian riffles; and the next 15 feet was lined with wire screen over carpet. The last 18 feet of the sluice contained no riffles.

The crew consisted of five men. About 1 1/2 hours of each 8-hour shift was spent in handling boulders. The plant had a capacity of 150 cubic yards per shift; the average daily tonnage, however, was only about 60 cubic yards. About 6 gallons of gasoline was used per shift for running the hoist and 2 1/2 gallons for the two pumps. The labor cost at 60 cubic yards per day and $2.25 per 8-hour shift was 19 cents. Gasoline and other supplies cost 8 cents per cubic yard. Miscellaneous costs were 3 cents. If supervision is disregarded the operating cost was 30 cents per cubic yard. (See table 5.)

Operations were unprofitable and were discontinued; digging under water was considered the reason for the low return in gold.

Nugget.- The Nugget Placer Mining Co. was mining an old channel on Libby Creek about 17 miles above Libby, Mont., in 1932.[14] The gravel was excavated by a 60-hp., gasoline, double-drum hoist on skids which pulled a Bagley 1-cubic-yard scraper. The tail block was about 250 feet from the hoist. The gravel was dragged up an incline and dumped on a shaking grizzly 8 feet long and 5 feet wide with 2 1/2-inch spacing. The lower end of the grizzly was pivoted, while the upper end was lifted about 2 inches and dropped on a bumper log by a stamp-mill cam mechanism. As the load was dumped it was sprayed with water. The fines were shaken through the grizzly, leaving nothing on it except clean boulders which were removed by hand and hauled away in a truck. The undersize was run through a sluice box 36 inches wide and 36 inches high with a grade of 4 inches to a 12-foot box. Riffles consisted of transverse 30-foot rails set 2 inches apart on 2- by 6-inch longitudinal chairs also set 2 inches apart. Concentrates from the main sluice were treated in a sluice 20 inches wide by 12 inches deep. The riffles consisted of 10-pound rails laid on 1- by 2-inch lumber like the rails in the main sluice. The concentrates from the small sluice were screened. The plus 16-mesh material was panned for coarse gold; the undersize was run over a small table covered with rubber matting held down by expanded metal. Assays of the tails from the table showed $40 per ton in gold, indicating that a clean separation was not being made.

The set-up did not prove satisfactory. Water level was encountered about 15 feet above bedrock, and the scraper functioned poorly under water. Bedrock was uneven and extended up into the gravel; also, there was a layer of sticky clay with embedded boulders 8 feet below the surface. When the bottomless bucket encountered a boulder in the clay bed or projecting bedrock it jumped and lost its load. The grizzly mechanism gave trouble, and the capacity of the grizzly would have been insufficient if a more efficient digging unit had been employed.

In October 1932 plans were drawn to use a Page-type bucket on a headline similar to the installation on Mammoth Bar which is described later.

Molsom.- Unsuccessful attempts were made to use scrapers at two properties near Molsom, Wash., in 1932. At one the soil overburden was stripped off and the gravel was dragged up an incline to a grizzly with 4-inch spacing. Material over 1 inch in size was separated by a Hum-mer screen and the plus 1/4-inch mesh material by a second screen. The undersize went to a patented gold saver. The scraper could handle the gravel much faster than it could be washed. The enterprise failed owing to insufficient gold in the ground and to the low capacity of the gold saver.

At the other property the gold occurred in narrow streaks on bedrock. After the overburden was removed by a scraper the gold-bearing gravel was taken up by hand and washed in a rocker. The handwork was very slow, and the scraper could be used only a part of the time.

14 Information supplied by Sidney M. Logan, president, Nugget Placer Mining Co., Kalispell, Mont.

Minnick.- In July 1932 F. L. Minnick had just installed a scraper to mine gravel along Peshastin Creek, near Wenatchee, Wash. The gravel was dragged up a plank ramp onto a pole grizzly with about 4-inch spacings. The scraper pulled the oversize across the grizzly to a dump, and the undersize went through a 25-foot sluice box. Water was brought to the head of the sluice in a flume. The scraper was of the Bagley type and about 4 feet wide. The hoist was about 100 feet from the grizzly, and the tailblock was attached to a 20-foot gin pole 50 feet on the other side of the grizzly. The gravel was pulled downstream in and alongside of the creek. The ground was bouldery, and only a small capacity could be expected from the set-up. Not enough work had been done to allow costs to be calculated.

Alaskan practice.- Wimmler[15] has described scraper operation as practiced in Alaska. Operating costs at five plants using Bagley scrapers in the Fairbanks district ranged from 45 to 90 cents per cubic yard. An operator using a Bagley scraper on Willow Creek for a period of 5 years had an average cost of 30 cents per cubic yard. The cost at a smaller plant on Flat Creek was 68 cents per cubic yard. The cost of scraping 4 feet of gravel and bedrock with a slip scraper after the overburden had been ground sluiced was $1.55 per cubic yard in the Innoko district. The cost of a similar installation in the Hot Springs district was $1.32 per cubic yard.

Slackline cableways

Mammoth.- F. W. Roumage was mining the Mammoth Bar on the Middle Fork of the American River near Auburn, Calif., in June 1932. The deposit consisted of recent river gravel containing a relatively small proportion of boulders. The gravel was excavated by a 1-cubic-yard Page-type dragline bucket running on a 1 3/8-inch track cable across the river to the washing plant. (See fig. 2,B.) The bucket was operated by a 3-drum logging hoist run by a 95-hp. gasoline engine. The track cable ran from the top of a 64-foot spruce mast to a bridle cable across the river. The mast was 24 inches in diameter at the butt and 15 inches at the top and was held by 7/8-inch guy ropes. The high line was a 1 3/8-inch cable. The inhaul rope that pulled the bucket was 1 1/4 inches in diameter; 3/4-inch tension cable running through double 20-inch blocks was used to raise or lower the track cable. The bucket was hauled in at a speed of 300 feet per minute when loaded and returned by gravity at a speed of 1,200 feet per minute.

Most of the digging was under water. It was planned to pump out the pit at the end of the scraper operations, recover any "islands" missed by the bucket, and complete cleaning up of the bedrock by hand if necessary.

The gravel was dumped on a grizzly with 4-inch spacing between the bars. The undersize dropped into a hopper about 20 feet above the ground and thence was washed by sprays into a sluice box. The oversize, after the dumping room below the grizzly was used up, was to be dragged away by a scraper operated from one drum of the main hoist. The boxes were 18 inches wide and 36 feet long with a grade of 9 inches in 12 feet. Riffles consisted of 1 1/4- by 1 1/4-inch angle iron 3/16 inch thick, set flat in 2- by 3-inch wooden chairs on either side of the box. Every 4 feet a 2- by 3-inch wooden crosspiece was placed tightly on the bottom of the sluice. The lower edge of the vertical side of the angle-iron riffles was about 2 inches from the bottom of the box. Water was pumped from the river by a 6-inch centrifugal pump run by an old automobile engine.

The crew consisted of a man on the hoist, one at the washing plant, a mechanic on each of two 8-hour shifts, and a superintendent on day shift. The hoist used 5 gallons of gasoline and the pump 1 gallon per hour. Second-hand machines were used in equipping the mine,

15 Wimmler, Norman L., Placer-Mining Methods and Costs in Alaska: Bull. 259, Bureau of Mines, 1927, 236 pp.

and considerable delay resulted from break-downs and repairs. Up to the middle of June as much as 240 cubic yards (but usually less than 200) had been handled in two 8-hour shifts. At 200 cubic yards per day the labor cost, including 1 1/2 cents per yard compensation insurance, would have been about 15 1/2 cents per cubic yard. Gasoline and other supplies cost 16 cents and supervision 5 cents, making a total operating cost of 36 1/2 cents. The cost of the plant was $7,500, and 100,000 cubic yards was expected to be washed. Amortization without interest would therefore have been 7 1/2 cents per cubic yard, making a total of 44 cents. If a larger average yardage could be handled the operating costs would be correspondingly less.

Power Shovels and Draglines

For many years power shovels and drag lines have been used for excavating earth and rock, consequently they have been improved so as to operate steadily and economically under severe conditions. They likewise have been tried often for placer mining. As early as 1897 a steam shovel was used on the placer gravels of Meadow Creek, below Warren, Idaho, for loading the gravel into tramcars which were then pulled up an incline and dumped into a sluice.[16]

Power shovels, as the term is used here, comprise machines that dig and load by means of a forward-thrusting dipper on a rigid arm or dipper stick. A dragline is a machine with a relatively long boom by means of which a scraper bucket, usually of the closed type such as is used for cableway excavators, is swung to any point within the range of the machine and filled by being pulled in by a separate hoist drum mounted on the machine.

Most power shovels can be converted to draglines by replacing the shovel boom, dipper stick, and dipper by a dragline boom and bucket, adding the fairlead for the drag cable, and sometimes adding an extra drum. Likewise, most machines can be equipped with booms of various lengths. If the boom length is increased the size of bucket must be correspondingly decreased.

Machines with dipper or bucket capacities of 1/4 to 20 cubic yards are available, but those most useful for placer-mining operations are the 2-yard or smaller machines. Two-yard and smaller power shovels ordinarily have digging radii of 12 to 25 feet, that is, can excavate cuts to grade 25 to 50 feet wide. They can dig, within a limited radius, to a depth of 5 to 10 feet below grade and can lift and dump their loads at heights of 15 to 25 feet above grade. Draglines designed to use buckets of corresponding sizes have much greater operating ranges both horizontally and vertically. One equipped with a 35-foot boom, for instance, and using a 3/4- or 1-yard bucket can usually dig within a radius of 35 to 45 feet (depending on conditions and the skill of the operator), can excavate to a depth of 15 feet below grade, and can lift its load and dump it at a height of 15 to 20 feet above grade. A dragline with a 90-foot boom, using a 2-yard bucket, normally has a digging radius of over 100 feet and can discharge at a height of about 45 feet; it can excavate to a depth of 35 feet below grade. The manufacturer's catalogs give operating ranges of particular models with given equipment and under given conditions.

Draglines and power shovels have respective advantages and disadvantages as applied to placer mining. Draglines have a greater excavating range and are used in placer mining chiefly with movable washing plants. Shovels, on the other hand, generally are used to load material into trucks or cars which transport it to the plant. With adequate truck service, a shovel thus used has greater capacity than a dragline with a bucket of equal size. When shovels load directly into the hoppers of washing plants the short digging and dumping radius

16 Lindgren, Waldemar, The Gold and Silver Veins of Silver City, DeLamar, and Other Mining Districts in Idaho: U.S. Geol. Survey, 20th Ann. Rept., 1898-99, pt. III, p. 234.

of the machine is a serious disadvantange, necessitating frequent move-ups with consequent lost time. The dragline, with its greater operating range, eliminates this disadvantage; in fact, it may be operated from the top of the bank, loading into a plant in the pit or on the side of the pit, whichever is most convenient. Its ability to dump at considerable height above grade may make an elevator on a movable washing plant unnecessary and thus simplify the flow sheet.

Much placer ground contains boulders, or is tight or even cemented. A power shovel moves boulders aside more readily than a dragline and digs better in tight or hard ground than a dragline of comparable size. Likewise the upper foot or so of bedrock is more easily dug with a shovel. For cleaning bedrock with a dragline the digging bucket may be replaced with one of the hoe type such as is used in digging trenches.

Neither shovel nor dragline is satisfactory for digging gold-bearing gravel under water. A shovel dipper usually leaks water badly, and gold may be lost in this way. Remedies are to use gaskets on the dipper, or to drain the dipper over the bank before swinging, hoping to pick up again any gold that is dropped. Although drag-line buckets may be made water-tight they stir the gravel considerably before picking up a full load, and the gold tends to settle out of reach. Moreover, the exact location of the bucket when under water is uncertain, and the tendency is to leave untouched islands or ridges of gravel on bedrock.

The balance of these considerations decidedly favors the power shovel for the majority of placer deposits, although in some instances the use of a dragline may be very economical. Of 13 operating properties visited in 1932 and described in the following section, 10 were equipped with shovels and 3 with draglines. It is noteworthy that in spite of adverse digging conditions, such that dippers could seldom be filled without 2 or 3 thrusts, the capacity of the excavator was almost always greater than the capacity of the washing plant; this resulted in unusually high excavating costs.

Shovels and draglines used for placer mining are always caterpillar-mounted and full-revolving. They are very mobile, can be moved readily over poor and steep roadways, and can be used for a great variety of services such as moving plants, building roads and reservoirs, or making bedrock cuts.

Electrically powered excavators are more economical in power consumption and mechanical efficiency than steam, gasoline, or Diesel machines. When equipped with proper controls they have nearly the flexibility of steam shovels. However, as electric power usually is unavailable gasoline-engine power is used at most placer operations.

When using a shovel or dragline for mining placer gravel care should be taken not to drop oil or grease on the dirt that is to be washed or into water that will be used in washing, as the oil may cause some gold to float away or cause fouling of the quicksilver used in the sluices. Especial care must be taken when the machine is standing or digging in water.

Table 7, supplied by a manufacturer of power shovels,[17] shows the comparative possible outputs with both dipper and dragline types and operating data in a 15-foot gravel bank under ideal conditions. Such conditions, however, seldom if ever are encountered in placer mining, and much smaller yardages should be expected when estimating capacity. With the exception of the 3-cubic-yard draglines the machines are readily convertible from one type of excavator to the other. Moreover, the draglines can be purchased with various boom and bucket combinations. The tabulation shows the largest bucket with its proper boom length. The machines are available with either gasoline-engine, Diesel-engine, or electric-motor drives.

As shown in table 4, the shovel-operating crew consisted of 1 man at 8 properties where relatively small machines were used and 2 men at 4 properties where larger machines were employed.

17 Bucyrus-Erie Co., South Milwaukee, Wis.

TABLE 7.- Approximate outputs of various sizes of drag lines and shovels[1]

	Machine no.						
	A	B	C	D	E	F	G
Drag line:							
Bucket capacity......cubic yards	1/2	3/4	1	1 1/2	2	2 1/2	3
Average bucket load (material free from boulders)...... do.	0.4	0.6	0.8	1.2	1.6	2	2.4
Length of boom......feet	35	35	45	45	45	50	85
Time of cycle......seconds	25	28	30	30	30	32	34
Possible capacity......cubic yards per hour	57	77	96	144	192	225	255
Capacity, at about 75-percent plant operation...... do.	43	58	72	108	144	160	180
Possible capacity per 8-hour shift, at 75-percent plant operation......cubic yards	344	464	556	864	1,152	1,280	1,440
Shovel:							
Dipper capacity......cubic yards	1/2	3/4	1	1 1/2	1 3/4	2 1/4	......
Average dipper load...... do.	0.4	0.6	0.8	1.2	1.4	1.8	......
Shovel cycle time......seconds	15	18	20	22	22	22	......
Possible capacity......cubic yards per hour	96	120	144	168	230	295	......
Capacity, at about 75-percent plant operation...... do.	70	90	108	127	170	220	......
Possible capacity per 8-hour shift, at 75-percent plant operation......cubic yards	560	720	864	1,016	1,360	1,760	......

[1]Under very favorable conditions in readily excavated gravel; digging depth, 15 feet; 100° swing loading into hopper 12 feet high.

Table 8 is an estimate, supplied by the same manufacturer, of the fuel or electric-energy requirements of the various sizes of machines listed in table 7. The fuel consumption is calculated for sea-level operation; at higher altitudes the fuel requirements would be proportionately higher. The fuel consumption at a number of properties operating in 1932 is shown in table 4.

The manufacturers estimate that repairs, maintenance, and operating supplies for the machines listed in the foregoing table, exclusive of fuel and lubricants, range from 0.9 cent to 1.1 cents per cubic yard of material handled. This includes overhauling at proper intervals:

In steady operation under average conditions operating repairs, lubricating oils, renewals of parts, and depreciation of a power shovel may be figured as 20 percent of the first cost per year. In small friction-driven machines 35 percent of the first cost may be necessary. In very large machines, however, this charge has been as low as 5 percent of the first cost. For example, if a 2 1/2-cubic-yard machine cost $30,000 and 200,000 cubic yards of material was handled in a year, the digging cost, exclusive of labor and power or fuel, would be 20 percent of $30,000 divided by 200,000, or 3 cents per cubic yard.

The October 1932 prices, f.o.b. factory,[18] of the machines listed in table 7, equipped for dragline service, were as follows:

18 Bucyrus-Erie Co., South Milwaukee, Wis.

TABLE 8.- Fuel or electric-energy requirement of various sizes of power shovels and drag lines

	A		B		C		D		E		F	G
Machines with gas or Diesel engines:												
Bucket capacity of drag line cubic yards	1/2		3/4		1		1 1/2		2		2 1/2	3
Dipper capacity of shovel..........do.	1/2		3/4		1		1 1/2		1 3/4		2 1/4	....
Gasoline consumption..........gal. per hr.	3-4		4-5		5.5-6.5		7-8		8-9		....	....
Lubricating oil..........do.	.02		.02		.035		.045		.07		....	....
Fuel oil, Diesel..........do.	....		2-3		3-4		3.5-4.5		5-7		6.5-7.5	8-10
Lubricating oil, Diesel engine do.	....		.045		.05		.05		.08		.10	.10
Machines with alternating-current motors:												
Driven by..........	Single motor		Single motor		Single motor		Single motor		Individual motors		Individual motors	Single motor
	Drag line	Shovel	Drag line	Shovel	Drag line	Shovel	Drag line	Shovel	Drag line	Shovel	[1]Drag line	Drag line
15-minute average input..........kw.	18	28	28	28	35	35	40	40	40	45	70	80
Momentary peaks..........do.	50	65	65	65	80	85	95	95	100	105	170	175
Energy consumption..........kw.-hrs. per cu.yd.	.3-.7		.3-.7		.3-.7		.3-.8		.3-.8		.3-.8	.4-.8

1 For a Ward-Leonard control (direct current motor under variable-voltage control) the input and energy consumption of class F drag line and shovel are:

	Drag line	Shovel
15-minute demand..........kw.	50	50
Momentary peaks..........do.	110	120
Energy consumption.....Kw.-hrs. per cu.yd.	0.3-0.6	0.25-0.4

Machine no.	Capacity, cubic yards	Cost (including buckets)
A	1/2	$6,200
B	3/4	9,300
C	1	11,000
D	1 1/2	13,700
E	2 or 1 3/4	17,250
F	2 1/2 or 1 1/4	29,300
G	3	48,400

Another Milwaukee manufacturer makes a series of shovels and draglines ranging in capacity from 1/4 to 4 cubic yards. Their draglines are priced at $6,000 to $50,000.

Still another manufacturer[19] quoted the following approximate prices in October 1932 for four models of power shovels, f.o.b. Marion, Ohio.

Size of dipper, cubic yards	Hourly capacity, cubic yards	Cost, f.o.b. factory
3/4	40-120	$10,250
1	45-140	12,000
1 1/4	50-160	13,500
1 1/2	60-175	16,000

A 3/8-cubic-yard machine, having three-fourths swing and a 15-foot bom and powered by a tractor engine, was priced at $4,250 on the Pacific coast in October 1932.[20]

During 1932 used power shovels in good condition could be acquired at very substantial reductions or hired at reasonable rentals.

The following descriptions of plants illustrate the practices followed with different set-ups and washing plants where the gravel was mined by power shovels or draglines.

In addition, various unsuccessful efforts were made during 1931 and 1932 to mine gravel with power shovels, but no noteworthy features were observed at any of these operations.

Stationary washing plants

Yellow Nugget.- S. A. Wells and partners began working a high bar on Pine Creek near Hereford, Oreg., n 1932. The gravel averaged 8 feet deep, was tight, and was hard to dig. The bedrock was soft, and about 1 1/2 feet was taken up with the gravel. The gravel and bedrock were excavated with a 5/8-cubic-yard gasoline shovel and hauled in 4-cubic-yard trucks about 2,000 feet to a washing plant which consisted of a grizzly, pump, high-pressure sprays, and a sluice box.

All boulders over 6 or 8 inches in size that came to light while t'e trucks were being loaded were thrown out. An extra man at the pit worked with the drivers on the trucks to do this work. The gravel was dumped on a rail grizzly with 6 1/2-inch openings; the oversize went to a rock dump which was leveled off by hand as it was built up. The undersize was washed into the sluice from a flat, steel-lined hopper under the grizzly, by water under 18 pounds per square inch pressure from five 2-inch sprays on goosenecks. The water was pumped

19 Osgood Co., Marion, Ohio.

20 Fordson-Tractor Sales, Ltd., Los Angeles, Calif.

44 feet vertically by a 5-inch centrifugal pump run by a 6-cylinder automobile engine; 900 gallons per minute was used. Three gallons of gasoline per hour was used for pumping.

The sluice was 18 inches wide and 40 feet long with a grade of 1 inch to the foot. Riffles consisted of 12-pound rails cut in 4-foot sections, laid lengthwise in the boxes; and 2- by 4-inch crosspieces between sections of rails. An undercurrent 10 feet long by 8 inches wide with 1-inch cross riffles of wood was used at the end of the sluice, mainly as an indicator. Quicksilver was used in all of the sluice except before the first riffle. Before quicksilver was used the loss of gold was appreciable.

One man operated the sprays and tended the upper end of the box. A second man tended the lower end of the sluice and kept the washed gravel from becoming dammed on the dump. The shovel and trucks could dig and haul the gravel faster than it could be washed. Little delay, however, was experienced in the operations. An average of 160 cubic yards was washed per 10-hour shift. The average gasoline consumption per shift was 30 gallons for the pump, 30 gallons for the shovel, and 27 gallons for the two trucks. The crew consisted of 6 men, 1 of whom acted as supervisor. Wages were 50 cents per hour for all except the shovel man, who was paid 60 cents per hour. The operating cost was 7 cents for labor and 5 cents for supplies for excavating, 9 cents per cubic yard (contract price) for hauling, 6 cents for labor and 1 cent for supplies for washing, 4 cents for supplies for pumping, 5 cents estimated miscellaneous, and 2 cents for supervision - a total of 39 cents per cubic yard.

Heine.- Dr. A. L. Heine and associates were mining a bar on Grimes Creek at Centerville, Idaho, in June and July 1932. The gravel averaged about 6 feet deep. It contained no boulders over 1 foot in diameter and few over 6 inches in size. The bedrock was decomposed granite; 1 foot of it was taken up with the gravel. The gravel was excavated by a 1 1/4-cubic-yard gasoline shovel and transported an average of 400 feet to the washing plant in three 4-ton trucks under contract. The contract price for excavation and transportation of the first 14,000 cubic yards was 25 cents per cubic yard and of the second 14,000 cubic yards 20 cents. The contractor's crew consisted of a shovel operator, oiler, mechanic, boss, and three truck drivers on each of two shifts.

The gravel was dumped into a hopper holding 6 cubic yards. No grizzly was used; one man at the hopper threw out all boulders over 6 inches in size. The gravel was fed into the sluice by means of a spray. Water for washing was supplied through a 14-inch pipe by a 12-inch centrifugal pump run by a 100-hp. electric motor. The head on the pump, including friction loss, was 37 feet. This water was discharged directly into the head of the sluice box. The water for the spray was pumped through a 7-inch pipe by a 10-hp. electric motor and discharged through a 2-inch nozzle. The electric-power bill for both pumps for 20 hours per day was $17. The sluice was 32 inches wide and 125 feet long and had a grade of 8 inches in 12 feet. Riffles consisted of 20-pound rails. In the first three boxes the rails were transverse; transverse and longitudinal sections alternated in the other boxes to the end of the sluice; 16 pounds of quicksilver was used in the riffles.

Three men were employed on each shift at the washing plant and pumps. At a wage rate of 40 cents per hour and 1,000 cubic yards per day the labor cost at the washing plant and pumps would be 2.4 cents. The estimated power cost would be 1.7 cents, supplies at the washing plant 0.4 cent, miscellaneous labor and supplies 3 1/2 cents, supervision 1 cent, and digging and trucking 20 cents - a total operating cost of 29 cents per cubic yard.

Great Bend.- A plant was built in the summer of 1931 to treat river gravels on the American River at Lotus, Calif.; operations were discontinued in November after the treatment of about 100,000 cubic yards. The gravel consisted mainly of old tailings and was dug by gasoline-power shovels and transported 500 feet in three 4-cubic-yard trucks to a washing plant. The trucking was done on contract at 6 cents per cubic yard. About 800 cubic yards was handled each 8-hour shift. The plant appeared to be well designed and was of substantial construction. The gravel was dumped from the trucks into a trap over a belt elevator which fed a 5- by 20-foot trommel with 9/16-inch holes. The oversize went to a belt stacker and the undersize over three 50-foot steel boxes 30 inches wide in parallel with 1/4-inch-square wooden cross riffles. The following electric motors were used: Belt elevator, 10 hp.; trommel, 15 hp.; stacker, 10 hp.; extension stacker, 15 hp.; feeder, 10 hp.; and pump, 50 hp.

Operations were discontinued, as the gravel did not carry the expected amount of gold. Cost data were not available.

Wallace.- The Gold Gravel Product Co. built a plant at Wallace, Calif., and washed about 30,000 cubic yards during the first half of 1931. The plant capacity was about 100 cubic yards per hour. The gravel was excavated by a 1 1/4-cubic-yard, full-revolving, caterpillar-tread, gasoline-driven shovel with a 30-foot boom and a 92-hp. engine. Haulage was by twelve 4-cubic-yard side-dump cars and two 8-ton gasoline locomotives running on a 36-inch gage track; 5 cars were run to a train. The distance from the pit to the washing plant was 1/2 mile. Gasoline consumption was 14 gallons per 8-hour shift.

The gravel was dumped through an 8-inch grizzly into a washer, consisting of a tube 5 feet in diameter and 16 1/2 feet long with a spiral vane 12 inches high on the inside and having 15 turns. Lifter bars also were used between the spiral blades. The washer which was revolved by means of a 30-hp. motor was set level; a particle would pass through in 2 1/2 minutes. The lower 4 feet of the tube outside of the spiral was flared outward and consisted of a screen with 1-inch round holes. The oversize from this screen went onto a belt stacker. An outside screen with 3/8-inch holes was used around the inner one. The plus 3/8-inch, minus 1-inch material was run through a 16-inch sluice 100 feet long and the minus 3/8-inch material through a 32-inch sluice also 100 feet long. The novel features of the operation were the use of cars and track for haulage and the spiral washer. About 3,000 gallons of water per minute was pumped for washing the gravel, or 1,800 gallons per cubic yard of gravel excavated.

Cost data were not available.

Grant Rock-Service.- The Grant Rock-Service Co. at Fresno, Calif., produced gold as a byproduct to the sand, gravel, and crushed-stone business. The ground contained about 3 cents per cubic yard in gold. The deposit consisted of 30 feet of river gravel which was easily excavated; a cubic yard in place weighed 2,850 pounds. The bedrock was volcanic ash. The gravel was excavated with a 5-cubic-yard dragline shovel with a 100-foot boom and transported to an inclined elevator in 20-cubic-yard dump cars pulled by a steam locomotive. The dragline could excavate 3,000 cubic yards in 9 hours. The gravel went through a standard sand-and-gravel screening and washing plant. The gold was extracted from the sand after it had passed through a 3/16-inch trommel screen. The oversize from the screen went to a sized gravel bin or a crushing plant. As the demand was greater for the rock and gravel than for the sand, most of the sand was washed back into the pit; however, all the sand was run through a 50-foot sluice 30 inches wide with dredge-type Hungarian riffles.

The work was on a large scale; the plant was of standard form, and the equipment used had all stood the test of time. A. H. Sienknecht, plant superintendent, made calculations which indicated that the cost of handling the gravel for the gold alone would be 18 cents per cubic yard. This included the cost of running all tailings back into the pit. By allowing amortization and general expense the total cost would be 20 cents per cubic yard. This cost should indicate what could be done with similar deposits on a large scale. It should be borne in mind, however, that the gravel was free from clay and large boulders, and almost ideal conditions existed for obtaining low costs. The digging was under water; with most types of bedrock this would have meant a relatively low recovery of gold in the pit.

Gold was obtained also as a byproduct from sand-and-gravel plants at Bakersfield, Calif., and at Denver, Colo. The gold was caught on riffles as at the Grant Rock-Service Co.

Skull Valley.- The Skull Valley Gold Corporation operated a placer mine in Skull Valley, Ariz., during 1932. Gravel was hauled to a central washing plant, and water was pumped from a distance. The gravel averaged about 8 feet deep, occurred on a clay bedrock, and contained a relatively large proportion of black sand. It was dug by a one-half-revolving, gasoline-driven shovel with a 3/8-cubic-yard dipper and hauled in two 2-ton trucks an average distance of 2,500 feet. The trucks dumped into a 110-cubic-yard bin. The gravel was pulled out through "Chinaman" chutes onto a 22-inch traveling belt and thence to a 4- by 9-foot trommel with 1/4-inch round holes. The oversize went to a dump via a stacker belt. The undersize went to a second trommel 3 by 8 feet in size with 1/8-inch square holes. Both trommels ran at 24 r.p.m. The launder between the trommels had traps to catch plus 1/8- to minus 1/4-inch nuggets. It was thought that about 70 percent of the material was rejected by the screens. The undersize from the second trommel went to four Wilfley tables in parallel. The tailings from the tables were elevated by a sand wheel onto the stacker belt. The concentrates from the tables were run over a 4- by 8-foot amalgamation plate. A quicksilver trap was used below the plate. The gravel contained cinnabar and native quicksilver; the latter was caught in the traps. About 10 pounds excess of quicksilver accumulated during the summer of 1932.

Water was pumped from a 12-foot well by a 2 1/2-inch centrifugal pump to a small tank, whence it was pumped 7,800 feet horizontally and 280 feet vertically by a 5 1/2- by 6-inch triplex pump to a 18,000-gallon tank at the plant. The same engine drove both pumps. About 100 gallons of water was used per minute; none was reclaimed.

The plant had a capacity of 120 cubic yards per day when it ran full time; however, the average daily yardage handled during the period of operation was about 90. Power was furnished by tractor engines; 1 was used on the shovel, 2 at the washing plant, and 1 on the pumps. Gasoline consumption per 8 hours was: Shovel, 10 gallons; trucks, 16; washing plant, 13, and pumps, 10. Gasoline cost 19 cents per gallon, but the State tax of 5 cents per gallon was refunded for all uses except the truck. The average daily cost for gasoline was $7.99.

Six men and a superintendent ran the plant. The wage scale was $0.75 per hour for the shovel men and an average of $0.40 per hour for the rest of the crew. The daily labor payroll was $22. Other daily operating expenses were estimated as follows: Trucking costs other than labor and gasoline, $2.70 (6 cents per mile); shovel, washing plant, and pump supplies and miscellaneous expense, $6.00; supervision, $10.00; making a total daily operating cost of $48.69. At the average daily capacity of 90 cubic yards the unit cost would be 54 cents; at full capacity the operating cost would be 40 cents per cubic yard.

Forbach and Easton.- Forbach and Easton worked a placer mine in Skull Valley, near Kirkland, Ariz., in 1931 and 1932. The gravel was 6 inches to 6 feet deep, the average depth being 3 feet. According to one preliminary test the gravel contained about 75 pounds of black sand per cubic yard, but in operation the table recovery indicated a content of about 35 pounds per yard. There were no boulders. The gold-bearing gravel was underlain by a false bedrock of yellow clay. The gravel was dug by a 3/8-cubic-yard, caterpillar-tread, gasoline-driven shovel and loaded into two trucks 1 3/4 and 2 3/4 cubic yards in capacity, respectively. The average haul to the washing plant was 1/2 mile. The gravel was dumped from the trucks over a 6-inch rail grizzly into a 55-cubic-yard bin. The oversize was thrown out by hand into a car and pushed to a dump. From the bin the gravel was taken by a belt feeder to a 4- by 9-foot trommel. The first 3 feet of the trommel was blank; the lower 6 feet had 1/4-inch round holes. This trommel was set on a slope of about three-eighths inch per foot and revolved at a rate of 21 r.p.m. Sprays under approximately a 30-foot head played on the outside of the trommel and into both ends. The undersize went through a nugget trap, in which it was reported $10 to $50 worth of coarse gold was recovered each shift, and thence to a second trommel 38 inches in diameter by 6 feet long, made of double-crimped, 18-gage screen wire with 1/8-inch square openings. The oversize from both trommels was carried to a tailings dump by two 16-inch conveyor belts, the first 50 and the second 150 feet long. It was estimated that about 5 percent of the material was rejected at the grizzly and an additional 35 percent by the screens. The undersize from the second screen went to three Deister diagonal-deck sand tables arranged in parallel and run at 280 r.p.m. The table tailings went to a 4-foot sand wheel with 11 buckets bolted to the rim; it turned about 3 r.p.m. The sand from the wheel went to the second stacking belt which elevated the material about 30 feet to the dump. A hose was used periodically for washing the sand away from the end of the stacker. The Deister table concentrate went to a Wilfley table used as a cleaner. The tailings from the Wilfley table were carried back by hand to the head of the Deister tables. The concentrate in 2 1/2-ton batches was treated in a 5-foot amalgamator. The amalgamator was first run about one-half hour to scour the gold; caustic soda was added to destroy any grease that might be present. Then 40 pounds of quicksilver and enough water to fill the tank were added, and the amalgamator was run 30 minutes more at 57 r.p.m., after which the top part of the charge was drawn off and put back over a table to catch any floured mercury. The rest of the contents were then drawn into a porcelain tub; the live quicksilver was decanted off and as much amalgam as could be collected taken out. The contents of the tub were run over the Wilfley table to catch the rest of the amalgam. The amalgam was squeezed in buckskin and then retorted over a wood fire; a condenser was used. The sponge gold was melted in a graphite crucible.

The trommels were driven by a 50-hp. gasoline engine that also operated a 10-kw. generator that supplied power to a motor to run the no. 2 stacking belt and the Wilfley table. A 9-hp., 1-cylinder gas engine drove the upper stacker, the Deister table, and the sand wheel.

The well from which water for operating the plant was obtained was 8,000 feet from the mine; it was cased with 8-inch pipe for a distance of 170 feet. A deep-well pump driven by a 25-hp. Diesel engine lifted the water 150 feet to a 2,000-gallon tank. A 5 by 6 triplex pump, run by the same engine, forced the water through a 4-inch pipe to 25,000-gallon tanks at the washing plant. The water from the washing plant was settled in a pond, and the clear water was returned to the tanks by a 2-inch centrifugal pump.

Ninety gallons was pumped per minute from the well over a period of 8 hours. About 250 gallons of water per minute was recirculated at the plant, and some was wasted. Clear water was used on the tables. About 175 gallons per minute was used for screening.

The mine was operated one 8-hour shift. The crew consisted of the following:

	Wages, rate per hour
1 shovel runner	$0.75
2 truck drivers	.40
3 plant men (1 at grizzly, 1 at feeder, and 1 at tables) each	.40
1 pumpman	.40
1 sampler (testing ground)	.40
1 superintendent	.

The fuel consumption was as follows:

	Gasoline	
	Gallons per shift	Cost per gallon
Shovel	15	$0.14
Trucks (2)	10	.19
Washing plant	30	.14
Main pump	[1]16	.17
Return pump	15	.14

[1]Distillate.

The plant had a capacity of 200 cubic yards per day when it ran full time; however, delays due to break-downs and adjustments reduced the average to about 120 cubic yards per shift.

The daily cost was as follows:

Labor	$28.40
Gasoline and distillate	13.02
Trucking (oil, tires, and miscellaneous costs, excluding depreciation) at 8 cents per mile	4.80
Shovel, washing plant, and pump supplies and miscellaneous supplies	7.50
Supervision	10.00
Total	63.72

At 120 cubic yards per shift the unit operating cost was 54 cents. If the plant was operated at full capacity the cost would be 31 cents per cubic yard.

Morning Glory.- The Morning Glory Placers, Inc., operated on Upper Lynx Creek near Prescott, Ariz., in July 1932. The gravel, which was about 8 feet deep, was excavated by a 1-cubic-yard, gasoline, full-revolving, caterpillar-tread drag line and hauled in two 2-cubic-yard dump trucks about 1,600 feet to a washing plant. The capacity of the plant was expected to be 300 cubic yards in 8 hours. The contract price for excavating the gravel, delivering it to the washing plant, and cleaning up bedrock was 19 cents per cubic yard. The gravel was dumped through a 6-inch grizzly; about 5 percent of the material was discarded at this point. The gravel then went through a 4 1/4- by 14-foot trommel with 5/8-inch holes. Six hundred gallons of water per minute was used under a 50-pound-per-square-inch pressure in the trommel. About 50 percent of the material was discarded at the trommel and passed onto a stacker belt 15 feet long. The undersize went through two 12-inch boxes 45 feet long in parallel, having various types of riffles. The clean-up material was put through a pulsating jig to separate the gold. About 1,000 pounds of concentrate was obtained from 900 cubic yards of gravel. The jig concentrate was treated in a pan amalgamator.

The automobile engine to run the washing plant took 10 gallons of gasoline every 8 hours. The water was pumped with a 6-inch centrifugal pump run by another automobile engine. The water was reclaimed in a pond and recirculated. Insufficient work had been done to permit calculating the total operating costs.

Octave.- A plant was built in 1931 and run a short time at Octave, Ariz. The gravel was excavated by a power shovel with a 1-cubic-yard dipper and trucked to a 10-cubic-yard car on an inclined track. The car was pulled to a washing plant and dumped into a hopper.

Batches were fed into and washed in a large concrete mixer, then run through sluice boxes. The use of the concrete mixer for washing the gravel was novel.

Mystic[21] - The Mineral Leasing Co. of Rapid City, S. Dak., erected a washing plant with side-shaking sluices on Castle Creek at Mystic in the central Black Hills of South Dakota in 1932. The gravel which occurred in a side gulch was 30 feet thick and covered with a few feet of soil. It was excavated by a power shovel with a 1/3-cubic-yard dipper; the pay dirt was transported by motor truck to a treatment plant a short distance away on Castle Creek.

The gravel was dumped upon a screen with openings 7 inches square constructed of old boiler tubes. The material passing through this coarse screen dropped into a bin with a capacity of 5 cubic yards, from which it ran by gravity to a 22- by 34-inch reciprocating pan feeder and thence to a trommel. The latter was 6 feet in length, set at a slope of 1 inch to 1 foot, and ran at 21 r.p.m. It was composed of two concentric wire-mesh screens; the inner one was 2 feet in diameter with 1-inch square openings and the outer one was 42 inches in diameter and was made of screen cloth with 1/8- by 5/8-inch rectangular openings. Spray water for the screen was provided by a centrifugal pump. A 50-foot stacker belt raised the oversize from the screen to an elevated hopper whence it was drawn into a motor truck for transportation to a dump. The undersize from the revolving screen ran into a shaking sluice 48 inches wide, 52 inches long, and hung on a grade of 1 1/2 inches to the foot. The sluice was shaken sideways by an eccentric at the rate of 100 strokes per minute; the throw was 1 inch. Transverse riffles were used. The tailings from the shaking sluice ran through a fixed sluice 25 inches wide with a grade of 1 inch to 1 foot. The shaking sluice had not proved satisfactory at this plant due to the large proportion of black sand in the gravel and the high rate of feed, and it was proposed to discontinue its use and substitute fixed sluices and Wilfley tables. The material from the sluice ran into a tailings ditch beside Castle Creek.

The treatment plant was run by a tractor engine and the stacker belt by a separate gasoline engine. The plant had a reported capacity of 300 cubic yards per 10-hour day, and the cost per cubic yard was said to be about 25 cents.

Britten and Murphy.- Britten and Murphy mined gravel from a side gulch of Goler Gulch near Randsburg, Calif., in the summer of 1932.

The gravel was dug by a gasoline-power shovel and trucked uphill about 1,500 feet to a mill built on the hillside. The gravel was dumped over a 4 1/2-inch grizzly. The oversize of the grizzly fell down the steep hillside. The undersize passed through a 5-foot concrete-mixer shell run as a pebble-mill to wash the gravel. It then ran through a 3 1/2- by 12-foot trommel which made two screen products - minus 1/16 inch and plus 1/16 minus 1/2 inch. The coarser material ran through an iron sluice box with riffles and the finer product over a Deister-Overstrom table.

At the start water was purchased for $1 per 1,000 gallons. Tests indicated that a cubic yard of gravel after washing would retain 60 gallons of water. The novel feature in the plant was the use of a concrete-mixer shell as a washer ahead of the trommel.

Movable washing plants

Haag.- In June 1932 the Haag Mining Co. was mining placer gravel with a power shovel and washing it in a portable plant on Benson Gulch west of Randsburg, Calif., under very adverse conditions. The gravel was tight and clay-bound and contained a large proportion of boulders A part of the gravel was cemented so that it could not be dug with the shovel in use. The shovel was full-revolving and had a caterpillar tread and a 7/8-cubic-yard dipper. In the

21 Reported by F. C. Lincoln, South Dakota School of Mines, Rapid City, S. Dak.

part of the channel being worked the shovel could dig 200 to 300 cubic yards in two 8-hour shifts, which was far in excess of what the washing plant could handle. The shovel, including labor and supplies, was rented for $36 per 8-hour or $55 per 16-hour day. It used 40 gallons of gasoline in 8 hours when operating steadily.

The gravel was dumped on a grizzly with bars spaced 6 inches apart. The oversize was thrown to one side by hand. The undersize went into a hopper from which it was fed into a double trommel; the inner screen had 3/4-inch and the outside one 5/16-inch holes. All plus 3/4-inch material was taken from the trommel by a belt stacker to a dump. The minus 3/4- and plus 5/16-inch material passed separately through an 18-foot sluice 30 inches wide to catch nuggets that might be contained in the gravel. The tailings from the end of the sluice were discharged onto a main belt stacker by means of an auxiliary bucket elevator. The minus 5/16-inch material ran through a 40-foot sluice 30 inches wide on the other side of the machine. Both sluices were floored with solid-rubber matting with transverse riffles 3/8 inch wide and 1/2 inch deep, spaced 1/2 inch apart. The riffles were kept about one half full of quicksilver. On the coarse-gold side one 2-foot section had every other riffle cut out to accommodate any large particles of gold. The washing plant was self-contained. It was propelled by means of a tractor over which it was built, and the trommel and stacker were run from the tractor engine. Water was purchased from wells in the valley near Goler at $1 per 1,000 gallons and delivered through a pipe line into a tank above the workings. The water, after going through the plant, was impounded and pumped back for re-use. About 180 gallons of new water was used per cubic yard of material washed. This high consumption was due mainly to losses from the impounding pond and evaporation; probably not more than 60 gallons per cubic yard was held in the tailings. The washing plant had a capacity of about 100 cubic yards per 8 hours, but due to delays caused by break-downs and moving the yardage handled per shift was reduced to less than one-half of this quantity. The trommel did not disintegrate the gravel thoroughly, and 15 to 20 percent of the oversize discharge was cemented material that contained gold. Although the plant probably would have proved satisfactory in material easier to handle, it was not strong enough for the conditions at this place and had insufficient disintegrating capacity to free the gold thoroughly from the gravel.

One man was employed at the hopper, one at the pumps at the impounding dam, and two on the washer each shift. One man operated the shovel. The total operating cost of handling 100 cubic yards of gravel per day was $1.30 per cubic yard. (See table 5.) The segregated costs are as follows:

	Daily operating cost	Cost per cubic yard
Shovel hire (2 shifts)	$55.00	$0.55
Washing plant labor (8 shifts at $4)	32.00	.32
Gasoline for washer circulating pumps, 30 gallons at 20 cents	6.00	.06
Water, 180 gallons per cubic yard at $0.001	18.00	.18
Other supplies (estimated)	4.00	.04
Miscellaneous	10.00	.10
Supervision	5.00	.05
Total	130.00	1.30

Triangle.- The Triangle Gold Mining Co. was making a placer cut at Therma, N. Mex., in July 1932. The gravel was dug by a 1 1/4-cubic-yard, Diesel-driven power shovel with a 28-foot boom. The washing plant was mounted on skids and consisted of a trommel 6 feet long with 3/4-inch holes and a line of sluice boxes on a trestle. The boxes had a grade of 8 inches to 12 feet. As the trommel was moved up section lengths of boxes were put in. Six hundred gallons per minute or 53 miner's inches of water under a 30-pound head was used for washing the gravel. The oversize from the trommel was hauled away in two 2-ton trucks. As the cut was extended not enough grade was available to carry the sluice out of the cut for the disposal of tailings; difficulty was encountered in keeping the roadway open for hauling away the oversize material and providing drainage in the cut. The plant had not been operating long enough for operating costs to be estimated.

Holland.- In May and June 1932 the Gold Mining Co. used a dragline to mine a placer deposit near Holland, Oreg. The gravel was 25 to 30 feet deep, and the pay channel was 40 feet wide along a present stream course. The dragline, which had a 40-foot boom and a 1 3/4-yard bucket, stood on the edge of the bank at the face of the workings and loaded into a patented, movable washing plant on one side of the pit and on the original ground surface.

The gravel was dumped into a hopper on the washer. From the hopper it was fed onto a traveling chain grizzly with 3- by 5-inch holes. The oversize discharged onto a 30-inch, rubber belt conveyor that discharged onto a second belt conveyor which elevated the material 50 feet to a dump. A wooden beam placed over the first conveyor diverted all boulders over 10 inches in diameter through a chute back into the pit. The undersize from the first grizzly dropped to a second traveling grizzly with 7/8- by 1 1/2-inch openings. The oversize joined that from the first grizzly on the belt conveyor. The sands were run through sluice boxes. An area 5 by 10 feet under the grizzlies and 33 feet of sluice boxes was lined with brussels carpets held down by heavy wire screen with 3/4- by 3-inch openings. Most of the gold from the excavated material was caught in the space under the grizzly. The sluice consisted of two 30-inch boxes in parallel, for 12 feet, joined for 8 feet in one box 60 inches wide and separated again for an additional 10 feet.

In cleaning up, the carpets first were shaken in a tub which removed about 75 percent of the gold. Then they were placed in a regular cylindrical laundry machine where the remainder of the gold was washed out.

The plant was on skids and was moved up about 20 feet every other day by the dragline. The gravel was easily dug and readily washed. The dragline was said to have a capacity of 400 cubic yards per 8-hour shift, but the washing plant could handle only a part of this yardage. The gravel was cleaned readily by the sprays while on the traveling grizzly. Where the gravel, however, was tight or contained appreciable clay, as at many places, this type of washer would not be satisfactory.

The plant was run by two motors of 8 and 20 hp., respectively. One and four tenths gallons of gasoline was used per hour. Three men worked each shift on the plant and in the pit; one man operated the dragline.

The bedrock was hard and could not be cleaned by means of the dragline bucket. After all material that could be excavated by the dragline had been removed from a section of bedrock it was cleaned with a giant. A line of sluice boxes was maintained in the pit for washing the clean-up material. Previously the mine had been worked by giants; the equipment included two hydraulic elevators. Then the material from the sluice boxes in the pit was discharged into the intake of one of the hydraulic elevators and thence elevated 31 feet into a second sluice. The head of water on giant and elevator was 160 feet. The necessity for maintaining the sluice in the pit prevented dumping the gravel washed in the plant directly back into the excavation. Along one side of the pit a dry wall was built of the boulders chuted into the pit from the washer. Operations were said to be unprofitable.

mainly because it was difficult to dispose of the tailings and because it was necessary to keep the pit open and drained.

Fontana.- The Fontana Washington Gulch Mining Co. mined a cut 350 feet long and 40 feet wide on Washington Gulch near Deerlodge, Mont., in 1931. The gold was contained in 2 1/2 to 3 feet of gravel on a clay bedrock. The gravel was overlain by 2 feet of loam and 6 feet of old tailings from workings farther up the creek.

The gravel was first stripped by a 75-hp., gasoline-driven dragline with a 90-foot boom and a 1 1/4-cubic-yard Page bucket. The overburden was first piled on one side of the cut; then the dragline was taken into the pit and the pay gravel dug and loaded into a movable washing plant on the other side of the cut. The gravel after going through a 12-inch grizzly was fed into a 4- by 16-foot trommel with 3/4- by 1 7/8-inch rectangular holes. The oversize from the trommel was discharged into the pit by a 28-inch belt conveyor 25 feet long. The undersize was divided into two streams and run through two 24-inch steel boxes 30 feet long with Hungarian riffles. The sluices also discharged into the pit. A drainage trench was dug in the middle of the pit by the dragline and lagged over with slabs. The washing plant used 1,000 gallons per minute, or 88 miner's inches, of water. The pumping plant consisted of a 6-inch centrifugal pump and a 45-hp. gasoline engine. The water was pumped through an 8-inch pipe line, from which connection was made to the washing plant by a 6-inch hose. The plant could handle 350 cubic yards in 8 hours when running full time. The dragline required 38 gallons, the pump 18, and the trommel and stacker engine 3 gallons of gasoline per 8 hours. Seven men were employed. The dragline was brought out of the pit to move the washing plant. Cost data are not available.

Driskill.[22] - A portable washing plant was operated on Bear Creek in the northern Black Hills of South Dakota during 1931 and 1932 by the Driskill Mining Co. of Spearfish. A 1 1/4-cubic-yard gasoline shovel stripped the overburden, mined the pay dirt, and moved the treatment plant. The pay dirt was delivered by the shovel to a flat grizzly 6 feet square with 8-inch square openings consisting of mine rails placed across pieces of drill steel. The oversize was thrown off the grizzly by hand; the undersize fell into a hopper from which it was fed upon an 18-inch belt conveyor 30 feet long and inclined at an angle of 30°. The elevator was driven by a 4-cylinder automobile engine which also turned a trommel 30 inches in diameter and 8 feet long into which the elevator dropped its load. The trommel had 5/8-inch square openings and was fitted with a 2-inch central spray pipe. The oversize from the revolving screen ran through a chute to the waste dump; the undersize was delivered to a sluice 24 inches wide and 50 feet long which zigzagged back and forth beneath the screen. The sluice was divided through its center into two equal compartments and provided with a two-way gate at the top so that one compartment could be used while the other was being cleaned. Each side of the sluice was fitted with transverse riffles made of 2-inch iron bars held at 8-inch intervals by strap iron. For convenience in cleaning, each compartment had a side chute at the lower end through which the concentrates could be drawn into a barrel for further concentration in a Richards pulsator jig with 4- by 14-inch screen. The sluice tender changed compartments and cleaned up every half hour or so, depending upon the richness of the ground. The concentrates contained values not only in gold, which ranged in size from fine colors to nuggets, but also in cassiterite, tantalite-columbite, and scheelite.

The tailings from the sluice were collected in a settling box from which the sand was removed to a tailings stacker by means of a flight conveyor composed of a belt with 2-inch angle-iron bars fastened across it at 1-foot intervals. The tailings stacker was driven by a 3-hp. gasoline engine.

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22 Reported by F. C. Lincoln, South Dakota School of Mines, Rapid City, S. Dak.

The water supply for the washing plant was obtained from a sump in the creek below the plant into which the tailings water and the creek water ran. This water was pumped through a 3-inch pipe to the spray pipe by a rotary oil pump at the rate of 200 gallons per minute (18 miner's inches); the pump was belted to the power take-off of a 15-hp. tractor.

The plant was reported to have a capacity of about 300 cubic yards per 10-hour day. The operating cost was about $25 for wages, $10 for fuel, $5 for miscellaneous, and $20 for overhead - a total of $60 per day. The average daily yardage treated was not available for publication.

Overpeck.[23] - In June 1932 mining was begun by the Mines Royalty Co. on Spring Creek above Sheridan, S. Dak., where a movable washing plant had been installed. Operations ceased September 17. The gravel was 8 to 25 feet thick and was covered with 1 to 7 feet of soil. The gold occurred mainly as coarse, flat colors and small, flat nuggets concentrated upon and in bedrock. From 2 to 8 feet of the gravel above bedrock contained fine colors, and higher layers of gravel occasionally were auriferous. Bedrock was a decomposed schist which was easily dug. The overburden was removed by a gasoline-driven dragline with a 3/4-cubic-yard bucket. The machine was then converted into a shovel with a 1-cubic-yard dipper for mining the gold-bearing gravel and bedrock. The shovel was used to move the washing plant which was mounted on two log skids 27 feet long and 11 feet apart. In moving the plant a cable fastened to the back of the shovel was run back through a snatch block on the plant, thence to the head of the shovel where it was attached to the dipper by means of a loop. The dipper was moved forward to pull up the plant.

The gravel was dumped at the top of the plant on a grizzly with 6-inch spacings between the bars set on an inclination of 15°. The oversize was thrown from the grizzly by hand; the undersize was fed by means of a 20- by 36-inch reciprocating pan feeder to a 24-inch inclined belt 12 feet long set at an angle of 23°, which delivered the material to an 8-foot revolving screen. The trommel was set at an inclination of 1 inch to 1 foot and made 21 r.p.m. It consisted of two concentric wire-mesh screens, the inner one having a diameter of 3 feet and openings 1 inch square and the outer one a diameter of 52 inches and 1/8- by 5/8-inch openings. A spray pipe supplied water to the interior of the revolving screen, the water being pumped by a 3-inch centrifugal pump. The oversize from the screen dropped to an 18-inch stacker belt 14 feet long. The belt, however, was too short; experience at this plant indicated that the belt should have been at least 25 feet long to dispose properly of the oversize. The undersize from the screen went to a shaking sluice which was supported by four hangers and given a sidewise reciprecating motion by an eccentric. The sluice was inclined 1 1/2 inches to 1 foot and given a side shake of 1 inch 100 times per minute. It was 6 feet long and 56 inches wide and had 1-foot sides sloping outward at 30°. Upon the bottom of the sluice were six transverse wooden riffles 1 inch high and 9 inches apart. A satisfactory saving was not made in the sluice, probably because of the difficulty of keeping the plant level.

A 4-inch centrifugal pump removed seepage water from the bedrock; the tailings were pumped away by a 4-inch sand pump.

The crew consisted of 6 men, of whom 1 acted as boss. From the time operations began in June, to September 1, an average of about 40 cubic yards was handled per 10-hour shift. During 2 weeks in September about 300 cubic yards was handled each shift. The small yardage handled most of the time was due to delays in making alterations and repairs to the washing plant. The shovel had a possible capacity of 500 cubic yards per shift.

La Cholla.- The La Cholla Mining Co. began placer-mining operations in the summer of 1932 about 5 miles from Quartzsite, Ariz. The gravel was dug with a full-revolving, gasoline-

23 Reported by F. C. Lincoln, South Dakota School of Mines, Rapid City, S. Dak.

powered dragline equipped with caterpillar treads, an 85-foot boom, and a 2 1/2-cubic-yard bucket. The gravel was washed in a self-contained movable machine; the oversize was screened out, and the tailings were dewatered in a tank on the machine. The tailings with the oversize were sent to a dump by a belt stacker. Water was hauled by truck from Quartzsite and cost, at the mine, $1 per 1,000 gallons.

The gravel was excavated to a depth of 10 to 12 feet and was said to be gold-bearing for a width of 300 feet. Most of the wash was angular in shape. The gravel was dumped into a 15-cubic-yard hopper through a grizzly with 10-inch square openings. Very few oversize boulders had to be thrown off the grizzly. The dry gravel from the hopper was fed over a rail grizzly with 3-inch spacing by means of a shaking feeder. The oversize went onto a belt conveyor to a belt stacker, where it was elevated to the tailings pile. The minus 3-inch material was elevated 30 feet by a bucket elevator to the front end of the trommel. There the gravel was picked up by a jet of water issuing from a 5-inch nozzle under a 100-pound head and thrown violently against a baffle plate at the far end of the trommel to disintegrate all friable material. The trommel was 8 feet long and 5 1/2 feet in diameter, with 3/4-inch round, punched holes. The oversize from this screen joined the plus 3-inch material on the stacker belt. The undersize and water went over a sluice consisting of two parallel, 14-inch boxes 40 feet long. Riffles were made in sections, each consisting of four 2-inch pipes, 36 inches long, spaced about an inch apart and welded at the ends to 14-inch lengths of 2 1/2- by 2 1/2-inch angle iron. From the sluice the tailings went into a tank holding about 40 tons of water and 35 tons of gravel and sand. The tailings were removed from the tank by a drag, such as used in drag classifiers. The drag ran at a very low speed and was held a few inches off the bottom of the tank by rails to let any gold coming through the sluice settle on the bottom. The tailings were discharged on the stacker. The stacker belt was 24 inches wide and 85 feet long. It operated on a boom that could be swung through an arc of 180°. Up to the first of August 1932 the plant had not been run on regular production; 3,600 cubic yards (bank measure) had been treated in a trial run with a consumption of 23 1/2 gallons of water per cubic yard of gavel. The dewatered tailing (25 percent of the total material moved) contained 15 to 40 percent of moisture by weight, depending upon the quantity of sand and clay present.

The machine was moved on skids with the dragline acting as a tractor. About 1 1/2 hours was required to move it 100 feet and re-level it by means of wedges placed under the rollers. An average of 47 cubic yards per hour was handled during the trial run. Improvements were under way to increase the capacity.

If the installation could have operated full time at the rate of 50 cubic yards per hour the following operating costs would be indicated:

Excavating:		
Labor (1 man at $0.75 per hour and 1 man at $0.45 per hour)	$0.023	
Gasoline (7 gallons per hour at $0.17 per gallon)	.024	
Other supplies	.020	$0.067
Washing plant:		
Labor (3 men at $0.45 per hour)	.027	
Gasoline (7 1/2 gallons per hour at $0.17 per gallon)	.026	
Other supplies	.024	.077
Water at $0.001 per gallon (24 gallons per cubic yard)		.024
Miscellaneous (including major repairs)		.050
Supervision		.025
Total		0.243

The above cost does not include interest on the investment, amortization, and costs of remodeling plant. High remodeling costs would be expected on any new design of such a large and elaborate installation.

Bemrose.- The Buffalo Exploration Co. was washing gravel in a patented gold saver near Breckenridge, Colo., in June and July 1932. The gravel was about 14 feet deep, contained relatively few boulders, not much clay, and only a very small quantity of black sand; it was easily dug. Most of the gold was relatively coarse, although some fine gold was said to be recovered.

The gravel was excavated by a 60-hp., caterpillar-tread, gasoline shovel with a 5/8-cubic-yard dipper. It was dumped into a hopper in front of the washing machine, where boulders were picked out, then elevated by a 36-inch belt conveyor to a double trommel 14 feet long. The inside trommel was 36 inches in diameter; the first 4 feet was blank, and the lower 10 feet had 1 1/4-inch round holes. The gravel was disintegrated and washed in the blank section of this trommel by high-pressure sprays (160 pounds per square inch). The outside trommel was 48 inches in diameter and had 1/8-inch holes, except for the last foot which had slots 1/4 by 3/4 inch in size. The trommel oversize was stacked by a 36-inch belt conveyor. The material going through the slots went over riffles in a special 4-inch box to catch any nuggets that it might contain. The balance of the undersize from the trommel went to four bowl-shaped, centrifugal concentrators. The feed was delivered through pipes to the bottom of the bowls; the tailings were discharged over the rims. A series of corrugations or riffles on the inside of the bowls caught the gold. The bowls weighed 1,200 pounds each and were driven at 100 r.p.m. The four bowls were cleaned up at the end of each shift in about one-half hour. First they were run a few minutes with the feed cut off; then, after the power was turned off, a plug at the bottom was pulled, and the contents of the riffles were washed into a tub placed underneath. The tailings from the plant were run to waste through a flume when dump room was available at the machine; otherwise they were removed farther by means of a no. 5 sand pump. The washing plant ran on a track and was moved forward by the shovel. About 200 gallons of water was used per minute. It was brought to the machine through a pipe line under a 400-foot head.

The shovel had a capacity of about 40 cubic yards per hour and could deliver gravel faster than the plant could wash it. About 200 cubic yards was washed per day when the plant was operating; delays, however, were numerous; the machine had been practically redesigned and partly rebuilt after being placed on the ground. One man ran the shovel and two men, of whom one was the superintendent, ran the washing plant. On the basis of a 200-cubic-yard daily production, the labor cost, including superintendence, would be 7.5 cents per cubic yard. The shovel and washing plant each used 15 gallons of gasoline per 10-hour shift; at 22 cents per gallon the cost of fuel would be 3.3 cents per cubic yard. Other supplies would amount to 2.7 cents and current replacements to about 4 cents, making a total operating cost of 17.5 cents per cubic yard. If a rental of $36 per 10-hour shift was paid for the shovel the cost of excavation would be 18 cents per cubic yard; if the shovel was operating at full capacity, however, the cost would be 9 cents. Remodeling and construction costs, which are charged to amortization, apparently would be very high. The washing plant was said to have cost $25,000 to install.

Grand Hills.[24] - In June 1932 the Grand Hills Mining Co. erected a washing plant equipped with four centrifugal-bowl gold separators on French Creek 2 miles west of Custer, S. Dak. The gravel where the plant was erected was 5 to 8 feet deep and was covered with 5 to 8 feet of soil overburden. The gold particles were small but not greatly flattened, so they concentrated readily.

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24 Reported by F. C. Lincoln, South Dakota School of Mines, Rapid City, S. Dak

The gravel was excavated with a 1 1/4-cubic-yard, 110-hp., gasoline shovel with caterpillar tread, which also stripped the overburden and moved the treatment plant. The plant was mounted on two 4-wheel trucks running on a 7-foot gage track. The gravel was dumped onto a grizzly with a 45° slope and 10-inch spaces between bars, which was set above a 5- by 5-foot steel hopper; from there the gravel was fed by a 2- by 5-foot reciprocating pan feeder onto a belt elevator 24 inches wide and 40 feet long. The elevator transported the material to a semicircular hopper at the top of the treatment plant.

From the hopper the gravel went into a trommel 60 inches in diameter and 21 feet long. A spray pipe which extended through the center of the revolving screen for its entire length supplied all the water required by the treatment plant. The trommel had a grade of 1 1/2 inches in 1 foot and made 11 r.p.m. It consisted of a blank scrubbing section 4 feet long, an 8-foot section perforated with 1/4-inch round holes, a 4-foot section with 3/8-inch round holes, and a 2-foot section with 1/2- by 1-inch slots. The oversize material was delivered to a 30-inch stacker belt 45 feet long which piled it upon bedrock behind the plant. The undersize from the screen, except that from the slotted section, was divided into four parts and fed to four 36-inch, centrifugal-bowl gold separators like those used at the Queen and Bemrose placers previously described. The coarse gravel which passed the 1/2-inch slots in the revolving screen was concentrated in a nugget sluice 5 feet long, 6 inches wide, and 4 inches deep. This sluice was set at a grade of 2 inches to 1 foot and provided with transverse riffles 1 inch in height set 1 1/2 inches apart. The tailings from the bowls and the nugget sluice flowed into a 15-foot settling tank 28 inches wide and 24 inches deep with its rear end inclined upwards. A flight conveyor with 18- by 6-inch steel blades attached to chains at 20-inch intervals scraped the settled gravel up the incline of the settling tank and delivered it to the stacker belt. Sand, soil, and excess water were pumped by a 4-inch centrifugal pump from the settling tank into settling ponds behind the tailings piles.

The water supply for the treatment plant, consisting of 250 gallons per minute (22 miner's inches), was obtained from a sump in the creek bed. It was pumped into the spray pipe of the trommel by a 4-inch centrifugal pump driven by a 4-cylinder, 14-hp. gasoline engine. The pump and engine were mounted upon a steel frame provided with wheels. Of this supply only about 50 gallons per minute was fresh water from the creek; the other 200 gallons was returned to the sump through ditches connected with the tailings ponds.

The following engines were used on the washing plant:

	Hp.
1. Driving screen, sand drag, tailings pump, and four bowls	30
2. Driving tailings stacker	12
3. Driving belt feeder and pan feeder	14

The bowls were cleaned once a day and the nugget sluice twice a month. The concentrates were panned to recover the gold. Practically no gold was found when the settling tank was cleaned, and no gold had been found on panning the tailings, which indicated that the recovery was very high. The entire equipment cost about $40,000.

The water supply was sufficient for running the plant only one 10-hour shift per day. An average of 400 cubic yards was handled daily.[25]

The labor was as follows: 3 men on the washing plant at 30 cents per hour, 1 shovel operator at 60 cents per hour, and 1 superintendent at 60 cents per hour. The gasoline

25 Cost and operation data were supplied by C. E. Gish, manager, Grand Hills Mining Co., Denver, Colo.

consumption was 100 gallons per shift. The total operating cost per cubic yard was as follows:

	Cents
Labor (including supervision)	5 1/2
Gasoline	4
Miscellaneous repairs	3
Compensation insurance, depreciation, and miscellaneous expense	3 1/2
Total	16

Two months after starting the plant just described, the company installed a second on French Creek about 1 mile above the first. The second plant was essentially the same as the first, except that a 3/4-cubic-yard gasoline shovel was used in place of the one with a 1 1/4-cubic-yard dipper. There was little overburden at the second location, but the gravel contained a large proportion of boulders over 10 inches in diameter. The plant had a capacity of 50 to 75 cubic yards per hour with a gasoline consumption of about 10 gallons per hour. It was operated by four men with a part-time superintendent.

No operating data are available for this plant.

Gold Dust.- The Placer Syndicate operated the Gold Dust placer near Hillsboro, N. Mex., during part of 1932. The gravel was excavated by a 5/8-cubic-yard, gasoline-driven shovel with a 60-hp. engine and treated in a portable washing plant containing four 36-inch centrifugal-bowl gold separators. The plant was constructed of steel and mounted on four wheels that ran on wooden stringers. It was moved ahead by jacks. The gravel was dumped into a hopper from which it was carried by an inclined feeder belt to a trommel with three concentric screens. The inside screen was 2 feet 4 inches in diameter and had 2-inch round holes; the next screen was 3 feet 5 inches in diameter and had 3/4-inch round holes; the outer screen was 4 feet 4 inches in diameter and had slots 1/4 by 1 inch in size. A housing around the outer screen acted as a further scrubber. Water under 70 pounds pressure was used in the sprays. The trommel was 12 feet long and had a slope of 3/4 inch to 1 foot. The oversize from the trommel went onto a belt stacker. The undersize was divided and fed to the four centrifugal separators. The tailings from the bowls were elevated by a sand pump to a settling pond which also was used as a reservoir. Plans were made for putting a dewatering tank on the machine and discharging the sands on the stacker belt. The machine was driven by a 60-hp. gasoline engine. Water was pumped from a well by a 7-inch centrifugal pump run by a 50-hp. gasoline engine; the pump capacity was 400 gallons per minute.

At the time the authors visited the plant it was shut down and had not run long enough for operating costs to be indicated.

The crew consisted of 1 man on the power shovel, 1 man panning and testing the gravel, and 4 men on the washing plant. The engines on the shovel and plant each used 25 gallons and the one on the pump 21 gallons of gasoline per 8 hours. The capacity was expected to be about 1,000 cubic yards per three 8-hour shifts.

The following table gives the approximate cost of the machine and of equipping the mine.[26]

26 Data supplied by H. S. Coulter, general manager of the Placer Syndicate Mining Co., Hillsboro, N. Mex.

Item	Cost
Four bowl washing plant, f.o.b. Denver, Colo	$15,180.00
Dewatering equipment, f.o.b. Denver, Colo	1,550.00
Freight and trucking, washing and dewatering plants	700.00
Rebuilt 5/8-cubic-yard power shovel	6,500.00
Freight on shovel	300.00
Seven-inch water well pump, 400 gallons per minute capacity	700.00
Fifty-horsepower engine to run pump installed	750.00
Freight, trucking, and installing pump	150.00
Pipe, 6,000 feet of 4-inch, used	1,500.00
Hose, 100 feet of 4-inch, new	75.00
Drilling well	400.00
General camp buildings	1,000.00
Miscellaneous expenses and equipment	2,500.00
Total	31,305.00

Floating washing plants

Kumle.- During the summer of 1932 H. T. Kumle was operating a placer property near Oregon House, Calif. The gravel was about 15 feet deep along the course of a present stream. It was excavated by a standard 3/4-cubic-yard, full-revolving steam shovel with caterpillar treads. Coal at $14 per ton and a daily cost of $11.40 was used for fuel. The shovel worked in 3 feet of water and dumped the gravel directly into a washing plant floating in a pond maintained for the purpose. The draft of the plant was 2 feet. A rise of 6 inches in the water level would drown the shovel, and operations would have to cease until the water level went down. The shovel discharged the gravel onto the upper ends of a grizzly 12 feet long with one-half inch between bars. The grizzly had a slope of 6 3/4 inches in 12 feet, which was to be increased. High-pressure sprays washed the oversize to the bottom of the grizzly and onto a 30-inch rubber belt 40 feet long which stacked it in tailings piles to 12 feet above water level. The undersize was divided into two parts and ran through boxes 27 inches wide and 30 feet long on either side of the float. Standard dredge-type Hungarian riffles were used in the boxes. Quicksilver was used in the riffles; a quicksilver trap was installed 6 feet from the end of each sluice. The method of operation was patterned after dredging practice. The washing plant floated on two wooden barges with a well between. It was moved by two headlines and a tail line by means of hand capstans. The sands were discharged into the pond at the rear of the float. The backwash would occasionally ground the plant, but it was easily pulled clear. Water for the sprays was supplied by a 7-inch centrifugal pump run at slow speed. The pump and conveyor belt were run by a 36-hp. truck engine. About 9 gallons of gasoline and 1 quart of oil were used per shift.

One 9-hour shift was worked per day. The average running time was 7 1/2 hours. The crew consisted of 3 men - 1 engineer at $4.50 per day and 1 fireman at $4.00 on the steam shovel and 1 man on the washing plant at $4.00 per day. The plant operator spent most of his time at the grizzly. About 250 cubic yards was being washed per day.

The steam-shovel expense per cubic yard was 3 cents for labor and 5 cents for fuel. The cost of washing was 2 cents for labor and 1 cent for fuel. The general expense, including replacements on the shovel and repairs on the washing plant, would be about 5 cents per cubic yard. With supervision at 2 cents, the total operating cost would be about 18 cents per cubic yard.

The washing plant was built at a cost of $1,200; with the exception of the elevator belt, second-hand material was used. Built of new material the cost would have been about $2,500. New timber cost $25 per 1,000 feet.

An unusual feature of the installation was the fact that the gravel was dug from under water with an ordinary steam-shovel dipper. Usually where this practice had been tried too much gold had been lost to make the enterprise profitable. At this plant, the dipper after being loaded was held or swung along the bank to be mined next until all the water had drained out. The bedrock was soft, and from 6 to 18 inches was taken up by the shovel after each cut. It was considered that very little gold was lost in the pit.

Sumpter.- Hofford and Johnson began placer operations in 1932 alongside an old dredged area on the Powder River near Sumpter, Oreg. The gravel had not been dredged originally because bedrock was too high. An unsuccessful attempt had been made later to work the ground with a light-draft dredge using standard washing and gold-saving equipment but substituting a suction pipe with a special agitating device for a digging ladder. The enterprise failed because the capacity of the plant was too low and because the gravel was too tight to be dredged successfully with the equipment used. This second dredge had been acquired by Hofford and Johnson for a washing plant; the digging device had been removed. The gravel was excavated for 5 feet below and 8 feet above water level with a 1-cubic-yard, full-revolving, caterpillar-tread, 75-hp. dragline working on top of the bank. The washing plant had a draft of 3 feet. A standard Page dipper was used for digging and a hoe-type trench digger for cleaning bedrock, which consisted of a layer of clay on volcanic ash. The plant was moved and held in place by head and tail lines operating from a power winch. The gravel was dumped into a hopper built on the plant at the end of the trommel. The trommel was 4 by 24 feet and had 1/2-inch round holes. A standard belt stacker was used for disposing of the oversize. Standard dredging practice was followed in saving the gold. The tables were 30 inches wide and had a total area of 900 square feet. Riffles were 1 1/4 by 1 inch in size and spaced 1 inch apart. Water was supplied by one 8-inch, low-pressure and two 4-inch, high-pressure pumps. A total of 2,000 gallons per minute was used. Electric power for operating the washing plant was generated by a 200-hp. Diesel engine. An excess of electric power was available as the principal demand for power on the suction dredge had been for the suction excavator. The present boat required 80 hp. which cost over 3 cents per kilowatt-hour. The shovel used 40 gallons of gasoline, costing 24 cents per gallon, per 8 hours.

Two 8-hour shifts were worked. Two men were employed on the shovel and two on the boat each shift. Supervision was furnished by the shovel operator on day shift. The plant had a capacity of 400 cubic yards per 8 hours, but due to time lost in cleaning up and making repairs an average of about 40 cubic yards per hour was handled during most of the first season.

Labor on the shovel cost 2 1/2 cents, gasoline 3 cents, and other supplies 1 cent, making a digging cost of 6 1/2 cents per cubic yard. The labor cost for two men on the boat was 2 cents per cubic yard for washing. About 1 1/2 kw.-hr. was used for each cubic yard of gravel washed; at 3 cents per kilowatt-hour the power cost would be 5 1/2 cents. Other supplies cost about 1 cent, making a total washing cost of 8 1/2 cents. Miscellaneous costs, such as trucking and insurance, were estimated at 2 1/2 cents per cubic yard, making a total operating cost of 17 1/2 cents.

Summary of Operations at Mines Using Teams or Power Equipment

At the time of writing none of the strictly placer operations in the Western States using mechanical excavators had operated long enough to get all the "kinks" straightened out of the lay-outs. Usually lower costs can be expected with improved practice. Operating costs range from $0.16 to $1.50 per cubic yard and on the whole are higher for this type of mining than for hydraulicking, ground sluicing, or dredging. The average combined yardage handled daily by all of these plants is less than that of one dredge. Moreover, the total quantity handled is insignificant compared to the total yardage dredged.

It should be borne in mind that the operating costs shown in table 5 and indicated in the foregoing descriptions are not the total costs of mining the gravel. Alterations to plants and major replacements of machinery have been charged to capital account and are not included herein. Amortization in some of the operations may equal or even exceed the strictly operating expense. For example, an operating cost for excavation of 4.4 to 10 cents per cubic yard is shown at some of the plants where the gravel is dug by power shovels or draglines. If depreciation of the machine, interest on the investment, and major repairs, or, in lieu, fair rental of the excavators, are included the total excavating cost would sometimes be more than double that indicated.

Ordinary sluices with riffles were used satisfactorily at most of the mines using mechanical methods for excavating the gravels. At three plants, side-shaking boxes were used to increase the capacity of the plant per unit of water available. At one, the side-shaking sluice apparently did not afford a satisfactory recovery of the gold, probably due to the difficulty of keeping the movable plant level on which it was used.

Standard concentrating tables were used at four places for treating screened products containing large proportions of black sands.

A patented, bowl-shaped, centrifugal gold saver was used at five plants described. A number of other plants had been equipped with this type of gold saver, but no operating data concerning these were available. Other types of patented gold savers were seen, but either operations had not been started or had ceased.

DREDGING

General

This paper does not propose to discuss gold dredging in detail, since other publications of the Bureau of Mines[27] have covered the subject adequately and are still up-to-date enough to serve as valuable references. However, an attempt will be made to show the present status of gold dredging in the United States, to discuss any noteworthy trends in design or operation, and to show the cost of dredging under present conditions. (1932)

As stated before, only tracts of placer ground large enough to justify the necessary investment are suitable for dredging. Moreover, the physical conditions of the deposit and the character of the gravel and bedrock must be favorable for successful dredging. Enough water must be available to float the dredge and wash the gravel. The material dredged must be tight enough to hold water in the dredge pond. The most successful dredging operations have been applied to valley deposits.

Status of the Dredging Industry

The production of gold by dredging in the United States and Alaska, by States, and the number of dredges in operation from 1896 to 1932 are shown in the first paper of this series.[28] In 1932 about 27 dredges were in operation in the United States (excluding Alaska).

27 Jennings, Hennen, The History and Development of Gold Dredging in Montana: Bull. 121, Bureau of Mines, 1916, 62 pp.
Janin, Charles, Gold Dredging in the United States: Bull. 127, Bureau of Mines, 1918, 226 pp.
Ash, S. H., Safety Practices in California Gold Dredging: Bull. 352, Bureau of Mines, 1932, 31 pp.

28 Gardner, E. D., and Johnson, C. H., Placer Mining in the Western United States: Part I. - General, Hand Mining, and Ground Sluicing: Inf. Circ. 6786, Bureau of Mines, 1934, table 2, p. 10.

Their total capacity was approximately 4,250,000 cubic yards per month; about 90 percent was dredged in California. Since 1922 the average annual recovery by dredges in California has ranged from 8 to 10.7 cents per cubic yard.

The present low cost of labor and supplies has prolonged dredging operations in some fields and encouraged the opening of new ones. Several new dredges have started in relatively small fields in recent years; for example, in the Rogue River area near Grants Pass, Oreg.; the Warren district in central Idaho; and the Steel district near Silver City, Idaho. However, modern dredging technique does not differ enough from that of 15 to 20 years ago to hold much hope for a revival of dredging in lower-grade gravels or under more difficult conditions; with the exhaustion of the Yuba and American River fields in California a decided falling off in total dredge production is likely. In 1929 it was reported that the Natomas Co., principal operator on the American River, had 10 years of life ahead of it in that field.[29] The Marysville field, on the Yuba River, now has only three boats, which probably will last less than 5 years.[30]

Tables 9 to 13 give the essential data on all dredges active in the United States in 1932.

Discussion of Modern Dredges

The average depth of gravel worked is 35 feet. The deepest dredging is done in the Yuba River fields above Marysville where one dredge in 1931 averaged 74 feet including the height of the bank above water level. One of the boats there can dig 82 feet below water.[31]

The bucket-ladder dredge is the only type that has been successful for placer mining in this country and until recently, at least, anywhere. The suction dredge, with or without cutter attachments, has failed repeatedly, although for river and harbor work it has proved of value, as evidenced by the recent construction of a huge hydraulic dredge for Panama Canal service, which has a capacity of 500 to 1,000 cubic yards per hour and can dredge "the hardest materials" to a depth of 60 feet.[32] Notwithstanding past failures, attempts to use the suction-type dredge for placer mining are still made occasionally. In 1928 several such boats were being built for service in the Malaysian tin fields. Some of the objectionable features of the hydraulic dredge are its relatively low power efficiency as a result of the volume of water that must be raised, the problem of moving oversize boulders or sunken logs, the variation in the table feed which is extremely erratic even when compared to that of a bucket dredge, and the often serious effects of pumping the heavily mud-laden water from the bottom of the pond over the tables.

About half of the boats now in commission, comprising mostly the smaller ones, have wooden hulls; the others have steel hulls. The life of a wooden hull is usually stated as 10 years. That this figure can be exceeded is shown by the story of the Feather River no. 1 dredge.[33] This boat was built in 1906 and operated practically without a shut-down until 1929, when the machinery was transferred to a steel hull, now in use south of Oroville by the Shasta Butte Gold Dredging Co.

29 Engineering and Mining Journal, vol. 127, Mar. 3, 1929, p. 458.

30 Since the price of gold has been changed from $20.67 to $35 per ounce low-grade gravels in the dredging fields that could not hitherto be handled can be worked at a profit. The change in the price of gold probably will extend the life of the dredging areas.

31 A new dredge being built in February 1934 in the Yuba River field (The Mining Journal, Arizona, Feb. 28, 1934, p. 19) is reported to have a digging depth of 110 feet and an estimated capacity of 15,000 cubic yards per day.

32 Engineering and Contracting, Twenty-four-inch Diesel Electric Hydraulic Dredge, Las Cruces: Vol. 68, January 1929, pp. 37-38.

33 Young, G. J., California Gold Dredge in Operation over Twenty Years: Eng. and Min. Jour., vol. 123, June 25, 1927, pp. 1042-1046.

TABLE 9.- Dredges in operation in United States in 1932 and depth and nature of gravel dredged

Dredges					Nature of gravel dredged			
Owner	Location	Dredge no.	Type	Bucket size, cu.ft.	Depth dredged, feet: Minimum	Maximum	Average	Remarks
Capital Dredging Co.	Folsom, Calif.	1	Stacker	8 1/2	15	30		
Do.	do.	2	do.	8 1/2	15	30		
Do.	do.	3	do.	18				
La Grange Gold Dredging Co.	La Grange, Calif.	2	do.	10	12	42	30	Loose; 5 percent boulders over 1 foot; almost no clay.
Lancha Plana Gold Dredging Co.	Camanche, Calif.		do.	6	20		40	Medium tight; 20 percent clay and loam.
Natomas Co.	Natoma, Calif.	2	do.	8 1/2	28	34	30	
Do.	do.	4	do.	15	23	35	28	
Do.	do.	5	do.	11	41	55	50	
Do.	do.	7	do.	9	30	46	36	
Do.	do.	8	do.	15	48	62	58	
Do.	do.	10	do.	15	46	57	51	
Placer Development, Ltd. [1]	Lewiston, Calif.		do.	7	10	45	35	Loose; few boulders over 1 foot; little clay.
Shasta Butte Gold Dredging Co.	Oroville, Calif.		do.	7 1/2				Fair digging; some clay and some hard gravel.
Snelling Gold Dredging Co.	Snelling, Calif.		do.	6 1/2	9	26	15	Easy-washing gravel; few boulders over 1 foot.
Trinity Dredging Co.	Lewiston, Calif.		Flume.	11		40	25	
Yuba Consolidated Gold Fields	Hammonton, Calif.	14	Stacker	14			54	
Do.	do.	15	do.	14			58	
Do.	do.	19	do.	14			74	
Do.	La Grange, Calif.	Merced unit.	do.	9	12	35	22	
Continental Dredging Co.	Breckenridge, Colo.		do.	7				Some boulders; some clay.
American Gold Dredging Co.	Murphy, Idaho		do.	2 1/2			15	No boulders or clay.
Crooked River Mining Co.	Idaho City, Idaho		do.	3		26	20	Some boulders over 1 foot.
Idaho Gold Dredging Co.	Warren, Idaho		do.	3 1/2			20	
Empire Gold Dredging & Mining Co.	Prairie City, Oreg.		do.	5		36	24	
Rogue River Gold Co.	Rogue River, Oreg.		do.	7	5	50		Hard digging; many boulders.
Superior Dredging Co.	Bridgeport, Oreg.		do.	7 1/2	20	40		Loose; few boulders; very little clay.

1 Formerly Lewiston Dredging Co.

TABLE 10.- Data on hulls, spuds, and digging ladders of dredges operating in the United States, 1932

Dredge	Hull					Number of spuds	Digging ladder		
	Material	Length, feet	Width, feet	Depth, feet	Draft, feet		Maximum digging depth below water, feet	Size of buckets, cu. ft.	Number of buckets in line
Capitol no. 3	Steel						70	18	
La Grange no. 2		104	44 1/2	9 1/2		2	30	10	60
Lancha Plana	Wood	98 1/2	41	7	5	2	54	6	82
Natomas no. 2	do.						35	8 1/2	78
Natomas no. 4	Steel						40	15	67
Natomas no. 5	Wood						60	11	101
Natomas no. 7	Steel						60	9	98
Natomas no. 8	do.						60	15	83
Natomas no. 10	do.						60	15	83
Placer Development	Wood	100	43	9	8	2	38	7	72
Shasta Butte	Steel					[1]2	411/2	7 1/2	73
Snelling	do.					[2]1		6 1/2	
Trinity	Wood	107	48	7 1/3	6	2		11	[3]42
Yuba no. 14							79	14	
Yuba no. 15							82	14	
Yuba no. 19							69	14	
Continental	Wood	133	40	10	8		65	7	95
American	do.	80	40		3 1/2 to 4	[4]1	18	2 1/2	46
Crooked River	do.	70	30		5	None	35	3	65
Idaho	do.			7	5	2	32	3 1/2	75
Empire	do.		40		5	[5]1	36	6	77
Rogue River	do.	100	50	9		[2]1	30	7	70

1 Spuds not used; digging on headlines.
2 Single spud on center line of hull.
3 Open-connected bucket line.
4 One of original two removed to reduce weight.
5 Built with two spuds, but only one used.

TABLE 11.- Washing and gold-saving plants on dredges in operation in 1932

Dredge	Screens						Gold-saving plants					
	Length, feet	Diameter, feet	Pitch, in. per ft.	Speed, r.p.m.	Diameter of holes, inches		Approximate total table area, sq. ft.	Slope of tables, in. per ft.	Size of riffles, inches			Water pumped on dredge, gal. per min.
					Upper part	Lower part			Depth	Width	Distance apart	
La Grange	36 1/2	6	1 1/2	11	1/2	5/8	2,000	1 1/4	1 1/4	1 1/4	1 1/4	7,500
Lancha Plana	33	6	1 3/8	9	7/16	1	2,000	1 3/8	1 1/4	1	1	3,500
Natomas no. 8	...	...	...	...	...	...	5,000	...	1 1/4	1 1/4	1 1/4	...
Placer Development	30 1/2	6	2	...	3/8	1/2	...	1 1/2	1 1/4	1 1/4	1 1/4	6,200
Shasta Butte	30	6	...	...	3/8	3/8	1,300	...	1 1/4	1 1/4	[1]1	...
Snelling	23	6	...	...	3/8	1/2	...	...	1	1 1/4	1	...
Trinity	15	5	...	...	6 to 10	...	[2]360	3/4	3	2	2	7,500
Yuba no. 14	35	9	...	...	3/8	3/8	9,000	...	...	...	...	...
Continental	40	6	...	15	3/8	1/2	1,300	1 1/2	1 1/4	1 1/4	1 1/8	4,700
American	30	4 2/3	...	...	3/8	3/8	1,000	1	1 1/4	1 1/4	...	...
Crooked River	25	4 1/2	...	13	3/8	3/8	870	...	...	...	...	4,000
Idaho	18	5	...	11	3/8	3/8	[3]510	1 1/2	...	...	...	...
Empire	36	6	...	...	1/4	5/8	1,300	...	1 1/4	1 1/4	1 1/4	...
Rogue River	40	6	...	...	3/8	[4]1 1/4 by 2 1/2	...	Various	1 1/4	1 1/4	...	...

[1]Being increased to 1 1/4-inch spacing.
[2]90 feet of 4-foot-sluice, lined with angle-iron riffles.
[3]Being increased to 2,000.
[4]Also two sections with intermediate size openings.

TABLE 12.- Monthly yardages, power, labor, wage scales, and miscellaneous operating data on dredges operating in 1932

Dredges	Average monthly yardage[1]	Average daily dredging time: Hrs.	Average daily dredging time: Min.	Number of man-shifts per day	Man-hours per cubic yard	Wage scales: Winchmen	Wage scales: Oilers	Wage scales: Shoremen	Total connected power on dredge, hp.	Kilowatt-hours per cubic yard dredged
La Grange	217,000	20	40			$5.20	$4.20	$3.60	[2]500	0.80
Lancha Plana	63,500	18	45	11	0.042	6.00	5.00	5.00	420	1.88
Natoma:										
No. 2	152,000	20	40							
No. 4	271,000	20	29							
No. 5	147,000	18	32							
No. 7	177,000	20	32							
No. 8	237,000	20	25							
No. 10	259,000	20	27							
Total	1,244,000	20	11							
Placer Development	100,000	20	40	15	.036	5.50	4.25		370	
Shasta Butte	130,000	18	00	12	.024	6.00	5.50	5.50	[3]440	
Trinity	100,000	20	30	13	.031	5.00	4.50	4.00	400	1.5
Yuba nos. 14, 15, and 19	[4]900,000	21	25						850	
Yuba-Merced	200,000	21	40	18	.021					1.5
Continental	122,000	20	00	14	.027	[5]4.00	[5]3.60	[5]3.20	400	1.1
American	50,000	20	00	9	.039	5.00	4.00		[6]130	.7
Crooked River	60,000	20	00	10	.040	5.00	4.00	2.50	[7]170	
Idaho	75,000	22	00	12	.038	5.00	3.75		[8]180	
Empire	75,000	20	30	13	.042				295	
Fogue River	120,000	22	00	16	.032					

[1]The following are the average monthly yardages (estimated in part) of the known operating dredges not included in this table:

Capital, nos. 1, 2, and 3 650,000
Snelling 150,000
Superior 90,000

[2]Usual demand charge 425 hp.
[3]Usual demand charge 400 hp.
[4]Totrl monthly yardage of 3 boats, 1931.
[5]Excluding bunus.
[6]Usual demend charge 100 hp.
[7]Diesel engine.
[8]Steam engines.

TABLE 13.- Dredging costs per cubic yard of dredges operating in 1932

Dredges	Labor			Power	Supplies			Supervision	General	Taxes and insurance	Prospecting and sampling	Deferred capital charges	Total	Remarks
	Operation	Repair	Total		Operation	Repair	Total							
La Grange	...	...	$0.0162	$0.0071	...	...	$0.0099	$0.0022	$0.0019	$0.0012	Excluded	Excluded	$0.0385	Fiscal year 1931-32.
Lancha Plana	$0.0286	$0.0052	.0338	.0199	$0.0058	$0.0359	.0417	.0172	.0114	.0045	do.	$0.0181	.1466	Costs given are for dredging 732,000 yards in 1930. In 1931 762,000 yards was dredged at a cost of $0.0994 per yard.
Natomas no. 2	.0121	.0038	.0159	.0131	.0036	.0136	.0172	(1/)	.0065	Excluded	do.	Excluded	.0527	All Natomas costs are for year 1931; approximately
Natomas no. 4	.0079	.0026	.0105	.0103	.0030	.0102	.0132	(1/)	.0037	do.	do.	do.	.0377	half of the operating supply cost is chargeable to
Natomas no. 5	.0133	.0063	.0196	.0154	.0066	.0249	.0315	(1/)	.0067	do.	do.	do.	.0732	the cost of water.
Natomas no. 7	.0114	.0042	.0156	.0139	.0044	.0137	.0181	(1/)	.0054	do.	do.	do.	.0530	
Natomas no. 8	.0103	.0033	.0136	.0144	.0051	.0142	.0193	(1/)	.0046	do.	do.	do.	.0519	
Natomas no. 10	.0085	.0025	.0110	.0132	.0031	.0136	.0167	(1/)	.0040	do.	do.	do.	.0449	
Average	.0101	.0035	.0136	.0132	.0041	.0143	.0184	(1/)	.0049	do.	do.	do.	.0501	
Placer Development	...	...	.0255	.0137	...	...	.0325	.0033	.0003	.0044	do.	do.	.0797	Costs given for 1929. In 1931 the cost from Apr. 1 to Oct. 1 was $0.0652 per yard.
Shasta Butte	.014	.005	.019	.010	...	...	.008	(1/)	.009	(1/)	$0.008	.008	.062	Approximate cost, first half of 1932.
Trinity	...	...	...	...	...	...	...	...	...	...	...	...	.0604	Cost for 1931, excluding only depreciation and depletion.
Yuba nos. 14, 15, and 19, average	...	...	...	...	...	...	...	...	...	...	...	...	.0408	For year ending Feb. 29, 1932, excluding taxes, insurance, and administrative expense.
Continental	...	...	.0195	.0189	.0039	.0145	.0184	.0026	.0043	.0024	.0013	Excluded	.0673	Cost for 1,340,000 yards in 11 months of 1930, excluding interest, depreciation, and royalty.
American	...	...	.04	.01	...	...	...	...	...	...	...	...	.07	Approximate cost in 1932.
Idaho	...	...	.045	.015	...	...	.040	(2/)	(2/)	Excluded	Excluded	Excluded	.100	Estimated cost in 1932. Power cost represents cost of wood fuel.
Empire	...	...	...	...	...	...	...	...	...	...	...	...	.0625	Total cost in 1932, including approximately $0.01 for depreciation. See Eng. and Min. Jour., vol. 128, Nov. 9, 1929, p. 737, for 1929 cost.

1 Included in General.
2 Included in Labor.

One feature of modern design and operation is a tendency to use only one spud or to work entirely on the lines. The new steel boat of the Snelling Gold Dredging Co., on the Merced River, has only one spud which is placed on the center line at the stern. This necessitates placing the stacker off center and using a rock chute to transfer the screen oversize to one side of the spud onto the belt; however, advantages in the design of the stern of the hull, as well as in operation, led to the adoption of the single spud. Many other boats are using only one of their two spuds and moving up on their lines. Considerable time is thus saved, but one objection is the possible difficulty of keeping the boat precisely on line and of securing just the desired advance while moving forward by using the shore lines. This might be a particular handicap when the bank is under water. The dredge of the Crooked River Mining Co., Idaho, has no spuds but moves and digs entirely on its shore lines.

Estabrook dredge

Although the Estabrook dredge in Trinity County, Calif., was dismantled recently, the following data on it are given because this dredge was the largest built in the country, and few large new dredges have been built since its time for which details are available.[34] It was built on the Trinity River, Calif., some 40 or 50 miles over mountain road from the railroad. It was 152 feet long, 68 feet wide plus 6 feet of overhanging deck on either side, and 13 feet deep, requiring about 1,000,000 board-feet of lumber, of which most was cut locally. The digging ladder, 125 feet long, carried eighty-three 20-foot buckets, weighing 5,650 pounds each. This line was driven through double gears by a 500-hp. motor. The screen was 9 by 54 feet and was driven by a single roller. Single-deck tables had an area of 4,400 square feet. The stacker carried a 44-inch belt 140 feet long, was arranged to swing 15° to either side of the center line, and was balanced by ballast tanks alongside the hull. The two 70-foot steel spuds were 3 feet 4 inches by 5 feet 4 inches in section. The dredge was designed to dig 400,000 to 450,000 cubic yards per month and to dig to a depth of 40 feet. After operating intermittently from 1920 to 1927, the boat was shut down and dismantled.

Fairbanks Exploration dredges

The Fairbanks Exploration Co., Fairbanks, Alaska, is working several modern dredges successfully under adverse conditions. As this operation has not been described previously, a brief description of it by H. W. Rice, vice president of the United States Smelting, Refining & Mining Co., is given here, although Alaskan placer-mining practice in general is not included in this paper.

The Fairbanks Exploration Co., a subsidiary of the United States Smelting, Refining & Mining Co., operates 5 dredges in the Fairbanks district of Alaska. Of these 3 are on Goldstream Creek about 14 miles from Fairbanks and 2 are on Cleary Creek about 25 miles from Fairbanks.

Gold was first discovered in the Fairbanks area in 1903. The greatest concentration of values was found in ancient stream beds covered with considerable gravel and muck. The gold in the gravel is principally on or near bedrock and may penetrate the latter to a depth of 5 feet where it consists of blocky schist. The gravel contains few boulders over 1 foot in diameter and very little clay. The gold-bearing areas were worked by drift-mining methods; later some areas were worked by opencut methods. The dredges handle ground that was too low in grade to be worked profitably by the earlier methods and some previously worked areas.

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34 Peake, H. G., Largest Capacity Gold-Mining Dredge in the World: Eng. and Min. Jour., vol. 109, May 15, 1920, pp. 1106-1109.

The gold-bearing gravel not only is frozen but also is covered with a layer of frozen overburden which in places is 120 feet thick. As this overburden must be removed and the gravel artificially thawed before dredging can be done, it is necessary to start operations years in advance of the actual dredging. The areas were prospected thoroughly, using Keystone drills, and open holes were drilled except in locally thawed spots where it was necessary to use casing. The dredge areas were laid out and the starting point for each dredge was determined from the prospect data.

Active work on the project was started in 1924; actual construction began in 1925. The construction included a steam power plant, a transmission line, a 90-mile ditch, dredges, and the necessary shops, bunkhouses, and miscellaneous items. The offices, power plant, and shops are at Fairbanks, the northern terminus of the Alaska Railway. The power-plant equipment includes two 1,000-hp. Stirling boilers with chain-grate stokers, two 3,750-kilovolt-ampere, 4,000-volt, General Electric turbo-alternators, one 625-kilovolt-ampere, 4,000-volt General Electric turbo-alternator, and necessary accessories. Lignite obtained from the Healy River district about 115 miles by rail from Fairbanks is used for fuel. Current is transmitted at 33,000 volts to the two dredge areas and carried onto the dredges at 2,200 volts.

The first step in ground preparation is the removal of the overburden which consists largely of frozen silt with a top covering of moss or tundra. This frozen silt, or "muck" as it is termed locally, usually contains 60 to 70 percent of ice by volume and considerable organic matter. Shallow muck is thawed in place and handled by the dredges. Deep muck is stripped off as completely as practicable, depending largely upon drainage conditions. The first step in stripping is to remove the covering blanket of moss by means of hydraulic giants and high-pressure water, thereby exposing the muck to the sun. Thawing of the muck then proceeds rapidly so long as a blanket of thawed material is not allowed to accumulate on the surface; to prevent such accumulation the surface is washed off from time to time with high-pressure water. As the hydraulic gradient of the local creeks is low, considerable water is necessary to transport the solids in the muck from the dredging area. This water could be obtained only at a distance.

The Davidson ditch, which furnishes water for the stripping operation, has a capacity of about 5,000 miner's inches and is about 90 miles long. The ditch line includes 15 steel siphons 46 to 54 inches in diameter aggregating about 6 miles in length and a 4,000-foot tunnel. Water is taken from the Chatanika River just below the junction of Faith and McManus Creeks and is delivered to the dredging areas on Cleary and Goldstream Creeks at a working pressure of 80 to 160 pounds per square inch, depending upon the location. Practically all of this water is used for stripping.

Frozen gravel is thawed by the Miles cold-water process which has been described by Janin[35] and Wimmler.[36] The practice at Fairbanks follows the general procedure outlined in these bulletins, although the equipment and procedure have been greatly improved through experience and research. The thawing season is from about May 10 until about September 20. Gravel less than about 35 feet in depth is thawed with driven points on 16-foot centers and at greater depths with points set in holes drilled on 32-foot centers. Thawing on 16-foot centers is completed in about one-half a season; thawing on 32-foot centers requires from one to two seasons. Most of the water used for thawing is circulated by pumps. So far as possible a reserve of thawed ground equal to at least one season's dredging is kept ahead of each dredge. No difficulty has been experienced with freezing of artificially thawed ground

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35 Janin, Charles, Recent Progress in the Thawing of Frozen Gravel in Placer Mining: Tech. Paper 309, Bureau of Mines, 1922, 34 pp.

36 Wimmler, Norman L., Placer-Mining Methods and Costs in Alaska: Bull. 259, Bureau of Mines, 1927, 236 pp.

except for a seasonal freeze-back at the surface of not more than 7 or 8 feet which thaws naturally early in the summer season.

The dredges are of all-steel construction; they were designed by company engineers, fabricated by a ship-building concern of San Francisco, and erected in the field by the company The design follows conventional lines but embodies certain special features to meet conditions existing in northern latitudes. The dredges are housed and heated; both the stacker and ladder are heated.

The more important data concerning these dredges are given in table 14. The dredging season starts early in April, the winter ice being cut and removed from the pond to facilitate an early start. The average operating season is about 210 days, and the maximum to date for any one dredge has been 270 days during which time the minimum temperature was minus 37° F. Excessive ice formation in the pond is the principal cause of the shut-down at the end of the season; a continuous temperature of 10° to 15° F. below zero, or several days of 30° to 35° below zero, causes ice to form too rapidly for operation.

Hungarian riffles are used on the gold-saving tables with quicksilver traps at the head ends and coco matting and expanded metal at the lower ends of the transverse tables. Practically all of the gold will pass 8-mesh, but a few nuggets up to an ounce in weight have been found. The dredges are cleaned up at about 2-week intervals; the amalgam and black-sand concentrates are taken to the gold room at Fairbanks where the amalgam is cleaned and the black-sand concentrates are treated to recover fine and rusty gold that did not amalgamate. These sands contain no platinum metals nor, except for gold, other metals or minerals of commercial value. The clean amalgam is retorted and melted in a single operation using graphite crucibles and a specially designed combination retort and melting furnace. The resulting bars after assay are shipped to the mint.

The following figures for 1931 give an idea of the magnitude of this operation. Stripping for the season totaled 7,011,000 cubic yards, averaging 52,000 cubic yards per working day. Thawing totaled 8,133,000 cubic yards, or 64,000 cubic yards per working day. The dredges handled 6,916,000 cubic yards of material, or 30,800 cubic yards per working day, part of which was muck that was too shallow to strip or remained after stripping.

General Operating Practice

No marked changes in operating practice have been made in the United States in recent years, and the general statements made by Janin as regards depth of cut, speed of swing, bucket speed, and distance stepped ahead still hold true. It is common practice to take a light cut and to swing fast. Small boats normally are stepped ahead 4 or 5 feet and large boats 6 or 7 feet. The average width of a single cut is about 125 feet, and usually two or three cuts are carried abreast.

Dredging time per 24 hours is the chief measure of operating efficiency, indicating both the success of the boat as a dredging machine and the competency of its operators. This factor has not been improved much recently, apparently having reached its maximum in the first 10 or 15 years of dredging in this country. Winston and Janin[37] present figures to show that the average operating time of the dredges in California about 1908 was only slightly more than 18 hours per day. By 1914 the average of Californian boats was about 20 hours.[38] In 1931 the average operating time of all dredges in California was about 20 1/2 hours; the same average also applies to all dredges in other States during the year.

37 Winston, W. B., and Janin, Charles, Gold Dredging in California: Bull. 57, Calif. State Min. Bur., 1910, pp. 100-103.

38 Janin, Charles, Gold Dredging in the United States: Bull. 127, Bureau of Mines, 1918, p. 128.

TABLE 14.- Data on dredges of Fairbanks Exporation Co., Fairbanks, Alaska

Dredge no.	2	3	5	6	8
Location	Goldstream Creek	leary Creek	Cleary Creek	Goldstream Creek	Goldstream Creek.
Type	Stacker	Stacker	Stacker	Stacker	Stacker.
Gravel:					
Average depth material dredged [1]	45.2	46.5	33.5	22.3	18.9.
Condition	Frozen	Frozen	Frozen	Frozen	Frozen.
Hull:					
Length, feet	128	148	108	108	99.
Width, do.	60	60	60.	60	50.
Height, do.	12	12	9	9	10 1/2.
Draft, do.	9 1/12	8 11/12	6 5/6	6 5/12	7 3/4.
Spuds:					
Number	2	2	2	2	2.
Location	Stern	Stern	Stern	Stern	Stern.
Digging ladder:					
Depth dug, total, feet	64	78	53	53	44.
Depth dug under water, do.	48	60	36	36	28.
Buckets:					
Number in line	93	104	78	78	68.
Size, cubic feet	10	10	6	6	6.
How connected	Close	Close	Close	Close	Close.
Trommel:					
Length, feet, inches	44, 7 1/2	44, 7 1/2	43, 1/2	43, 1/2	36, 2 1/2.
Diameter, feet	8	8	6	6	6.
Pitch, inches per foot	1 5/8	1 5/8	1 5/8	1 5/8	1 5/8.
Speed, r.p.m.	6.74	6.74	8.9	8.9	8.9.
Diameter of holes:					
Upper part (round), inch	3/8, 1/2, and 5/8	3/8, 1/2, and 5/8	3/8, 1/2, and 5/8	3/8, 1/2, and 5/8	3/8, 1/2, and 5/8.
Lower part (slotted), do.	7/8 by 1 1/2 and 1 1/8 by 1 3/4.	7/8 by 1 1/2 and 1 1/8 by 1 3/4.	7/8 by 1 1/2 and 1 1/8 by 1 3/4.	7/8 by 1 1/2 and 1 1/8 by 1 3/4.	7/8 by 1 1/2 and 1 1/8 by 1 3/4.
Tables:					
Total area, sq. ft.	4,535	4,535	2,125	2,125	1,460.
Slope:					
Transverse tables, in. per ft.	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4.
Longitudinal tables, do.	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8.
Riffles:					
Type	Hungarian	Hungarian	Hungarian	Hungarian	Hungarian.

[1] Figures for 1931 season

TABLE 14.- Data on dredges of Fairbanks Exploration Co., Fairbanks, Alaska - Continued

Dredge no.	2	3	5	6	8
Pumps:					
Number	3	3	2	2	2.
High pressure:					
Size ... inches	14	14	12	12	10.
Pressure ... lb. per sq. in.	27	27	25	25	22.
Water pumped ... gal. per min.	5,500	5,500	4,000	4,000	4,000.
Low pressure:					
Size ... inches	14	14	12	12	10.
Pressure ... lb. per sq. in.	14	14	14	14	11.
Water pumped ... gal. per min.	5,500	5,500	4,000	4,000	3,000.
Hopper:					
Size ... inches	6	6			
Pressure ... lb. per sq. in.	27	27			
Water pumped ... gal. per min.	1,000	1,000			
Power:					
Kind	Electric	Electric	Electric	Electric	Electric.
Motors:					
Digging ... hp.	250	250	150	150	150.
Screen ... do.	75	75	60	60	40.
Swing winch ... do.	40	40	25	25	25.
Stacker ... do.	50	50	25	25	25.
High-pressure pump ... do.	150	150	100	100	75.
Low-pressure pump ... do.	75	75	60	60	40.
Hopper pump ... do.	40	40			
Fire pump ... do.	25	25	25	25	25.
Miscellaneous motors (3) ... do.	44	44	44	44	44.
Total ... do.	749	749	489	489	424.
Average load ... do.	640	640	360	260	260.
Maximum 3 minute peak [1] ... do.	925	925	455	360	470.
Cuts:					
Width of each cut ... feet	120 to 190	150 to 230	100 to 180	90 to 170	70 to 100.
Number of cuts	2 to 4	2 to 3	2 to 7	2 to 5	2 to 3.
Average total width of advance ... feet	471	549	445	395	310.
Total distance stepped up	1,482	3,061	2,302	3,634	5,057.
Method of moving up	Spud	Spud	Spud	Spud	Spud.
Number of operating days [1]	204	224	226	225	243.
Number of shifts per day	3	3	3	3	3.
Average yards per day [1]	5,800	8,770	5,990	5,600	5,040.

1 Figures for 1931 season.

Screening

The feature of dredge design and operation that is of most interest in other types of placer mining where the gravel is washed mechanically is the screening, washing, and gold-saving plant. An attempt has therefore been made to gather detailed information on the subject.

Although horizontal shaking screens formerly were used to some extent in this country and still are used by some foreign dredge builders, cylindrical revolving trommels are used universally in the United States for washing and screening. These range from 4 1/2 to 9 feet in diameter and from 20 to 40 feet in length. The screen plates are of rolled steel or cast-manganese steel, punched or drilled with holes 3/8 to 5/8 inch in diameter. It is common practice to use two sizes with the smaller holes in the upper portion of the trommel to distribute the load to the tables better. One dredge in Oregon is using a trommel having four sizes of holes with satisfactory results. The uppermost section is punched with 3/8-inch round holes. The second section is punched with ablong holes or slots 3/8 inch wide and 1 1/8 inches long. The third and fourth sections are punched similarly with oblong holes 3/4 inch by 1 1/2 inches and 1 1/4 by 2 1/2 inches, respectively. As shown in table 14, holes of five different sizes are used on the dredges of the Fairbanks Exploration Co. The slots are arranged so as to parallel roughly the movement of the gravel over the screen and are tapered to an outside diameter one eighth inch greater than the inside one. The last feature is practically universal practice in dredging and is effective in reducing the blinding of screens.

The function of a dredge trommel is as much to disintegrate as to screen, except in rare instances of very free-washing, loose gravel. Hence, high-pressure internal sprays are used with water under 25 to 50 pounds pressure per square inch. Lifter bars are used to raise and agitate the bed of gravel; the lifter bars, however, are too small and the speed too low to cause appreciable cascading.

Gold saving

Riffled tables are used to save gold on the dredges in the Western States; at the Natomas Co.'s operations Neill jigs are used as auxiliary traps for the fine and rusty particles of gold that do not amalgamate readily. Excepting the Natomas practice and the two flume-type boats in Trinity County, Calif., the standard and only gold saver is a single or double bank of tables 1,000 to 9,000 square feet in area and covered with transverse riffles. In addition to riffles, an amalgam trap is used at the head ends and a section of expanded metal over coco matting at the lower ends of the transverse tables of the boats of the Fairbanks Exploration Co. The tables on dredges are set on grades of 1 inch to 1 1/2 inches per foot. The so-called Yuba-type riffle, or modifications of it, is used on most stacker-type dredges. The riffles consist of wooden cross strips 1 1/4 by 1 1/4 inches in cross section, capped by strap iron and spaced 1 1/4 inches apart. One modification consists of the substitution of angle irons welded into sections of convenient size and approximating the dimensions of the wooden riffles. Dredge riffles were discussed in more detail under Sluice Boxes and Riffles in a previous paper.[39]

The sluices of flume-type boats commonly are set on grades of 1/2 or 3/4 inch per foot and paved with riffles of 2- to 3-inch angle iron.

39 Gardner, E. D., and Johnson, C. H., Placer Mining in the Western United States: Part II. - Hydraulicking, Treatment of Placer Concentrates, and Marketing of Gold: Inf. Circ. 6787, Bureau of Mines, 1934, 89 pp.

Quicksilver is always used on the tables and in the sluices. Clean-ups are made at regular periods of a week or 10 days; dredging then ceases, and advantage is taken of the opportunity to perform routine repair work.

Dredging recovery

The question of the percentage of recovery of the total gold content in the gravel dredged is still unsettled. Estimates by experienced dredge operators range from 60 to 90 percent. The first point of loss is under water where depressions in bedrock may be missed, gold may be retained in crevices in hard bedrock, or gold-bearing gravel may be left by unskillful operation. Moreover, the action of the buckets and occasional caving of the bank may throw some gravel and gold back beyond reach of the bucket line. The solids in the water near the bottom of a dredge pond may increase the density of the water sufficiently to hinder settling greatly, thus permitting gold to be carried away from the digging face in suspension. Some material drops from the buckets, not all of which is caught by the save-all sluice. Some gold is not washed free in the trommel but adheres to clay lumps or boulders which are discharged onto the stackers. Moreover, occasionally a nugget too large to go through the screen is carried through to the tailings pile. Some further loss occurs on the tables, as not all of the fine gold, especially if rusty, is caught in the riffles. All of these losses, except those of nuggets, can virtually be eliminated by suitable regulation of operations, but only in the sluices can any tests be made that will indicate what the losses are and show how successfully they are reduced by changed conditions.

Thurman[40] states that the short sluices of the early dredges were responsible for much loss of gold, as tests by the Natomas Co. showed that at least 90 feet of sluice length was necessary for a nearly perfect recovery. His statement that the modern dredge is capable of making a 99 percent saving, however, must be doubted.

Smith[41] presents an excellent summary of the many factors responsible for dredging losses. Among the unfavorable physical characteristics of the placer deposit itself he lists clay; heavy soil overburden; hard or rough bedrock; and fine, flaky, or rusty gold. The clay strata, according to Smith, seldom contain gold but often are overlain by rich streaks so closely associated that the digging action may knead the clay and gold-bearing strata into a mixture which is not broken apart in the screen or on the tables. A thick clay or soil overburden may muddy the water so as to lower the efficiency of the gold-saving sluices. He also states that a number of dredge operating features likewise may cause loss of gold, such as failure to clean bottom properly between adjacent cuts, thus leaving unseen submerged ridges of the best "pay dirt" over 5 to 10 percent of the total bedrock area; an uneven feed, varying grade, quickly fouled or floured quicksilver, and careless clean-up of the tables; insufficient water supply due to the lowered efficiency of the pumps after long service; and various human factors such as the lack of attention to the tables and screen by a crew primarily concerned with yardage. Tests were made on a number of dredges in the Oroville and Natoma fields, apparently by taking large samples of the tail stream. Assuming that the gravel that passed over the tables was 50 percent of that dug and that 1 cubic yard loose was equivalent to 3/4 cubic yard in place, 2 dredges lost 15 percent of the gold in the table feed and 1 lost 30 percent. Another dredge, in the Oroville field, lost 6.8 cents per cubic yard. Samples were taken of the sand pile behind a sunken dredge in the Natoma field which

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40 Thurman, C. H. Possibilities of Dredging in the Oroville District, Calif.: Min. and Sci. Press, vol. 118, Feb. 22, 1919, pp. 257-258.

41 Smith, R. G., The Discrepancy Between Drilling and Dredging Results: Eng. and Min. Jour., vol. 112, Nov. 19, 1921, pp. 812-815.

indicated a loss of 3.9 cents per cubic yard, or 31 percent. One dredge digging entirely in old dredge tailings recovered 2 1/2 to 4 cents per cubic yard (recalculated to original bank measure) due to an estimated loss by the first dredge of 18 to 25 percent. In view of the above data Smith concludes gold saving on dredges holds more hope for improvement by study than the technique of sampling and valuing dredging ground.

Bellinger[42] states that by cleaning up a sluice line from distributor to tail sluice, section by section, and plotting the amounts of gold recovered along a horizontal axis a close estimate can be made of the total gold fed to the sluice and the amount lost. The additional work in this "sampling" process devolves chiefly on the retort house where it is necessary to clean up and retort many small batches of concentrates. There should be little delay in actual dredge operation. The results of a series of such tests should be of great value to any dredge operator.

Dredge sluices unquestionably are the most efficient gold-saving devices known in placer mining, partly because they treat a screened product but chiefly because they are closely adapted to conditions. They work under severe space limitations imposed by the size of the boat, and the grades of the sluices vary 1 or 2 percent because of raising or lowering the heavy digging ladder. As a rule all of the tables of a dredge are set on a uniform grade. An interesting exception to the rule is on the boat previously referred to where the trommel produces four sizes of sluice feed. The grade of each sluice is set to give the best results on its particular size of gravel, all grades being relatively steep as compared with usual dredge practice.

Water Consumption

The amount of water and the spray pressure used in dredging are of interest but seldom are known from actual measurement. The total water used on stacker dredges ranges from 3,000 to 15,000 gallons per minute, depending on the size of the boat and the easy-washing, tight, or clayey nature of the gravel. If high-pressure streams are needed to wash the buckets at the upper tumbler 25 to 50 percent more water is used than otherwise. Pressures corresponding to heads of 60 to 90 feet usually are maintained on the spray nozzles. In more than a dozen dredges, including several cited by Janin,[43] the water consumption on the boats ranged from 1,400 to 2,800 gallons per cubic yard dredged and averaged 1,900, equivalent to a duty of about 9 cubic yards per miner's inch. This excepts two flume-type boats on which the pumps furnished 3,600 and 4,800 gallons, respectively, per cubic yard dredged. According to Janin, a stacker dredge usually discards over half of the volume of material dug, hence the quantity of water used per unit of gravel passed over the tables is much greater than these figures imply.

The quantity of water required to maintain a dredge pond situated above the natural water level depends upon the porosity of the ground. At the Lancha Plana dredge it was noted that 2,000 gallons per minute, or roughly 180 miner's inches of water, was needed for this purpose. This quantity lies well within the range of 100 to 300 inches given by Janin. Likewise the Trinity Dredging Co. near Lewiston, Calif., has to pump about 2,000 gallons per minute to maintain the dredge pond at the desired level.

Power

Only 2 of the 25 or more dredges operating in the Western States in 1932 used other than electric power. (See table 12.) One of these was the steam dredge of the Idaho Gold Dredg-

42 Bellinger, B. W., Dredge-Sluice Efficiency: Eng. and Min. Jour., vol. 132, Nov. 9, 1931, pp. 403-4.
43 Janin, Charles, Gold Dredging in the United States: Bull. 127, Bureau of Mines, 1918, pp. 130-132.

ing Co., at Warren, Idaho. It was powered by two 90-hp. boilers. One 90-hp. engine drove the digging ladder and winch. Another operated the screen, stacker, and all pumps. Electric lights and small auxiliary electrical equipment were provided for by a 15-kilowatt generator. The owners expressed satisfaction with their power plant. Its choice doubtless was indicated by the remote locality and plentiful supply of firewood. The dredge used an average of 3 1/2 cords of dry lodgepole pine per day which cost $5 per cord delivered to the bank. This included a year-round daily average of one-half cord used in the auxiliary heating boiler. A liberal estimate of the cost of power for this boat was 1.5 cents per cubic yard. That the power plant functions well was indicated by a reported average dredging time of 22 hours per day.

The dredge of the Crooked River Mining Co. near Idaho City, Idaho, was equipped with a diesel power plant. This was reported to have two serious disadvantages: (1) Excessive vibration, which led to high repair costs on the dredge, and (2) fouling of the dredge pond with oil, which was believed to have an adverse effect on gold recovery.

Cost of Dredging

Cost figures collected by the authors for 1931 represent about 75 percent of California's yardage and 50 percent of that of other States, or slightly more than 70 percent of the total. The average cost, on a yardage basis, excluding taxes, insurance, and capital charges, for the sake of uniformity, was approximately 5.1 cents per cubic yard for all States. The cost for the Californian dredges was 4.9 cents. The range was from 4 to 12 cents per cubic yard. (See table 13.)

The above figures, based on an annual yardage of about 36,000,000, may be compared with 1914 costs as given by Janin.[44] Costs in that year, based on a yardage of about 70,000,000 for which data were available and excluding taxes, insurance, and capital charges, ranged from 2.65 to 5.3 cents and averaged 4.2 cents. Wages in 1914 were lower than the 1931 Californian wage scale, winchmen receiving $4 to $5, oilers $3 to $3.50, and shoremen and helpers $2.50 to $3.50 per 8-hour shift. In 1932 wages were being reduced by some of the large companies.

Cost of dredges

Few entirely new dredges have been built in the United States in recent years. There appears to be a large reserve of old but serviceable dredge machinery not in use as a result of the decline in the number of boats in operation. The following communication from L. D. Hopfield[45] is nevertheless of value in stating a range of costs for new boats:

> Dredges are built in various sizes from 2 1/2 to 18 cubic feet of bucket capacity and designed to dig from 12 to 80 feet below water level. The cost ranges from $50,000 to $500,000, depending on the capacity and design.
>
> A dredge with 6 1/2-cubic-foot bucket capacity recently built in California, with steel hull and wooden superstructure, designed to dig 25 feet below water level, cost approximately $140,000. A 10-cubic-foot capacity dredge designed to dig 40 feet below water level costs from $250,000 to $275,000. A 15- or 18-cubic-foot capacity dredge that will dig 60 to 80 feet below water level is estimated to cost between $450,000 and $500,000. These figures do not include the cost of

44 Janin, Charles, work cited, pp. 157-179.

45 Department manager, Natomas Co., Natoma, Calif.

land, camp buildings, roads, or freight. Smaller dredges than the ones mentioned will cost less, according to their size.

A 200-ton steel hull for a 7 1/2-cubic-foot capacity dredge cost $19,000 in about 1929. The 9-cubic-foot, flume-type Madrona dredge, in Trinity County, Calif., was reported to cost $150,000, being made partly from salvaged material.[46] In 1928 the dredge of the Empire Gold Dredging & Mining Co., after working 12 years on the John Day River, in Oregon, was dismantled and rebuilt at a new site 14 miles upstream.[47] It was a stacker-type electric dredge, with seventy-seven 6-cubic-foot buckets and capable of digging 30 feet below water. The machinery was hauled in 5-ton trucks at a cost of $2.25 per ton, or a total cost of $1,200. A new hull, sheathed with 4-inch fir, cost $12,000. The total cost of dismantling, moving, and rebuilding was $32,000.

Resoiling

So far as is known no dredge is resoiling its ground in the United States at present, although much money has been spent in experimentation involving the resoiling of considerable areas. Von Bernewitz[48] states that in 1919 Natomas boats had dredged and resoiled about 250 acres each and that the land appeared to be left in good condition. The equipment necessary was said to involve 2 cobble stackers, 2 pebble stackers, and 2 long, double tail sluices. The extra cost of operation, in addition to the considerable capital cost, comprised extra power for the stackers and the pay of one extra attendant.

It is noted that a large dredge built in this country and recently operating in Japan[49] was equipped to resoil its ground, obviously a necessity when dredging agricultural land in such a thickly populated country. The extra labor, if any, was no serious drawback there, as the dredge company employed 120 men for the operation of this boat, the average wage being 40 cents per day; 30 men were employed on the dredge alone in three shifts of 10 men, and 10 bankmen were employed on day shift. The resoiling equipment on this boat included two stackers with double chutes at their ends, sand wheels, and sand pumps. The resoiled area was said to lie at first about 3 feet above its former level, but soon it subsided to nearly its original level. The resoiling operation was said to be largely automatic.

Accident Prevention

The work of a dredge crew, involving the handling of large boulders, heavy cables, buckets, blocks, and other mechanical parts of the dredge, is done in an environment that requires constant alertness on the part of the men if accidents are to be avoided. However, Ash states:[50]

> As in many other industries of the country, considerable safety work has been done, and at present the gold dredges of this State are among the most adequately guarded types of mechanical equipment.

The provision and maintenance of the best-known physical safeguards against injury to the workmen and the strict enforcement of suitable safety rules will eliminate most accidents

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46 Engineering and Mining Journal, vol. 124, July 9, 1927, p. 62.

47 Engineering and Mining Journal, vol. 128, Nov. 9, 1929, pp. 736-737.

48 von Bernewitz, M. W., Dredging and Resoiling: Min. and Sci. Press, vol. 118, Apr. 5, 1919, p. 471.

49 Little, H. S., Japanese Gold-Dredging Enterprise: Eng. and Min. Jour., vol. 130, Nov. 24, 1930, pp. 513-514.

50 Ash, S. H., Safety Practices in California Gold Dredging: Bull. 352, Bureau of Mines, 1932, p. 1.

even in this naturally hazardous occupation. The bulletin cited gives details of accident-prevention methods in the Californian industry.

DRIFT MINING

General

Drift mining in the United States has been applied chiefly to the exploitation of buried Tertiary river channels in the foothills of the Sierra Nevada in California. It has also been applied extensively, although on a smaller scale, to the mining of rich streaks on or near bedrock in more recent gravels where pay dirt is covered with a thick mantle of unproductive material. Ground may also be drifted where there is insufficient grade or water for hydraulicking or where conditions are unsatisfactory for dredging. Bedrock under rivers has also been drifted where it was impracticable to divert the stream; however, loose gravel containing a large quantity of water cannot be mined successfully by drifting. Usually the method is one of last resort and can be applied only to rich gravel. Even under favorable conditions 6 feet of gravel on bedrock generally must average at least $2.50 per ton to be mined profitably by drifting. Ground that has been drifted by the oldtimers with limited capital has been worked by other methods later; in these instances the overburden carried enough gold to pay for mining on a large scale.

In the latter part of the nineteenth century many large and productive drift mines were operated in California; according to Hill,[51] 11 million dllars in gold was produced in California by this method from 1900 to 1928, inclusive. In the summer of 1932, however, there were no large-scale operations in the United States, and the production of gold by this method was relatively unimportant. Two well-equipped properties, Vallecito Western and Calaveras Central, were doing development work but no regular breasting.[52] The washing plants were used when enough gravel had accumulated to run the plant most of a shift. A few men were employed at a number of old properties in an endeavor to find new deposits of gravel. At a few other old mines lessees were taking out a very limited tonnage from around old workings. Throughout the western placer districts small operations were under way, but relatively little systematic breasting was being done.

Most of the present drift mines are operated through shafts, although in the past some large and productive mines were worked by adits. In many districts large quantities of water must be pumped.

In mining, the gravel is either drilled and blasted or picked by hand to break it down, then it is shoveled into cars and trammed to the surface or to the hoisting shaft. At the surface the gravel is sluiced or put through a washing plant to recover the gold. The gravel from most drift mines requires mechanical methods of washing to disintegrate it and free the gold.

Milling practices bear no direct relation to mining methods at drift mines and are treated separately in this paper.

51 Hill, J. M., Historial Summary of Gold, Silver, Copper, Lead, and Zinc Produced in California, 1848 to 1926: Econ. Paper 3, Bureau of Mines, 1929, 22 pp.

52 "Breasting" is the term used in drift mining to designate the mining of the gravel; it corresponds to "stoping" as used in lode mining.

Development

General development

The general development plan of a drift mine usually resembles that of a lode mine where similar flat-lying deposits are exploited. Lateral development and the blocking out of the pay gravel are modified to fit local conditions.

Bench deposits or old channels exposed by later erosion or covered by only moderate depths of overburden may be opened and mined through adits. Ventilation shafts, however, may be required in extensive workings.

Deeply buried deposits must, of course, be mined through shafts. This form of entry also is used for mining relatively shallow deposits where adits are not practicable. Occasionally long drain tunnels will be run and the gravel mined through a series of shafts sunk along the course of the pay gravel. Moreover, shafts may prove more economical for mining shallow deposits where their use obviates long underground trams. Conversely, adits may be run for drainage and to work gravels which have been developed through shafts.

Some of the ancient channels are buried as much as 500 feet deep by later gravel and lava flows or beds of volcanic ash. The gravel is hoisted through a central shaft; one or more auxiliary shafts usually are required for ventilation. A buried gravel deposit generally is prospected by a drift along the course of the channel and crosscuts from the drift to either rim. Raises also are occasionally put up to prospect for possible rich strata above. As stated elsewhere, the buried Tertiary channels of the Sierra Nevada are not related to the present stream system; competent geological advice is needed to plot their probable course and aid in their development.

Adits should be run at such a horizon or shafts sunk deep enough to insure drainage in the workings. Drifts generally are run upstream on bedrock to allow drainage to the shaft or out of the entrance adit. Where water is not a serious item drifts may be run both ways from a crosscut or a shaft; any water from the downstream branch is pumped into the drainage system. The breasting is done upgrade by retreating toward the shaft or crosscut. At drift mines in the frozen gravels of Alaska the common practice is to drift in both directions from a shaft.

Ideal conditions, of course, would be an even bedrock and a grade sufficient to allow drainage but not too steep for easy tramming; such conditions, however, seldom exist. A prospecting drift may be run partly in bedrock to avoid swinging it from trough to rim and back again so as to keep a practical grade for tramming. With a rapid rise of bedrock, however, as where a waterfall or rapids existed in the original stream, the drift has to be run entirely in bedrock with raises put up to prospect the gravel above or the drift continued on a higher level with a transfer point at the break. This, of course, increases the cost of handling the material. If the size of the deposit as shown by the development work justifies the initial expense, tramming drifts may be run on an even grade in bedrock and the gravel from breasting operations above dropped into raises from which it can be drawn into cars. Then the development drifts and crosscuts are used for extracting the gravel.

Sometimes drifts at different levels are run from the shafts to mine deposits at these horizons. More than one channel may be worked from the same shaft.

In shallow deposits little or no mechanical equipment may be used except for hoisting; in small-scale work hoisting also may be done by hand. The development and mining of deeply buried channels require expensive installations and usually must be done on a moderately large scale. Hoisting and pumping equipment and air compressors such as those used for lode mining are required for mining this type of deposit, as well as air drills and mechanical haulage equipment.

Shafts.- Shafts seldom have over three compartments; in small-scale work one compartment usually suffices. Untimbered shallow shafts may be as small as 2 by 5 feet, the minimum section in which a man can dig.

Sinking practices are similar to those at lode mines except that blasting is seldom done; the gravel is loosened by picking or moiling. The shaft lining usually consists of lagging back of standard framed-timber sets.[54]

Considerable water may have to be handled in sinking deep shafts in gravel, in which case ample pumping capacity is needed. Ordinary sinking pumps usually are employed. Steffa[55] has described the sinking of a 2-compartment shaft at Vallecito, Calif., in which a novel method of handling the water was used; other sinking practices at this mine, however, conformed to the general practice. He states:

> The shaft of the Vallecito Western was located at a point 50 feet north of the actual channel in order that the shaft station, at a depth of 153 feet below the collar, might be in the solid slate bedrock. At the point selected the shaft passed through 143 feet of volcanic cobble, ash, and sand and gravel before reaching the slate. It was sunk a total depth of 167 feet, providing a 14-foot sump below the station.
>
> The shaft is 4 feet by 7 1/2 feet in the clear and has one 4- by 4 1/2-foot skip compartment and a 2 1/2- by 4-foot manway. It is timbered with 8- by 8-inch Douglas fir, excepting that 6- by 8-inch material was used for dividers, and is lined with 1- by 12-inch boards.
>
> The shaft was sunk to bedrock without blasting, picks and gads being sufficient to loosen the material for shoveling. The 24 feet through rock was sunk by hand drilling, using 10 to 12 holes per round, light charges of powder, and electric delay detonators.
>
> A 12-inch churn-drill hole was sunk first at one end of the shaft to handle the flow of water which was struck at a depth of 8 feet and amounted to about 35 gallons per minute throughout the work. The hole was sunk to a depth of 187 feet and cased with perforated 7-inch inside diameter stove-pipe casing. A deep-well type of turbine pump was installed which was powered with a 20-hp. vertical electric motor, the motor resting on staging about 4 feet above the shaft collar. Three-foot lengths of pump column were used, and as the shaft deepened from day to day enough blocking was removed from under the motor support to keep the pump intake at the level of the bottom of the shaft. When blasting, during the latter part of the work, the casing and pump column, exposed in one end of the shaft, were protected from damage by a heavy plank hung from the bottom end plate directly in front of the drill hole.
>
> Numerous strata of sand and volcanic ash were encountered, one such bed at a depth of 70 feet being 7 feet thick. A large part of this fine material was carried to the surface by the pump. A test showed that at one time the pump discharge was one-third sand by volume. The pump impellers wore rapidly, three sets being used. Moreover, the drill hole rapidly filled with sand to the level of the pump, after which the pump could not be lowered farther. Twice the pump was removed and the hole cleaned with a sand pump. Finally, at a depth of 75 feet, this difficulty was remedied by cutting a slot in the casing pump. As the shaft

54 Gardner, E. D., and Johnson, J. F., Shaft-Sinking Practices and Costs: Bull. 357, Bureau of Mines, 1932, pp. 48-60.

55 Steffa, Don, Gold Mining and Milling Methods and Costs at the Vallecito Western Drift Mine, Angels Camp, Calif.: Inf. Circ. 6612, Bureau of Mines, 1932, p. 7.

deepened the slot was likewise cut down. To secure suction with a shallow sump, such as could be dug out easily by hand in this manner, a 4-inch strainer was substituted for the original 3-foot one. The pump was run continuously and regulated by the gate valve on the discharge pipe to the exact amount of water flowing into the small sump.

It required 90 days to complete the shaft. The average progress in sinking, including timbering, was slightly less than 1 foot per shift, working two 8-hour shifts per day. The cost was $39.50 per foot. Shaftmen and the foreman received $6 per day and engineers $5. Timber and lumber laid down at the shaft cost $42 per thousand board-feet.

Drifts and crosscuts.- As used in this paper, a "drift" designates a development working parallel to the major axis of the deposit; a "crosscut" is a transverse working. This distinction is not observed strictly in the terminology of the mining districts.

Drifts may be run as small as 3 1/2 by 5 1/2 feet in section where the handling of a minimum of material is desirable. In pay dirt they may be run up to 7 by 9 feet in size or as large as they can safely be held. The size of crosscuts depends upon the service required of them.

The gravel in the ancient channels generally is compact enough to stand without timbering; blasting usually is reqired. The number of holes required to the round depends upon the compactness of the gravel. A simple toe-cut round - that is, one with the cut holes pointing downward - usually suffices for breaking the ground. It is desirable when blasting pay dirt in both development work and breasting to pulverize it as much as possible to facilitate washing operations. Heavy blasting, however, should be avoided so as not to scatter the gold-bearing gravel. In loose gravels the main difficulty in driving may be to prevent caves until the timbering is in place; the gravel is excavated by picks and shovels.

Wheelbarrows may be used in short drifts or buckets on trucks in small-scale work where the broken material is hoisted. In more elaborate workings, however, cars running on rails are employed.

For drifting in pay dirt, a wide drift may be run and the boulders piled at the side to form dry walls. Where timber is brought from a distance regular drift sets of square timber generally are used for supporting the drifts, but if round timber is available locally sets usually are made of it. The posts of the sets generally are stood with a batter so that the drift may be given a section more nearly approaching an arch. (See fig. 3.)

In loose or running ground spiling or forepoling must be used. The first step in spiling is to place bridging over the foremost standing set. Bridging usually consists of a 4- by 8- or 4- by 10-inch lagging laid parallel to the cap on top of 6-inch blocks at either end. This lagging is blocked solidly to the ground above, leaving a space 6 inches high above the cap through which the spiling is driven. If side spiling is necessary bridging is placed on the outside of the posts. Spiling usually consists of 2- to 5-inch timber 4 to 10 inches wide and as much as 9 1/2 feet long, depending upon the weight to be borne and ease of driving; one end of the spiling is sawed as shown in figure 4. The top spiling is driven at an upward angle into the caved or loose ground. In mines having compressed air a drilling machine with a special tool may be used for driving the spiling. The spiling extends over the cap far enough to provide room for placing a complete set. The upward angle is sufficient to allow bridging to be placed over the new set. The first spiling usually is driven at one side of the bridging close to the bridging block at such an angle that the forward end when in place will be 6 or 8 inches beyond and above the cap and close to the wall. The remaining ones are driven at such angles that they "fan" and form a complete covering for the set of timber to be put in place. As each spiling is driven ahead some of

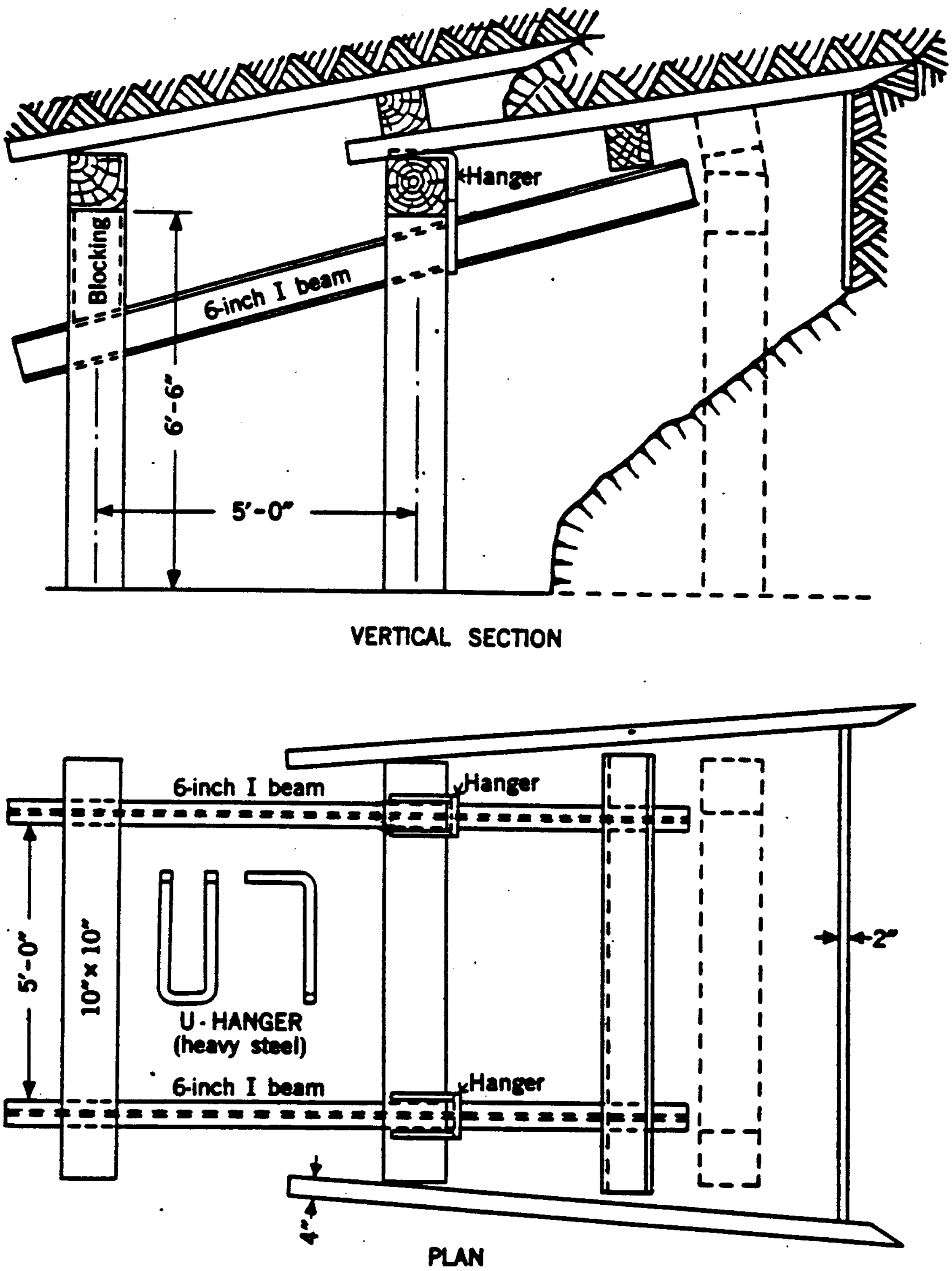

Figure 4.—Method of spiling in loose ground.

the gravel is cleared away from underneath it so that if any large boulders are encountered ahead of the spiling they can be barred out of the way or taken down. After the top spiling is in place side spiling, if necessary, is driven in the same manner, beginning at the top. Two 6-inch I-beams, or heavy timbers, are then hooked on the last cap (fig. 4) by heavy steel hangers. The ends of these beams are extended forward to just back of where the cap of the next set will be when in position. A crosspiece is then placed across their forward ends and brought up snugly against the spiling; the back ends of the beams are blocked down under the second cap back. When the gravel is removed the next set is put in. The beams support the top spiling while the set is placed. Posts and caps of ordinary drift sets are used.

The same method of top spiling is used for breasting in running ground. The I-beams or timbers with overhead lagging may be used in firmer ground to protect men working ahead of the last set in position from falling material, both in drifting and breasting operations.

Steffa[55] gives the drifting practice at the Vallecito drift mine as follows:

> Both gangways and crosscuts are generally 7 by 7 feet in section. The usual drill round consists of six holes drilled 5 or 6 feet deep and breaking an average of 4 feet per round. The gravel drills easily, 2 1/2 hours generally being sufficient to drill the round. Drill steel is of 7/8-inch hollow-hexagonal material, sharpened with cross bits. Slightly more than 9 pounds of 25-percent strength powder is used per round, with 4 sticks in each of three lifters, 3 sticks each in the two cut holes, and 2 in the single back hole. Caps are treated with a standard waterproofing compound.
>
> The broken gravel is shoveled by hand into 18-cubic-foot, end-dump, roller-bearing cars holding 1 ton each. Track consists of 16-pound rails laid to 18-inch gage. The grade of the channel has proved uniform over considerable distances and averages 75 feet to the mile. Track has been laid therefore on a grade of 1 1/2 percent upstream. It has seldom been necessary to take up bedrock to maintain the grade; wherever a dip in the floor has been found the track has been kept on grade, and bedrock has alway been found at the expected elevation when reaching the opposite side of the dip.
>
> In the opening of new areas by drifts or crosscuts, samples are taken from the skip at the collar of the shaft, a sample consisting of one full pan or about 20 pounds of gravel. Samples taken at this point have the advantage, as compared with samples taken from the solid face, of being representative of a larger volume of ground and of being mixed thoroughly by the blasting and by the handling of the gravel from muck pile to car and to skip. Thus an experienced panner is able to make fairly accurate estimates of the value of the gravel developed.
>
> Drifts and crosscuts are driven by crews of three or sometimes four men, making an average advance of 4 feet per shift. The cost of driving main headings averages $16 to $17 per foot. In a pay area 65 feet wide, where gravel can be breasted 10 feet high, each foot of heading developed 45 tons of gravel. (It is estimated that the gravel expands one-quarter on being broken, and a ton of broken gravel has a volume of 18 cubic feet.)

The cost of running a drift under average conditions at a small-scale mine where no other work was being done was shown by the Golden Belt Gold Mining Co. which was developing a drift mine on Magpie Gulch near Helena, Mont., in the summer of 1932. An 80-foot shaft

55 Steffa, Don, Gold Mining and Milling Methods and Costs at the Vallecito Western Drift Mine, Angels Camp, Calif.: Inf. Circ. 6612, Bureau of Mines, 1932, pp. 8-9.

had been sunk, and a drift was being run up the channel; the drift was 160 feet long and 5 by 6 feet in section and was timbered with 8-inch round timber sets placed 4 feet apart. The top and sides of the drift were lined with split lagging. The timber was cut and sawed on the ground. The gravel was picked by hand and trammed in a 6-cubic-foot car. It was hoisted in the body of the car, which at the surface was placed on a truck and trammed to the washing plant. The cost of running the drift was $6 per foot, excluding supervision. The surface equipment at the shaft consisted of a headframe and a hoist run by a 15-hp. electric motor. Power cost 1.07 cents per kilowatt-hour.

An example of the cost of running a drift under adverse conditions in small-scale operations was illustrated at the Lucky Charles Mining & Milling Co. small drift mine on North Clear Creek, Blackhawk, Colo., which in July 1932 was being developed through a 40-foot 2-compartment shaft; 50 feet of drift had been run but no breasting done. The property was well equipped with an electric hoist, a deep-well pump, a substantial headframe, and an ore bin. About 20 gallons of water was being pumped per minute. A 10-hp. motor operated both the pump and a hoist which had an 18-inch drum. The gravel was hoisted in a 7-cubic-foot bucket attached to a 1/2-inch cable.

The gravel was 3 to 5 feet thick and was overlain with 5 feet of quicksand which required both top and side spiling. The drift was 6 feet high, 5 feet wide at the top, and 6 feet wide at the bottom. Sets of 6-inch round timber were placed 2 feet apart. Top spiling was 3 by 6 inches by 5 1/2 feet; side spiling was 1-inch boards.

An advance of 1 foot per day was being made by 2 men underground and 1 man on the surface. The cost per foot of drifting was as follows:

Labor (3 men at $4)	$12.00
Power (hoisting)	1.00
Timber	1.80
Other supplies	1.00
Total	15.80

Breasting

A number of different methods of breasting are employed at drift mines, depending mainly upon the nature of the deposit. Drift-mining methods were evolved in the early Californian diggings; present methods do not differ materially from those of the early days.

In narrow channels the gravel may be mined on either side of the drift as it is advanced or the drift advanced the full width of the pay streak. In wider deposits the drift may first be run to the limit of the deposit and then the gravel mined, retreating toward the shaft. In extensive deposits the gravel usually is divided into blocks preparatory to mining. The blocks generally are mined by retreating. Pillars usually are employed only to protect haulageways. A modified room-and-pillar system, however, has been used at some mines in which the pillars, if in rich gravel, were later removed.

Breasting may be done from crosscuts or from drifts run parallel to the haulageway. Breasting from the crosscuts may parallel the haulage drift on the retreat toward it. When working from drifts the line of retreat usually is parallel to the drift although sometimes toward it. The spacing of crosscuts or drifts at different places ranges from 40 to 200 feet, depending mainly on the system of breasting. Crosscuts generally are turned off at such an angle as to give the proper gradient for tramming.

Cuts or slices range from 2 1/2 to 8 feet wide. If cars are used in long faces the tracks are shifted after each cut. Usually all of the gravel rich enough to mine and enough of the overlying gravel to provide headroom is taken out. Rooms generally are 6 or 7 feet high; the minimum height in large operations is 5 feet. At the Vallecito mine, described later, the thickness of the pay dirt varied up to 14 feet, although at most mines it was less than 6 feet. The rooms may be broken to a strong strata of ground where such strata occur. In some California drift mines volcanic ash makes a strong roof.

In compact or cemented ground the breats are broken by blasting drill round; holes may be 2 1/2 to 6 feet apart. At most places, however, breasting is done with picks. At many places the gravel is undercut, usually in the upper and softer part of the bedrock; the remaining gravel in the face is then broken to the undercut. Usually 1 or 2 feet of bedrock is taken up. Often, bedrock with deep crevices containing gold can be picked. Hard bedrock is cleaned carefully by hand, as in surface mining. Boulders and gravel too low in grade to take out are piled back of the working face.

Low-built cars usually are preferred for the sake of easier shoveling and tramming in the low workings. Scrapers in drift mines have not proved successful, but with the recent improvements in equipment and technique this method of moving gravel offers possibilities.

Some timbering usually is required in breasting, if only an occasional stull which may be recovered later. Regular timbering consisting of stulls with headboards is used at most mines. If the bedrock is soft, footboards also are used; in soft ground lagging is required overhead. Heavy ground generally is supported by lines of sets. In narrow channels tunnel sets with long caps may be used.

The following descriptions of individual mines illustrate current breasting practices, beginning with the simplest form and progressing to more elaborate operations. Two mines worked in the early days in California and one in Alaska are included to show typical methods not illustrated by modern operations.

Representative Mining Practices

Recent gravels

Greaterville.- Simple and more or less haphazard methods of drift mining have been followed in the Greaterville district in southern Arizona for many years. Along the poorly defined channels or pay streaks untimbered shafts 6 to 15 feet deep are sunk at random to bedrock, which often is a clay stratum. At the bottom of the shaft, galleries are run about 3 1/2 or 4 feet high in the middle and tapered down to the thickness (usually less than a foot) of the pay streak on either side. The pay streak of gravel is then gouged out as far as it can be reached. The gravel is fairly compact, and no timber is used in the workings. The pay gravel is scooped into pails and generally hoisted hand over hand; in the deeper shafts a hand windlass is used. The galleries are extended as far as pay streak can be followed economically by such primitive methods or until the working becomes unsafe, then a new shaft is sunk. The dirt too low in grade to wash is piled in old workings. The ground is dry, and no running water is available except after storms. The gravel usually is washed in rockers, for which water is packed on burros to the workings.

Bear Creek.- Two men were drift mining in a bench deposit on Bear Creek above Bearmouth, Mont., in July 1932. Short adits were run across the bar on bedrock which was there about 40 feet above the creek. About 2 feet of gravel on bedrock was then gouged out by hand for 6 feet on either side of the drift. Boulders removed in this work were used as rock packs to help support the back. No timber was used. When all the gravel that could be mined safely was removed from one drift another parallel working would be run.

The gravel was taken in a wheelbarrow to the surface where it was dumped over a 2-inch bar grizzly. The undersize dropped into a 2-cubic-yard bin whence it was taken in a wheelbarrow to a sluice box on the creek and washed. About 3 tons per day or 1 1/2 tons per man-shift was mined and washed.

Magpie.- In deeper gravel more systematic methods are followed, as shown at the Magpie Gulch, south of Helena, Mont. Here the gravel was 40 to 50 feet deep. A drain tunnel had been extended upstream about a mile until bedrock was reached; it was then continued on bedrock. Working shafts were sunk 100 to 200 feet apart, and the gravel was hoisted to a washing plant. As the drift was extended upstream from the working shaft the gravel was breasted out; when ventilation became a problem a new shaft was sunk or raised and the surface plant moved. The wate continued to flow out the drain tunnel. Below the point where the drain tunnel reached bedrock shafts were sunk in the same manner, but pumping was necessary.

Dakota mine.- As stated previously, a narrow deposit can be mined by advancing an adit the full width of the channel. This practice was followed by Anton Gustafson and three partners at the Dakota mine on the head of Quartz Creek in the Cedar Creek mining district near Rivulet, Mont. (See fig. 5,A.) The drift started in the face of old hydraulic diggings under a cover of about 80 feet. In July 1932 it was 450 feet long. Ventilation at the face was poor, and an air raise to the surface would soon be required. The channel was 6 to 20 feet wide. Seven feet of gravel was mined; it contained a large proportion of boulders. The tops of clay streaks in the gravel contained relatively high gold values.

The method of mining was as follows: Sets 4 feet between centers were placed as room was made. Top lagging 4 1/2 feet long, consisting of split poles, was driven ahead as the ground was picked out. A false set held up the top lagging until the regular set was placed; no side lagging was necessary. Round timber cut on the ground was used for sets; the caps were 12 to 15 inches, posts 9 to 12 inches, and girts 6 inches in diameter. Caps were 10 to 14 feet long, depending on the width of the channel; a minimum width of 10 feet was required to provide room to stack boulders. All rock over the size of a man's fist was left behind, except occasional large boulders for which room was not available. Dry walls were built up on either side of the 18-inch gage track, leaving barely room enough to push out an 8-cubic-foot car 3 feet wide. Some boulders too large to move by hand were drilled and blasted; about 150 pounds of 40-percent-strength gelatin dynamite was used per year. A derrick at the portal of the tunnel was used to dispose of large boulders brought to the surface.

Two men worked on each of two shifts and brought out 7 or 8 cars per shift. A set was put in every 2 days, including the time for cutting the timber. A set of ground averaged 13 feet wide, 7 feet high, and 4 feet long and contained 13 cubic yards or 20 tons of gravel. An average of 2.5 tons of gravel was mined per man-shift; including the time for washing the gravel. At $4 per shift the labor cost per ton of gravel mined at the face amounted to $1.60 per ton. Thirty cubic feet or 1.7 tons of gravel was brought to the surface each man-shift. The total labor cost, therefore, was $2.35 per ton of material trammed. No hoisting or pumping was necessary, and there was no overhead nor cost of supervision. The total cost for supplies was about 25 cents per ton, making a mining cost of $2.70 per ton of material trammed. Seven months of preliminary work was necessary before any gold was produced. Considerable excavation was required in the face of old hydraulic workings to get down to bedrock, and the adit was driven through 150 feet of previously drifted ground to reach virgin gravel.

Townsend and Hornbrook.- Relatively small-scale drift mining by a retreating method with inexpensive equipment is illustrated by the work of Townsend and Hornbrook on the Klamath River a few miles south of Hornbrook, Calif., in 1932. The mine was worked through a 46-foot, 2-compartment shaft, situated about 50 feet from the river. The first 20 feet of the shaft was concreted to hold out surface water; the lower 26 feet was cribbed with 3-inch plank. Although the lower 12 feet was said to be gold-bearing, only 6 feet, which carried most of the values, was mined. Drifts stood without timber, except that an occasional stull set was necessary. In preparation for breasting, a drift was run to the limit of the area to be worked, then the ground was taken out on either side 10 feet from the center of the drift. (See fig. 5,B) retreating toward the shaft. Two rows of stulls 4 feet apart with

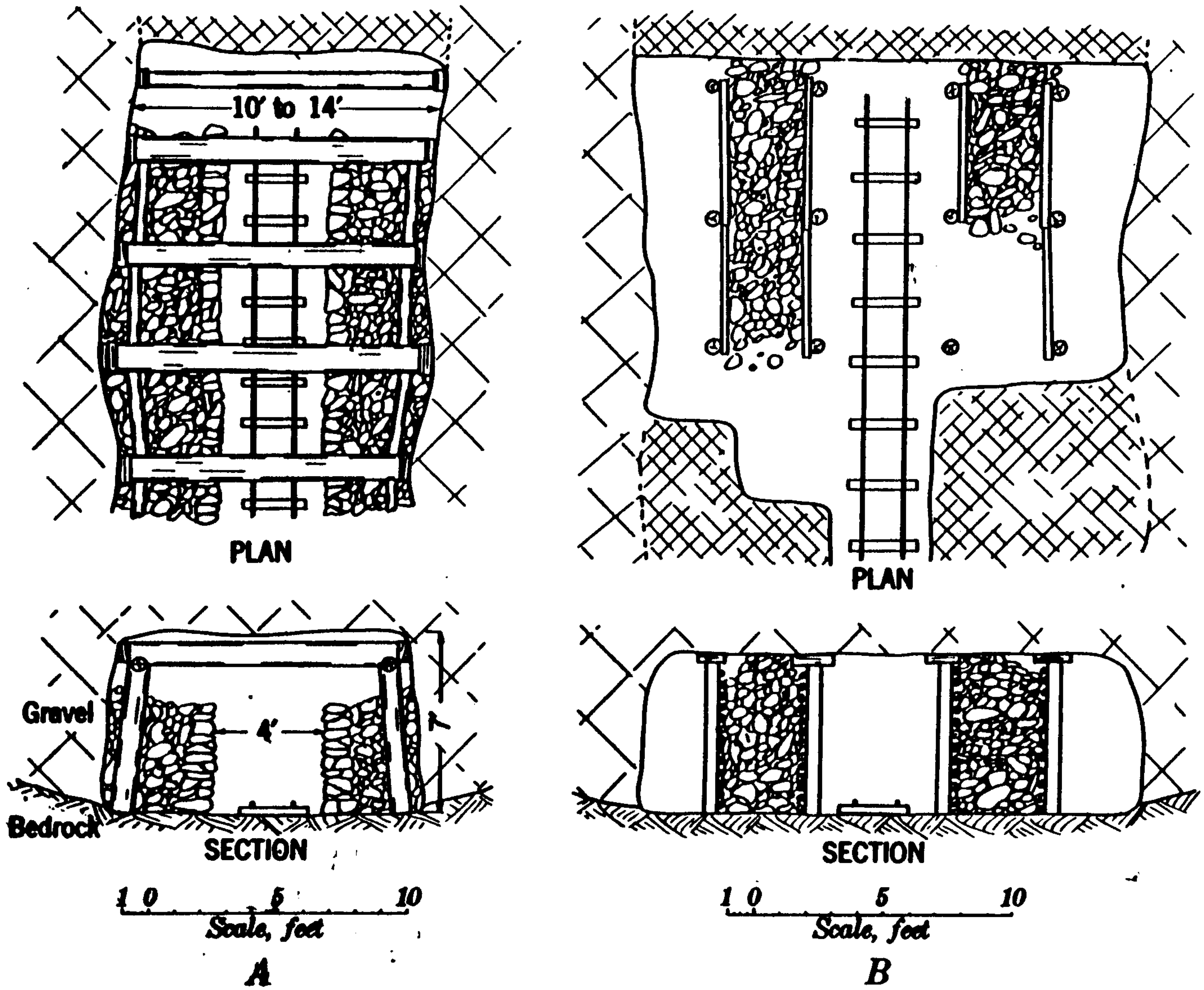

Figure 5—Breasting methods in narrow channels: *A*, Advancing from shaft, Dakota mine, Rivulet, Mont.; *B*, retreating to shaft, Townsend and Hornbrook mine, Hornbrook, Calif.

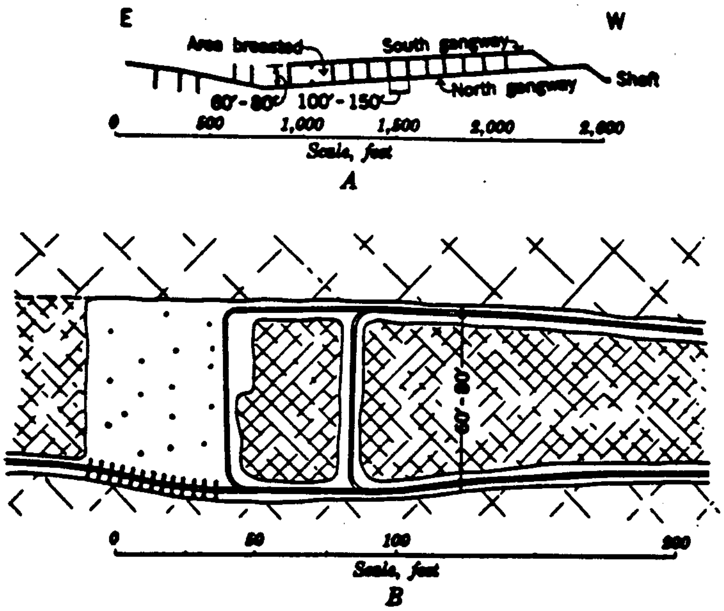

Figure 6.—Mining methods at Vallecito Western mine, Vallecito, Calif.: *A*, Plan of principal workings; *B*, breasting method.

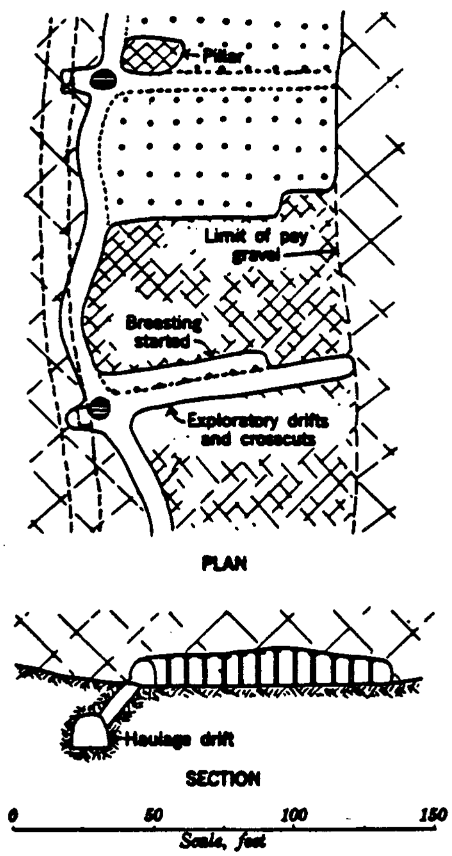

Figure 7.—Proposed method of breasting, Calaveras Central mine, Angels Camp, Calif.

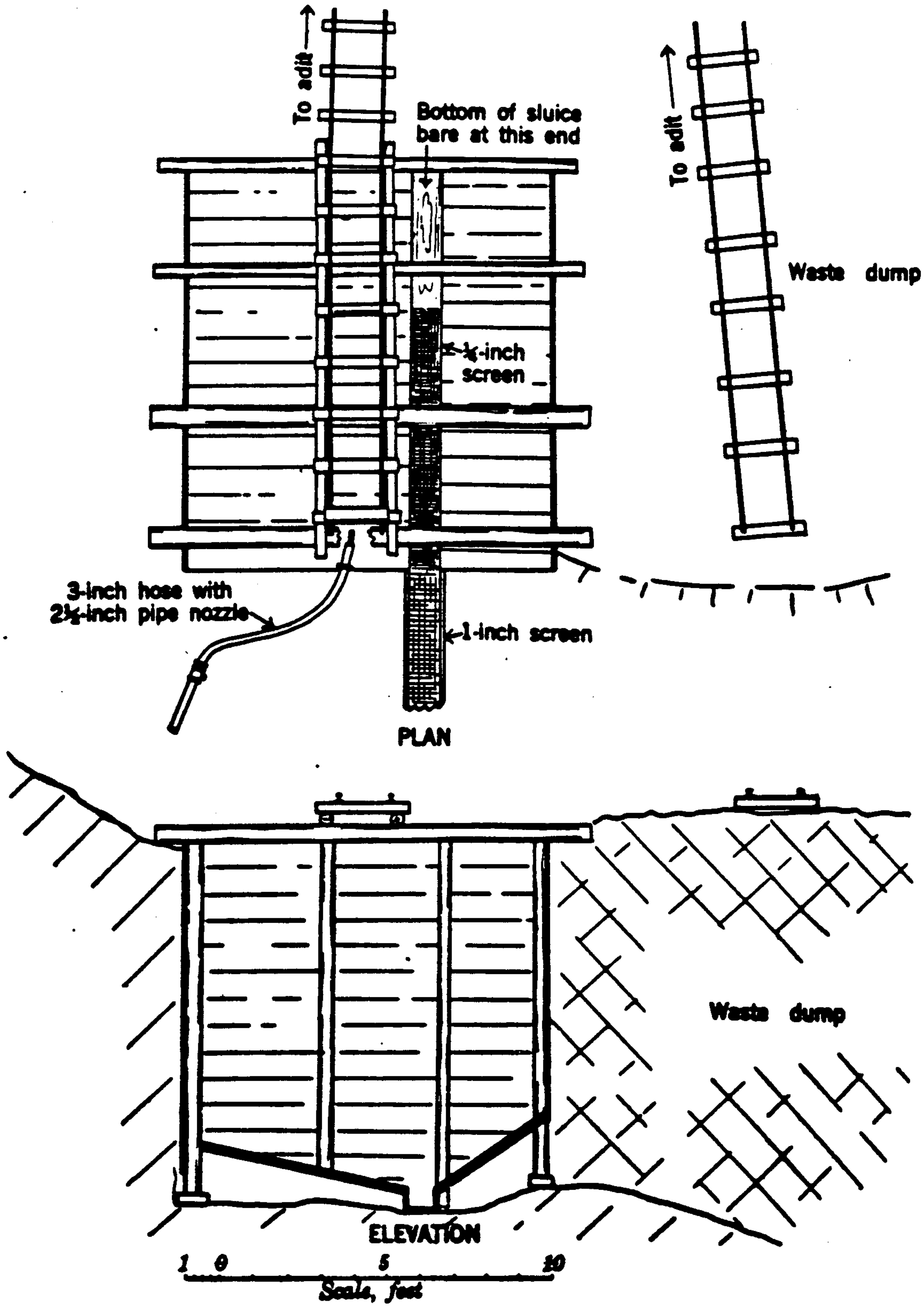

Figure 9.—Washing plant, Baker Divide mine, Michigan Bluff, Calif.

winze at the south rim showed it to be 5 1/2 feet lower on this side than on the north. This was due probably to the channel here being entirely in slate, which had permitted the cutting of a deep trough next to the abruptly rising south rim.

To the eastward a harder granite floor gradually encroached from the northward upon the channel until it covered its entire width, whereupon the bedrock assumed equal elevations on both sides. However, it was necessary to reach grade on the south side, and therefore a crosscut was started, as shown in the diagram, about 250 feet from the shaft. At this point the site of an ancient waterfall had been encountered with a rise of about 5 feet, and the grade of the north gangway had been raised correspondingly by the installation of a transfer platform. Loads coming down were dumped at this point through a hole in the platform into cars, which were then trammed to the shaft. The crosscut was therefore extended along the west or low side of the falls and at the south rim was turned east and driven in slate on a grade to intercept the bottom of the deep trough discovered at the first crosscut.

Crosscuts are run at intervals ranging from 100 to 150 feet. A total of 44 have been driven to date (August 1931), 18 of which were in the first or westernmost of the pay areas developed. Of these, several connected to the north and south drifts or gangways, serving both to improve ventilation and to speed up the work of breasting. The other crosscuts were projected away from the pay areas onto benches and were extended short distances up the rims to prospect for potential concentrations. The total footage of drift and crosscut to date is 6,300 feet.

Figure 6,A indicates the location of the one area breasted so far. This averaged 65 feet wide, ranging from 60 to 80, and was 240 feet long. Near its center the pay gravels extended to a height of 14 feet and were extracted to that distance above the floor.

Breasting began at the upper end, the gravel being broken down along the side of a crosscut (fig. 6,B). Holes 6 feet deep spaced 4 feet apart in two rows, one at the top and the other at the bottom, were drilled across the face. Light explosive charges sufficed to make a clean 6-foot break and to loosen a foot or two more of ground to be picked down by hand. Heavy blasting is avoided because of the scattering effect on the fine gravel and its gold content.

The gravel is compacted so strongly that it stands without scaling over great widths with only occasional light stulls for support. The stulls are 8-inch round timbers set about 10 feet from the face, topped by headboards or caps, and wedged tight to withstand blasting. In the entire area breasted only 48 stulls were used. The roof is arched from a height of as much as 14 feet in the center to 7 to 10 feet at the sides, which increases its strength and tends to prevent sloughing.

As soon as the first slice is broken down along the crosscut mucking begins. The gravel is shoveled by hand into the cars. Large boulders, constituting about 30 percent of the whole mass, are rolled back from the face and sometimes stacked up to the roof to furnish additional support. Very heavy boulders, weighing from a few hundred pounds to several tons, are rare. Fully 80 percent of the total weigh less than 100 pounds.

The top of the pay gravel is defined by a capping of coarse sand. Horizontally, the extent of breasting is controlled by pan sampling underground, the number of colors in a single pan indicating to an experienced gravel miner the approximate value of the ground. In places at this mine the pay lead is heavily con-

5 feet between the rows were placed on either side of the drift. Boulders were piled between the two rows of stulls on either side to form a solid pack to the back. No drilling or blasting was necessary.

The surface equipment consisted of a 15-foot headframe made of round timber cut on the ground, a 7-hp. gas engine, a small hoist, a pump, a 500-gallon tank, and a sluice box. The hoist and pump were run by the same engine. About 30 gallons of water per minute was pumped from the mine. The gravel was hoisted in a 1/4-cubic-yard bucket on a 3/8-inch cable.

The crew consisted of 2 men underground, 1 hoist engineer, and 1 man who attended to the washing. Five gallons of gasoline was used per 8-hour shift for pumping and hoisting. The average production was about 6 cubic yards or 9 tons per day.

The daily operating cost of mining was as follows:

Three men at $4	$12.00
Gasoline, 5 gal. at 16 cents	.80
Timber	1.20
Miscellaneous	2.00
Total	16.00

The daily washing cost was:

One man at $4	$4.00
Supplies	.50
Total	4.50

Then mining costs would be $1.78 and milling costs $0.50 per ton, or a total operating cost of $2.28 per ton. The cost of sinking the shaft and of the surface equipment must be prorated to each ton mined to obtain the total mining cost.

Ancient gravels

As stated before, relatively large-scale operations are necessary for operations to be profitable in mines in the ancient channels in California.

Vallecito Western.- The method of developing a single channel is illustrated at the Vallecito Western drift mine at Angels Camp, Calif. Up to June 1932 the mine had not been put on regular production. The channel gravel, buried by volcanic ash and late sediments, was well compacted, and explosives were required to break it. Drifts stood without timbering The mine was worked through a 2-compartment timbered shaft 153 feet deep. Gravel was hoisted in skips from a single level. Surface equipment consisted of a hoist, air compressor, blacksmith shop, and washing plant. The trommel in the mill was driven by a 10-hp. electric motor; a 15-hp. motor was required for pumping.

The general plan of development, breasting methods, drainage, and costs of mining and milling are described by Steffa as follows:[56]

> A diagonal crosscut was run southeast from the shaft to the north or near side of the channel and a drift started upgrade (east) along the north rim (as shown in figure 6,A). About 600 feet east of the shaft a crosscut was driven through the pay gravels to the south rim. Bedrock dropped away southward, and a

56 Steffa, Don, Gold Mining and Milling Methods and Costs at the Vallecito Western Drift Mine, Angels Camp, Calif.: Inf. Circ. 6612, Bureau of Mines, 1932, pp. 8, 10, and 13.

The gravel was similar to that in the Vallecito Western mine in the same district. It varied up to 21 feet thick, averaging 7 feet, and was overlain by an average of 350 feet of volcanic ash and later sediments. The mine was well equipped and had a complete surface plant. Air was furnished by an electric-driven, 350-cubic-foot-per-minute air compressor; the hoist and pumps were also electrically driven, and the mine was lighted by electricity.

The mine was operated through a 350-foot, 3-compartment shaft. The gravel was trammed by two 4-ton battery locomotives in 2-ton side-dump cars and hoisted in two 2 3/4-ton skips. A total of 250,000 gallons of water was pumped per day.

Two levels 100 feet apart had been opened up. Development and exploration drifts were run on bedrock and extraction drifts in the bedrock, which was slate; drifts were 7 by 7 feet in section. In the gravel a 10-hole round 5 1/2 feet deep could be drilled and blasted and the broken gravel loaded out in a shift. Ten to fourteen holes were required in slate, and an average of 1 1/4 shifts was taken to a round. Drift rounds usually were loaded by a mechanical shovel. Drifts or crosscuts were not timbered. Crosscuts were run from the exploration drifts preparatory to breasting.

In breasting, slabbing rounds 2 to 6 feet wide will be blasted from the sides of the crosscuts and the gravel dragged by scrapers into raises from footwall drifts. (See fig. 7.) It will then be drawn into cars for tramming to the shaft. Boulders will be piled to one side. Pillars will be left where necessary and weak places in the back held up by stulls. In rich ground the pillars will be robbed upon retreating. The normal capacity of the mine would be about 75 tons of gravel per 8-hour shift. Development costs are estimated at 50 cents per ton and mining and milling costs at $2.50 - a total of $3.00 per ton. The wage scale in July 1932 was $5 for shovelers and $5.50 for miners.

Hidden Treasure.- The Hidden Treasure in Placer County, Calif., is reported by Powers[57] to have been the largest deep-drift mine in the world. He states that the channel gravel was not cemented and therefore required little or no blasting. The slate bedrock had a tendency to swell when exposed to the air. The channel system was mined for a distance of about 4 miles and for a width ranging from 200 to 800 feet. In the early days of the mine 1 1/2 to 2 million board-feet of timber was used yearly. Timber was plentiful and was cut on the company's holdings. The mine was operated through adits. The timbering of the main tunnel, on a swelling bedrock, is shown in figure 3,B.

In preparation for breasting, gangways were driven to the rim rock at right angles to the haulage-way adit and at intervals of about 200 feet. Drifts were then run 110 feet upstream and 90 feet downstream from the ends of the gangways. The gangways were timbered with sets using 10- by 10-inch posts 6 feet long and caps of the same material 5 feet long; the lagging was 1 1/2 by 6 inches by 5 feet long. The drifts on the rim were timbered with 8- by 8-inch sets with both the posts and caps 5 feet long; the same lagging as that above was used.

Breasting began on the inside of the rim rock drifts and proceeded toward the main tunnel. (See fig. 8,A.) The breasts were timbered in the same manner as the drifts with the sets 5 feet apart. If the ground was heavy, as it usually was, a line of posts and caps of the same size as those used in the sets was placed under the lagging midway between the row of sets. In addition, it was often necessary to place a center post under the caps of the sets; thus the lagged back was held up by posts on 2 1/2-foot centers. Moreover, if the ground was wet foot blocks were required. Lagging was driven forward ahead of the set nearest the face; it was held up by a false set until the regular set was placed. All waste and boulders excavated in breasting were piled into packs for further support of the roof. The roof was maintained only at the working faces.

57 Powers, Harold T., Timbering in Deep Placer Mining: Min. and Sci. Press, vol. 115, Aug. 11, 1917, p. 191.

centrated and narrows to a width of 20 feet with barren ground on both sides. At others, as noted, the width of pay gravel is 80 feet. The width of face is varied accordingly.

The gravel is trammed by hand in 1-ton (18-cubic-foot) cars to the shaft and dumped directly into a 1 1/2-ton skip. The skip raises the gravel to the top of the 80-foot headframe where it is dumped into a 75-ton gravel bin.

The breasting operation was conducted to discover by a mill test the actual value of a given large mass of gravel, as well as to learn the north-south limits of the pay streak. Only one face was attacked, whereas in regular operation each crosscut would give a starting point for two faces. In full-scale operation, moreover, mechanical loading at the breasts and motor haulage should lower the cost of operation.

Breasting operations extended over a 10-month period, during which development work also was being pushed. The tonnage from breasting was segregated and treated separately, totaling 9,500 tons. Five men breasted and trammed 1,300 feet to the shaft, an average of 5 tons per man shift. Powder consumption averaged 1/2 pound per ton, and the timber cost was 1/2 cent per ton.

The gravel is treated in a plant near the collar of the shaft having a capacity of about 15 tons per hour.

The gravels are wet when first opened but drain rapidly, and at present the flow of approximately 48,000 gallons per day is confined to bedrock, flowing between rails in the drifts. Drips from walls or roof are found only occasionally. At the shaft a vertical centrifugal pump, driven by a 10-hp. motor, is mounted in the manway about 10 feet above the station level. This pump has a capacity of 100 gallons per minute. It is controlled by a float switch and handles the regular mine drainage with about 8 hours of pumping per day. A second turbine of double that horsepower and capacity is installed at the opposite side of the shaft ready for use in emergency. Power is taken from a Pacific Gas & Electric Co. line which passes 600 feet south of the shaft.

The following costs are for combined extraction and milling of the 9,500 tons taken from the area breasted as described above. Prevailing wages during the 10 months in question were $4.50 a day for muckers and trammers and $5 for miners. The costs, apportioned to the mining and treatment of the breasted gravels, excluding development but including all other operating costs of mining and milling, were as follows:

Cost of mining and milling

Labor	$2.02
Supervision and insurance	.40
Explosives	.25
Timber	.01
Power	.30
Other supplies	.12
Total, per ton	3.10

Milling at this mine is discussed later.

Calaveras Central.- The Calaveras Central mine at Angels Camp, Calif., was reopened in 1931 by the Calaveras Central Gold Mining Co. Up to June 1932 underground work had been confined to developing new deposits; regular breasting operations had not begun. Twenty men were employed.

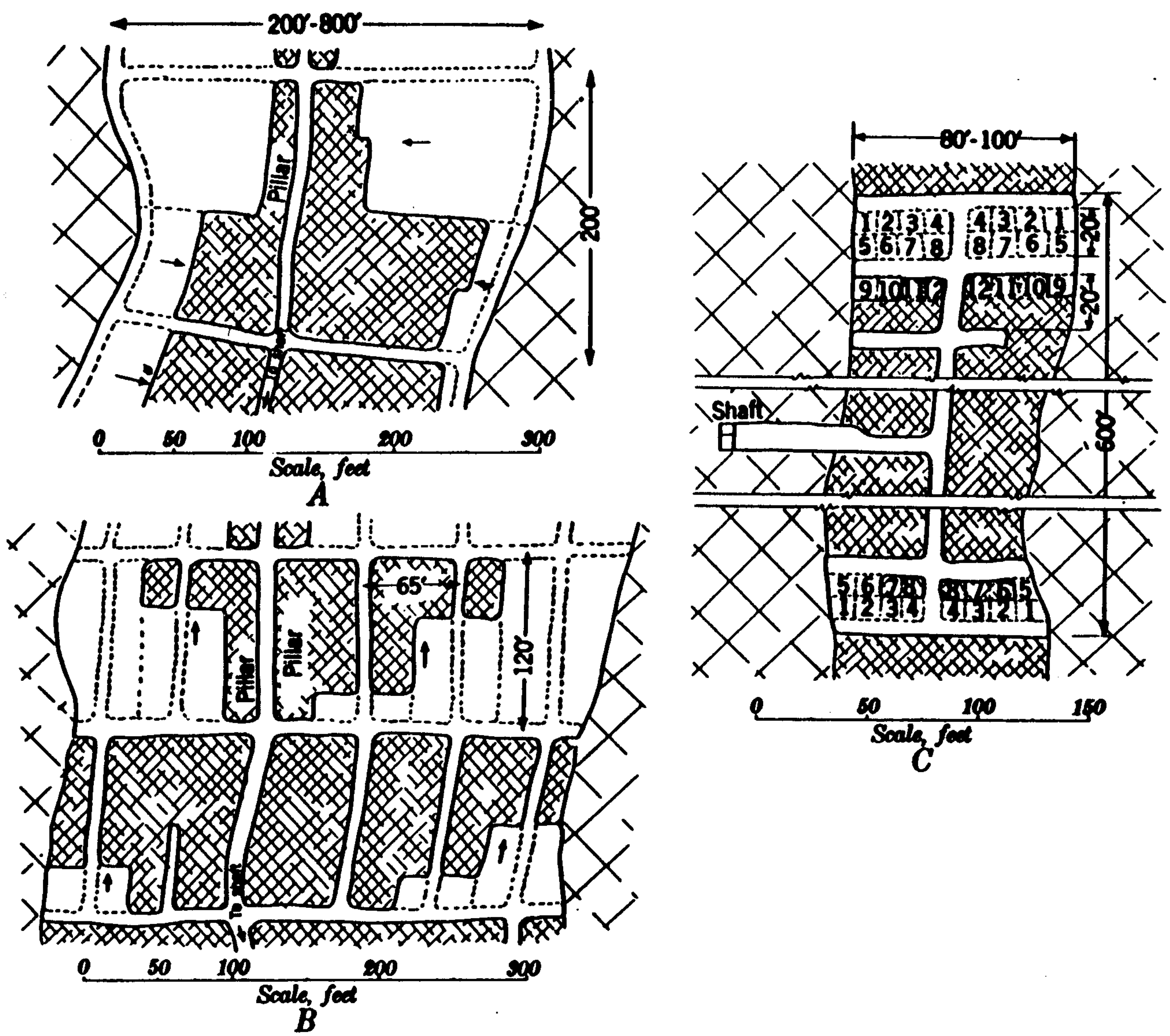

Figure 8.—Breasting methods used in former drift mines: *A*, Hidden Treasure mine, Placer County, Calif.; *B*, Red Hill mine, Placer County, Calif.; *C*, Wild Goose mine, near Nome, Alaska.

shaft timbers. This method may have been used elsewhere before, but it was original with us at the time and was adopted afterward throughout the Nome district in all the deep mining in thawed ground. Frozen ground did not present any difficulties, as no timber was required.

Our greatest difficulty was caused from swelling bedrock in the main gangways. To overcome this trouble we used the methods described by Mr. Power (Hidden Treasure mine).

In block stoping we commenced at both ends of each T and took out a block of ground (each marked no. 1 in fig. 8,C), never more than 10 ft. square, using 8- by 8-in. posts set on 3-ft. centers, with 3- by 12-in. caps 1 1/2 ft. long, never permitting the caps to cross two posts. When the gravel was so loose that it ran, we filled the spaces with false lagging. When this 10-ft. square block was out and the bedrock cleaned up, we pulled every post (using double or triple block and tackle) except the row against the two solid walls of unworked ground on two sides of the block. Behind this row we lagged solid with 2- by 6-in. lagging against the unworked walls. Usually the roof caved as fast as we pulled the posts and the block was immediately filled. Then we took out all blocks marked no. 2 and worked back toward block no. 1 (which we had just left) until we struck the wall of lagging, cleaned up the bedrock, and pulled as before, repeating until the main gangway was reached.

In the meantime new crosscuts had been cut from the main gangway to the rims, leaving a pillar 20 ft. wide of unworked ground to make a new T. The blocks were worked out as before. We kept these crosscuts just ahead of the stopers. This method permitted us to work in four places in the mine, besides the crosscuts, and was sufficient to keep the hoist on a single-compartment shaft busy.

We gradually worked back toward the shaft and, as before stated, recovered practically all our timber and never lost a man, the secret being that we always worked under solid ground and moved ground so quickly that it had no chance to get heavy and take weight.

Milling

As stated before, nearly all gravel mined by underground methods requires some mechanical or hand method of washing to disintegrate it and free the gold from the clay. In recent stream gravels little preliminary washing may be necessary, while in some of the Tertiary channels the gravel must be crushed by machinery to free the gold. The simplest washing device is a box at the head of a sluice in which the gravel is puddled by hand with hoes, shovels, or rakes or washed by water from a nozzle. Washing is performed in trommels at a majority of mines. The screening out of the coarse material assists in the gold-saving operation.

Gold-saving devices other than sluices or amalgamation plates have been used or have been proposed for treating gravels from drift mines, but none was in actual use in June or July 1932, and no first-hand information as to their efficiency could be obtained. Amalgamation plates were used successfully for treating stamped material in one mill, but they are not suitable for anything except screened material as gravel or coarse pebbles scour off the amalgam.

Milling methods are illustrated at the following representative plants visited by the authors in 1932. It is the authors' opinion that these plants represent the best practices under the conditions given.

Red Point.- The method of blocking out the ground, used at the Red Point mine in Placer County, Calif., is given by Dunn.[58] A main haulage drift, which was kept as straight as possible, was run in the center or lowest depression of the channel. Gangways were then run on about 120-foot centers at right angles to the rims of the channel or the limits of the pay lead. (See fig. 8,B.) The gangways were connected with drifts parallel to the haulage-way on 65-foot centers, thus cutting the gravel in blocks 65 by 120 feet in size. The ground was hard and compact, and except in the breasts openings required no timber.

In the Bald Mountain mine at Forest City, Calif., the practice was to run both the gangways and drifts 80 feet apart, leaving a pillar of 40 feet to protect the main tunnel.

Wild Goose.- The mine of the Wild Goose Mining & Trading Co. was situated in the Nome district of Alaska. It was being worked in 1905. The gravel was not frozen and was very difficult to hold up. The bedrock was a micaceous schist; from 1 1/2 to 2 feet of bedrock and 2 feet of gravel overlying bedrock were run through sluice boxes to save the gold. Timber was costly ($60 per thousand feet plus the freight from Nome) and difficult to secure. A method in which a minimum of timber was required was devised to mine this gravel. According to Fleming[59] the method of working was as follows:

> The channel, which ran nearly straight, making it easy to follow, was divided into sections 600 ft. long, and a shaft was sunk midway between the end lines of each section, care being taken to sink the shafts on the lower side of the channel and not nearer than 25 ft. from the lower rim so that caving would not affect the alinement of the shafts when the channel was worked out, and always permitted our shaft houses, bunkers, and strings of sluice boxes to be on solid ground. The shafts were 6 by 8 ft.; they had a single compartment, with a manway for ladders and pipes. They were from 69 to 140 ft. deep; 140 ft. being the depth to bedrock on the crest of the divide.
>
> A drift was run from the bottom of each shaft at right angles to, and toward, the middle of the channel. From the shaft this drift was wide enough for a double track for a distance (usually about 40 ft.) sufficient to give a sidetrack for holding empty cars. When the middle of the channel was reached the drift was split and continued lengthwise with the channel a distance of 300 ft. each way, thus covering the section of 600 ft. into which the channel had been divided.
>
> At each end of the main gangway the drift was teed by a crosscut to each rim. The channel was from 80 to 110 ft. wide. At first we tried breasting as described by Mr. Power (Hidden Treasure mine), using 10- by 10-in. and 12- by 12-in. posts, placing them on 3-ft. centers, but we soon abandoned this method as we could not recover any timber when once placed and it proved dangerous. One breast or stope, after it had been opened clear across the channel, caved in a rush to the surface, and we not only lost the breast and all the timber but nearly lost the men who were working in the face.
>
> We then devised the method of block-stoping. This proved successful, permitting us to save all our timber, using it over and over again, only now and then losing a stick. To show to what extent we succeeded, we worked out the entire channel in one 600-ft. section, losing only 5,000 ft. B. M., for we waited until fall, when the frost set the gravel walls of the shaft. We even pulled the

58 Dunn, R. L., Eighth Annual Report of the State Mineralogist of California, 1888, quoted by Haley, C. S., Gold Placers of California: Calif. State Min. Bur., Bull. 92, 1923, p. 58.

59 Fleming, E. E., Block Stoping and Timbering in Deep Placer Mining: Min. and Sci. Press, vol. 115, Sept. 15, 1917, p. 378.

<u>Van Patten, Nensiis, and McKim</u>.- These men were developing a claim on Burnt River near Bridgeport, Oreg., in June 1932. The gravel was 16 feet deep and occurred in a relatively narrow channel under the present course of the stream. A shaft had been sunk 18 feet to bedrock and drifting begun. Steel caissons had been used in sinking the shaft through loose surface gravel to keep out the water from the river. The ground on bedrock was tight, and relatively little water was coming into the workings.

A well-built, portable, labor-saving surface plant had been installed. The washing plant consisted of a 1 1/2- by 4-foot trommel with 1/4-inch holes, three steeply inclined steel boxes 6 inches wide with wooden cross riffles, and a wooden tail box with riffles. Water from the mine was discharged into a small settling basin whence, with an added supply from the river, it was forced by a high-pressure pump through sprays in the trommel. One man ran the hoist and pumps and shoveled into the washing plant all the gravel two men below could send up. A 4-cylinder automobile engine drove a hoist drum, a deep-well pump, the trommel of the washing plant, and the high-pressure pump. On hoisting the bucket was swung by hand on a crane and dumped on a platform, whence the gravel was shoveled into the trommel. It was expected that 5 cubic yards per shift could be handled with 2 men underground and 1 on top.

<u>Golden Belt</u>.- The Golden Belt mill of the Belt Gold Mining Co. was on Magpie Gulch near Canyon Ferry, Mont.. The gravel consisted of angular wash containing a high percentage of clay. It was dumped from a 6-cubic-foot car on a platform, whence it was shoveled in 3-cubic-foot batches into a concrete mixer and washed for 2 1/2 minutes. The concrete mixer was then dumped over a grizzly made of 1-inch pipe spaced 1 inch apart. About two-thirds of the material hoisted went through the grizzly and thence into a sluice. The oversize was shoveled by hand into a car and trammed to a rock dump. The sluice consisted of three 12-inch boxes 12 feet long. The grade was 8 inches to 12 feet; riffles consisted of 2- by 4-inch lumber cut diagonally and placed flat side up in the box.

<u>Rising Hope</u>.- The Rising Hope mill was near Auburn, Calif. The ore was drawn from a bin into a 4- by 5-foot blank trommel where it was disintegrated and washed. It then ran over a 3- by 4-foot screen with 1-inch square holes. The oversize dropped into a car and was trammed to a dump. The undersize went through 150 feet of 16-inch steel boxes with Hungarian and cast-iron riffles. The trommel was run by a water wheel which was operated by 4 miner's inches of water under a 200-foot head. The water cost 25 cents per miner's inch per day. Quicksilver was kept in the first 2 1/2 feet of the sluice and a little sprinkled occasionally along the first two boxes. In cleaning up, the concentrates were first panned, then put through a barrel amalgamator with quicksilver.

<u>Vallecito Western</u>.- According to Steffa:[60]

> The gravel is treated in a plant near the collar of the shaft having a capacity of 15 tons per hour. (See fig. 10.) From the shaft bin the gravel is washed by water from a 2-inch line through the bin gate, into and through an 11-foot Hungarian-riffled sluice. From the lower end of this sluice the gravel discharges into the hopper of a 3- by 18-foot trommel, set at right angles to the line of the sluice. This trommel has two compartments, one for washing and disintegrating, the second for screening and further washing. The first, 8 feet long, is of unpierced steel, lined on the inside with 4-inch angle irons. As the trommel revolves these fins lift the gravel and cascade it to the bottom again, producing a crushing and disintegrating action similar to that in a ball mill.

60 Steffa, Don, Gold Mining and Milling Methods and Costs at the Vallecito Western Drift Mine, Angels Camp, Calif.: Inf. Circ. 6612, Bureau of Mines, 1932, 14 pp.

Representative milling practices

Dakota.- At the Dakota mine, previously described, gravel was brought to the surface from the adit and dumped from an 8-cubic-foot car directly into the head of a sluice box. When much clay was in evidence the gravel would be partly puddled by hand. The first 50 feet of the sluice was built inside the adit for protection against snow and frost in winter. The sluice line was 250 feet long; the first two boxes were 20 inches wide and the rest 10 inches. The grade was 5 inches in 12 feet. Riffles were used only in the first 96 feet of the sluice. Concentrates were panned; no quicksilver was used. Water was brought into the sluice by a pipe line from the creek. An ample supply was available.

Ralston.- Two men were working a drift mine on Magpie Gulch near Canyon Ferry, Mont. The gravel was dumped in a puddling box where it was disintegrated and freed of clay by means of a hoe, rake, or shovel. After it was washed a gate was opened and the material run into a sluice box 36 feet long.

Lucky Charles.- The gravel from the Lucky Charles mine at Blackhawk, Colo., was pulled from an ore bin into an iron box 8 feet long, where it was puddled by hand to dissolve the clay. All gravel over 1 inch in diameter was then forked out and the remaining material run through a 10-inch box 24 feet long, set on a grade of one-half inch to the foot. Riffles consisted of 1/2-inch round iron bars set one-half inch apart lengthwise in the box, held at intervals by 1/2-inch iron crosspieces that fitted tightly on the bottom of the sluice. By the time a batch of gravel was puddled the box was full of water; the gate was then opened and the stored water assisted the regular stream of 20 gallons per minute in carrying the material through the sluice. The hoist engineer did the sluicing.

Townsend and Hornbrook.- At the Townsend and Hornbrook mine near Hornbrook, Calif., the gravel was dumped from 1/4-cubic-yard buckets onto an inclined grizzly of 18-pound rails laid upside down with 1 1/4-inch spacing between. The gravel was washed on the grizzly by a spray of water under about a 10-foot pressure from a tank. The oversize dropped into a car which was pushed by hand to the rock dump. The undersize went through three 16-foot sluice boxes 12 inches wide, set on a grade of 1 1/4 inches to the foot. Steel matting was used for riffles. No quicksilver was used. Water pumped from the mine shaft (30 gallons per minute) was used for washing. It was stored in a tank and only turned into the sluice when gravel was being dumped. The top crew consisted of a hoist engineer and sluice tender.

Milling costs for a production of 9 tons per day were $4.00 for labor and $0.50 for supplies, making a total daily cost of $4.50, or $0.50 per ton. The pumping of water was charged to mining.

Baker Divide.- The Baker Divide drift mine is near Michigan Bluff, Calif. The washing plant consisted of a washing bin, where the gravel was disintegrated with water from a high-pressure hose, and a line of sluice boxes. (See fig. 9.) Boulders over 6 or 8 inches in size were sorted out underground. The gravel was dumped from mine cars along one side of the bin, which was 10 feet deep, 11 feet wide, and about 12 feet long with an open end. The bottom sloped from both sides to a 10-inch sluice box, 3 1/2 feet from one side.

The hose used for disintegrating the gravel had a 2 1/2-inch nozzle; the water pressure was 45 pounds per square inch. The gravel was washed back and forth on the bottom of the tank until it was clean. The high sides and end prevented the fine material from splashing out of the tank. Boulders were thrown out by hand on a rock pile. The riffles in the box in the washing tank were covered with a wire screen with 1/4-inch openings. For 8 feet below the tank the riffles were covered with wire screen with 1-inch square openings. Below this was 200 feet of sluice with alternating sections of transverse and longitudinal riffles. The riffles were 1 by 2 1/2 inches in section, spaced 8 inches apart and topped with strap iron.

The trommel is set on a slope of 1/2 inch per foot and is revolved at a speed of 28 r.p.m. by a 10-hp. motor.

The lower 4 feet of the trommel consists of two concentric screens, the inner perforated with 1 1/2- and the outer with 3/8-inch holes. All the material from the disintegrating section of the trommel passes by gravity onto the 1 1/2-inch screen. The oversize is discharged into a steel-lined sluice 60 feet long. It is forced through this by a stream of water from a 6-inch line and passes first over 6 feet of Hungarian riffles, then over 100 feet of pole riffles, and then to the waste dump. The pole riffles are constructed of longitudinally placed 8-pound steel rails.

The undersize of the 1 1/2-inch trommel drops onto the 3/8-inch outside screen, where it is washed by a stream of water from a 1-inch line. The washed oversize of this screen joins the discharge of the coarse screen. The minus 3/8-inch material drops to a 4-foot Hungarian riffle and passes over this onto a 3 1/2- by 6 1/2-foot "screen table." The latter is simply a 1/4-inch mesh heavy-wire screen laid flat in a widened sluice box of the dimensions noted. Spreading the fines over this table permits most of the fine gold which has escaped the riffles above to settle in the interstices of the screen. No quicksilver is used. It has been found that under the conditions at this property the mercury "flours" and gradually migrates under the action of swiftly flowing water. Fine gold which would otherwise remain in the riffles is then caught up and carried to the dump.

From the screen table the fines pass through a 20-foot section of Hungarian riffles, then over two 12-inch by 6-inch baffle plates, then over a final 12-foot Hungarian riffle. After this they join the coarse discharge of the trommel at the head of the pole riffles and pass eventually to the waste dump.

Above the baffle plates sluice boxes are 16 inches wide at the bottom and below the baffles are 12 inches wide. The function of the baffle plates is to smooth out the flow of sand and water, giving a more or less even feed to the last riffles. The first sluice box, between the bin and the trommel, is set at a slope of 2 inches per foot. The 4-foot segment between the trommel and screen table, the screen table itself, and the succeeding 20-foot section are all set on a 1 1/2-inch slope. Below the baffle plates the grade of the last section of Hungarians and of the pole riffles is 1 1/4 inches per foot. Any lower grades in the upper section of the plant result in crowding of the riffles with sand and overburden and the escape of fine gold due to the obstruction of effective water action.

Practically all of the coarse gold and 60 percent of the total is recovered in the first 11-foot riffle immediately below the gravel bin. Following the washing and screening in the trommel, a very large part of the remainder is caught in the 4-foot Hungarian above the screen table. Occasionally very large nuggets will accompany the oversize of the trommel and be caught in the first few feet of pole riffles.

When gold-bearing gravels are being milled, the upper two sluices are cleaned up twice a week, regardless of the tonnage, and daily if the gravels are unusually rich. The screen table is cleaned about once a month and the lower riffles only every 6 or 8 months.

Clean-ups are started in the uppermost sluices. The riffles are lifted from the box, maintaining a reduced head of water just sufficient to wash the sand and lighter material through the box as the mass is agitated slowly by hand and to precipitate the gold to the bottom. The last riffle remains in place and serves as a dam until the contents of the box have been reduced to a pan or less of concentrates. Coarse gold, if any, is screened out, and the fines are recovered on a small concentrating table. The percentage of flour gold is negligible.

The plant requires about 500 gallons of water per ton of gravel treated or in cubic measure about 3.7 cubic feet of water per cubic foot of gravel. The mine drainage water is discharged into a 400,000-gallon reservoir close to the shaft. From the reservoir the water is forced into a 1,500-gallon, steel pressure tank by a 15-hp. automatically controlled centrifugal pump. When the air pressure in the top of the tank drops below 15 pounds per square inch the pump is started; when it reaches 40 pounds the pump is stopped. A pressure of about 25 pounds is maintained when operating the plant, and the pump runs continuously.

A second and higher reservoir of 4,000,000 gallons capacity has been constructed in a gulch 1,200 feet northeast. In the rainy season this serves to store run-off water which can be drawn off as needed. It is dry during the summer months.

The centrifugal pump has a capacity of 500 gallons per minute, but only about 300 of this is needed for sluicing operations - 100 in the upper line to carry the gravel through the trommel and 200 to carry away the oversize to the dump. The mill capacity varies from the 15 tons per hour noted above, with the character of the gravel, which ranges from well-rounded easily washed material to clayey or sandy gravel containing angular pieces of bedrock and flat pebbles.

The effectiveness of the gold recovery has been shown by a mill test of the tailing. Two hundred tons of these, rehandled, yielded $0.175 per ton. As the original gravel had averaged $8 per ton the losses were only slightly over 2 percent.

Calaveras Central.- The Calaveras Central mill at Angels Camp, Calif., has a capacity of 75 tons per 8 hours. The gravel was passed over an 8-inch grizzly into a 3 1/2- by 8-foot trommel with 1 1/2-inch holes. The oversize from the grizzly and trommel, which comprised 60 to 75 percent of the feed, was taken to a dump by a belt stacker run by a 3-hp. motor. The undersize ran through 32 feet of 12-inch, steel-lined sluice boxes with a grade of 1 inch to the foot. Riffles were cut on a bias with the top horizontal; they were 1 3/4 inches high and 1 1/2 inches wide, topped with 1/16-inch strap iron and sot 2 inches apart. A trap at the head of the first box caught about 90 percent of the gold saved in the 36-foot sluice. The gravel contained considerable black sand; whenever the riffles had a tendency to pack with the sand more water was used. At the end of the first sluice the gravel was run through a second trommel with 5/8-inch openings. The oversize was taken to the dump by a belt conveyor. The undersize went to the dewatering box of a secondary washing plant, whence the sands were taken by a drag classifier to two 34-inch by 6-foot rod mills, each run by a 15-hp. motor. The sands were ground to pass an 8-mesh screen and were run over a steel-lined table 7 feet long and 30 inches wide with a divider in the middle. Wooden dredge-type riffles were used on the first 2 feet of the table. Gold passing over the riffles was caught in two traps containing quicksilver. The secondary mill was used only part of the time gravel was being washed; about 90 percent of the gold recovered was caught in the first sluice. About 250,000 gallons of water per day was pumped from the mine, and a plentiful supply was available for the mill.

Baltimore.- The Baltimore mill of the Mayflower Gravel Mining Co. is at Foresthills, Calif. Gravel from several adjoining drift mines had been treated in this plant. The gravel handled was tight and partly cemented. Boulders were coated with clay which contained placer gold. The flow sheet of the plant is shown in figure 11. The gravel as brought from the mines was dumped into a 150-ton bin from which it was drawn dry over a 5- by 12-foot grizzly with 1 1/2-inch spaces between the bars. The oversize went to a platform where fragments of cemented sand or gravel were sorted out and fed by hand into a 12-inch jaw crusher. Boulders and rock went to a trommel washer where the clay and sand were freed from the coarse material. The trommel had rows of 1/4-inch holes, 8 inches apart, and lugs to cause cascading of the material and thus facilitate washing. The oversize went to a belt conveyor and thence to the rock pile. The undersize from the trommel went through 48 feet of 12-inch sluice boxes set on a grade of 1 1/2 inches to the foot. Riffles consisted of 1- by 3-inch wooden strips, 2 inches apart, inclined downstream; the tops of the riffles were parallel with the bottom of the box. Riffles in the first box were covered with a 1/4-inch screen. Material from this sluice emptied into the tail sluice. The gravel from the crusher and the undersize from the grizzly went to three batteries of three 1,200-pound stamps each. The batteries had triple discharges; the material was crushed to pass through a 1/4-inch screen. The stamps dropped 107 times per minute and had a drop of 7 inches. Quicksilver was used in the battery box, where 85 percent of the gold was recovered. The stamped material went over three standard amalgamation plates 6 by 12 feet in size. A 6- by 1 1/2- by 1-foot trap was used at the bottom of each plate to catch nuggets or balls of amalgam. The material in the traps was agitated by water under pressure to prevent packing. Standard quartz mill practice was followed in cleaning the plates and treating the amalgam.

The mill had a capacity of 180 tons per 24 hours but has been run only periodically of late years. Electric power for running the mill was made below the mine by a Pelton wheel. The boulder washer was run by a 15-hp. motor, the crusher by a 30-hp. motor, and the stamps by a 25-hp. motor - a total of 70 hp. Plenty of water was available, and no measurements had been made of the quantity used. A saving of 95 percent of the gold was reported to have been made.

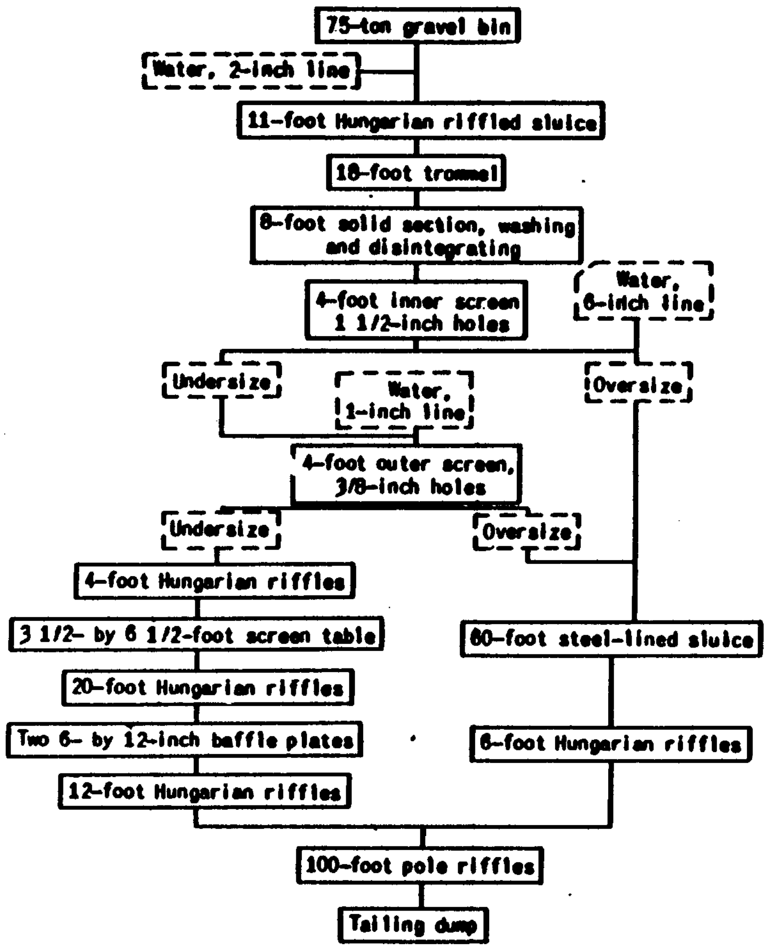

Figure 10.—Flow sheet, Vallecito Western mill.

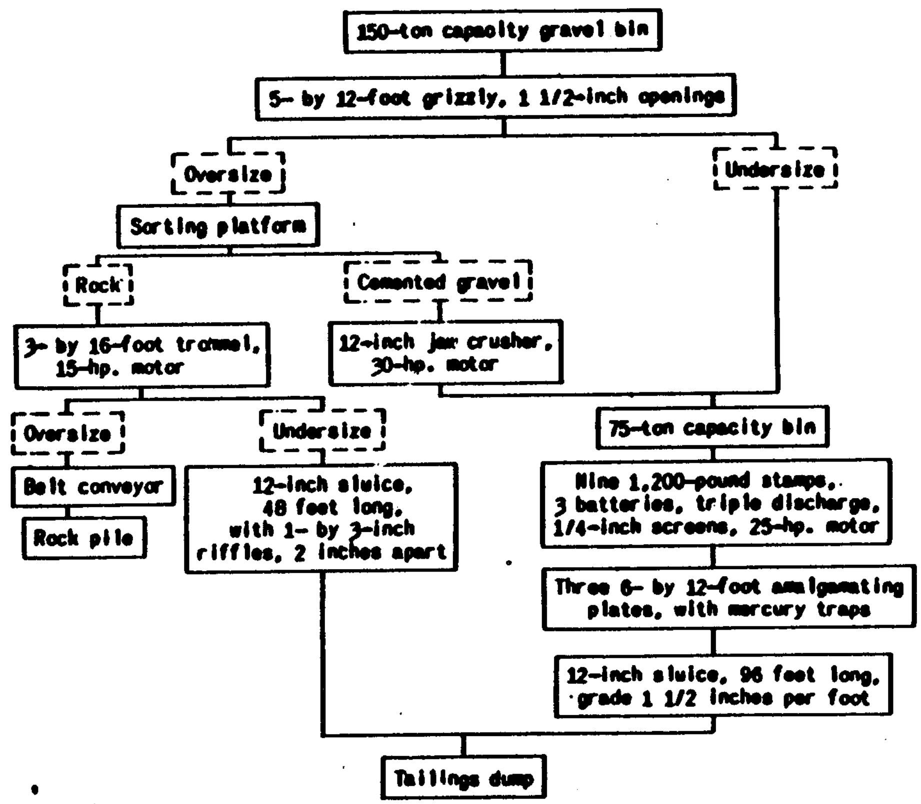

Figure 11.—Flow sheet, Baltimore mill, Foresthill, Calif.