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Bulletin No.

Placer Mining Methods and Costs in Alaska

by

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For ~~binding purposes only,~~ original copy of ~~report is divided into 3 parts~~.

~~Map forwarded under separate cover~~.

Original sketches and photographs are appended to ~~this report~~ original copy.

Note: Operating data for 1924 on the Wild Goose Dredge No. 1 (see p. 419a) and on the Ferry Dredge (see p. 419f) are not yet available. This data will be forwarded as soon as received and is to be added to the report on pages stated.

~~Part I~~


PLATE
MAP OF
ALASKA
SHOWING LOCATIONS OF PRINCIPAL
GOLD PLACER MINING CENTERS AND OCCURRENCES.
Base map by the U.S.Geological Survey.
ARCTIC OCEAN
BERING SEA
BERING STRAIT
No.
1. Nome.
2. Solomon.
3. Bluff.
4. Council.
5. Koyuk-Dime Cr.
6. Fairhaven-Candle.
7. Fairhaven-Inmachuck.
8. Kougarok.
9. Pt.Clarence-Teller.
10. Noatak.
11. Kobuk-Squirrel River.
12. Kobuk-Shungnak.
13. Koyukuk-Hughes.
14. Koyukuk-Nolan.
15. Chandalar.
16. Wade Hampton-Marshall.
17. Goodnews Bay.
18. Kuskokwim-Tuluksak-Aniak.
19. Kuskokwim-Georgetown.
20. Kuskokwim-Mt. McKinley.
21. Iditarod.
22. Innoko.
23. Tolstoi.
24. Lake Clarke.
25. Swentna-Rainy Pass.
26. Yentna-Cache Cr.
27. Kantishna.
28. Ruby.
No.
29. Gold Hill-Indian River.
30. Hot Springs.
31. Rampart.
32. Tolovana-Livengood.
33. Fairbanks.
34. Chena-Salchaket.
35. Bonnifield.
36. Richardson-Tenderfoot.
37. Circle.
38. Woodchopper-Coal Cr.
39. Seventy Mile.
40. Eagle.
41. Forty Mile.
42. Valdez Cr.
43. Delta.
44. Chistochina-Chisna.
45. Nabesna.
46. Chisana-Shushana.
47. Nizina.
48. Nelchina.
49. Girdwood-Crow Cr.
50. Hope-Sunrise.
51. Kodiak beaches.
52. Yakataga beaches.
53. Yakutat beaches.
54. Lituya beaches.
55. Juneau.
56. Porcupine.

Original map accompanies original
copy of report

Pl. No. 1 - Map of Alaska showing relative locations of principal gold lode mining centers and occurrences.

Placer Mining Methods and Costs in Alaska

and the Conditions Affecting Them

by

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Introduction

A placer deposit is a mass of gravel, sand, or other alluvium containing particles or nuggets of gold, platinum, tin, or other valuable minerals or metals, that have been derived through erosion from rocks or veins. Placer mining is therefore a form of mining by which this material is excavated and washed to recover its valuable content.

Active placer mining in Alaska began near Juneau in 1880, and while conducted elsewhere in the Territory from that time on, it was not until the discovery of the Klondike in 1896 that the first gold rush started. This discovery brought gold seekers from all parts of the world and from all walks of life. A few of these brought with them the experience gained in other fields, but the greater number had no knowledge whatever of placer mining. There was a great deal to be learned, for even the experienced found entirely new conditions which presented many difficult problems. A few years later gold was found on the Seward Peninsula and in the interior districts, where different conditions were again encountered. As a result, many different methods of mining and of thawing frozen ground, etc., were used and developed to contend with the widely differing conditions encountered in the North. The more efficient ones and those adapting themselves best to present conditions, or the resources of the operator, have survived, while most of the others have passed with the depletion of the higher grade gravels. All the known placer fields have been mined to a certain extent. Some of these have been mined so thoroughly as to be practically depleted. In most of the fields, however, large quantities of lower grade gravels remain, sometimes including small isolated areas of richer gravels which could not be successfully mined because of restricting physical conditions or the limitations of the method of mining employed. These fields are now the scene of most of the present placer mining, which is conducted by dredging, hydraulicking, drifting, mechanical methods of open-cut mining, and ground-sluicing or booming followed by shoveling-in.

As the average gold content of the gravels mined began to decrease, the number of mines operated became less and the production declined. This was further intensified by the economic conditions brought about by the World War. Economic conditions are now greatly improved, the cost of equipment and supplies is dropping, and transportation to most of the important districts has been much improved, especially to those districts reached by the Alaska Railroad and its river steamers. Mechanical equipment, power generation, etc., has been made more efficient. The methods of thawing frozen gravel with water at natural temperature has been developed. All of these, along with experienced and businesslike management, have made it possible to reduce mining costs, and account for the recent placer mining developments and the increased amount of prospecting that is being done.

The work of the U. S. Geological Survey in Alaska extending over a period of more than 30 years, and as published in its geological reports, water supply papers, investigations of placer mining and the annual reports on the Alaska mining industry, have been of invaluable aid to the industry. Most of this work was under the direction of the late Dr. Alfred H. Brooks, who as chief geologist of the Alaskan division for 25 years did more to aid mining in Alaska than any other person. In 1904, when Alaska placer mining was nearing its peak of production, the late C. W. Purington made an investigation of the methods and costs of gravel and placer mining and the results therefrom were published as Bulletin No. 263 of the U. S. Geological Survey. This excellent work has been widely consulted and accepted as authoritative on Alaskan practice. Since that time, however, many other districts have been discovered and actively mined, many changes and improvements have been made in mining practice, and there have been decided changes in economic conditions.

The object of this bulletin is to set forth the present condition of the Alaskan placer mining industry, the placer mining methods now employed, the cost of placer mining, and the conditions affecting them, so as to be of interest and help to the placer miner, the engineer, and all interested in the industry. The wide field which this report covers makes it necessary to hold closely to Alaskan practice and conditions so it must be considered that the reader has some knowledge of placer mining, as a volume could readily be written on most of the subjects involved.

The occurrence of gold placer in Alaska is widespread, there now being more than fifty placer mining centers, the relative locations of which are shown on the map, Plate I. It has been impossible to visit all of them, but those visited are the more important ones and those affording the best opportunity for study. In the comparatively short season during which it is practical to conduct a study of placer mining operations, many delays are encountered and a great deal of time is lost in traveling from one district to another, especially so to those districts reached via the Yukon River.

The field work in connection with this report was started by the writer in June, 192_, going directly to Nome, from where the Nome, Solomon, Council and Bluff districts on Seward Peninsula were visited, then the Ruby, Hot Springs, Rampart and Fairbanks districts. In 1923, his itinerary included the Iditarod, Innoko, a part of the Kuskokwim, the Fairbanks, Yentna, Nizina and Girdwood districts. The Circle and Eagle districts were to have been visited that season, but an attempt to reach those districts by aeroplane from Fairbanks failed because of general forest fires and dense smoke. The writer was unable to return to Alaska in 1924, until early in August, when an aeroplane flight was made from Fairbanks to Eagle, a distance of about 220 miles, as flown. Three hours and twenty minutes were required for the trip, which by the regular means of travel would have required ten days at the best. Conditions permitted visiting only a small part of the Forty Mile district, after which the Eagle, Seventy Mile and Circle districts, and later, the Fairbanks and Girdwood districts, were visited. In the writer's stead, Jno. A. Davis of the Bureau staff visited the Koyuk, Candle, Inmachuck, Nome, Solomon and Council districts on the Seward Peninsula to obtain further and recent data on placer mining practice there.

Operating data and costs have been most willingly given by the operators whenever available. At many of the operations, especially at most of the smaller ones, such data is not taken into account and could only be estimated in a very general way. In some instances, data was given confidentially, in part at least, and must therefore be withheld. Only such information as was considered consistent has been used, but it was generally impossible to check any possible errors as to the area or yardage mined, the average amount of water used and similar details, nor could some of the desired but lacking data on past construction or operation be revived. It was not the purpose of this investigation, or was it permissible, to sample the gold bearing deposits, ascertain the placer reserves, investigate the water resources or similar features.

In addition to the information obtained in the field, valuable data on placer operations and general conditions in some of the districts which could not be visited was obtained through conference or correspondence with those operators and other responsible parties.

The publications of the government, and the many fine articles by different writers that have been published in the technical press from time to time, on matters pertaining to placer mining in Alaska, have been liberally consulted.

The costs given are operating costs only, unless otherwise noted. They include all costs excepting such items as royalty, taxes, etc., and charges for depreciation, interest, amortization and depletion, which may or may not be given consideration by the operator. These capital charges may be nominal in some instances, but they are generally large, and at some operations may be as much or more than the operating cost. The operations are conducted under too widely differing conditions to state average costs, as such average costs would be very misleading. Therefore, the normal range of the cost of conducting the different kinds of placer operations, with some exceptions, are stated. For specific examples, representative operations have been described.

Annual reports on Placer Mining in Alaska in 192[illegible], 192[illegible], and

1924 have also been written by the writer to give early publication to a review of the placer operations and developments, and include descriptions of the mining methods employed and the conditions existing at the more representative operations in the various districts. These reports have been published in the Annual Reports of the Territorial Mine Inspector, B. D. Stewart.

Many requests have been received asking for information concerning government reports, technical press articles and text books, on placer mining. To aid those desiring such information, a selected bibliography has been added. Complete lists of the publications of the U. S. Geological Survey and the U. S. Bureau of Mines can be obtained by writing these respective departments at Washington, D.C. The trade catalogues distributed by the manufacturers of placer mining equipment also contain very useful information, tables and formulas.

The hearty cooperation and help which has been obtained from the operators, business men, transportation companies, and government officials is most gratifying, for it is through their kind

assistance that this work was made possible. The wonderful hospitality and courtesies shown the writer while in the field reflects those notable traits of the Alaskan. Acknowledgment and thanks are given to all.

Special acknowledgment is made to the late Dr. Alfred H. Brooks and S.R.Capps of the U.S.Geological Survey; B.D.Stewart and Jno. A. Davis of the U.S.Bureau of Mines; and to Charles Janin of San Francisco, California, the latter acting in a consulting capacity.

History and Production

The first reported discovery of placer gold in Alaska was made by a Russian engineer in 1850 in the Kenai River basin and a small amount of placer mining was done but soon abandoned. During the early 70's gold was found in the Tanana valley, but it was not until the discovery near Juneau in 1880 that the Alaskan placer mining industry obtained its start. Prospectors then began their search and in 1886 gold was found in the Forty Mile district and in 1893 and 1894, the Rampart district and the Birch Creek placers in the Circle district, were discovered. While these districts were actively mined, the annual productions were not sufficiently large to cause any unusual interest, but with the discovery of the Klondike in 1896 and the very rich bonanzas which were found there, excitement ran high. Those unable to strike it there soon left to look elsewhere. A few years later the rich deposits at Nome were discovered, followed by Koyukuk, Hot Springs, Fairbanks and others until the Tolovana discovery in 1915.

This has been the last important discovery made. The map, Pl. No. 1, shows the location of the principal gold placer mining centers and occurrences. The localities designated do not, however, cover all the placer gold occurrences, and in some of the districts but little if any placer mining is now being conducted.

The following table has been compiled to show the year the principal districts made the first recorded production and the total value of placer gold and its alloyed silver produced to 1922 inclusive.

Value of the Placer Gold and Silver Produced by Districts to 1922 Inclusive[1]

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(1) Compiled from statistics published by U.S.Geological Survey.

District	First Year of Production	Value of Gold and Silver Produced
Forty Mile	1886	$ 6,506,000
Circle	1894	6,775,000
Rampart	1896	1,610,000
Seward Peninsula	1897	83,650,000
Koyukuk	1900	4,904,000
Hot Springs	1902	6,300,000
Fairbanks	1903	72,340,000
Bonnifield	1903	286,500
Kantishna	1903	512,000
Richardson	1905	1,738,000
Chandalar	1906	255,000
Ruby	1907	5,450,000
Innoko-Tolstoi	1907	3,023,000
Eagle & Seventy Mile	1908	349,000
Iditarod	1910	19,108,000
Chisana	1913	648,000
Marshall	1914	1,136,000
Tolovana	1915	4,055,000
All others	Since 1880	12,955,000
	Total	$231,620,500.

During 43 years of mining, Alaska has produced gold to the value of $335,526,460, and of this amount $230,507,000 is to be credited to her placer mines. In addition to the gold, $1,113,500 worth of silver, practically all of which was alloyed with the gold, was recovered.

"Of this total, more than $200,000,000 has been mined since 1900, when the industry received its first great stimulus by the gold output of the Nome district. Other bonanza deposits were soon discovered, and by 1906, the value of the annual output of placer gold had reached $18,600,000 and the industry employed 8000 men. From 1906 the annual output declined, and by 1913 its value was reduced to $10,680,000 and the number of miners to 4,700. It should be noted that this reduction (45 per cent) in the value of the placer output took place before the war and that it indicated the rapid exhaustion of the bonanza deposits.
....

"The output of gold dredging increased in value from $20,000 in 1903 to $2,200,000 in 1913. Dredges had been built so actively before the war, that in spite of adverse conditions, they continued to increase their output, which did not reach its maximum until 1916 when its value was $2,679,000. The hard times that followed led not only to the shutting down of the dredges already built but to the abandonment of some new projects. The dredges reached their minimum output of gold in 1920, when its value was $1,130,000. This rise and decline before 1920 was paralled by similar though smaller fluctuation in hydraulic and other mechanical mining".[2]

[2] Brooks, A.H., and Capps, S.R., Alaskan Mining Industry in 1922, Bull. 755, U.S.Geol. Survey, p. 10.

The following tables, as published by the U. S. Geological Survey,[3] are of much interest as they give, annually, the placer gold

[3] Brooks, A.H., and Capps, S.R., Alaska Mineral Resources and Production, 1923: U.S.Geol. Survey Bull. 773.

production, yardage mined, value of gold recovered, etc. The increased yardage mined and the great decrease in the average value of the gold recovered per cubic yard during 1923 is noteworthy and is due mainly to the two large dredges at Nome which started operations that year.

Gravel sluiced in Alaskan placer mines and value of gold recovered, 1908 - 1923

Year	Total Quantity Gravel (cu.yds.)	Value of Gold Recovered per cu. yd.	Year	Total Quantity Gravel (cu.yds.)	Value of Gold Recovered per cu. yd.
1908	4,275,000	3.74	1916	7,100,000	1.57
1909	4,415,000	3.66	1917	7,000,000	1.40
1910	4,035,000	2.97	1918	4,931,000	1.20
1911	5,790,000	2.17	1919	4,548,000	1.10
1912	7,050,000	1.70	1920	3,439,800	1.13
1913	6,800,000	1.57	1921	4,812,700	.88
1914	8,500,000	1.26	1922	5,225,000	.84
1915	8,100,000	1.29	1923	6,015,595	.60

Relation of Recovery of Placer Gold per cubic yard to Proportion Produced by Dredges.

Year	Percentage of Placer Gold Produced by Dredges	Recovery per Cubic Yard		
		Dredges	Mines	All Placers
1911	12	$0.60	$3.36	$2.17
1912	16	.65	2.68	1.70
1913	21	.64	3.11	1.57
1914	22	.53	2.07	1.26
1915	22	.51	2.33	1.29
1916	24	.69	3.64	1.57
1917	25	.68	2.21	1.40
1918	24	.57	1.84	1.20
1919	27	.77	1.51	1.10
1920	29	.69	1.53	1.15
1921	37	.57	1.31	.88
1922	40	.55	1.29	.84
1923	51	.40	1.28	.60

Gold Produced by Dredge Mining in Alaska, 1903 - 1923.

Year	Number of Dredges Operated	Value of Gold Output	Gravel Handled (Cu.Yds.)	Value of Gold Recovered per Cu.Yd.
1903	2	20,000	---	---
1904	3	25,000	---	---
1905	3	40,000	---	---
1906	3	120,000	---	---
1907	4	250,000	---	---
1908	4	171,000	---	---
1909	14	425,000	---	---
1910	18	800,000	---	---
1911	27	1,500,000	2,500,000	$ 0.60
1912	38	2,200,000	3,400,000	.65
1913	36	2,200,000	4,100,000	.54
1914	42	2,350,000	4,450,000	.53
1915	35	2,230,000	4,600,000	.51
1916	34	2,679,000	3,900,000	.69
1917	36	2,500,000	3,700,000	.68
1918	28	1,425,000	2,490,000	.57
1919	28	1,360,000	1,760,000	.77
1920	22	1,129,932	1,633,061	.69
1921	24	1,582,520	2,799,519	.57
1922	23	1,767,753	3,186,348	.55
1923	25	1,848,596	4,645,053	.40
	--	$26,723,001	---	---

Gold and silver produced from placer mines in Alaska in 1922, by regions.

Region	Gold		Silver		Gravel mined	
	Fine ounces	Value	Fine ounces	Value	Cubic yards	Recovery per cubic yard
Southeastern Alaska	145.16	$ 3,000.	25	$ 25.	1,800	$ 1.67
Copper River region	7,951.08	165,000	861	861	305,747	.54
Cook Inlet and Susitna region	14,170.36	293,000	2,035	2,035	353,750	.83
Yukon basin	102,506.61	2,119,000	13,751	13,751	1,399,187	1.51
Kuskokwim region	26,219.25	542,000	2,616	2,616	215,300	2.50
Seward Peninsula	81,194.37	1,665,000	6,730	6,730	2,103,691	.80
Kobuk region	387.00	8,000	44	44	5,857	1.37
	212,606.12	4,395,000	26,269	26,269	5,220,000	.84

Statistics of placer mining in Alaska in 1922 and 1923.

Region.	Number of mines				Number of miners				Value of gold produced.		
	Summer		Winter		Summer		Winter		1922	1923	Increase or decrease, 1923.
	1922	1923	1922	1923	1922	1923	1922	1923			
Southeastern Alaska	2	0	1	----	3	12	2	---	[illegible]	[illegible]	[illegible]
Copper River region	8	9	5	3	91	56	16	11	165,000	144,000	-21,000
Cook Inlet and Susitna region	36	35	1	----	174	180	2	---	293,000	247,000	[illegible]
Yukon basin	321	301	99	64	1,254	1,078	321	243	2,119,000	1,644,000	-475,000
Kuskokwim region	30	23	---	2	137	106	---	4	542,000	292,000	-250,000
Seward Peninsula	104	60	11	6	628	606	81	23	1,266,000	1,270,000	+5,000
Kobuk region	6	8	3	----	11	13	8	---	8,000	[illegible]	--------
	507	436	120	75	2,198	2,081	402	287	4,395,000	3,608,000	-788,000

The Future of Alaska Placer Mining

It was not within the scope of this study to ascertain the gold placer reserves of Alaska except in a very general way. Estimates, however, have been made from time to time by members of the U. S. Geological Survey and others. The volume of the gravels remaining in the known fields, and their gold content, can be roughly approximated by careful study of all the available geologic, statistical and mining data, although with so many widely differing conditions affecting the cost of mining these reserves, it is a most difficult and almost impossible task to even approximately state how much of this gold can be profitably recovered. Gravel of a profitable tenor in one locality under certain favorable conditions would be worthless somewhere else, and gravels now considered unprofitable may at some future time permit profitable operation through improved economic conditions and improvements in mining practice. Brooks,(4) in considering such

(4) Brooks, A.H., The Future of Alaska Mining: U.S. Geological Survey, Bull. 714, p. [illegible]-11, 1921.

limitations, but assuming that profitable mining will be possible in the future on the same grade of placers as it has in the past, estimates that the available placer gold reserves in the developed districts of Alaska have a value of at least $360,000,000 and perhaps of twice that amount, and adds that there is also the possibility of discoveries of new deposits, of which not even a rough estimate can be made.

Some years ago it was estimated that the value of the gold reserves in the gravel plain, ancient beach and high bench placers of Seward Peninsula, was about $215,000,000, and that of the creek deposits about $50,000,000.(5)

(5) Brooks, A.H., et al, Gold Placers of the Seward Peninsula, U.S.Geol. Survey, Bull. 328, p. 139, 1908.

The gold placer reserves of the Fairbanks district were estimated by Prindle(6) to contain about $50,000,000 and excluded some

(6) Prindle, L.M., Geologic Reconnaissance of the Fairbanks Quadrangle, Alaska: U.S.Geol. Survey Bull. 525, p. 115, 1913.

areas which have since developed possibilities for dredging.

In 1919, a committee of the Alaska Chapter of the American Mining Congress consisting of experienced Fairbanks mine operators under the direction of John A. Davis of the U. S. Bureau of Mines, gathered all available information on the creeks immediately tributary to Fairbanks and estimated that these creeks contained a total of 219,200,000 cubic yards of dredging ground with an average gold content of about 46 cents per cubic yard and a total gold content valued at $100,200,000.

An instructive comparison may be made between the placer mining in Alaska and that in the Klondike district in the Canadian Yukon. During the eight years of bonanza placer mining ending about 1905, this district produced $107,000,000 in gold. It was generally believed that the days of placer mining there were about over, but by the use of hydraulic and dredging plants the district has since produced gold worth more than $70,000,000. Yet compared with the placer mining in the Klondike, placer mining in some of the Alaskan districts is but in its infancy. Dredging operations recently started at Nome and investigations which have been made around Fairbanks would indicate the start of a somewhat similar era in those districts.

These estimates all indicate that far more gold still remains in the known placer fields than has so far been mined. It is, however, improbable that the quantity of gold produced in the future from these known fields, will ever reach these estimates, even though the present indications all point favorably to a future gold production from the Nome and Fairbanks districts which will closely equal if not exceed the past yield from these districts.

In the early days of Alaska placer mining, conditions were such that rich deposits were necessary for success and success in Alaska at that time demanded larger returns than in a country affording more favorable conditions or as the conditions now are in Alaska. Subsequent development of the country, and improvements in mining practice made it possible to mine lower grade gravels. The selective system of mining under the earlier existing conditions was the cause of much waste of ground. Many deposits were so gouged as to place them beyond the possibility for future profitable mining. Much of the past mining was done in an inefficient manner, or because of adverse factors, the thoroughness of the operation was restricted. Earlier mining operations left the lower grade gravel, or that which could not be profitably mined by the methods employed. There were many operations where considerable gold was lost in the tailing or the bedrock was not properly cleaned. Such placers are now the scene of most of the present day operations and there are still many awaiting investigation. Bench deposits occur in most of the districts, and while many of them have been mined to some extent, the possibilities of most benches are still to be determined.

A great amount of prospecting and drilling was done during the earlier days when richer gravels were sought and in many cases considerable placer was found which at that time was not considered as affording sufficient inducements for mining. Much of this placer would now be accepted as being very satisfactory. Records of such work have unfortunately either been lost or forgotten, and such areas must be reprospected. The same holds true with the early prospecting of many of the creeks, which while known to be gold bearing, have in many cases never been sufficiently prospected to determine their possibilities. Development in certain districts have also been retarded because of excessive purchase prices or royalties asked.

Prospecting in virgin fields is again on the increase and while some new gold discoveries have been recently made, they have been of little importance. However, with a great area of country still to be prospected, there is every reason to expect new discoveries of importance, although it is not reasonable to expect any of such magnitude and richness as some of the discoveries of the past.

Placer mining methods such as groundsluicing and booming followed by shoveling-in, are well adapted for the mining of small isolated areas which will not support more extensive operation. These methods employ mainly manual effort with a minimum amount of capital invested in equipment, and while they are rapidly passing in most of the districts, they will always be popular with a considerable number of miners of very limited resources and who are content with small returns.

often little if any more than wages, but more often only a bare livlihood. Drift mining is on a decided decline, the operations are becoming smaller in scale, less profitable, and fewer in number, as the tenor of the gravels diminishes and the more favorable areas are being acquired for other methods of mining. It is generally, however, the only practical method for mining those deep frozen channel deposits having the main gold content concentrated in a comparatively thin, defined horizon occurring usually at bedrock.

Shallow placers of favorable character for dredging but in general too small in area to justify the cost of installing a dredge, afford opportunities for open cut mining by mechanical means. The deposit must, however, be of a character affording favorable digging conditions for the means of excavation employed, and unless the gravels are shallow or can be cheaply stripped so as to reduce the volume of material to a practical limit for subsequent excavation, unprofitable operation may result. Most of the mechanical devices formerly used were too immobile and too costly to operate to be successful. The steam scrapers, especially the bottomless type, have done satisfactory work in the past but their period of usefulness is passing; their field being taken over by the dredges; and requiring more power, labor and material in their operation, must for future operation give way to the dragline excavator or the cableway excavator. The dragline excavator and the cableway excavator answer the requirements for economical and efficient operation better than other types, for besides the above mentioned features, they possess a favorable degree of mobility and can deliver the material directly to the sluices, without intermediate transportation requiring additional equipment, or labor.

Hydraulic mining will always be a favored method where conditions permit, but in most of the districts the operations will be restricted to a comparatively small scale because of the generally low stream gradients, the generally adverse conditions for obtaining cheap ample water supplies and the lack of deep extensive deposits under conditions necessary for large scale, low cost operation. The small, inexpensively equipped hydraulic mine requiring only a small crew is in general best adapted for Alaskan conditions, and the field for such operations is extensive.

The increasing search for dredging ground and the increasing number of dredge operations, especially those of recent development on a large scale, are indicative of the condition of the Alaskan placer mining industry. While dredging now produces more than half of the Alaskan placer gold production, this proportion will rapidly increase in the near future but at the expense of other methods of mining which are giving way to its more efficient and less costly operation.

It must be admitted that the richer and more favorably located placers have been or are being rapidly depleted. The glamour of the bonanza days is over, the remaining gravels are lower in tenor and the inducements offered under the present day conditions are not as good as they formerly were. Short operating seasons, frozen ground conditions, generally adverse conditions for obtaining suitable water supplies, isolated geographic position with difficult transportation conditions and high freight rates, high priced labor, etc., all prohibit low cost operation, but in spite of them there is still a vast field of opportunity for the experienced and efficient operator. Alaskan placers in general can never be mined as cheaply as those in other countries where more favorable conditions exist, so that while much low grade gravel remains, much of it will never permit profitable mining, although under certain favored conditions, placer mining has been and can be conducted in Alaska at costs comparing favorably with those attained elsewhere.

The necessity for properly prospecting the property and investigating all conditions affecting its mining so that the right method of mining can be selected and the property equipped with a plant best befitting the conditions, cannot be too strongly emphasized, for a disregard of these features has lead to many failures. Not only has too much been taken for granted in many instances concerning the placer, but plain business principles have been disregarded by handicapping an otherwise suitable property with an astounding amount of overhead or capital invested in equipment.

The conditions affecting placer mining, the methods of mining that have been developed through experience to meet those encountered in Alaska, and the cost of conducting such operations under widely differing conditions are discussed in the following pages.

Geography and Topography[7]

[7] Compiled mainly from data by Brooks, A.H., Geography and Geology of Alaska: U.S.Geol. Survey Prof. Paper 45, pp 14-17, 1906.

Alaska in its greatest extent is included between the meridians of 130° west longitude and 173° east longitude and between the parallels of 51° and 72° north latitude.

It is in approximately the same latitude as the Scandinavian Peninsula; Point Barrow, its northernmost point, is in about the same latitude as North Cape; Dixon Entrance, which marks its southern boundary, is nearly on the same parallel as Copenhagen; St. Elias is in the latitude of Christiania and St. Petersburg; and Sitka, is in the latitude of Edinburgh. The longitude of the western terminal of the Aleutian Islands is almost identical with that of the New Hebrides Islands and is the same as that of New Zealand; and Cape Prince of Wales, the most westerly point of the mainland, is nearly as far west as the Samoan Islands.

The Territory has an area of 590,880 square miles, which is more than twelve times the size of the State of New York, or practically one-fifth of the size of the United States proper. At its southern point it is 700 miles from the northwest point of the State of Washington by the usually traveled route. Thence, the southeastern Alaska Archipelago and a strip of mainland lying west of the Canadian boundary extend northwesterly for about 620 miles to the major portion of the Territory, which lies west of the one hundred and forty-first meridian, and has a dimension of approximately 900 miles north and south and 700 miles east and west, with the Alaska Peninsula and Aleutian Islands reaching out from the southwestern portion nearly 2500 miles toward Siberia.

A map of Alaska superimposed on a map of the United States of the same scale, demonstrates that the distance, from the easternmost to the westernmost point in Alaska is equal to the distance from the Atlantic to the Pacific in the latitude of Los Angeles and that its northernmost and southernmost points are nearly as far apart as the Mexican and the Canadian boundaries of the United States.

The topography of Alaska is varied and complex and it is not easy to present briefly even the salient features. Having an important bearing on placer mining the reader is referred to the many topographic maps published by the U. S. Geological Survey.

Geological Features

The formation of placers is determined by (1) the occurrence of gold in bedrock to which erosion has access; (2) the separation of the gold from the bedrock by weathering or abrasion; (3) the transportation, sorting, and deposition of the auriferous material derived by erosion.

The placers of Alaska may be classified in two ways. The first is a classification based according to genesis, or origin, which divides them into residual, sorted and re-sorted placers.[8] Residual placers

[8] Brooks, A.H., Mineral Resources of Alaska, 1913, U.S.Geol. Survey Bull. 592, p. 25-32.

are those in which there has been little or no water transportation of the gold, the concentration being due primarily to rock weathering, settling, and removal of soluble rich constituent with more or less movement on the hill slopes. The sorted placers are those in which the gold is the result of transportation, sorting and deposition by water. The re-sorted placers are those in which the gold has passed through two or more periods of erosion before its final deposition.

The second classification[9] is according to form, as follows:

(9) Brook, A.H., Genesis and Classification of the Placers: U.S.Geol. Survey Bull. 328, p. 114-145, 1908. Lakebed placers not included.

Creek Placers: Gravel deposits in the beds and intermediate flood plains of small streams.

Bench placers: Gravel deposits in ancient stream channels and flood plains which stand from 50 to several hundred feet above the present streams.

Hillside placers: A group of gravel deposits intermediate between the creek and bench placers. Their bed rock is slightly above the creek bed and the surface topography shows no indication of benching.

River-bar placers: Placers on gravel flats in or adjacent to the beds of large streams.

Gravel-plain placers: Placers found in the gravels of the coastal or other lowland plains.

Sea-beach placers: Placers reconcentrated from the coastal-plain gravels by the waves along the seashore.

Ancient beach placers: Deposits found on the coastal plain along a line of elevated beaches.

Lake-bed placers: Placers accumulated in the beds of present or ancient lakes; generally formed by landslides or glacial damming.

It is evident that these two classifications contain intermediate types which may belong to either of two groups. Most of the Alaskan placer gold has been obtained from the creek, bench and beach deposits.

Residual placers have been found at a number of localities, but have not constituted an important source of placer gold. The most notable examples of residual placers are found at the head of Flat, Happy and Chicken Creeks in the Iditarod district. Creek and bench deposits are found in practically all the districts. They may be of either ancient or modern origin, or of the sorted or re-sorted types. The modern creek placers occupy the present creek channels and contain gravels from a few feet to ten feet or more deep. The sorted ancient placers are those in the benches or terraces along present streams, and have all the characteristics of the modern creek placers except that they have been dissected. Such bench placers are quite common in many of the districts. The deeply buried channels or "deep gravels" are deposits of ancient water courses, which occupied the present valleys but are now buried under a deep covering of alluvium. These deep channels usually have a rather straight course with only a few large bends and lie on a bedrock floor whose downstream slope is generally a little steeper than that of the present valley bottoms, and in most cases are centrally located with reference to the bedrock slope of the valley. In the headwater regions of the creeks the deep gravels may merge with those of the present streams and here the entire section may consist of gravels. The best examples of these deposits are found in the interior of Alaska, particularly in the Fairbanks, Hot Springs, Tolovana, and other districts in the Yukon Tanana region. Here the gravels which ordinarily are from 10 to 40 feet thick are buried under an accumulation of muck or black humus, fine gray sand, silt and clay, 10 to 300 feet and more thick.

Bench placers have all the characteristics of modern stream placers, but their bedrock floor is higher than the stream bed. Gravel terraces are wide flat gravel deposits, the surfaces of which are considerably above the high water level of the stream and the bedrock floors only slightly, if at all, higher than the stream bed. The present streams have cut into the deep muck covering of the deep channel deposits, forming a surface terracing resembling benching. While the bedrock floor is generally the same elevation as that in the present stream bed, such deposits are often wrongly classed by many of the miners, as bench deposits. High bench deposits have resulted from stream action of a former drainage system, now preserved only in fragmental form. Unlike the bench deposits of the present valleys, they have no direct relation to the existing drainage channels. These high gravels are sometimes referred to as "bar" deposits. The best examples are found in Rampart, Hot Springs, and Ruby districts, where they are low grade and have not been workable to any extent. Some of the high bench placers near Nome, forming the divide between Dexter and Anvil Creeks, have, however, been quite productive.

Sea beach deposits of the modern type are practically all of the resorted kind and are formed by the action of the surf in destroying adjacent alluvial deposits and concentrating their gold contents along the beach. They occur along the Pacific seaboard at Lituya Bay, at Yakataga, Kodiak Island and elsewhere. The most important ones are found at Nome and vicinity where large amounts of gold have been won from them. Sea beach placers are usually of small extent, each high surf causing new enrichments. The ancient re-sorted sea beach placers probably include the same types as the modern ones. At Nome there are both submerged and elevated beach placers formed at a time when the land stood at a different altitude relative to the sea. These beach lines have been very productive. The gravels are covered with muck and overburden, and, in general, the total depth of these deposits ranges from 30 to 100 feet.

River bar placers contain mostly fine gold, deposited at certain places of minimum water movement. Some of these have been profitably mined by hand labor, but as a rule are not extensive enough to support larger operations such as dredging. Hillside placers do not occupy well defined channels but are a transitional type between residual and gulch placers. River bar and hillside placers are not commercially important.

Gravel plain placers are in part modern, but chiefly ancient placers, and are somewhat intermediate in type between the creek and river placers. The so-called "tundra" placers of Nome are of this type. Their present importance has been derived chiefly from the fact that they furnished gold to some of the resorted beach and stream placers. Glacial deposits may contain gold, but have little economic value unless they have been re-sorted by post-glacial streams or have derived their gold from an unusually rich primary source.

In most of the Alaskan placers the greater portion of the gold occurs on or near bedrock. It may, however, occur in economic quantities from 10 to 20 feet and even more above bedrock, although it is seldom that the upper portion of the gravels contain sufficient gold to be profitably mined by themselves. It is, however, not uncommon for some of the placers to contain two or more distinct strata of pay gravel separated by beds of muck, sand, clay or low grade or barren gravel. Gold also works its way into the bedding planes and crevices in bedrock. As a general rule it descends but a foot or two below the top of bedrock although in blocky, slabby or creviced formation, particularly limestones and some schists, it may continue 10 feet or more in the bedrock. In many placers, the decay of the bedrock has formed a sticky clay or "gumbo". Under such conditions, the gold will lie on this clay or be more or less distributed through it. The coarsest gold is generally found in the lower portion of the gravels becoming finer toward the top. The coarser gold in the creek and bench deposits, especially in the richer deep channel placers, holds, as a rule, to defined pay streaks or channels, and as the outer limits of these are reached and the tenor of the gravels diminishes, the gold becomes finer. This ~~finer~~ gold in the marginal gravels is known as "side pay". There are, however, numerous placers particularly in the interior, where no defined pay streaks or channels exist, the generally coarse gold occurring in irregularly shaped disconnected areas or spots, locally re-sorted from older placers or from local bed rock sources.

The placers range from about 50 to 500 feet in width in the smaller valleys, and in the narrower instances these valleys are usually V shaped. In the broader or wider valleys, the gold may be distributed in quantities sufficient for profitable dredging over maximum widths up to 1000 feet or more. There are several instances where this gold distribution holds over a maximum width of 2000 feet. The general character and depths of the placers being mined are stated in more detail in the description of mining methods.

Associated with placer gold are found those accessory rock forming minerals as magnetite, pyrite, garnet, ilmenite, tourmaline, ruby, and others of rarer occurrence. In the Kisina district, much native copper, and some silver, is recovered in the sluices. Native silver has been found in a number of other districts. Alluvial tin or cassiterite, is found with the gold in the Ruby, Circle and other districts, and is a valuable by-product in the Hot Springs district. Alluvial tin was at one time a by-product of gold placer mining in the York region on the Seward Peninsula where it occurred in such quantities that those placers were later mined for the tin content. Cinnabar, scheelite, wolframite, barite, galena and other minerals are frequently found in the gold placers of many districts. Platinum has been found on a number of creeks in the Yukon Basin and Southwestern Alaska, and a considerable amount is recovered with the gold at Dime Creek on the Seward Peninsula.

Climate

Alaska's geographic position, extent, and varied topographic features have brought about physical conditions producing strong contrasts between the different districts. Most people, unfamiliar with Alaskan conditions have the mistaken impression that it is a land of ice and snow, with extremely cold temperatures. They do not realize that nearly three quarters of its area lies within the North Temperate Zone and that the climate is by no means so uniformly Arctic as believed. It is true that some of the farther North districts experience some very cold weather during the winter months, but in general climatic conditions, so far as the temperature is concerned, form the least of the hardships with which the miner has to contend. The open season, while somewhat variable, averages from May to October. A no more generally healthful and invigorating climate than Alaska's can be found anywhere. Climate has an unusually important bearing on Alaskan placer mining, and with the exception of certain advantages favorable to some of the drift mining, is decidedly adverse. The climate establishes the length of the mining season which in Alaska varies from 3 to 6 months, depending on the locality and the method of mining employed; it governs the water supply; affects transportation, the vegetation and numerous other factors bearing directly upon placer mining. One unusual effect of Alaskan climate is the frozen condition of the ground which prevails in most of the districts. The extent to which the climate affects these different factors will be shown under their separate headings.

Three general climatic provinces, each of which in turn includes a number of subordinate provinces, are recognized in the following:[10]

(10) The Report of the Alaska Railroad Commission: House Doc. 1346, 62d Cong., 3d sess., pp. 28-32; the figures have been revised by the U.S. Weather Bureau, Department of Agriculture.

The first is the maritime province lying adjacent to the Pacific Ocean. This has a heavy precipitation (60 to 190 inches), comparatively high mean annual temperature (35° to 40° F), cool summers (mean temperatures 50° to 55° F.), and mild winters (mean temperatures 20° to 35° F.). It has small variations of annual extremes of temperature compared with the western provinces, the records showing from -27° to 94°. The second is the inland province lying beyond the coastal mountains with a continental climate characterized by semiaridity (precipitation 9 to 15 inches), comparatively warm summers (mean temperatures 60° to 68° F.) and cold winters (mean temperature 0° to -15° F.). Its most striking feature is the extreme annual variation in temperatures, which are from -76° to 100° F. The mean annual temperature varies from 15° to 27° F. The third province includes the region tributary to the Arctic Ocean, which, according to a few records, has a precipitation of only about 5 to 8 inches, an average summer temperature of from 40° to 45° F., and a winter temperature of about -10° to 16° F., and an extreme variation of -54° to 66° F.

The climate of the Coastal province is comparable with that of Scotland and the Scandinavian Peninsula in Europe, but is somewhat warmer. That of the Inland region is not unlike the climate of Alberta, Saskatchewan and Manitoba in Canada. The Northerly province bordering the Polar Sea is the only one in which the Arctic conditions prevail.

It is usual to have marked seasonal differences in climate, although the climatological averages over a period of such years may show but little departure from the normal. Two very unusual seasons were experienced in 1922 and 1923. The season of 1922, in most of the placer districts, was a cold rainy one, a season of slow thawing, but one of an unusual large water supply, while 1923 was a dry, hot season, resulting in a prolonged drought of several months. Each of these seasons were such decided changes from the normal that they can for general consideration be taken as seasons of maximum and minimum performance. The accompanying climatological tables are therefore given for these two years, although they do not bring out the marked difference which existed during the summer season. They have been compiled from the annual weather reports of the U.S. Weather Bureau at Juneau.(11,12)

(11) Summers, L.B., Climatological data, Alaska section, 1922.
(12) Mize, R.C., Climatological data, Alaska section, 1923, Dept. of Agriculture, U.S. Weather Bureau, Juneau office.

Transportation and Freight Rates

Ocean transportation between ports in the United States and the Pacific Ocean ports in Alaska is maintained throughout the entire year, excepting to those ports on Cook Inlet which are closed during a few of the winter months. Ocean service to Bering Sea ports is, however, limited to the open season, which is from about the early part of June until about the latter part of October.

Before the completion of the Government railroad between Seward and Fairbanks, transportation to the interior districts was via the Yukon River, up from St. Michael, or down from Dawson, via Skagway. The upper Yukon River as far down as Rampart is now best served via Skagway, over the White Pass and Yukon Railroad to White Horse, thence via the company's river boats to Dawson and points down the river, these boats going as far as Nenana. The rivers are open to navigation from about the latter part of May to about the early part of October. The Government railroad under the direction of the Alaska Engineering Commission maintains regular service throughout the year between Seward and Fairbanks over a standard gauge track, a distance of 470 miles, with a narrow gauge branch line between Happy Station, near Fairbanks, and Chatanika, a distance of 32 miles; and a standard gauge branch of 40 miles connecting from Matanuska with the neighboring coal fields. The Alaska Engineering Commission in 1923 placed in service two river boats which operate on weekly service during the open season between Nenana on the Tanana River and Holy Cross on the Yukon River. Privately owned launches operate on the lower Yukon River below Holy Cross, and to points on the various navigable tributaries of the Yukon River. The Copper River and Northwestern Railroad operates between Cordova and Copper River points to Kennicott, a distance of 192 miles.

Ocean freight rates and through rates to most points on the Yukon River are now appreciably higher than during the boom days, accountable by reason of the great decrease in the volume of the freight now handled, practically no competition and the increased cost of operating the boats. Since the completion of the Government Railroad, a great reduction in freight rates has been made to points along its line and to some of the interior points. The rates to points on the Yukon River touched by the Government steamers mentioned, while still high, are in general much lower than they would have been had this service not been established. One of the greatest benefits of this railroad has been to improve the accessibility of many of the interior districts making them "all year" camps. Were it not for this railroad many of the mining operations there could no longer continue nor would the large dredging projects under consideration in the Fairbanks district be practical.

The tables given on ocean, rail and Yukon River rates were compiled from tariffs for 1923. No changes in the base rates were made in 1924, and while subject to change in the future, no reduction is looked for.

Under the conditions encountered, the combined ocean, rail and most of the river freight rates to all but the most isolated districts cannot be considered as being unreasonable even though they are high; nor a severe handicap to placer mining unless it be at the start when the equipment and initial supplies are shipped in.

The average small Alaska mining operation will require from a few tons to not over [illegible] tons of supplies per season (exclusive of fuel). Some of the larger steam scrapers and hydraulic operations may require about 60 tons; and the dredging companies from 50 to 300 tons per season, which would include the fuel supply. Add to these rates the additional cost of overland transportation, which in many cases doubles and often more than quadruples these freight rates, it can readily be seen that they then become prohibitive. Where a property is within close distance to the main supply point or tributary to a good road system, the effect is not so keenly felt but in the more isolated districts it has brought about a rapid decline in operations and retarded development. The urgent necessity of improving these conditions is one of the best arguments to be advanced for more road building, or at least the construction of suitable trails. In most of the districts, it is necessary to do the bulk of the overland freighting in the winter, which is often most unsatisfactory, but it can then be done more cheaply. Recourse is taken by many in using the parcel post, which at 12 cents per pound is much more reasonable in many districts than the usual freight rate. The heavy rainfall on the seaward slope creates an almost unpassable footing over the mossy and swampy sections, and in the interior and Seward Peninsula districts conditions are even more difficult because of the surface thawing of the frozen ground.

Alaska's road system has been developed under the Alaska Road Commission, which body during its eighteen years of existence has expended about $8,000,000 upon a system of roads and trails, consisting of 1,114 miles of wagon road, 623 miles of sled road, 4,404 miles of permanent trail and 713 miles of temporary flagged trail.(13)

(13) Report of the Chief of Engineers, U.S. Army for the year 1922, Part 1, p. 2235, and report of Board of Road Commissioners for the fiscal year, 1922, Part 2, p. 6-101.

The appropriations made by the Territorial and Federal government for roads and trails have been too inadequate to extend this system and maintain it according to the plans outlined by the Commission. Such projects under construction as the roads between Chatanika and Circle, Talkeetna and Cache Creek, Ruby and Ophir, Tacotna and Ophir, Nome and Bearing (via the Seward Peninsula Railroad route), Nome Creek and Candle, and others, should be hastened to an early completion, being projects of greatest benefit to the development of these important districts. The Seward Peninsula Railway, a narrow gauge line between Nome and Shelton, a distance of about 90 miles, after being idle for many years, has recently been acquired and repaired by the Territorial Government and turned over to the public's use in transporting passengers and light freight. Small gasoline driven cars and light trucks pulled by dogs are privately used for this. Road construction in the forest reserves is now being done by the Bureau of Public Roads, some of which will be of direct benefit to placer mining. The provisions of the Federal Aid Road Act are not applicable to Alaska, but should be. If this could be brought about, Alaska's appropriation would be large enough to assure the extensive and much needed construction of roads and trails.

The practicability of air service in Alaska has recently been demonstrated. Numerous flights from Fairbanks to various placer camps within a radius up to 250 miles have been made during 1924 by the planes of a private company. Flights were made in two to three hours which under regular transportation means would have required as many weeks. Conditions for operating aero and hydroplanes in Alaska are stated to be unusually satisfactory and the early development of this means of transportation is predicted and will be of the greatest benefit in the development of the country. A Government subsidy extended to aviation companies in the form of mail contracts or some other means would greatly assist the development of air service in Alaska.

The tables given show the distances, freight rates on the more important commodities to and between the principal Alaska ports and placer mining centers by the different means of transportation.

Diesel oils, distillate and other oils are generally shipped in drums. The 55 or 110 gal. steel drums are usually used for containers. These drums, empty, weigh 55 lbs. and 210 lbs., respectively, and when shipped full are accepted on ocean lines on the measurement basis of 12 and 24 cu. ft. each. An appreciable saving can be made by using the 55 gal. drums where freight rates are based on the weight basis as the shipments going over the railroad are. These drums are also more easily handled and the loss by leakage is therefore lessened. The new I.C.C. 55-gal. steel drums now being used measure 11 cu. ft., they weigh less than the old style and are cheaper in first cost.

The steam-ship lines handle most articles on the measurement

ALASKA FREIGHT RATES - 1923

Seattle or Tacoma, Wash. to	Ketchikan	Juneau	Cordova Valdez Seward	Anchorage	Bethel 2170 McGrath	Nome (ships side) (e)
Miles from Seattle	754	1032	1603-1666	2144	2670	2500
Coal-sacked-per 2000 lbs.	(a) 4.00	4.00	5.00	6.00		(b)13.65 (c)15.65
Freight N.O.S.ordinary) General Merchandise) " Groceries)	(a) 7.50	8.50	13.00	15.00		(b)16.00 (c)19.00
Grain,feed,-per 2000 lbs	(a) 7.50	8.50	12.00	14.00		(b)15.50 (c)18.00
Hay-in bales- 22 lbs or more To 1 cu. ft.	(a)11.00	[illegible]	14.50	16.50		(b)[illegible].00 (c)21.00
High explosives-powder	(a)14.00	14.00	21.50	24.00		(b)23.00 (c)26.50
Lumber-common-not over 32 ft. long per 1000 B.M.Ft.	(a)7.00	8.00	1[illegible].00	16.50		(b)21.00 (c)23.00
Mining machinery-no single Piece over 4000 lbs.wt.(d)	(a)7.50	8.50	13.00	15.00		(b)12.50 (c)15.00
Oils-explosive 110 gal.drum at 24 cu.ft.	(a)7.50	7.50	12.50	14.50		(b)16.00 (c)20.00
Oils-fuel,engine,coal	(a)7.50	7.50	12.50	14.50		(b)15.00 (c)18.00

(Bethel column, printed vertically:) All commodities- To Bethel $22.50 / Bethel to McGrath $22.50 / Rates per ton at ships option-wt. or meas.

RETURN FREIGHT SOUTH BOUND

	Ketchikan	Juneau	Cordova Valdez Seward	Anchorage	Bethel McGrath	Nome
Carriers-empty drums 110 gal.drum at 24 cu.ft.	(a) 3.50	3.50	4.25	4.75		(b) 3.50 (c) 3.50
Ore + concentrates,value not exceeding $50.per 2000 lbs.	(a) 4.00	4.00	4.50	5.75		(b) 7.50(f) (c) 7.50(f)

25¢ additional for each 100$ or fraction over.

FOOT-NOTES

All rates in dollars and unless otherwise specified, are on basis of ships option- per ton of 2000 lbs by weight or 40 cu.ft. per ton measurement.

Rates do not include charges for handling, wharfage, storage, transfer, lighterage or other terminal charges, or marine insurance. Average handling and wharfage charges at both ends are about $3. to $4. per ton.

(a) Commodity rate as specified.
(b) In carload lots.
(c) In less than carload lots.
(d) Additional charge for pieces over 4000 lbs.
(e) Lighterage from ships side to shore from $6. to $12 per ton additional.
(f) Rate for valuation not exceeding $100 per 2000 lbs.

Bethel to McGrath $22.50
Rates per ton at ships option-wt. or meas.

...ethel 2170 ...Grath	Nome (ships side) (e)	St.Michael	Golovin (Ships side) (e)	York Teller Deering Kiwalik Kotzebue (e)
2670	2500	2620		
	(b)12.65	20.00	14.00	14.00
	(c)15.65	23.00	17.00	17.00
	(b)16.00	23.50	17.00	21.00
	(c)19.00	28.00	21.00	29.00
	(b)15.50	23.00	17.00	21.00
	(c)18.00	27.00	21.00	29.00
	(b)16.00	24.00	20.00	24.00
	(c)21.00	31.50	23.50	31.50
	(b)33.00	47.50	40.00	53.00
	(c)36.50	52.00	44.50	60.00
	(b)21.00	25.50	22.50	25.50
	(c)25.00	30.50	24.00	27.50
	(b)15.50	20.50	13.50	17.50
	(c)18.00	24.50	17.00	27.00
	(b)16.00	25.50	18.00	21.00
	(c)20.00	31.50	23.50	25.50
	(b)11.00	23.00	16.50	20.50
	(c)18.00	29.50	22.50	20.50
(b)	3.50	7.00	4.50	4.50
(c)	3.50	7.00	4.50	4.50
(b)	7.50(f)	11.00	7.50	—
(c)	7.50(f)	13.50	7.50	9.00

...asis of ships
... measurement.

...[illegible]
... average
... $4. per ton.

... additional

19[illegible] JOINT FREIGHT RATES BETWEEN SEATTLE OR TACOMA AND ALASKA POINTS, VIA ANCHORAGE AND THE ALASKA RAILROAD

Miles from Seattle	Talkeetna 2256	Nenana 24[illegible]1	Fairbanks 2497	Chatanika 2622	Holy Cross 3164	I[illegible] 3[illegible]
Article				a	b	
Coal in sacks						
C.L.min.20 tons, class D	16.00	[illegible].40	[illegible].20	28.6[illegible]	2[illegible].40	[illegible]
L.C.L. Class 4	30.40	45.80	4[illegible].20	51.80	50.80	[illegible]
High explosives, caps, fuse, etc.						
C.L.min. 15 tons, Class 1	48.20	72.60	76.40	80.40	77.60	116.
L.C.L. less than 6 tons, g	72.40	109.00	114.60	119.20	116.40	155.
Groceries, mixed, carload lot						
Min.wt. 1[illegible] tons, class 5 g	27.80	41.00	41.00	47.00	46.00	86.
L.C.L. Class 1	48.20	72.60	76.40	80.40	77.60	116.
L.C.L. Class 4	30.40	45.80	46.20	51.80	50.80	89.
Grain, flour in sacks						
C.L. mixed or straight, Min. wt. 18 tons g	19.40	27.00	28.20	35.00	32.00	71.
L.C.L. class 4	30.40	45.80	46.60	51.80	50.80	59.8
Hardware, iron or steel						
C.L. Min.wt. 15 tons Class 3	34.60	52.80	55.60	59.20	57.80	96.
L.C.L. Class 2	40.00	60.80	64.00	67.80	65.80	104.
Hay-in bales, 22 lbs. to cu.ft.						
C.L. Min.wt. 1[illegible] tons g	21.40	2[illegible].[illegible]0	27.00	30.20	31.20	70.
L.C.L. Class 3	34.60	52.80	55.60	59.20	57.80	96.
Lumber, common						
C.L. min.wt.[illegible] tons g	16.80	[illegible].60	21.20	24.60	25.60	[illegible]
L.C.L. Class 4	30.40	45.80	46.20	51.80	50.80	[illegible]
Mining machinery, any quantity g single pieces not over 4000# g	2[illegible].00	28.00	30.00	35.00	30.00	[illegible]
Oils, explosive, fuel, in drums cases						
C.L. Min.wt. 13 tons Class 5	27.80	41.00	41.00	47.00	46.00	85.
L.C.L. Class 3	34.60	52.80	55.60	59.20	57.80	96. e 72.0
Return freight						
Used empty oil drums, L.C.L. to Anchorage only f	6.80	1[illegible].40	1[illegible].60	19.00	20.20	[illegible]
Ore and concentrates in sacks, declared value not over $50. per ton g						
C.L. min.wt. 20 tons g	7.20	10.50	12.00	15.70	------	
C.L. min.wt. 15 tons g	9.00	13.75	15.00	18.90	------	54.
L.C.L. under 15 tons e	10.80	16.50	18.00	22.00	------	57. 60.

All rates in dollars and cents per ton of 2000 lbs. Rates via Seward higher on classes No. 1 to 4. Rates on Tanana, Yukon, [illegible] and Iditarod rivers effective only during season of navigation until Sept. 1 of each year. All wharfage and handling charges at Seattle or Tacoma, Anchorage, Nenana and at destination included in rates given.

a [illegible] ton transfer charge from [illegible] [illegible] trucks.
b [illegible] points [illegible] river between [illegible] Holy Cross have same rate as Holy Cross.
c Special commodity rate.
d Additional charge made for all heavy pieces weighing over 4000 lbs.
e [illegible] carload commodity rate, min. wt. [illegible] tons.
f No thru rate. Rate given is to Anchorage only, to which [illegible] rate must be added.
g Additional charge of [illegible] for each $100 or fraction thereof of excess valuation declared.

SKA

Grass	Taliaferro	Marshall via [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Via [illegible]			
164	3564	[illegible]	3540	2714	2589	3062	3237
[illegible]							
[illegible].40	66.40	42.60	[illegible].40	42.40	51.40	57.30	63.40
[illegible].80	69.80	53.80	70.80	63.80	72.80	78.80	70.80
7.60	116.60	90.60	97.60	106.20	114.20	130.20	148.20
[illegible].40	155.40	129.40	180.40	162.60	180.60	172.60	184.60
[illegible].00	86.00	59.00	66.00	59.00	66.00	74.00	80.00
[illegible]7.80	115.80	90.60	97.60	90.60	99.60	105.60	111.60
[illegible].80	89.80	63.80	73.80	63.80	72.80	78.80	84.80
32.00	71.00	45.00	52.00	45.00	54.00	60.00	66.00
50.80	69.80	63.80	70.80	63.80	72.80	78.80	84.80
57.80	96.80	70.80	77.80	70.80	79.80	86.80	91.80
[illegible].80	104.80	76.80	86.80	76.80	87.80	93.80	99.80
[illegible].20	70.20	44.20	51.20	44.20	53.20	59.20	65.20
57.80	96.80	70.80	77.80	70.80	79.80	85.80	91.80
25.60	64.60	38.60	45.60	38.60	47.60	53.60	59.60
[illegible].80	69.80	63.80	70.80	63.80	72.80	78.80	84.80
30.00	69.00	43.00	50.00	40.00	50.00	61.00	67.00
[illegible].00	86.00	59.00	66.00	59.00	68.00	74.00	80.00
57.80	96.80	70.80	77.80	70.80	79.80	85.80	91.80
	e 72.00						
22.20	[illegible]						

------ 64.50
------- 67.75
------ 60.50

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JOINT FREIGHT TARIFFS VIA RAILWAY AND YUKON TERRITORY, 1923

Between Seattle or Tacoma and Alaska points on upper Yukon River.

Miles from Seattle		Eagle 1776	Circle 1951	Beaver 2124	Rampart 2290
Article	**Classification**				
Coal in sacks, carload	Commodity	$ 51.00	$ 56.00	$ 59.00	$ 60.00
Less than carload	Class A	74.00	74.00	74.00	74.00
High explosives, caps, etc.	1 1/2 Class A	137.00	137.00	137.00	137.00
Groceries A	Class A	74.00	74.00	74.00	74.00
"	Class B	90.00	90.00	90.00	90.00
General hardware, merchandise	Class A	74.00	74.00	74.00	74.00
Lumber, common	Class A	74.00	74.00	74.00	74.00
Hay and grain	Class A	74.00	74.00	74.00	74.00
Mining machinery, single pieces weighing not over 4000 lbs. C carload	Commodity	56.00	56.00	58.00	58.00
L.C.L.	Class A	74.00	74.00	74.00	74.00
Mill-locomotive, engine, etc.	Class B	90.00	90.00	90.00	90.00
Oils- fuel, coaloil, etc.,	Class A	74.00	74.00	74.00	74.00
Southbound shipments to Seattle or Tacoma.					
Empty oil drums, containers,	1/2 Class A.	37.00	37.00	37.00	37.00
Ore and concentrates, value not over $100. per ton,	1/2 Class A	37.00	37.00	37.00	37.00

Notes: All rates are for <u>less than carload lots.</u> In dollars per ton of 2000 lbs. unless otherwise noted. Wharfage, storage and handling charges are in addition to above rates. Class rates apply only from opening of navigation to Sept. 10, 19[illegible]; commodity rates until August [illegible]th.

Carload lots of minimum weight of 20,000 lbs. Carload class rates are the same to all points given and are: For Class A, $68 per ton of 2000 lbs.; Class B, $80; Class C, $92.

a. Also special commodity rates on certain groceries in mixed carload lots from $53 to $65 per ton to Eagle and $62 to $65 per ton to Rampart.

b. Additional charge made for all heavy pieces weighing over [illegible] pounds.

COASTWISE AND RIVER FREIGHT RATES.

1	2	3	4	5
From	To	Miles	Rate in dollars per ton of 2000 lbs.	
SEWARD PENINSULA				
Nome	St. Michael	120	$20.00	Gasboat via Norton Sound
"	Solomon		10.00	Gasboat via Norton Sound
"	Golovin		15.00	Gasboat via Norton Sound
"	Teller		15.00 to 17.50	Gasboat via Bering Sea
"	Deering		27.50 to 35.00	Gasboat via Bering Sea
"	Kewalik		30.00 to 37.50	Gasboat via Bering Sea
* Golovin (ship side)	Dime Cr.		27.00	Gasboat via Koyuk R.
* "	Council		36.00	Gasboat horsescows via Fish-Niukluk R.
* Teller (ship side)	Davidson	40	15.00	Gasboat
INTERIOR				
Nenana	Roosevelt	256	40.00	Gasboat via Kantishna R.
"	Lake Minchumina	360	80.00	Gasboat via Kantishna R.
"	Livengood		180.00	Gasboat + team via Tolovana R.
Koyukuk Sta.	Bettles	495	50.00	Gasboat via Koyukuk R.
Bettles	Nolan	75	160.00	Horsescow via Koyukuk R.
Holy Cross	Cripple		40.00	Gasboat via Innoko R.
Cripple	Ophir	70	100.00	Horsescow via Innoko R.
Holy Cross	Iditarod	400	39.00	Steam & gasboat via Iditarod R.
Bethel	Akiak		8.00	Steamer via Kuskokwim R.
Bethel	McGrath	500	25.00	Steamer via Kuskokwim R.
McGrath	Takotna	65	25.00	Gasboat via Takotna R.
Rainbow	Hope	9	6.00	Gasboat via Turnagain Arm

* Rates include lighterage from ships side.

OVERLAND FREIGHTING RATES & DISTANCES.

From	To	Distance in miles	Rate and means Summer		Winter
SEWARD PENINSULA					
Nome	Boulder Cr.	14	2 1/2¢	wagon-rd	
"	"		1 1/4¢	Auto-rd	
"	Submarine Beach	3	$4.00	wagon-rd	
"	Dexter Cr.	8	16.00	wagon-rd	
"	Osborn Cr.	11	17.50	wagon-rd	
"	Anvil Cr.	4	5.00	wagon-rd	
"	Glacier Cr.	9	15.00	wagon-rd	
Davidson	Taylor Cr.	40	10¢	wagon-rd	$50. winter trail
Candle	Candle Cr.	6			
Solomon	Eskimo dredge	8		tractor-rd	
"	Shovel Cr.	10	20.00	wagon-rd	
"	Big Hurrah Cr.	11	25.00	wagon-rd	
"	Canyon Cr.	27	50.00	wagon-rd	
Council	Warm Cr.	10	25.00	wagon-rd	
"	Ophir Cr. lower	4	10.00	wagon-rd	
"	Ophir Cr. W.C.Co.	10	10.00	R.R. horse-car	
IDITAROD					
Iditarod	Flat	8	20.00	tram or auto $18.	
Flat	Willow Cr.	7	30.00	wagon-rd	20.
"	Chicken Cr.	7	40.00	wagon	
"	Upgrade Assn.	5	20.00	wagon-rd	20.
"	Granite Cr.	4	40.00	wagon	20.
"	Dredges	1	10.00	wagon-rd	5.
"	Moore Cr.	40	25¢	pack-horse	8¢ dog team
INNOKO					
Ophir T.	Ophir Cr.	4	4¢	pack-horse	1 1/2¢ winter trail
Ophir T.	Spruce Cr.	6	8¢	pack-horse	
McGrath	Tacotna	13	25.00	gasboat	2¢ winter "
Tacotna	Yankee Cr.	14	10.00	tractor-rd	
"	Yankee Cr.	14	30.00	wagon-rd	$28.
"	Ganes Cr.	19	5¢	wagon	3¢
"	Little Cr.		5¢	wagon-pack horse	2¢
"	Ophir T.	24	10 ¢	wagon-pack horse	2 1/2¢

OVERLAND FREIGHTING RATES & DISTANCES, cont'd

EAGLE FORTY MILE

Eagle	Gravel Gulch	11 1/2	3 1/2 ¢ road	1 ¢
"	Dome Cr.	38	10¢ packhorse	3 ¢
"	Steel Cr.	52	14¢ "	4 ¢
"	Jack Wade Cr.	67	19¢ "	6 ¢
"	Franklin Cr.	80	23¢ "	6 1/4 ¢
"	Chicken Cr.	91	25¢ "	6¢

(Winter rate to Forty Mile camps via Forty Mile on staples from 1 to 2 1/4 cents less than that given above.)

CIRCLE

Circle	Central House	34	5¢ wagonroad	2¢
	Deadwood P.O.	42	8¢ " "	3¢
	Miller House	50	10¢ " "	$50.
	Eagle Cr.	60	11 1/2 ¢ wagonroad-trail	4 1/2¢

FAIRBANKS

Fairbanks	(Ester, Engineer, (Goldstream & (Pedro Cr.		1¢ Auto-road	
"	(Ester, Fox, Gilmore (Ridgetop, Olnes (Eldorado & Chatanika	5-32	1/5 to 1/2 ¢ via narrow gauge rr.	
Fairbanks	Caribou-Cr.	90	Tractor-road	Tractor-sleds
Gilmore	Goshen	14	$15. tractor-road	

RAMPART.

Rampart	Hunter Cr.	5	1¢ wagon-road	1/2¢
"	" "	7	2 1/2¢ wagon	1 1/2¢
"	Little Minook	8	1 1/2¢ wagon-rd	1 ¢

HOT SPRINGS.

Landing	Hot Springs	1 1/2	[illegible]5. wagon-road
Slough	Tofty	12	2 1/2¢ wagon-rd.
"	Woodchopper	17	3¢ " "
"	American Cr.	22	
Hot Springs	Eureka	22	2 1/2 ¢ tractoreroad

OVERLAND FREIGHTING RATES & DISTANCE.. Cont'd.

TOLOVANA.				
Dunbar	Livengood	65		5 & 6¢ winter trail
Olnes	"	54		5 & 6¢ "
RUBY				
Ruby	Long	29	2¢ wagon road.	2¢
"	Greenstone Cr.	36	10 ¢ wagon	3¢ winter trail
"	Meketchum Cr.	46	14¢ wagon	4¢ " "
"	Spruce Cr.	44	16¢ wagon	4¢ " "
"	Flat & Solomon Crs.	65	20-25¢ wagon	5¢ " "
KANTISHNA.				
Roosevelt	Eureka Cr.	35	5¢ wagon-road	
Kobe	Eureka Cr.			10¢ dog team
BONNIFIELD				
Rosena	Platte Cr.	23	Man-packhorse	
VALDEZ CREEK.				
Cantwell	Valdez Cr.	65	packhorse	10¢ winter trail
YENTNA.				
Talkeetna	Cache Cr.	40	20¢ wagon	$65. winter trail
"	All camps except		20¢ "	65-75" "
~~"~~	Dollar Cr.- head		~~25¢ "~~	~~75. " "~~
SHUSHANA.				
McCarthy	Chisana	100	25¢ packhorse	
"	Creeks (various		27 1/2-30¢	20¢ dog team.
NIZINA.				
McCarthy	Dan Cr.	11	6¢ packhorse	$20.
"	Chititu Cr.	17	7¢ "	$24.

Rates given in cents per lb. or dollars per ton of 2000 lbs.
Wagon-road means road all the way.
Wagon- partly road, partly trail.

basis, whereby 40 Cu. Ft. is considered equivalent to a ton. A ton, according to this basis is usually from 15 to 20 percent less in weight than where billed under the weight basis of 2000 lbs.

On the Seward Peninsula, summer hauling by team over made roads is normally $1.60 per ton mile; where there are no regular roads, or with cross country travel, $2.50 per ton mile. Winter hauling averages $1.50 per ton mile. Two-horse teams with a driver can be hired for $18.50 to $22.50 per day and four-horse teams for $35.00 and $40.00.[14]

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[14] From W.J.Rowe, Freighter, Nome, Alaska, 1922

The overland freighting rates are governed by many conditions, and averages which might be drawn cannot be taken as being of general application.

In the interior placer districts, summer freighting rates over wagon roads by team range from $2.50 to $4.00 per ton mile, and where it is necessary to travel part of the distance by wagon road and part of it by cross country travel without roads, necessitating at times a change of conveyance, $5 to $10 per ton mile. By pack horses, $6 to $27. Winter hauling by team and sled, $1.25 to $3 and by dog team $4.

The use of trucks and tractors is rapidly increasing where suitable roads are available and where adopted has greatly reduced the cost of overland haulage.

Summer hauling by tractor in the Innoko district costs $1 per ton mile; in the Hot Spring district, $2.50; in the Fairbanks district $1.25. These costs are unusually high when compared to the winter hauling of large tonnages by tractor and sleds over well broken sled roads, as done by some of the larger lode mining companies. For example, the Treadwell Company, in the Mayo district, Y.T., is reported as now hauling its ore from the mine to Mayo Landing, a distance of about 40 miles, for $7.50 per ton. Six to eight sleds are used and as much as 60 tons are hauled by one tractor per trip. Before this present system was established, the winter freighting cost was $25 and more per ton.

Labor

Alaska placer mining labor is paid a high wage but this cannot be considered excessive when it is understood that the average placer miner is employed but three to five months of the year on hard manual labor under conditions which are generally very uncomfortable and trying. As board is also furnished in addition to the wages paid at all of the placer operations, the cost of general labor ranges from $4.50 per day at some of the larger and more accessible camps to as much as $12 per day at some of the most remote ones. The cost of boarding the men ranges from $1.50 to as much as $4.00 per man day, varying mainly according to the cost of transporting the supplies to the camp and the number of men employed. In some of the isolated districts the cost of board would be even higher were it not for the fact that game is plentiful in these districts and in some cases garden produce is grown. In a few instances, the men board themselves, under which arrangement the wages are proportionally increased. The old winter scale of reduced wages is no longer in effect.

Skilled labor commands a higher wage, the rate varying more according to conditions. Hoistmen or engineers at the drift mines are usually paid the same as general labor. Pointmen and nozzlemen generally receive from 50 cents to a dollar more per shift than general labor. Wages for skilled labor varies so that no average scale can be stated. Cooks are usually paid the same as the miners or general labor. Hospital dues, generally $2.00 per month, are collected from the men by some of the operators, in districts where such service is available.

The following table gives the wages and cost of boarding the men in Alaskan camps. It does not include dredge labor, which is mentioned under "Dredging".

Underground labor works an 8-hour shift; but one shift being worked at the smaller drift mines, and usually but two at the larger operations. Ten-hour shifts are general at the open cut mines and 10 or 11, and in a few cases 12-hour shifts, are worked at the hydraulic operations. When the shifts are longer than those given in the tables, wages are increased proportionately. The size of the operation, the labor, and water supply available, and other conditions regulate the number of shifts which can be worked. At many of the operations

Scale of Wages and Cost of Board in Alaska Placer Camps

District	Wages per Shift (b) General Labor	Wages per Shift (b) Skilled Labor	Cost of Boarding Man per Day
Nome	$5-5.50- 10 hrs.(0)	(Foreman-$6.50-8.00 (Pipeman - $6.00 (Carpenters - $7-$9	$1.90-2.25
Solomon	($4 - 8 hrs. (D) ($5 - 10 hrs.(0)		$2 - $3
Council	$6 - 10 hrs. (0)		$2.15-$2.50
Kougarok	$6 - 10 hrs.(0)		$3.00
Fairhaven	$6-$7 - 10 hrs.(0)	Pipeman $7 - $9	$2.25-$3.00
Marshall	$6 - 8 hrs. (0)		$2.50 -$3.00
Ruby	$6 - 8 hrs. (D)		$3.00 - $4.00
Koyukuk) Chandalar)	($6 - 8 hrs.(0)(D) ($10 - no board		$3.50-$4.00
Iditarod	($6-$7 - 10 hrs.(0) ($10 - no board	(Engineers - $8 (Blacksmith - $9	$3.00-$3.50
Moore Cr.	$8 - 10 hrs. (0)		$3.50
Innoko	$6-$7 - 10 hrs.(0)	Engineers - $8	$3.50
Rampart	($5 - 10 hrs. (0) ($8 - no board		$2.50 - $3.00
Circle) Eagle) Forty) Mile)	($5-$6 - 10 hrs.(0) ($5 - 8 hrs. (D)	(Pointmen - $6 (Blacksmith - $7 (Engineers - $6-$8	$2.25 - $3.50
Fairbanks	($5 - 8 hrs. (D) ($6 - 10 hrs.(0)	(Pointmen - $6-$7 (Blacksmith - $7 (Engineers - $8-$10	$1.75 - $2.25
Tolovana	($5 - 8 hrs. (D) ($6 - 10 hrs.(0)	Pointmen - $6	$2.25 - $3.00

District	Wages per Shift (b)		Cost of Boarding Man per Day
	General Labor	Skilled Labor	
Hot Springs	($5 - 8 hrs. (d) ($5-$6 - 10 hrs.(O)	(Pointman- $6 (Pipeman - $6	$2.00-$3.00
Kantishna	$5 - 8 hrs. (O)	Pipeman - $6	$2.75 - $3.00
Yentna	$6.25 - 10 hrs. (O)	Blacksmith - $6	$2.00-$2.50
Shushana	($8 - 10 hrs. (O) ($12 - no board		$4.00
Nizina	($5 - 10 hrs. (O) (Plus bonus a	(Foreman - $8 (Stackerman - 5.25 (Hoistman - $5.25 (Pipeman & (Powderman-$5.50	$1.75
Cooks Inlet	$6 - 10 hrs. (O)		$1.50-$2.00

See also dredge wages

a Bonus of $.50 per shift given to all employees working entire season.

b Board furnished in addition to wages paid, except where especially mentioned.

(O) Open cut.

(d) Drift mine.

where two 10 or 11 hour shifts are operated, arrangements are often made to keep some part of the operation going between shifts. By using the "swing" shift, the operation can be made continuous, without the necessity of overtime.

Most of the placer mining labor in the smaller or more remote districts is provided by the prospectors and others who live in these districts, although there is generally some itinerant labor. The more experienced and efficient miners are as a rule not content in working for others and may have their own operations. It is a common practice to form a partnership of 2 to 6 to operate a mine. This is especially true in drift mining and while often due to limited finances, also helps to promote that personal interest which increases not only the number of hours worked but the efficiency. The average itinerant labor is not experienced placer labor, which accounts, in part, for the inefficiency of much of it. A placer miner bundled up in the heavy waterproof clothing and rubber boots which he must wear most of the time along with the veil and gloves for protection from the attacks of the many mosquitoes is certainly handicapped.

In the larger and more accessible camps there is generally sufficient labor for all demands. In the isolated camps labor is generally difficult to obtain after the season has started. Men must be sent in and be retained, if possible, for the entire season. Under such conditions, poor workmen cannot be readily replaced, or because of occasional dissatisfaction or restlessness, some of the crew may quit, leaving the operation shorthanded for the balance of the season. Some operators give the men a bonus if they remain for the entire season.

Cost of Supplies

The larger placer operations purchase practically all supplies in the States, shipments being made either in the fall so as to be freighted to the property during the winter, or where transportation permits, the shipments are made early in the spring, or as required. Provisions, hardware, dynamite and general supplies can be purchased from local merchants in all of the districts. A great deal of used machinery and equipment is available in most of the camps, and as it can be purchased for a very small part of its original cost, it has been the main source of such supply for many years. New machinery and equipment can seldom be obtained locally, unless through special order with the merchants. Supplies can be purchased in most of the coast towns and points on the railroads at reasonable prices. In the smaller and more remote districts where only a small volume of business is transacted and freighting rates are high, the prices are proportionately increased and in many instances become almost prohibitive.

Economic conditions in the States are naturally reflected in Alaska and the great increase in the cost of machinery, equipment and general supplies since the war had a marked effect on Alaskan operations and development. Fortunately, prices are now on the decline. Fluctuating prices in the States and the varying freight rates to the different mining camps make it impractical to give the cost of supplies in Alaska except in those specific cases as given in the following pages. By consulting outside prices and the freight rates given in this report, a close estimate can be made of the cost of supplies landed at the property.

Timber, Lumber and Fuel

The best and most extensive forests are found in southeastern Alaska, where unfortunately there is but little gold placer. Southwestern Alaska has, in general, a good supply of spruce and hemlock, diameters up to 18 and 24 inches at the butt being quite common. In the Tanana valley and its tributaries around Fairbanks there are good growths of spruce with some birch and cottonwood. Most of the districts in the interior on the tributaries of the Yukon and Kuskokwim Rivers have fair supplies of timber.

Former mining operations, especially in those districts where extensive drift mining has been done or where enormous supplies of wood have been used for steam thawing and power purposes, have almost stripped the near-by forests, so that it now often becomes necessary to bring it in from considerable distances thereby greatly increasing its cost.

With the exception of small spruce timber east of the Council district and around Dime Creek in the Koyuk district, Seward Peninsula has no tree growth except small willows, and therefore, has to depend on outside sources. Saw mills are operated in most of the coast towns and the larger interior centers. Many of the larger hydraulic companies operate their own saw mills. Most of the operations use the native spruce for lumber, and spruce or birch for wood fuel. Native spruce lumber answers some of the requirements of placer mining, but the greatest difficulty is to obtain good clear wide boards for sluice boxes, for much of it is 10 inches or less in width and full of knots. It also warps badly. One of its best qualifications is that it does not split as easily as outside lumber. In some of the remote districts the lumber is whip-sawed by hand at a cost of from $100 to $150 per thousand board feet, which is often much cheaper than freighting it in from a distant source.

Contracts are generally made for getting out logs, mining timber and wood, although many of the operators who would otherwise be idle, cut their own supply and haul it to camp during the winter. The cost of cutting small spruce wood is generally $5 to $7 per cord for 4-foot wood and $3 to $5 for 16 foot wood. The latter is later cut by power saws at the camp as needed. The hauling is in many cases the largest item of cost. On Goldstream Creek near Fairbanks where there is an exceptional supply of good wood, the contractors agree to deliver 4-foot spruce and birch wood alongside of the railroad track for $7.50 per cord. Birch wood is considered better than spruce for fuel, but for timbers and sluice box lumber the spruce is used. Forest fires are frequent during dry seasons in the interior, destroying much timber and causing a serious menace to the community.

Average dry native lumber weighs about 3000 lbs. per thousand board feet. Lumber planed on one side and two edges costs from $25 to $50 more per thousand than rough lumber. Some operators buy rough lumber and dress it by hand. Where lumber has to be hauled long distances, it will cost as much as $200 to $250 per thousand board feet landed at the property. On Dan Creek, spruce lumber was at one time produced in the company's mill for $25 per M. and a few years later when suitable logs were difficult to obtain near by, the cost of the lumber was $45.

In the Fairbanks district, the following are average prices for spruce timber delivered to properties within a mile of the railroad: 40-foot poles, 2-1/2 to 6 inch diameter, $9 per cord; 16-foot poles for drift mining timber, 4 to 6 inch diameter, $12 per cord; 18-foot timbers, diameter 12 inches, $1 each; 60-foot gin poles, $40 each.

The following tables have been compiled to show the cost of wood and lumber in some of the districts. As the supply, hauling rates and numerous other conditions affect these costs, there are bound to be many exceptions. The examples given are selected as they show the general maximum and minimum costs. The cost of lumber is for native rough sawn, except where otherwise noted.

COST OF WOOD AND LUMBER

Districts	Wood per cord	Mill or Supply points	Lumber per 1000 B.M. Ft.	
Koyuk District	$15. to $16 (Dime Cr.)	Nome	$100.	A
Marshall Dist.	$14 to $15.(Willow Cr.)	Ruby	$ 40.	
Ruby "	$ 8.to $12.	Iditarod	$75.	
Iditarod "	$18 to $25.	Flat.	$100.	
Innoko "	$ 9 to $20.	McGrath (Medfra)	$85.	
Circle "	$ 5 to $14.	Tacotna	$100.	
Fairbanks "	$10 to $14.	Fairbanks	$ 45.	
Tolovana "	$10 to $12.	Livengood	$100.	
Hot Spring"	$10.to $12.	Hot Springs	$ 40.	
Koyukuk "	$16 to $18 (Nolan)	Kantishna (Glacier Cr.)	$80.	
		Seward	$40.	
		Cordova	$35.	
		Talkeetna	$45.	
		Forty Mile (McKinley Cr.	100.	
		Circle (Miller House)	80.	
		Circle (Miller House) (dressed)	$125.	

A Outside supply.

Coal and Oil Fuel

The use of coal for steam purposes in connection with Alaska placer mining is practically confined to a few steam scraper and small drift mining operations in the Fairbanks district. These operations are located along the line of the Government railroad and the lignite coal can be landed at the properties for $6 to $8 per ton and Matanuska bituminous for $10 to $12 per ton. Unless it be at those operations within close hauling distance from the railroad, coal mine, or shipping point where it can be cheaply purchased, its use in placer mining is not practical. The use of coal for steam purposes at the mines in the Fairbanks district, will no doubt be more generally adopted in the near future. Extensive coal fields are of widespread occurrence in Alaska.[15] Good bituminous coals are mined in the Matanuska fields

(15) Brooks, A.H., Alaska Coal and Its Utilization: U.S.Geol. Survey, Bull. 442 - J, 1914, p. 47 - 100.

about 50 miles northeast of Anchorage and in the Bering River field about 20 miles inland from Katalla. Lignite coal is mined at several places in the Nenana or principal interior coal field. A good bituminous coal is found near Cape Lisbourne about 200 miles north of Nome, and at different periods small shipments have been made to Nome, but the field has not been further exploited. In the Yentna district, the Cache Creek Dredging Co. operated its dredge with lignite coal mined close by, but its use was not satisfactory. Lignite coal is also found at numerous other places along the Pacific Coast, in the Yukon River Basin and on Seward Peninsula where small quantities have been mined at different times.

While odd shipments of coal have been made to Nome, the supply now practically all comes from British Columbia. This coal is shipped in sacks and sells for $36 per ton during the summer season and $39 in the winter. Healy River lignite coal sells for $3 per long ton in carload lots at the mine and $4.50 per short ton in the cars at Fairbanks and $6.50 at Anchorage. The bituminous coal from the Matanuska fields sells for $5.50 to $7.00 per ton at the mine and $8.00 on the cars at Anchorage. One ton of lignite coal is equivalent in heat units to about one cord of spruce wood.

Gasoline, distillate, crude oil and diesel oil now supply the power for most of the dredges. The Nome district and other Seward Peninsula districts depend entirely on such fuel for power purposes. In 1922, at Nome, gasoline sold for $5.65 per case and distillate $4.85 per case. Most of the operators ship in their oil supply from Seattle. Shipments are made in drums and after paying freight, lighterage, depreciation and return freight on the drums, 1922 shipments of diesel oil 24° gravity cost 25 cents per gal. and distillate 30 cents, landed in the warehouse at Nome. Oil is now being shipped to Nome in tank boats for a large dredging company there. One of the large oil companies has established a station at Seward where diesel oil 24° gravity was quoted during Sept. 1923 at 3 cents per gal. higher than the Seattle price. This oil, landed at Fairbanks in drums cost 22 cents per gal. Details on drum containers and freight rates are given under transportation and freight rates.

A high gravity paraffin base oil is being produced and refined in small quantities at Katalla, practically all of which is used locally. Drilling operations are under way at Cold Bay where the geological conditions are considered favorable for oil. Oil seepages and favorable geological formations are reported in many places in Alaska.[18]

[18] Martin, G.C., Preliminary Report on Petroleum in Alaska: U.S.Geol. Survey Bull. 719, 83 pp., 1921.

Prospecting

The necessity for prospecting cannot be too strongly emphasized. Most of the failures in placer mining have been due either to lack of prospecting or the incorrect interpretation of prospecting results before the equipment was installed. Why such past experiences do not serve as a warning to others is difficult to explain. A mining proposition seemingly attractive enough to equip with a plant should certainly be worthy of prospecting. A preliminary investigation of the main features will usually show if further work is justified; if it is, careful prospecting should then be done to develop an area of profitable ground sufficient to justify equipping the property. In those days of high grade virgin deposits when the margin of profit was usually large, prospecting to obtain a high degree of accuracy was in many places not considered so important. The present remaining lower grade deposits in most instances have been selectively mined, leaving small isolated areas of unworked ground which present a more difficult problem, the solution of which makes careful prospecting even more necessary. There are many deposits which can be quite easily and cheaply prospected by the average miner, but with most of the remaining known placer, especially when accurate determination of the gold content and volume of large areas of low grade material must be made, the investigation is no simple matter and requires skill and experience to obtain the proper results. With proper prospecting and the correct interpolation of the results, it is possible to ascertain within a comparatively small margin of uncertainty the amount of gold in the ground to be exploited and in this respect makes placer mining less speculative than most lode mining. The accuracy of the prospecting results, however, are governed principally by the character of the deposit, the distribution of the gold, the amount of prospecting done, and the experience and judgment of the man in charge.

Prospecting involves the determination of many factors, the more important ones being: the extent, depth, volume and value of the deposit; depth and character of the overburden and the gravel; distribution and character of the boulders, the clay, the gold, and the frost; and the character and contour of bedrock. To obtain such information, it is necessary to penetrate the placer deposit with shafts, adits, open cuts, or drill holes.

Prospecting practice is governed by the resources of the miner, the equipment available, the amount of prospecting to be done, and the depth and character of the ground. Shafts or open cuts are generally the most practical for the average Alaskan miner where the condition of the ground permits. Drilling is very satisfactory for most deposits, especially for the deep deposits or in ground where excess water prohibits the use of shafts and open cuts.

Alaskan prospecting methods in unfrozen ground differ but little from those used in other countries. In frozen ground, however, different conditions are encountered and prospecting methods of special application to such ground are used.

The choice of a method for prospecting placer ground is discussed by Hutchins[17] as follows:

[17] Hutchins, J.P., Prospecting and Mining Gold Placers in Alaska: U.S. Geol. Survey Bull. 345, 1908, p. 54-77.

"Without regard to the geology, all Alaskan placers may be classified as shallow or deep. For convenience of consideration in this paper, all placers less than 20 feet deep are arbitrarily called shallow. Such placers, at or near sea level, if so wet as to require pumping, can be investigated with shafts while the pump is set on the surface of the ground. The practical limit of suction at sea level is about 25 feet. Placers deeper than 25 feet or of less depth and at higher altitude, if wet, must be drained by sinking pumps to the necessary depth. This necessitates a larger shaft to accomodate the pump, pipes, etc., and obviously will increase the cost per foot.

"The choice of prospecting method is governed by a number of considerations, some of which are influenced by conditions foreign to the actual prospecting. For instance, a deposit well adapted to investigation by the steam drill may be so inaccessible as to make it good practice to use hand drills or shafts instead. The rapidity, cost, and accuracy are the governing factors in making a choice of method. Many deposits have features that make one method particularly applicable. In some places conditions are such that either the shaft or the drill method may be employed with equally good results; both may be used advantageously. The frozen condition of many of the Alaskan placers makes it possible to use the shaft method in alluvium which, if unfrozen, could be tested by shafts only at a large cost for pumping and timbering.

"Where shallow narrow creek beds are to be prospected, it is often good practice to make open cuts clear across the bed, or far enough to delimit the pay streak. Such creeks generally have extremely irregular pay streaks, and cuts of this character would determine the distribution of gold content with thoroughness. Work like this may be costly, but the compensating advantages often justify it.

"In a shallower placer less than 10 feet deep and containing no water, or so little water that it can be easily bailed, prospecting can generally be more cheaply and rapidly done with shafts or open cuts than with drill holes sunk with a steam churn drill. Material can be thrown out of a shaft 10 feet deep and no timbering is ordinarily required if the shaft is kept free of water during the sinking. Only one man per shaft is required if there is only a small amount of bailing and if the gravel is unfrozen and easily broken down.......Under such conditions the steam churn drill is at a disadvantage, for much time may be consumed in frequent moving from hole to hole. This is particularly true if the surface is so rough or marshy as to make moving difficult. The hand drill, being more mobile, can be used advantageously in such shallow gravels, where it can generally drill 25 to 40 feet or more per day............

"If the alluvium to be tested has a depth of about 25 feet and is so wet as to require a steam pump, drill methods are more applicable than shafts. Such unfrozen gravel is generally loose or becomes loose on exposure to the air or by reason of water running into the shaft. Shaft sinking will be slow and costly, as close timbering and breast boarding or sheet piling may be necessary. Samples taken under such conditions are likely to be inaccurate, for running ground may enter the shaft. The fact that the material from the shaft is shoveled under water, possibly from a rough bedrock or from a soft bedrock, which may become sticky by reason of the man puddling it as he works, also introduces inaccuracies........Under such conditions the churn drill method is preferable. The circumstances that cause a low and costly progress and inaccurate sampling with shafts have no bad effect on steam or hand churn drills. In general, where the gravel is dry, as accurate or more accurate sampling can be done with shafts as with drill holes, but the presence of water in such volume as to require pumping makes drilling preferable.

It is good practice to use both drill holes and shafts, the idea being to use enough shafts to allow inspection of the physical character of the gravel, bedrock, etc., and to depend on the drill holes for the determination of the tenor, extent, and thickness of the gravel...........The peculiar conditions of the alluvium under consideration must therefore be the determining factor.

The irregularity of gold distribution in the alluvium of Alaska makes careful prospecting necessary in order to determine the limits of the pay streaks. Many samples may thus be needed. As a general rule, drill holes are better suited to this work, for they can ordinarily be sunk more rapidly and more cheaply.

Where bench gravel is to be tested, cuts can be easily made. Vertical sampling is thus done, and this method has been used with good results. It is assumed that gravel in the same stratum or at the same perpendicular height above bedrock has the same general tenor and characteristics.

Prospecting has so far in this paper been treated as the obtaining of samples merely. Sometimes it may be conducted as a working test. This is particularly applicable where there is an available water supply. Thus cuts may be ground-sluiced through bench gravel and considerable amounts of material washed. Such cuts also permit subsequent sampling of the gravel section to good advantage. Inasmuch as this is a working test, data relative to operating cost may thus also be obtained.

A governing factor in the choice of the prospecting method is the kind of information that is required. Thus in testing alluvium thought suitable for hydraulicking, or dredging, information concerning the section from grass roots to bedrock is desired, and generally this can best be obtained by sinking shafts or drill holes. In testing alluvium for drift mining little information is required in regard to any of the gravel section, except that adjacent to bedrock. Openings that follow this lower stratum will, of course, give a maximum of information with a minimum of excavation."

Prospecting can be conducted at all times of the year, in fact the winter season is often the more favorable time. Shaft sinking can often be best conducted during the winter months, especially in deposits containing much water during the summer, and which may drain, or be frozen during the cold season. Marshy areas or areas covered by water can be more easily tested with steam drills during the winter. Heavy steam drills can then be readily moved about without miring, and it is easier to drill a stream bed from the ice. Seasonal frost interferes to some extent with drilling in the winter, but permanently frozen ground can be drilled just as rapidly in the winter as in the summer, and unless the weather is very cold, no unusual trouble is experienced if steam is available and a heated shelter is provided.

The usual small prospecting outfit for sinking shafts in frozen ground consists of a 4 or 6 horsepower boiler mounted on a sled or skids, with steam point or pipe, steam hose, and a hand windlass costing when new from $300 to $600, but many second-hand outfits can now be purchased for $100 to $200. Two men are employed, one on the surface and one in the shaft, which is generally made just large enough for a man to work in, or 36 to 42 inches in diameter.

Methods of thawing and sinking such shafts depend on the character of the deposit. Frozen muck can be readily picked but it is more customary to thaw all the material. Some miners thaw only a sufficient depth at a time as may be most practical to their method of working. A procedure often followed in sinking these shafts is to sink to bedrock or insert in a drill hole one long 3/8 inch pipe, steaming the ground at the rate of 30 to 45 minutes to the foot of depth. Too long a period of steaming will cause a thaw of irregular form. The practical limit of depth at which one man can handle a windlass is about 75 to 80 feet, for greater depths a steam hoist is required.

In established camps where drift mining is being done, and the regular steam equipment is available, the shafts are made larger, for if successful in striking pay, they are later used as operating shafts. In ground prospected by shafts, the distance between them is most variable and they are rarely placed as closely together as drill holes. Prospect shafts in deep frozen ground are usually located at a point where "pay" is expected and when bedrock is reached, prospecting may be continued by running drifts and cross cuts. Shafts in shallow wet ground can be dug during the winter by "freezing down". The shafts are dug to water level and allowed to freeze during the night. The following day the frozen material at the bottom of the shaft is removed and process repeated until bedrock is reached. It is a slow process but one man can handle a number of shafts and it is generally cheaper and more accurate than when live water is present.

The cost of sinking prospect shafts or drilling holes depends on a number of conditions, the principal ones being the amount of prospecting done and the character and depth of the material investigated. Under average conditions the cost of prospect shafts varies from $2 to $8 per foot. Pits in shallow dry or frozen ground 4 to 8 feet deep can be dug for 50 cents to $1 per foot, while some of the larger and deeper shafts in adverse or difficult ground may cost over $15 per foot.

On the Seward Peninsula in the Nome district, it is customary to consider a 22-foot shaft, 3-1/2 feet in diameter, in frozen ground, a year's assessment work or costing $100. In this same district on the Submarine Beach, shafts of this size, 30 to 50 feet deep in frozen ground, requiring no timber, cost $3.50 per foot, and the 5 x 6 foot drifts from the bottom of shaft cost $4 per foot. On the Third Beach at Nome, where the general character of the ground is more favorable, shafts 40 to 50 feet deep cost $2 per foot, and drifts $2.50. On Ophir Creek shafts 5 by 6 feet, from 5 to 14 feet deep, in unfrozen ground except a thin surface crust, but requiring no timber, were dug during the winter at a cost of $1.75 per foot. In the Kougarok district, in frozen ground 5 to 6 feet deep an average of 4 pits were thawed and excavated by two men in 10 hours at a cost of 55 cents per foot. On the Third Beach, in ground partly frozen, requiring timbering with imported sawn lumber, a 90-foot shaft 4 by 5 feet, sunk during the summer, cost $8 per foot.

In the Iditarod district on Otter Creek, shafts 41 inches in diameter, with no timber, in frozen gravel, 14 to 17 feet deep, cost $4 per foot, and on Willow Creek in 16 to 18 feet of frozen muck and gravel, cost $3 per foot. In the Ruby district, a 4 by 6 by 80 foot shaft with no timbering in frozen ground 20 feet of which was muck cost $6 per foot.

In the Fairbanks district on Goldstream Creek, 5 by 7 shafts, 20 to 22 feet deep in easy digging material but partly frozen, although requiring no thawing, with only the upper 5 feet crib timbered, cost $2.50 per foot. A 4 by 6 foot shaft 100 feet deep in frozen ground, the upper 20 feet crib timbered, cost $8 per foot. The cost of large prospect shafts in the interior in deep frozen ground requiring but a small amount of crib timbering but without square set, ranges from $6 to $15 per foot. Drifts, untimbered, cost from $4 to $8 per foot. Details on such shafts and drifts will be given under "drift mining".

In prospecting a deposit by shaft, all the gold bearing gravels should be sampled in sections so that the horizontal distribution of the gold can be definitely located. Not only should all the gravels be sampled by taking careful samples from the walls of the shaft, but all the material excavated from the shaft should be sluiced. The large samples so obtained tend to greater accuracy and are one of the advantages of shaft sampling over drill holes. The material excavated from an average shaft is about fifty times larger in volume than that obtained from a drill hole of similar depth made with the standard

6-inch drill. Yet there are numerous instances where prospect shafts or open cuts have been sunk, and for a sample but a few pans of material were taken.

The prospecting and sampling in drift mining involves special consideration as only the richer horizon is mined. A face 5 to 6 feet high is generally carried, consisting of from 4 to 5 feet of gravel and 1 to 2 feet of bedrock. Drifts are run up and down stream and across the channel and as work proceeds, vertical samples are taken at intervals along the face. Bedrock and the roof are tested so that no pay will be overlooked. The samples are panned and the gold weighed, but more often the experiencedminer will closely estimate it. A check is sometimes made by taking a wheelbarrow sample from the face or every tenth wheelbarrow load excavated is taken to the surface and either separately panned or rocked, or the accumulated amount sluiced as one sample.

Drift miners have different ways of calculating the results of their sampling although they are generally based on the value of the gold per square foot of bedrock while in the Seward Peninsula the cubic yard is often used. The value of the gold per pan, wheelbarrow, car or bucket are other units used. In most instances calculations are made on the approximate basis of seven pans of gravel to the cubic foot of material in place, although five or six pans are so considered at some places. Usually one heaping load on a No. 2 round nosed shovel is considered a pan full, which closely equals seven pans to the cubic foot. Knowing the thickness of the pay mined, and the value of the gold per pan, the calculation is made as follows:- Cents gold per pan, times the number of pans to the cubic foot, times the thickness mined in feet, equals the value of gold in cents per square foot. The average wheelbarrow load contains from 12 to 14 pans or approximately 2 cubic feet, or there are from 11 to 14 wheelbarrow loads to the cubic yard. These units vary with conditions, although in the Fairbanks and other interior districts seven pans to the cubic foot or 189 pans to the cubic yard is generally used; In the Seward Peninsula, the average is about 170 pans to the cubic yard. In other instances as low as 135 pans is considered the proper basis. It can readily be seen that such variable and approximate units are conducive to misleading results but an experienced miner can usually obtain a close approximation. Many failures result from overestimating, which is often due to not taking the samples properly, or taking enough of them. The bedrock surface is often very irregular and the gold distribution spotty. In many instances the pay is concentrated on the rougher, slabby bedrock or on spots of high bedrock with the rest of the deposit being too low to yield a profit. Unless closely and carefully prospected and such conditions understood, failures or disappointments are bound to result.

Drilling procedure and the calculation of the results in unfrozen ground is conducted according to general practice as described in literature issued by the drill manufacturers, and Janin[18] covers

[18] Janin, Chas., Gold Dredging in the United States, Bull. 127, Bureau of Mines, 1918, p. 26-68.

the subject of prospecting dredging ground in a most thorough and satisfactory manner. In frozen ground, special methods become necessary. Partly frozen ground is the most difficult and hazardous to drill for the holes must be cased, usually necessitating drilling well ahead of the drive shoe, a procedure leading to inaccuracies. In frozen ground the drill casing may freeze tightly to the ground when warm water or steam is turned into it to release it. This may happen especially in the deeper ground, where several days may be required to complete the hole.

It is generally not necessary to case the entire hole in solidly frozen ground. A short length of pipe is used at the top to seal off any surface water. A small amount of water is poured into the hole and until pay is encountered 5 feet and more is drilled at a time before pumping. When pay is reached this should be reduced to one foot or so. With the 6-inch churn drill a 5-5/8-inch chisel bit is generally used for the drilling. When properly done, this bit cuts a smooth straight hole about 7 inches in diameter. As many of the deposits have a deep covering of muck or barren material rapid progress can be made. Special precautions are necessary while drilling the frozen pay gravel, for should too warm or too much water be used an irregular shaped hole will result.

In addition to the customary measurements of the core, etc., the careful driller pumps all the water from the completed drill hole and then adds a measured amount of cold water, usually 5 gallons at a time, and measures the depth to the surface of the water. Another measured amount of water is then added, and the new water level determined. In this way, knowing the amount of water added each time and its displacement, the volume of each section of the hole can be accurately checked. Unless some check of this kind is made, drilling without casing is hazardous practice, for some material will slough off the sides of the hole and cause the salting of the sample.

Hand operated drills are now seldom used in Alaska, as they are usually not adaptable to the conditions. Steam and gasoline driven drills of 4, 5 and 6 inch diameters are used, the size and type of drill depending on the character and depth of the ground and the locality. The heavy 6-inch steam traction drill has been largely used in the deeper ground and where difficult conditions are encountered. They weigh from 8 to 10 tons when fully equipped and cost from $4000 to $5000.

while the light 4-inch gasoline driven drills, of which there are several different makes, weigh with full equipment from 1000 to 3500 pounds and cost from $900 to $1500.

The heavy steam drill works most rapidly when drilling and is usually best adapted where moves are infrequent. The moving of these heavy drills over rough or swampy ground is slow and difficult and often causes much loss of valuable time, so much so that the smaller and lighter gasoline drills will often drill a greater footage in a given time. A specially constructed drill to meet such conditions has been in service near Nome for the greater part of 16 years. It is known as the Brower drill. It was primarily a No. 5 Keystone, steam driven drill, but was reconstructed and equipped with an 8 H.P. gasoline engine and a special traction with double chain drive to the front wheels which drives it at a speed of 4 miles per hour and can climb a 45 per cent grade. The back wheels are 4 feet in diameter and 2-1/2 feet wide; the front wheels are 6-1/2 feet in diameter and 5 feet wide; they are constructed of 6 x 8 inch timber or light railroad ties and shod with heavy chains.

The drill is also equipped with special appliances for operating the jars and pulling casing. Under average conditions the drill can leave a set-up, move to the next location 200 feet away, and be drilling again in 30 minutes. In setting up at a new location, the wheels are blocked and the drill carriage leveled and swung into place with jack screws. This drill is shown in Pl. 22446. Double extra heavy 6-inch casing, generally flush joint, inside coupling, is used with 7-3/8 inch shoe, when ground is not solidly frozen. The drill crew consists of one drillman at $8 per 8-hour shift and a helper at $5. One to two panners are used and are paid $7 per shift.

The drill has been used for contract drilling under which arrangement the contractor provides everything but the panners. The average contr act price for drilling, depending on the size of the contract, in frozen ground without casing, is 75 cents to $1 per foot, and in thawed ground up to 50 feet in depth, $1.25 to $1.50 per foot; 50 to 75 feet, $2.50; 75 to 100 feet, $3; 100 feet and over $4 per foot. The average rate of drilling with this drill is about 30 feet per 10 hours

(22466) Prospecting by drilling. The old Brower drill near Nome.

(22449) Drilling shallow ground with 4 inch drill operated by gasoline engine.

in deep frozen ground. Two 50 to 55 foot holes have often been drilled in 12 hours. In thawed ground the average rate is from 35 to 40 feet per 10 hours.

A very light drill equipped with a 4-horsepower gasoline engine and using 4-inch pipe for casing is popular in the Seward Peninsula for drilling unfrozen light shallow gravels up to 15 feet deep, which are underlain by soft bedrock. It has proved very practical for preliminary drilling and for testing ahead of the dredge. While it can be used as a churn drill, the pipe is more often driven through the entire depth of shallow gravel and into bedrock without pumping. The pipe is then pulled and the core for the entire section removed. Such a procedure usually returns a low percentage of core, so that the results of such drilling should not be too strongly relied upon. The entire outfit weighs but 1000 pounds and being mounted on two wheels, which are detachable when drill is in use, it can be moved around with ease. Pl. 22449. Three men including the panner constitute the crew. From 60 to 75 feet of drill hole can be made per shift of 10 hours.

The close spacing of drill holes is imperative in Alaska, especially so in the rich but often erratic gold distribution of the creek deposits. It is seldom that a spacing of more than 100 feet can be relied upon. On the Nome tundra and vicinity, a spacing of about 200 feet along rows with the rows 400 feet apart is often used. On the average creeks, for dredging, the holes along the rows are sometimes spaced as closely as 30 to 50 feet apart with the rows from 100 to 1000 feet apart. Depending on the results and the conditions intermediate holes and rows may be drilled. In unusually spotty, shallow creek deposits, containing coarse gold, spacing as close as 12 feet with the rows 20 feet apart, has been used and even then a constant average has not always been obtained.

The average cost of drilling with a 6-inch churn drill varies from $2.50 to $5 per foot. In some of the districts the drilling may be contracted, although there are but few contractors now in the business. In the Fairbanks district, contract drilling in all frozen ground from 150 to 200 feet deep, the greater portion being muck, has been done for $1 per foot, exclusive of the fuel consumed. In the same district a drill and crew can be contracted for on the basis of $60 per 9-hour day, although drills alone can often be rented for $10 per day. In the Ruby district contract work has been done for $1.50 per foot in frozen muck and $2.50 in frozen gravel, of any depth. At some recent prospecting in the Fairbanks district for dredging ground, shafts and drill holes were spaced 25 feet apart on the rows and the rows 2000 feet apart. The ground varied from 18 to 40 feet in depth and most of it was frozen. The average cost of the prospect shafts was $5.50 per foot, the drilling of both cased and open holes cost $3.25 per foot, including the panning.

(24467) Typical small brush, gravel and sod dam for diverting water to ditch.

(24542) Dam and flume on Dan Creek, Nizina district.

Water Supply

The water supply is a factor of utmost importance to placer mining. It must be ample for the required output and be brought to the property under conditions best suited for each system of mining. It is governed by different factors, the more important ones being the precipitation, temperature, topography, vegetation and evaporation. While all forms of placer mining require a water supply, the facilities for obtaining a supply for those operations not requiring water under pressure, are not so generally adverse and while they will be considered in the following, the main consideration will be given to water which can be conducted to the mines for use under pressure.

In southern Alaska, especially on the south and west slopes of the Alaska Range, conditions are generally the most favorable for comparatively large and steady supplies. The drainage basins, as a rule, are located above the general level of the mines so that the water may be made available for mining by ditches or pipe lines of comparatively short lengths. Annual precipitation is heavy and seasonal temperature variations, as a rule, are not extreme. In the Nizina, Chistochina, Girdwood, Valdez Creek and other districts, where many of the streams head in the glaciers or perennial snow of the higher mountains, unique supplies, under favorable conditions for utilizing them are obtained. During the dry summer months from about July 15th to Sept. 1st, as a general rule, when most of the Alaska water supplies are low, these streams maintain a constant or increased flow through the melting of these glaciers.

The Yukon-Tanana or interior regions are dissected uplands and while hilly or mountainous, the predominating features are series of long branching ridges of uniform elevation. Natural storage basins are generally lacking with but small drainage basins or catchment areas above the diversion point of the stream, and with uniformly low stream gradients. As a rule, the precipitation is considerably less than for other parts of Alaska, and the higher summer temperatures cause the rapid melting of the snow. Frozen ground, and a country much of which is denuded of timber, causes the water to run directly to the streams, causing a less uniform distribution of the run-off with a widely fluctuating stream flow almost directly dependent on the precipitation. Under these conditions it can be stated that the interior districts, in general, are not favorable for obtaining satisfactory water supplies.

The greater part of the Seward Peninsula is characterized by a more or less elevated country, much dissected by streams. The precipitation is heavier and the temperature lower than in the interior. The high mountains in the central part receive the heaviest precipitation and many of the higher elevations are covered with perennial snow. Catchment areas are generally large, located at a level well above the point of diversion, with some good natural storage basins. Most of the important placers are, however, located at considerable distances from the diversion point which has necessitated the construction of long costly ditches and pipe lines.[19]

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[19] The topographic maps and water supply papers of the U.S.Geological Survey and the climatological data issued by U. S. Weather Bureau at Juneau will be found to be of invaluable aid in the investigation of water resources.

Dams and Reservoirs

Water is impounded in reservoirs or directly diverted from streams, by the use of dams and then conducted to the operations through ditches, flumes, pipe or hose. In Alaska, the thick sod or moss has proved efficient material for the construction of small dams. Owing to permanent frost in most districts such dams will stand at a small angle especially if brush is laid alternately with the sod. In laying the brush, the butts are pointed down stream. Heavier dams are constructed by placing one or more logs across the stream, which act as a support for spiling or smaller logs driven on the upper side of them, pointing upstream at angles of 50° to 65°. These are then covered with gunny sacking or lined with sod to prevent leakage. Small dams have also been quickly constructed where sod was not available by using sacks filled with gravel and sand.

In streams of higher velocities and larger volume, heavier and stronger dams are necessary and most of these are constructed of timbers up to 12 inches in diameter, notched and placed to form square cribs. These cribs are then filled by hand with clay and gravel, or where means are available, are hydraulic filled. All dams must be provided with gates and spillways of sufficient size to handle the excess water.

The timber and hydraulic filled dam which is under construction on Canyon Creek in the Sunrise district, will when completed, be the largest dam used for placer mining in Alaska. This dam is in a narrow rock canyon and will be 50 feet long at the base, 150 feet at the top, 125 feet thick at the base and 45 feet at the top. Total height will be 110 feet or 92 feet to the bottom of the main spillway, which is 24 feet wide and cut through the solid rock formation to one side of the dam. There are also two 12 by 12 foot outlets at the base. The upper slope of the dam is 20 percent, the lower 12 percent. The timber portion of the dam is constructed of hemlock timbers ranging from 9 to 20 inches in diameter. The main central timbers run diagonally through the dam, starting from the right and left walls of the canyon on the lower side of the dam, and intersect at an angle of about 50°. Other main timbers are radially arranged from the same points and all are keyed and braced with cross timbers. As construction advances the spaces between timbers are filled with clayey gravel which is hydraulicked from the benches above.[20] This

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[20] Information from E.O.Anderson, Mgr. of Canyon Creek Dev. Co., district not visited.

dam is to be used both for storage and diversion purposes.

A timber and filled dam used for diversion purposes at Dan Creek, Nizina district , is shown in Pl. 24542. This dam is 54 feet long and 8 feet wide and is typical of such construction.

In the higher altitudes and under conditions as in the interior where drainage basins are small and the water supply is obtained entirely from the melting snows and rainfall, continuous operations are generally restricted to a period of two or three months, and can only be conducted on a small scale. During periods of low run-off, reservoirs are constructed by throwing up embankments on the hillsides to impound the water or by constructing dams across the natural drainage channels or taking advantage of natural depressions along the ditch line. Such reservoirs are rarely more than a few acres in area and but a few feet in average depth, holding only sufficient water for small intermittent operation. There are but few places where natural lakes can be utilised for storage or where the topography affords large storage facilities which would be practical. Where small amounts of water are stored and used intermittently the dams or ditches are equipped with gates which are hand operated or may be controlled automatically. Details on the use of water under such conditions will be given in following chapters.

Settling ponds must be constructed where it is necessary to use the water over and over for successive operations. On Willow Creek in the Iditarod large amounts of sand are brought down with the water from other operations. To keep the ditches from filling with sand, a combination moss, brush and sand dam has been built. As the sand accumulates, the dam is heightened. It is 500 ft. long, 12 ft. wide, and is now 18 ft. high. The cost for construction and maintenance during its life of 6 years has been about $20,000. The water is used by two operations and during the greater part of the average season, the supply is so small that each operation takes the water on alternate 12-hour shifts. (Pl. 24483).

The usually short and meager water supply available for those operations well above the general level of the surrounding country as in the case of high bench, residual and similarly located deposits and

(24603) Small reservoir with automatic gate, barrel trip.

(24483) Settling pond for tailing. Iditarod district.

where there is little opportunity for snow to accumulate, can be much improved by the use of snow fences. When used on the Upgrade Assn. in the Iditarod district, most satisfactory results were obtained. These fences are similar to snow fences used along railroads, being constructed of 2 by 4 uprights to which are nailed 1 by 6 boards, leaving a space of 6 inches between each board. The completed fence section is 12 feet long and 5 feet high. These are braced to stand at an angle of about 60°. Two parallel tiers of fences each a mile long were placed near the summit of the mountain at right angles to the prevailing wind. As the snow built up, the fences were dug out and placed on top of it, and the cycle repeated until a final depth of from 40 to 50 feet of snow had accumulated. Two to three men were used at odd periods during the winter to look after the work and were paid $1 per hour. The total labor cost was about $1500. This work lengthened the average water season by five weeks or until August 1. Such depths of snow soon "glacier" with the early thaws and prevent the otherwise rapid spring run-off. In the vicinity of Nome and also in other districts, brush has been used as fencing by sticking it upright down the center of the gulch with laterals along the side hill and when covered with snow the operation is repeated, until a deep drift has accumulated.

Ditches

Thousands of miles of ditches were constructed in Alaska during the earlier days of the camps when the rich and extensive gravels were still to be mined. Many of these ditches have since been abandoned, while in the case of others only portions of them are still in use. Subsequent operations have fallen heir to many of these ditches and in so doing placer mining can still be conducted on some of the creeks which would otherwise remain idle. Only a comparatively few and short ditches of small capacity have been constructed in recent years and these are located principally in the interior districts. No new methods have been used in their construction, although through the experience gained in the past and the use of steam-shovels or tractors, and modern plows and graders, large ditches such as the Miocene, Fairhaven, Candle, and similar Seward Peninsula ditches, could now be constructed at a considerable less cost and many of the difficulties which were then encountered, could be avoided.

Seward Peninsula has been most prominent in the construction of large and long ditches and such an era of ditch building as that region once experienced will never be repeated in Alaska. Had dredging reached the stage of development in those days that it now holds many of those ditches would never have been dug. Conditions for ditch construction in the interior are quite similar to those found on Seward Peninsula, but although the ground is more favorable for ditching in some respects, the interior is generally adverse for obtaining large volumes of water under pressure, so that no ditches of such large capacities or length have so far been constructed there. Favorable conditions for ditching are found in Southern Alaska where frozen ground is rarely encountered, and by nature of the favorable topographic features, long ditches are seldom necessary. A 3 or 4 mile ditch there is considered to be long. Where the ground is free of permanent frost and where other conditions are similar to those encountered in a temperate climate, no unusual difficulty in construction is experienced.

The greatest obstacle encountered in ditching in the Seward

Peninsula and in the interior is the frozen condition of the ground which may be found on both the slopes and the creek valleys. This is especially true where the ground is frozen muck or where irregular bodies or seams of ice, called "glacier" occur. These ice seams are from a few inches to 3 or more feet in thickness and from 25 to 150 feet in maximum dimension, generally somewhat oblong in shape and are explained as due to freezing seepage water. Most ditches encounter muck but the occurrence of "glacier" ground while common, shows no regularity in distribution. In such frozen ground, special methods of construction must be used and precautions taken to keep under control the thawing of the frozen muck. The necessity of keeping the grade of the ditch and the velocity of the water low in this character of ground is very important. Muck thaws rapidly on exposure to air and water and when once beyond control is the cause of much ditch trouble. So few ditches are now being constructed that the opportunity to study the methods used and the conditions which are encountered, is generally lacking. It is, therefore, necessary to rely on other writers for much of this information.

Henshaw and Parker[21] state that over 400 miles of ditch with a

(21) Henshaw, F.F., and Parker, G.L., Surface Water Supply of Seward Peninsula, Alaska: U.S.Geol. Survey Water Supply Paper 314, pp. 258-260, 1913.

capacity of 20 second-feet or greater have been built on the Seward Peninsula. Frozen ground has caused serious difficulties there as well as in the Yukon-Tanana region and they describe the methods of construction and means of overcoming difficulties as follows:

"Ditches are constructed by several different methods, according to the conditions of the ground encountered. Horses have been used for the work wherever possible. In one method the ground is first prepared by removing the moss and turf from a strip 40 or 50 feet wide on either side of the ditch. This should be done, if possible, the summer before actual construction is begun, in order that the ground may thaw more readily. Actual construction begins with plowing, after which some of the material is moved with a grader from the upper side of the ditch to the lower bank until a practically flat bench is produced. The cut is then excavated with horse scrapers down to grade, and the material piled up on the lower bank. The ditch is finished by hand, and both bottom and bank are trimmed to an even grade and alignment. The method above described is practicable where the ground contains only small or medium sized rocks and is about the cheapest and most rapid that can be used, but it requires exceptionally favorable conditions to make it a success. Where the ground is naturally unfrozen or can be made to thaw easily, and where other conditions are similar to those encountered in a temperate climate, no difficulty is experienced.

"Wherever the ground is frozen muck, or so-called 'glacier', it melts rather slowly when exposed to the air, and the work of excavation must be done by hand while it thaws. The best practice is to keep exposed as large an area as possible and to remove the soil in thin layers.

"More or less rock work has to be done on all the ditches. Some of them have had to pass around cliffs of practically solid rock where the construction required a large amount of blasting. Rock cuts offer no problems not met in other fields, except in the method of making the ditch tight, which is done by the use of a peculiar tough and tenacious sod abundant in many places in the north. The sod is cut with mattocks into pieces 1 to 2 feet square and placed in the ditch, bottom up. Two layers are usually placed in the bottom, breaking joints as well as possible, and the whole is carefully and solidly tamped into place. The sides of the ditch are made tight with a sod wall, the pieces being laid one above another, bottom up. Where the sod is above the water line part of the time, the grass usually continues to grow and its living roots bind the material more closely and firmly together. The best sod, and the only kind which fully meets the requirements, is that containing grass roots and very little moss, for the moss is less tenacious and decays more rapidly. Grass, however, is not abundant in many places, and it is, therefore, often necessary to use sod of inferior quality, with correspondingly unsatisfactory results.

"Canvas has been used in some places to line ditches, but is expensive and is reported to be not wholly satisfactory. If it is disturbed, after it is once laid down, it is likely to be torn, in which event it becomes practically useless.

"In ground composed largely of frozen muck or ground ice, special methods and precautions must be taken. This material when it thaws leaves a soft residue, largely mud and decomposed vegetable matter, which may be only 20 to 20 percent of the original volume. Water flowing across such material causes it to thaw rapidly, and consequently when a ditch is built through it precautions must be taken to prevent too much thawing. Where the muck is present the portion nearest the surface usually contains much more earthy matter than that just below, and in many places there is a layer of blue clay just beneath the moss. The vegetable matter close to the surface is also less completely decayed and therefore more solid and tenacious than that lower down.

"If this surface covering is allowed to remain in place and the ditch built over it by building up the lower bank with sod and with material stripped from the top, good results can usually be obtained. When stripping is carried to just about the right depth, the water, after being turned into the ditch, will cause the ground to thaw a little. The bottom will settle a few inches, and then the ditch practically builds itself, so that eventually the water is carried in a section entirely below the surface of the ground, and the ditch cannot leak because its sides are all soft, fine material, mostly muck and clay, backed by solid and impervious frozen ground. These ideal conditions are generally aimed at by ditch builders but are attained only at certain localities and by special care in building and watchfulness in maintaining the ditch."

Experience has proved that wherever possible ditches should be carried along the south slope of the hills. As the south slopes receive more sunshine and usually accumulate less snow, the ditches will clear more quickly of snow in the spring and afford an earlier water supply than those on the other slopes. South slopes generally afford good deposits of earth for ditching and which are less liable to contain permanent frost, and less bare rock than the north slopes. Water conducted along south slopes will also be appreciably warmer, a feature of importance when used for thawing frozen placer.

Ditches are only in use during the open mining season of 4 to 6 months, so that each spring considerable work must often be done on the ditch line in opening it and in repairs. In the spring, deep snow drifts often cover parts of the ditch and before the water can be turned in a channel must be dug along the bottom. Where the drifts are unusually deep as on the Seward Peninsula, shafts are sunk from the surface of the drift to the ditch bottom at about 100 foot intervals, which are then connected by tunnels of small cross section, for they quickly enlarge when the water is turned in. Great care must be exercised in turning the water into the ditch in the spring. Only a small volume should be turned in at a time. otherwise the frost will be drawn too quickly and bad breaks may result. Where there is much slush ice and snow running with the water it should be run off through the waste gates, which should be placed along all ditches not less than every third of a mile and be of ample size. Failure to draw off such slush may result in damming the ditch, causing overflows and consequently damage to the sides. At the close of the season the ditch should be drained and all waste gates left open. Pl. 22462 shows the remaining portion of a snow drift which in the early spring was over 50 feet deep in places entirely covering several miles of the Miocene ditch. The picture was taken on July 5, 1922, after a serious break in the ditch just a short ways ahead. This break stopped all mining operations for 4 days requiring the work of 40 men and 3 teams of horses to repair it.

Different means have been tried to keep the water running in the ditches in the late fall, one method being to raise the level of the water permitting the surface to freeze, then lowering the water level leaving an ice cover. Such measures, however, are seldom practical for as soon as the freezing weather starts the water supply diminishes

(22462) Remaining portion of snow bridge over Miocene ditch, July 5, 1922.

(22447. The Canyon ditch, Council district. Seward Peninsula.

very rapidly, although until the final freeze up comes there may be a good flow during the middle of the day.

In ground free of permanent frost standard methods of construction and the standard ditch constants will produce satisfactory results in Alaska, and the tendency under such conditions is for deeper narrower ditches and higher grades to permit less excavation and consequently reducing the construction costs. The more grade used on the ditch, however, utilizes just so much of the head which would otherwise be available for pressure. Experience has proven that for ditches constructed through frozen muck, a low velocity of not more than 2 feet per second is most desirable, and the ditch built comparatively wide and shallow. In frozen soil, gravel or clayey slide material, grades up to 9 feet per mile have been used without giving trouble. The dimensions of Alaskan ditches under average conditions are constructed with bottom widths from 2 to 3 times the depth, top widths from 1-1/3 to 1-1/2 times the bottom widths and the slope of the sides from 45 to as much as 65 degrees. Such high slopes to the sides, however, quickly cut down.

With such variable conditions as found in Alaska, the losses in conducting water through ditches has received study at only a few places. The principal feature affecting seepage loss is the character of the country over which the ditch is built. Ditches properly built through frozen ground, ordinarily have very small seepage losses, and unless the season is an unusually dry one, both seepage and evaporation losses are usually compensated for by the seepage running into the ditch or small side streams which can be turned in. Seepage measurements of several ditches made by Henshaw and Parker[22] in 1908 in the Seward Peninsula showed the leakage of the Fairhaven ditch, which is built over frozen muck to be almost negligible, and for the others the average loss per mile under varying conditions of supply, size, character of ditch and climate was about 0.5 second-foot and may be as much as 1 second-foot and in a few places where soil or rock is unusually porous or fractured it may be much higher. On the Seward Ditch which passes through 12 miles of limestone formation, there was at one time an unusually large loss of

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[22] Henshaw, F.F., and Parker, G.L., op. cit., pp. 268-269

water, which investigation showed amounted to about 70 percent and was going through the limestone crevices. This was mostly overcome by lining with sod, and by fluming the worst places.

The seasonal maintenance of some of the ditches is a large item of expense, although if properly constructed and handled at the start, no unusual trouble should result. The greatest maintenance cost is generally during the first two years after construction or until the ditch has established itself. Short ditches, as a rule, require but occasional attention, while on the longer ones, ditch tenders must be employed - one man being allotted from 5 to 8 miles of ditch to look after.

The cost of ditches is regulated principally by varying local conditions, and methods used, but under average conditions, can be dug for $.75 cents to $1.25 per cubic yard. Hand dug ditches in frozen ground to carry up to 100 miners inches cost from $600 to $1800 per mile. Ditches with 4 to 5 foot bottoms and carrying up to 400 miners inches have been constructed by using horses and plow for breaking the ground and excavating by hand for $1500 to $3000 per mile. Ditches from

700 to 1500 miners inches have been constructed for $2500 to $5,000 per mile. There are many exceptions to the above and special consideration must be given those requiring much rock work and flume construction. The construction of large ditches in Alaska is costly and unless the builder constructs his ditch properly at the start the subsequent maintenance and repairs in many cases more than double the original cost. Considering that the water is in use for only 3 to 5 months of the year, and the small amount of water most of the ditches deliver, the cost per miners inch or per cubic yard of placer mined is in many instances, a considerable item of expense. As many of the ditches now in use have either been written off the books or obtained by present operators for only a small fraction of the original cost, this charge may be very low, and, therefore, permits mining in some of the districts which would otherwise not be permissible. The sale of ditch water is no longer practiced, although in a few places the ditch is maintained by several of the operators and the water divided either in amount or time it may be used.

The Miocene ditch system on the Seward Peninsula is the largest and most extensive in Alaska and originally included 31 miles of main ditch and 24 miles of lateral feeders and distributing ditches. Further extensions were at one time under construction but were not completed. This ditch diverts water from upper Glacier Creek, upper Snake River, Nome River and its tributaries, and the Grand Central River drainage basin for use on claims along Glacier, Dexter, Anvil and Little Creeks. Construction on the ditch was started in 1901 and was active until 1907. The main ditch runs from Robson Creek to the tunnel. This ditch as far as the "X", or where one branch goes to Dexter Creek, was constructed 10 feet at the bottom, 14 feet at the top, and 3 feet deep, the grade being 3.37 feet to the mile. Seventeen miles of ditch from the head of Nome River to Robson Creek were built 6 feet wide at the bottom, 11 feet on the top and 3 feet deep with a grade of 4.5 feet to the mile. From the "X" to the tunnel the dimensions were the same as the upper end of the main ditch but on a grade of 6.5 feet to the mile. There are 5 miles of rock work along the ditch including the 1800 foot tunnel between the Glacier Creek side and Anvil Creek. The main ditch was originally constructed to carry 3000 miners inches of water. From 1910-1912 the main ditch was enlarged to a width of 16 feet by the use of steam shovels, and the rock cuts and tunnels were also widened to increase the capacity to 5000 miners inches. The longest siphon is across Hobson Creek. It is 3100 feet long and 66 inches in diameter. The largest siphon is at Flume Camp and is 82 inches in diameter. Only 40 miles of the ditch system are now in use, the Dexter Creek branch and several of the other branches no longer being maintained. The ditch has not been cleaned out since its widening and now carries from 3000 to 3500 miners inches of water, all of which is used at the Little Creek hydraulic elevator and water thawing operations at a maximum head of 320 feet.

The cost of construction of the original ditch system is stated to have been about $500,000 and the cost of the water rights and other incidental expenses were about the same amount. The cost of enlarging the ditch was about $250,000. The cost of maintenance averages about $600 per mile per season. This does not take into consideration the cost of extensive repairs as are sometimes necessary. Ten ditch tenders are employed throughout the season. In 1921, 312,489 - 24 hour miners inches of water were used and the cost of ditch maintenance alone was about $20,000.

The Fairhaven ditch takes its water from Imuruk Lake where a dam 800 feet long and 5 feet high was built to form a storage reservoir of sufficient size to hold the total inflow at the lake for two years, if necessary. The upper section is 17 miles long and empties into Pinnell River. Six miles below this point of discharge it enters the lower ditch which is about 19 miles long. The ditch has a grade of 4.2 feet to the mile and was built 11 feet at the bottom but because of difficulties in controlling such ground it has in many places widened to 15 or 20 feet or more. It has been an exceedingly troublesome and costly ditch to maintain. While the ditch was constructed to carry 5000 miners inches it has never carried more than about 2700 miners inches. Only the lower ditch is now in use. A maximum head of 550 feet can be obtained from the upper penstock, but this head has been found to be too great for practical use, so a lower penstock was built and the head reduced to 330 feet. The cost of the original ditch construction is stated to have been about $650,000 and before the ditch was finally gotten into shape this cost was practically doubled.

The following examples are characteristic of many of the ditches of recent construction.

In the Hot Springs district, two ditches 4 and 2 miles long, both 4 feet wide at the bottom, were constructed through partly frozen muck and slide material, using horses and plow for breaking ground and finishing by hand, for 50 cents per foot. Cost includes dam, and waste gates.

In Ruby district, a typical small hand dug ditch through frozen muck, 3600 feet long, 3 feet wide at the bottom, was dug at a cost of $700; another in the same district, 4 feet at bottom, 2 feet deep, 2-1/2 miles long for $1000 per mile.

In the Rampart district, a shallow ditch 4000 feet long on a 9 foot per mile grade, 6 foot bottom width, 3/4 of ditch through frozen muck, the rest in gravel and slide rock, was dug entirely by hand for

25 cents per foot. There is also 600 feet of 3-foot flume set on trestle on a grade of 18 feet per mile. Cost of fluming was $2000. Annual maintenance averages about $500. Much trouble was at first experienced along that part of the ditch in frozen muck.

A 1-1/2 mile ditch with 4-foot bottom constructed with horse and plow and finished by hand in the Yentna district through clayey gravel and soil, and a short distance through muck, all free of permanent frost, cost 50 cents per foot.

In the Fairbanks district, a 2 mile ditch with 4-1/2 feet bottom and 8 foot top width with a carrying capacity of about 1000 miners inches dug through clay and soil at upper end and slide and loose material at the lower end, was constructed with plow and scraper and hand finished for $5250 per mile. This is high for this type of ditch. One man is kept in attendance on ditch as tailing from operations above cause much trouble.

On Candle Creek in the upper Kuskokwim district, a ditch 8 feet wide at the top, 6 feet at the bottom, 2-1/2 feet deep, and the lower bank sod lined, was constructed for $1 per foot. The average carrying capacity is about 200 miners inches. The ditch is through frozen muck, clay and soil. The low maintenance of this ditch is a good proof that sod lining fully repays the added cost. Sod is cut in one foot squares and starting at bottom of lower side of the ditch, one square is placed on top of the other in much the same manner as laying bricks. the lining, however, conforming to the slope of the side.

A new ditch 1-1/2 miles long has just been completed in the Innoko district. With the exception of about 1500 feet of frozen muck all the material ditched was decomposed slate and schist in place or as slide rock, free of frost. A large portion of the ditch follows the steep hillside, where a cut in the solid formation 1-1/2 feet deep on the lower side was necessary. The ditch is 5 feet at the bottom, 7 feet at top with a grade of 5.5 feet to the mile and constructed to carry about 350 miners inches. The sod was first removed by hand, then plowed and leveled off with a drag scraper with horses and dug and finished by pick and shovel. From 2 to 5 men were employed for two seasons. The total cost of the ditch was $6000.

A survey has recently been made for an enormous ditch project in the Fairbanks district. The main ditch would run from the intake on Chatanika River, 3/4 of a mile below the junction of Faith and Homans Creeks, following the north side of the valley, then carried across the Chatanika River under a 560 ft. head through a 7930 foot wood stave syphon 4 feet in diameter, to Cleary Creek, then past the head of Little Eldorado and Dome Creeks to Vault Creek, then through a 4000 foot tunnel to Fox on Goldstream Creek, where the head would be 350 feet. Here one branch would follow up the north side of Goldstream Creek to Golden, the other branch continuing westerly as far as Ester Creek. This ditch line, would be 100 miles in length, the ditch to be dug with steam shovels, about 15 feet wide at the bottom, carried on a grade of 2.64 feet to the mile and having a carrying capacity of about 5000 miners inches. To avoid as much frozen ground as possible, the southern exposure of the hills would be followed and the water carried across the deep draws and valleys, through syphons 4 feet in diameter. There would be 4?,000 feet of this continuous wood stave syphon on this main ditch. The syphons would be placed with a fall of 4 feet for each 1000 feet and the grade in the 5 by 6 tunnels 2-1/2 feet per 1000 feet. The minimum flow of water expected at the intake is about 1600 miner inches. To assure a sufficient water supply at low water periods, a lateral ditch is planned which would double the supply, bringing it from Beaver River to the main ditch at Bell Creek, a distance of 40 miles, including the 2 miles of syphon and 1-1/2 miles of tunnel. Double syphons would then be installed on the main ditch.

Flumes and Syphons

Flumes, and in some cases, pipes, are used for conducting water across ravines or places below the grade line of the ditch, or along the face of vertical cliffs, or over ground containing shattered or porous material productive of large seepage and absorption losses, or over ground which is most difficult and costly to excavate. Most ditches encounter some of these conditions and some flume must generally be constructed. Many miles of flume have been constructed in Alaska, but because of their generally high cost of construction and the difficulty experienced in maintaining them, their use should be minimized as much as possible and not generally used where ditching can be done or where pipe is permissible.

Flumes are less permanent than ditches for as the waterway is not in use for the greater part of the year they are subjected to exceptional deterioration. Sand and gravel in the water cause deep scouring of the lining boards when in use and during the winter the action of the ice and frost loosens and warps the boards. Snow and rock slides, floods, the weight of the deep snow, forest fires, and other acts, may all cause heavy damage to flumes. Where flumes are constructed over frozen ground special precautions are necessary to protect the ground from thawing, otherwise the foundations may settle, open the joints, loosen the boards and cause the flume to break to pieces. Thawed ground on freezing expands raising the flume and throwing it out of line and grade. On subsequent thawing, the flume will rarely return to its former position and after several such successive periods will be so out of position as to render it useless.

Successful flume construction over frozen ground has been accomplished where the heavy sod covering is still intact by placing lengthwise with the proposed flume two heavy paralleling log stringers on top of the sod; on these are placed the sills upon which the flume is then constructed. Where there is no sod, the frozen ground is covered with a thick blanket of sod to keep in the frost. A thick covering of clay has also been used but it is not a permanent protection. Satisfactory foundations have also been made by digging shallow holes, filling them with gravel and placing on top a wide plank or timber to distribute the load.

A notable example of successful flume construction over frozen ground was done on the Miocene ditch.(23)

(23) Henshaw, F.F., and Parker, G.L., op. cit. p. 262.

"This flume is 1100 feet long and has a width of 8 feet and a depth of 28 inches. It was constructed in 1901, and until 1906 or 1907 it retained practically perfect alignment, both horizontal and vertical. No extensive repairs were necessary on it until 1909. In putting in the foundation, trenches were dug 3 or 4 feet in the frozen ground, which was practically all ice. A sill was laid in the bottom of the trench and the uprights fastened to this sill. The excavated material was then replaced in the trenches and allowed to freeze again into itsoriginal condition. Sod was carefully placed over the trench. the uprights were then sawed off to grade, and the flume constructed on them. Even with all these precautions, however, at the end of about

(22501) Flume in the Rampart district.

(22448) Flume across Crooked Creek, Canyon ditch, Council district.

eight years the flume was in such bad shape that extensive repairs had to be made."

The grade to be given a flume is generally governed by topographical features. While increasing the grade, increases the velocity, and thereby permits the use of a small size flume at less expense, this practice is not the rule in Alaska. Most of the Alaskan flumes are set on the same or at a slightly increased grade as the ditch. There are a few places where the flume grade is twice that of the ditch. The iron fluming which has in recent years been placed on the market, has many advantages over the ordinary board flume and should be given consideration in districts where lumber is expensive and a long life with low maintenance is desired.

It often happens that a big saving in the expense and length of ditch can be made by carrying the water across a valley or other deep depression through a syphon. This has been done on a number of Alaskan ditches in the Seward Peninsula and on a few of the larger ditches in the interior. In the Yukon Territory many large syphons have been used. Riveted steel pipe has been used for many of the Alaskan syphons, although wood-stave pipe has also been used along a number of ditches. Two wood-stave syphons, 42 inches in diameter, and 1050 and 800 feet long, were built along the Seward ditch across Hobson and Clara Creeks. Two large riveted steel syphons were built on the Miocene ditch, as already stated.

Pipe Lines, Giants and Nozzles

Water is used under pressure for hydraulic mining and also for other forms of placer mining for removing the overburden, leveling old tailing piles or for thawing purposes. For such uses it goes from the ditch or flume into the pressure box or penstock, from where it is conducted through pipes to the giants. The practice in penstock construction in Alaska does not differ from that followed elsewhere. Alaskan conditions do, however, govern to some extent the kind, size and methods of installation of pipe lines.

Riveted steel pipe with slip-joints is generally used in Alaska. It is cheaper than other types of steel pipe, lighter and more easily transported and can be easily and quickly laid. With average topography, experience has proved that slip-joint pipe will stand great pressure when of proper gauge. In the present Alaskan practice from 10 to 16 U.S. standard gauge pipe is used, in diameters from 7 to 36 inches. ~~In most cases 14 to 16 gauge pipe is used in diameter from 7 to 24 inches.~~ Long pipe lines are not the rule.

With slip-joint pipe an allowance of three inches to each length must be made for joining as one end of one length slips into the end of the next one. The larger sizes of pipe should not be less than 14 gauge, as pipes of lighter material become battered and are otherwise damaged too easily. In making slip-joints, the pipe whose end is of larger diameter is heated, generally by placing burlap dipped in kerosene around it and ignited and while expanded the pipes are driven together with a heavy ram, which is directed against a driving plate covering the opposite end of the pipe. As many of the pipe lines are moved quite often, the end becomes enlarged and battered and the joint becomes leaky. In joining pipes it is more usual to wrap the smaller end with burlap or canvas soaked in tar and then drive it into the large end of the pipe next to it. Slip-joint pipe is equipped with lugs for wiring to hold the pipe together.

Manufacturers nest hydraulic pipe for shipment, so that from 3 to 5 different diameters of pipe are placed one within the other; the ends are either fastened together and so shipped, or the pipes are wedged to keep them from moving and the ends sealed with wooden or metal caps and held together by a central iron tie rod. This last method is the better as the caps save the ends from damage. Knock-down pipe or the shaped plates punched for rivet holes have been shipped in bales, to be later riveted together on the ground. This is, however, not advisable as a poor job generally results. Pipes before leaving the factory are usually given a double coating of asphaltum, to protect them from rust and to give a smoother surface to the interior. The nesting of pipes for shipment makes a large saving in freight, as they are generally rated according to measurement; it also prevents injury to the pipe and further facilitiates transportation.

Little attention is given to the upkeep of pipes in Alaska. They soon rust and scale and when this happens on the inside the internal friction rapidly increases. Pipes in such condition should be dipped in asphaltum or a similar substance. A preparation commonly used is made of 28 per cent crude asphaltum and 72 per cent coal tar (free from oily substances).

Spiral riveted pipe with slip-joint but more often with steel or cast iron flanged joints is also in use in Alaska, especially on the Seward Peninsula. Spiral riveted pipe will stand harder usage and higher pressures than the ordinary riveted pipe but is considerably higher in cost. Flange joints also have advantages but they are heavy, expensive in first cost and as it is best to have them fitted to the pipe at the factory, they do not permit nesting for shipment.

Wood-stave pipe lines and syphons have been constructed in the Seward Peninsula, and to a less extent in the Interior. The Grand Central pipe line of the Wild Goose Mining and Trading Co., was constructed of continuous wood-stave pipe, the intake being 48 inches in diameter and balance of the pipe being 42 inches. Wood-stave pipe should give satisfactory service in Alaska when properly put together and laid on proper foundations. The redwood pipe has proved less susceptible to deterioration under Alaskan conditions than those made of other woods. Temperature does not cause it to expand or contract like steel pipe. The internal friction is less than the riveted pipe and under freezing conditions will carry water much longer. Its first cost is less than the heavy steel pipe and for large installations for long life in districts favorably located for transportation it is worthy of serious consideration.

Changes in temperature will cause the expansion or contraction of steel pipe lines. The lines are usually laid when the weather has a more or less constant temperature, as early in the spring or at night. Where the line can be laid on a slight lateral curve, contraction will then tend to straighten out the line, and expansion will return it to its normal position. When in use and full of water, the pipe line is practically not affected by outside temperatures. The average small pipe line is generally taken down and moved each season so that expansion joints are seldom used. Large and long pipe lines which are practically installed for the life of the property should be equipped with expansion joints of some kind or they may be pulled apart by contraction. Pipe lines are further protected by covering them with sod, moss or earth and on steep side slopes are buried or covered with a timber shed to prevent injury from slides or falling rocks.

Near Nome, 6 men laid on an average of 500 feet of 20 inch slip-joint pipe which had been used elsewhere but was in good condition, in a 11-hour shift at a cost of about 9 cents per foot. This was on a gradual slope requiring practically no excavation or foundation work.

On Chitita Creek in the Nizina district the pipe was laid during the night shift, the foundations and excavations were made during the day. It required six nights for 15 men to lay 6500 feet of slip-joint pipe 26 to 18 inches in diameter. The entire construction consisting of a timber crib, gravel and clay filled dam 100 feet wide, 10 feet high, 12 feet at the base with 24 foot spillway, 144 feet of 2 foot flume, an 8 by 12 foot penstock with sand box and the installation of the pipe line required a total of 534 one-man days at a labor and mess cost of $2,871.50.

At one mine in the interior 6 men lay from 300 to 500 feet of

16 to 32 inch slip joint pipe or about one mile of small diameter pipe in 10 hours.

Alaska practice is to use a considerable number of different diameters of pipe in the line. Starting with a bell mouthed entrance pipe at the penstock followed by a length or more of large diameter pipe, the size of the pipe is reduced from 1 to 4 inches at a time. A pipe line of but two or three different diameters is not common. This is to a large extent due to nesting in shipment and to save on the cost of larger pipe or pipe of heavier gauge. By cutting down the diameter of the pipe the heavier pressure can generally be handled with safety with pipe of a lighter gauge. The small diameters of many of the pipe lines and the sharp bends commonly made are the cause of much internal friction or loss in head, a matter of importance in Alaska where the available head is usually low. This may be justified, where other considerations outweigh the resulting loss in head. Most engineers agreed that in order to secure efficiency and economy in construction, water should flow in the pipe at a velocity of not more than 2 feet per second. Such a restriction in Alaska can seldom be economically met.

Much of the pipe now in use has been obtained from former hydraulic plants and has been purchased for a very nominal figure. In many instances pipe more befitting the new conditions, could have been obtained if a new outfit had been purchased. As it stands many of the operations are getting along the best they can with what they have been able to get.

Canvas hose is used by a few small operations in remote districts for ground-sluicing and hydraulicking under low pressure. There are a few places where it is used under as much as an 85 foot head. This hose is generally 10 to 14 ounce duck in 6 to 9 inch diameters. Regulation canvas fire hose and nozzles are also used. Canvas hose kinks, chafs and cuts easily in dragging it over the rocks and is difficult to handle. One ingenious operator has tarred his hose inside and out and has suspended it from timber bents so as it may drain easily and dry and also keep it from chafing when the water is turned in. With shallow ground to mine and under low head, it has the advantage of portability, but is usually more costly than pipe of similar capacity.

Giants or monitors, and nozzles used in Alaska are of standard makes, principally of Seattle and San Francisco manufacture. The double jointed giants, with or without ball bearings, are used and under heads of 150 feet or more deflectors are generally used for handling the giant. Deflectors handle a giant so much easier and quicker that more and better work can be accomplished. Small giants under low heads are pointed by hand. The average operations use from No. 1 to No. 3 giants with 2 to 4 inch nozzles. The 2-1/2 and 3 inch nozzles are the usual size in the interior, 3 to 4-1/2 inch on the Seward Peninsula, and in southern Alaska where larger volumes of water are obtainable giants in sizes Nos. 4 and 5 are quite often used with 4 to 6 inch nozzles. No. 7 giants with 5 and 6 inch nozzles are used at one operation there, and while the giants are too heavy for the present work they are a part of the old equipment. The largest nozzle used in Alaska as far as known is at Valdez Creek and is 8 inches in diameter. When water supplies get low all operations are obliged to reduce the size of the nozzles used, many dropping to 2 or 2-1/2 inch. For undercutting and for cutting frost a smaller nozzle has been found the most satisfactory, a 2-inch being usually used. Grit in the water seems to be a common occurrence in Alaska, it quickly cuts out the gaskets in the giants, cuts the nozzle and destroys the shape of the jet, causing it to spray. Air in the pipe also causes spraying. Glacier water contains such fine grit.

The unit of water measurement in most general use for all classes of work is the "second-foot" and from it the quantity expressed in other terms may be obtained. It is an abbreviation of "cubic foot per second" and may be defined as the unit for the rate of flow of water flowing in a stream 1 foot wide and 1 foot deep at the rate of one foot a second. To obtain the actual quantity of water it is necessary to multiply the number of second-feet by the time. It is a unit not often used by Alaskan placer miners who are more familiar with the "miners inch" and the "sluice head".

The "miners inch" expresses the rate of flow and is applied to the volume of water flowing through an orifice of a given size with a given head. The head of the water and the size of the orifice differ in different states where they are defined by the law. The California "miners inch" is now the one in most common use and was defined by an act approved March 23, 1901, as follows: "The standard miners inch of water shall be equivalent or equal to 1.5 cubic feet of water per minute, measured through any aperture or orifice". This miners inch corresponds to the so-called '6 inch head' and is equivalent to one-fortieth of a second-foot.

Experiments made in California by A.J.Bowie, Jr.(24) to determine the volume of the miner's inch, defined as the one two-hundredth part of the quantity of water which would flow through an opening 12 inches high by 12-3/4 inches wide in a 1-1/2 inch plank, under a constant head of 6 inches above the top of the discharge, showed that one miner's inch was equal to a discharge of 1.4994 cubic feet per minute. For all practical purposes this may be taken as equivalent to 1.5 cubic feet or 11-1/4 gals. of water per minute, or, in other words, 1 cubic foot per second equals 40 miner's inches. A miner's inch is so interpreted and used

(24) Bowie, A.J., A Practical Treatise of Hydraulic Mining, 1885, p. 126.

in this report.

The "sluicehead" is a term used by many of the placer miners as expressing the volume of water that is necessary to separate the gold from the gravel in a sluice box. It is an indefinite and unsatisfactory term as the rate of flow necessary varies with the size of the sluice boxes, the grade at which they are placed, and the character of the gravel. A sluicehead in Alaska is usually considered as equivalent to the amount of water necessary to properly carry all the gravel that 6 to 8 men can shovel into a 12 inch sluice box set at a grade of 6 inches to 12 feet. A sluice head under varying conditions has been found to range from 0.75 second-foot to 2.50 second-feet or from 30 to 100 miners inches. The sluicehead as used in New Zealand is equivalent to one cubic foot per second or 40 California miner's inches.

There are three distinct methods of determining the flow of water in open channels; (1) by measurement of slope and cross section and use of formulas; (2) by means of a weir; (3) by measurements of the velocity of the current and of the area of the cross section. The method chosen for any case depends on the local physical conditions, the degree of accuracy desired, funds available, and the length of time that the record is to be continued. A simple method of ascertaining the approximate amount of water flowing in an open channel is to select a straight portion of nearly uniform cross section along the ditch, flume or stream where the water runs smoothly. Me sure off 110 feet along the channel and set stakes at each end or stretch a line across it and call the distance 100 feet. Floats made by weighting empty shot gun shells with shot or small gravel and fitting into them cylindrical wooden plugs 4 to 6 inches long are then placed in the canal as quietly as possible. Note the average time which it takes several of them to traverse the distance, divide the distance in feet (100 feet) by the average time in seconds and the result will be the velocity in feet per second; this multiplied by the area of the cross section of the stream in square feet will give the number of cubic feet of water flowing per second. If channel is not uniform in cross section, an average should be made from the measurements of the cross section at different places. Different kinds of surface floats are used but floats of such shape and weighted at the bottom so as to be least affected by wind should be used. In surface float measurements of ordinary streams with rough bottom a deduction of 10 percent from the surface velocity at the center of the stream is generally made for the mean velocity, while in canals, ditches and flumes, 5 to 6 percent may be a fair deduction according to the smoothness of their walls and form of area.

The table on Alaskan water conduits, Table ________ contains some of the salient features on ditches delivering water under various conditions for placer mining. As there are so many ditches and it is impossible to obtain reliable detailed data on most of them, only a few selected examples are given. Many of the ditches carry but a small proportion of the water for which they are constructed, and there being great fluctuation in the quantity that item as given is only approximate. The cross section is also variable. The data given have been obtained from many sources, principally from the operators, as it was not practical to measure and check such details. Alaskan miners seldom take account

MR195-5

ALASKAN WATER CONDUITS

Locality or ditch	Length in Miles.	Width, ft. top	Width, ft. bot.	Grade ft. per Mile	Head ft.	Average water carried Miners Inches.	Cost of construction.	Average cost of annual maintenance	Remarks.
Seward Peninsula									
Miocene ditch	40 a	12-16		3.57-6.34	320	3600	-	$20,000	See p. 99
Osborne Cr.	8	4	10	5.28	175	700	$39,000	600	
Penny R.	6	12-20		3.17	90	-	-	-	
Big Hurrah Cr.	8	-	8-10	3.3	190	700	40,000	-	
Fairhaven Ditch	36 b	11	-	4.22	650	1200	650,000 a	very high	Lower part only used See p.
Candle Ditch	24 1/2d	-	7	3.7	200	400	-	8,000	Includes 2 1/2 miles of siphon.
Canyon Cr. Ophir	17 a	.10	8	3.17- - 4.2	230	1500	175,000	6,000	
Circle-Eagle-Forty Mile									
Mammoth Cr.	10.3	-	7	5-5.3	-	-	-	very high	Upper ditch 3.8 miles Lower 6.5 miles Now in disuse.
Mastodon Cr.	1.	7	4	6.6	100	350	2500	-	
Fourth of July Cr.	10 3/4	6	4	5.3	160	600	20,000		Cost includes two years maintenance upper ditch 8 1/4 miles long. 100,000 sq. ft. reservoir.
Crooked Cr.	6000 ft.	10	6	8	100	500	4,500	very little.	1000 ft. flume included

Included

Dome Cr.	8	9	-	5.5	170	very variable	35,000	1500	No flumes built partly by hand
Fairbanks									
Chatanika	a	-	4	-	-	500	-	200	
Pedro Cr.	1 1/2	3	3	4.6	-	75	-		
" "	3000 ft.	6	4	4.6	120	200	1,000	low	Main ditch, hand dug
" "	2	8	4 1/2-6.6		130	300	10,500	700.	Cost high-rebuilt. Sand troubles.
Hot Springs-Rampart.									
Hunter Cr.	4000 ft.	9	6	9.1	185	500	1,500	500	600 ft. of flume.
Pioneer Cr.	4	6	4	4.6	75	250	6,500	low	
Eureka Cr.	3500 ft.	6	4	5.0	70	100	1,000	-	
Kantishna									
Moose Cr.	2 1/4	10	6	10	250	1500	10,000	-	Exclusive of 258 foot siphon.
Ruby District (f)									
Greenstone Cr.	2	4	3	9.1	-	100	[illegible]	350	Hand dug
Solomon Cr.	1 1/2	4	2	3	-	85	2,000	-	Hand dug
Poorman Cr.	3/4	3	-	-	-	60	[illegible]	-	"
Spruce Cr.	3/4	4	2	4.4	-	65	600	-	"
Cooks Inlet.									
Canyon Cr.	1 1/4	9	5	17.6	350	3000	-	-	
" "	2	5	3	17.6	-	1000	7,000	-	
Crow Cr.	1 1/4	6	4	15.8	150	1200	-	250	Small reservoir along ditch.
Kenai									
Peters Cr.	2 1/2	6	4	9.1	180	400	3,500	low	
Falls Cr.	1600 ft.	6	4	-	100	250	1,200	"	
Cache Cr.	1	12	6	7.9	80	2300	-	"	For Hydro-electric power
Iditarod-Kuskokwim									
Flat Cr.	6000 ft.	6	4	4.6	140	350	-	-	
Willow Cr.	2750 ft.	5	3	3.7	50	200	-	high	Sand troubles.
Otter	4	8	6	3.54	75	300	-	-	Used for water thawing
Moore Cr.	2800 ft.	7	5	5	100	250	800	-	
Victor Gulch	1 1/2	7	5	5.5	-	250	6,000		
Candle Cr.	6000 ft.	8	6	6.6	100	300	6,[illegible]	-	Sod lined-muck & soil see p.

a - Dexter Cr. branch not in use.
b - Only lower 22 miles in use at 375 ft. head.
c - Subsequent repairs almost doubled this cost.
d - Total length formerly 34 miles.
e - Other portions abandoned.
f - Ditches supply drift operations water not under pressure.

of the volume of water used. The amount of water carried by the ditch as given, is not its carrying capacity, but the average volume of ditch water actually carried, and while the amount may in some cases appear very small, it must be remembered that "ground sluice" or "bank-head" water, when used, is generally not drawn from the ditch supply. The head or pressure is the difference in elevation between the water level in the penstock and point where it is discharged, and as the work proceeds upstream the head will diminish accordingly.

Many of the drift mines and some of the steam scraper operations, being unable to obtain water otherwise, pump water for sluicing purposes. Having some steam equipment already in use and in those districts where fuel is not too expensive or the lift too great, it has been found that the cost of pumping water is little, if any, higher than if a ditch of average length had to be constructed and its cost of construction and maintenance were taken into consideration. Pumping water with steam equipment or water power for hydraulic mining has been tried, but in practically all cases was found to be too costly to be financially successful. In some districts, as certain parts of the interior, where power can be produced by the use of cheap fuel or in other districts where cheap water power is available, it is, however, a matter for further investigation before large and extensive ditch systems are constructed in districts of small or erratic water supplies. There it is necessary to pump water and a large volume of water can be obtained under a comparatively low head, the newer and more efficient types of hydraulic rams afford a cheap and satisfactory method for raising a part of that available water to a height many times greater than the original head. Under satisfactory conditions, the larger size rams or a battery of rams can pump water for small hydraulic purposes directly to the giant.

<u>Waste Ditches, Drains, etc.</u>

In the mining of creek deposits, the excess creek water must be kept out of the working pit and means provided for draining off the seepage water. Sod or timber dams similar to those described are constructed across the creek at a point above the area to be mined. These dams are equipped with gates to deliver groundsluice water to the pit when required, and

(24550) Dam, penstock, head of pipeline. Nizina district.

(28280) Bedrock drain below hydraulic operation.

with an ample spillway from which by-pass ditches or flumes conduct all excess water around the workings. In narrow rock rimmed valleys, the use of a large by-pass flume may be the only way out. In the wider valleys, the creek is generally diverted to the opposite side of the valley by the use of wing or diversion dams. The excess water is sometimes also handled by using an adjoining pit as a by-pass. The by-pass conduits should be made large, and all safeguards taken to protect the operation from flood conditions, which so often cause heavy losses.

Open drains leading from the pit afford drainage under average conditions. These are carried along as the work advances on as steep a grade as conditions will permit. In small open cut mines, where the grade is low, the accumulation of tailing will soon stop drainage, in which case a box or enclosed drain may be carried along with the operation. Depending on conditions, these drains may be carried on or in bedrock on xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx grades as low as 1-1/2 inches to 12 feet. After the first cut has been made, the sides and top of the drain are timbered and covered with moss. These drains as used at the shovel-in operations are usually 1 or 2 feet in width and height on the inside and have a wooden box stand pipe set at the lower end of each cut. While they will handle the average seepage water, they are usually called upon to carry much of the sluice water for which purpose they are generally too small.

In the Fairbanks and other districts, principally at the steam scraper operations, it is not always practical to carry a long open bed-rock drain. The pit is then kept drained by steam pumping. The amount of seepage water is usually small, most of the water coming from the thawing of the frozen gravels and rains, so the pumps are generally operated only at intermittent periods. Under such conditions the operators state it is the most practical means of keeping the pit free of water.

Frozen Ground

The frozen condition of many of the Alaskan placer deposits governs to some extent the method of mining, and is a factor affecting the cost. Drift mining is to a great extent benefited by it, for were it not for the frozen condition of most of the deep ground, it would be impossible to drift mine it except at a prohibitive cost for timbering and pumping. There are two kinds of frost to contend with - that which is permanently frozen, and that which is seasonal.

No permanently frozen ground is found along the Pacific littoral. In the regions of southwestern Alaska back from the coast, permanent frost is seldom encountered, being found only in a few isolated areas of deep ground manteled with a moss and deep overburden. East and north of the Alaskan Range in the Yukon and Kuskokwim Basins and on the Seward Peninsula, a permanently frozen state is the rule, especially where covered with moss and muck. The ground may be solidly frozen to bedrock.

and instances are known where this is over 400 feet in depth. The shallower creek deposits up to 10 feet or so in depth are usually free of permanent frost, especially those which are mainly of gravel and free of moss and muck covering. The beds of the larger water courses are generally unfrozen, although there may be irregular frozen patches, while the ground in the flats adjacent to such streams is often solidly frozen. The gravel benches along the valley walls, and the deep creek placers, often develop, through drainage, thawed areas which may occur in more or less defined streaks or channels or in irregular isolated areas. Such drainage may be natural, or, as on some of the creeks, subsequent mining has created drainage resulting in the thawing of much of the gravel. It is not uncommon to find thawed gravels overlain by frozen muck or overburden. While not an infallible rule, thawed areas are generally found underlying heavy growths of willows, particularly so on the Seward Peninsula. Willows as well as other brush and timber assist in the accumulation of drifting snow forming a blanket which lessens to some extent the depth of seasonal frost.

The occurrence and depth of seasonal frost varies according to local climate and conditions. In areas underlain by permanently frozen ground and covered with sod or moss, the seasonal freezing affects only a few feet of the surface. Under other conditions this frost will penetrate to a depth of 2 to 10 feet or more each winter. This frozen blanket thaws slowly and in mining often breaks off in large slabs which are troublesome to handle and are conditions which especially handicap dredging operations during at least the earlier part of the season.

The composition and physical characteristics of muck and frozen gravel are variable but under average conditions muck is composed of 25 to 40 per cent organic matter, fine silt and sand, and 60 to 75 per cent ice. The average frozen gravel contains from 10 to 20 per cent ice, although some gravel containing a large percentage of voids may contain more ice while some of the finer or tightly packed gravels may contain less than 5 per cent. In some instances the voids are only partly filled with minute ice crystals, when it is known as "dry frost".

Muck is defined by McCarthy[25] as follows:

(25) McCarthy, E.E., Stripping Frozen Gravel: Min. Mag. (London) Vol.10, April, 1914, p. 289.

"A frozen substance having the following physical characteristics: Color, gray to black: composed of organic matter, particles of sand and silt, cemented by ice. In hardness it may be likened to a soft sandstone. The temperature of the frozen muck varies between 19° and 24° F., or 8° to 13° below the freezing point. The average physical characteristics are as follows:

Physical Characteristics of Muck

Specific gravity	1.392
Specific heat	.192
Weight of 1 cubic foot, pounds	87.
Weight of solids in 1 cubic foot, pounds	49.33
Volume of solids in 1 cubic foot, per cent	31.9

"The figures are taken from a number of experiments made in 1912 by engineers in the employ of the Yukon Gold Co.

"The weight of the frozen gravel per cubic foot has been found from the average of a number of experiments to be 137.3 pounds, of which 17.4 pounds is ice and 119.9 pounds solid. The temperature varies between 18° and 22° F., averaging 19°. At one place, where it was possible to get a reading 38 feet below the surface, a temperature of 2° F. was recorded. The temperature of the frozen bedrock varies between 8° and 14°, averaging 11-1/2° F. ...."

Payne[26] made an extended study of frozen ground in the

(26) Payne, H.M., Development and Problem of the Yukon Trans. Canadian Mining Inst., Vol. 16, 1913, p. 228-240.

Klondike in 1912 for the Yukon Gold Co. From his tests on 46 samples

he has drawn the following averages.

Physical Properties of Frozen Materials

	Black Sand & Muck	Gravel and Sand	Bedrock
Specific gravity, frozen	1.401	2.189	2.590
Specific gravity, thawed and dry	2.411	2.691	2.655
Specific heat, frozen	0.196	0.172	0.183
Percent ice, frozen ground (by vol.	68.2	29.1	9.6
(by weight	44.7	16.0	4.26
Percent solids, frozen ground (by vol.	31.8	70.9	90.4
(by wt.	55.3	84.0	95.74
Percent voids, frozen	0.0	1.28	0.0
Percent voids, thawed	6.1	2.97	1.65
Pounds ice per cu. ft. frozen ground	39.11	22.0	6.96
Pounds solids per cu. ft. " "	48.39	118.80	154.96

The results of 27 tests on temperatures made by Payne showed the bedrock temperature to vary from 2° to 14° F. with an average of 9° F.; gravel from 17° to 22° F., average 19°; black muck from 17° to 24° F., average 20°; and sandy muck from 12° to 24° F., average 21°, and, he states, show that the mean temperature is solely dependent upon the nature of the material and not on its depth, depth of frost line or water level, or on the presence or absence of muck overburden.

A. Gibson[27] states that the temperature of perpetually frozen

[27] Gibson, A., Thawing frozen ground for placer mining; Min. & Sci. Press, Jan. 17, 1914, p. 143.

ground on Seward Peninsula, as far as known, remains nearly constant around 28° F., excepting close to the surface where the temperature is affected by the atmospheric heat or cold during the summer or winter months or in the immediate proximity of subterranean water channels or thawed ground.

The Stripping of Overburden

Unless previously removed by natural agencies, the Alaskan gold bearing gravels are usually covered with moss or sod, and a barren or low grade overburden of muck, sand, gravel or similar material. In areas of permanently frozen ground this foot or two of moss or sod acts as an impervious and insulating blanket to the underlying material. Excepting where the deposit is drift mined or is thawed by artificial means, this blanket must be removed before the overburden will thaw and for a similar reason this overburden must be removed to expose the underlying gravels. By stripping the gravels of this material, a season or two in advance of actual mining, the frozen gravels will, under certain favorable conditions, become naturally thawed.

It is generally customary and good practice, where an appreciable depth of barren or very low grade overburden exists, to first remove as much of it as is consistent with the conditions and the facilities available, before the actual mining and the sluicing of the gravels is started. This is not done for the possible purpose of thawing alone, but because this overburden can generally be more cheaply handled in this way than by the mining method used in putting it through the sluice boxes. It may also be necessary in connection with the tailing disposal, or it may be better practice to keep such material as clay, roots, etc., from passing through the sluice boxes.

Under present conditions many of the Alaska placers are too low grade to be profitably mined unless this overburden can first be removed at a comparatively low cost. This stripping reduces the volume of material to be subsequently handled by the more expensive methods, and the gold content of the deposit is proportionately increased. These are features of most important consideration in the investigation of the possibility of a placer deposit, and the stripping operation should be considered in the light of preparing the ground for mining, much the same as the stripping of some of the porphyry copper, coal, phosphate, and other kinds of deposits, as is done in the States.

The removal of overburden by hydraulic methods, i.e., with water under pressure from nozzles, and which is usually supplemented with water running through open channels, is called "stripping". When hydraulic methods are not employed, but the water is conducted through open channels and ground-sluices, it is commonly known as "ground-sluicing". As a general rule stripping is stopped when the gravel is reached, while ground-sluicing is carried deeper into the deposit removing more of the gravels so as to concentrate the gold content in the ground sluice, when it becomes a distinct method of placer mining, as discussed in a following chapter.

The removal of overburden from extensive areas is seldom permissible under most Alaskan conditions, because of the generally inadequate water supply during the greater part of the season and the low creek gradients. The depth of overburden removed ranges from a few feet to more than 60 feet, depending on the conditions. It cannot be carried below the creek gradient, unless it is practical to elevate the material. The water supply at most of the placer operations is not sufficient to permit both stripping and mining at the same time. The area which can be stripped, therefore, often limits the volume of ground that can be mined during the season. The removal of overburden is generally prosecuted during the spring high water periods, or later in the fall after the regular mining has been completed.

In preparing ground for placer mining, the timber or brush which may be present is first removed. The moss or sod is best removed during the summer or fall after it is free of frost and should be so disposed of that it will not fall into the cuts later. It is removed by hand methods, by plow and drag, or scraper, by steam scrapers or with water under pressure.

After the moss or sod blanket has been removed, the muck thaws and cuts up quickly upon exposure to the air and the action of water, and when free of heavy material can be readily transported over grades as low as one-half of one per cent. As most muck is, however, mixed or interbedded with heavier material as sand, gravel, clay, roots or buried timber, much higher gradients and large volumes of water are required for low stripping costs. Under average conditions grades less than 2 per cent are generally troublesome. The duty of water in stripping naturally depends on many conditions, but will range from about 3 to 10 cubic yards per 24 hour miners inch. Under very favorable conditions this may even be larger, although 4 to 5 cubic yards is generally the maximum under average conditions.

Where the ground has formerly been mined and the surface is covered with sand and heavy gravel tailing, stripping becomes more complicated and the cost may become so high as to obviate its purpose. Stripping such ground requires water under high pressure and special plans for handling the material. This material, if barren or very low grade, may be driven to one side of the ground to be mined, or dumped into the worked out cuts adjoining.

One of the most satisfactory methods for stripping overburden and one in most general use at the larger operations is to conduct the creek or ditch water to the highest point from where it is distributed in a series of cross ditches in the muck, or at some operations, longitudinal ditches are used. These ditches or trenches are dug by hand, or a furrow is made with a plow, just large enough to get the water properly started and are placed from 10 to 25 feet apart, depending on local conditions. The water is then turned into them and quickly

(24462) Ground-sluicing muck overburden.

(24452) Stripping overburden by hydraulic means ahead of dredging.

thaws and cuts a channel through the muck and carries the material to the main drain and to the creek. Pl. 24462. The best results are obtained if the drain is straightened so as to procure the maximum grade and avoid curves which retard the velocity. The cutting action of the water in the trenches is improved by using water under pressure to keep the cuts clear of caved material and removing the material as it thaws. After the water has cut down to the creek gradient, and the cuts widen and the velocity becomes low, the frozen ridges of muck remaining are but little affected by the running water. Water under pressure is then used to cut them up and remove them. Pl. 24452. The continuous application of water under pressure on frozen ground is inefficient practice for such water performs its principal work in removing the material as it is thawed by the air and sun. This work should, therefore, be so arranged that the nozzling is done at periods best suiting the rate of thawing, which generally ranges from 3 to 6 hours. The frozen ridges or high muck banks are sometimes blasted with a slow powder to hasten their removal.

At many of the smaller operations, especially where a long narrow area is to be ground-sluiced, the entire creek is turned into a single longitudinal cut and when it has cut as deep and as wide as conditions will permit, the water is diverted by the use of small temporary wing dams and shear boards to undercut and cave the banks. This process is generally slow as the frozen banks do not cave readily and when they do they break off in large chunks often troublesome to handle.

Where the water supply is too small for efficient continuous use it is often impounded and released at intervals by hand or automatically operated gates. The sudden rush or booming of the water down the cut greatly increases its carrying power. After the first cut, the water must be diverted against the banks as explained. At such operations only one or two men are in attendance for part of the time and when the time lost between splashes is not considered, the work can often be done at a very low cost.

One of the largest stripping operations in Alaska is conducted by the Kuskokwim Dredging Co. on Candle Creek in the upper Kuskokwim region. The gold bearing gravels here are now covered with from 30 to 60 feet of frozen overburden which must be removed before dredging can proceed. Most of this overburden is a yellow and gray muck, the lower 6 to 12 feet being a tough blue clay gumbo which is most difficult to disintegrate. Stripping has been kept well in advance and an area about 400 feet wide and over 2000 feet long has been stripped to the gravel. The creek gradient is 2 per cent. The sod and moss blanket is cut with sod knives and removed by hand at a cost of one cent per square foot. Trenches are plowed at right angles to the main drain and spaced 20 feet apart. In the early spring for a period generally of about six weeks when the maximum water supply is available, the water from the main ditch and nearby streams is turned into these trenches and as large an area as possible opened up. While heavy rains increase the water supply, they are also of additional help in thawing and washing down the muck faces. The water quickly cuts to the tough clay, where its cutting action has but little effect. It is necessary to blast this clay which is further disintegrated and removed with difficulty by two giants with 2 inch nozzles under 100 foot head. The frozen muck ridges are removed with the giants. Buried timbers, roots and old beaver dams, unless removed as soon as possible, clog and dam the cuts and main drain. The limited water supply permits the operation of only one giant during the greater part of the season, yet with a crew of ten men as much as 300,000 cubic yards of overburden have been stripped during a particularly favorable season. The average cost of stripping is 10 cents per cubic yard.

On Goldstream Creek in the Fairbanks district, the sod is often removed with a Bagley scraper. The maximum gradient here is about 2 per cent, with water conditions adverse for hydraulicking. Several of the operations pump the water for stripping, using their steam equipment. At one operation an 8 foot depth of frozen muck, or 24,500 cubic yards, was removed in 70 ten-hour shifts, using about 1800 gallons of pumped water per minute through an 11-inch canvas hose with 4-inch nozzle, at a cost of 10 cents per cubic yard. At another operation 7 feet of muck, or 10,000 cubic yards, were removed in 60 ten-hour shifts with pumped water at a cost of 19 cents per cubic yard. Powder was used at this latter operation for blasting the muck. A nearby operation used water from a ditch at 80 foot head through two giants with 2 inch nozzles. In 21 ten-hour shifts, 4 men stripped a depth of 5 feet of muck or 22,000 cubic yards at a cost of 5 cents per cubic yard.

In the Iditarod district on Willow Creek sod was stripped from an area of 130,000 square feet with two 2-1/2 inch nozzles under 100 foot head by 3 men in 20 shifts, at a cost of 1/2 cent per square foot. In the spring, with surface water and water under pressure, a depth of 13 feet of muck or 67,400 cubic yards was stripped at a cost of 4 cents per square foot. The cost of stripping the full depth of 14 feet was 9 cents per cubic yard.

On Eagle Creek in the Circle district, a depth of 6 to 8 feet of soil, sand and tailing is stripped well ahead of hydraulic operations by piping it to either side of the narrow valley to keep it from passing through the sluice boxes. On Mammouth Creek, from 2 to 5 feet of moss, muck and gravel is stripped well ahead of the dredge mainly for thawing purposes. The cost of stripping at these two places ranges from 9 to 15 cents per cubic yard.

In the Klondike, Yukon Territory, where exceptionally large water supplies are available and the stream grades are 1 to 2 per cent, extensive stripping has been done. Here the North West Corporation, Ltd., using 5600 miners inches of water, stripped 3,307,670 cubic yards of muck from 1911 to 1914, inclusive, at a cost of 2 to 8 cents per cubic yard.[28] Some large scale experiments in stripping were also

[28] The Yukon Territory, Dept. of the Interior, Ottawa, 1916, p. 76.

conducted by the Yukon Gold Co., the results of which are commented on by McCarthy[29] as follows:

[29] McCarthy, [illegible], Stripping Frozen Gravel: Min. Mag. (London), Vol. 10, April, 1914, p. 292.

"During the seasons of 1906, 1907, and 1909, the Yukon Gold Co., conducted some large-scale experiments with the removal of muck overburden. The tests were conducted at three different points on Bonanza Creek, where every convenience was at hand. Two 5-inch giants under 400-foot head were used at one point, and an additional supply of 3000 miner's inches was available on Bonanza Creek after it had been used in the hydraulic mines. No trouble was experienced in getting rid of the muck in favorable localities, but the solid matter was deposited a short distance from the operation and had to be driven along. The serious drawbacks were that nothing could be done with the areas which were covered with a tailing of sand and gravel on top of the muck, within the limits of reasonable expense. As the cross ditches cut down to the base level, they lost grade, and more and more hand labor had to be employed. Buried roots and stumps had to be cut out by hand at great expense. I have endeavored to show that the stripping alone had its serious difficulties and that it cannot be accomplished with the ease and cheapness to be inferred from recent articles on this subject."

Sod and moss, after it is free of frost and under average conditions, is stripped at a cost of from 1/2 to 2 cents per square foot. With hydraulic methods it has been removed for as low as 1/4 cent, and will vary from that up to one cent per square foot. At the larger operations it should not exceed 1/2 cent. By manual means the cost will range from 1/2 to as much as 3-1/2 cents per square foot. On an average, one man will strip and remove by handwork from 1000 to 1200 square feet of moss per day.

Over short periods and under favorable conditions with a large water supply, frozen muck has been stripped for as little as 2 cents per cubic yard, but under average conditions a cost of from 5 to 10 cents per cubic yard can be considered good work. The average cost of stripping is 10 cents per cubic yard, while under unfavorable conditions or where much gravel is removed as in some of the ground-sluicing, costs of 20 to 35 cents per cubic yard are not uncommon.

The Thawing of Frozen Gravels

Frozen gravel and bedrock must be thawed before it can be excavated or sluiced. The thawing is accomplished by the use of: Hot rocks, woodfires, natural agencies, steam, hot water, or water at natural temperature. The method used is dependent on the character, depth and position of the placer and the available resources.

The methods of thawing in drift mines are described under "Drift Mining", so the following will apply principally to thawing from the surface ahead of open-cut mining and dredging. Under "Frozen Ground" it has been stated that ground may be wholly frozen or only partly so. In partly frozen deposits there are naturally thawed channels or irregular thawed spots or patches, or one or more horizontal stratum may be naturally thawed with frozen beds above or underneath them. At the larger and more systematic dredging operations, the areas to be mined are prospected for frost by driving long steel bars from the surface to bedrock or by sinking drill holes. Colored maps are then made to show the outline of the frozen, thawed and partly thawed areas.

The generally irregular occurrence of such areas make these maps resemble a crazy quilt, but show that the thawed areas are almost invariably connected to a thawed bedrock channel.

The physical characteristics of muck, gravel and bedrock, and the amount of ice present, are most variable, but as an example to illustrate the amount of heat necessary to thaw one cubic yard of frozen gravel, it will be assumed that the frozen gravel weighs 3500 pounds per cubic yard, containing 425 pounds of ice and the temperature at 20° F. above zero. It is desired to heat this gravel from 20° above zero to 36° or 4° above the freezing point to assure complete thawing. The specific heat, or the coefficient of thermal capacity for the solids, is taken as 0.2, that for ice as 0.5, and for water is 1.0. The latent heat of fusion of ice is taken at 144 B.t.u. per cubic yard. Then:

		B.t.u.
3075 pounds of solids raised 16°, from 20° to 36°, 3075 x 16 x 0.2		9840
425 pounds of ice raised 12°, from 20° to 32°, 425 x 12 x 0.5	2550	
425 pounds of ice at 32° raised to water at 32°, 425 x 144	61200	
425 pounds of water raised 4°, from 32° to 36°, 425 x 4 x 1.0	1700	
Total heat required for the ice		65450
Total heat required per cubic yard of gravel		75290

This corresponds very closely to the average British thermal units required at the Yukon Gold Co. operations in the Yukon territory. The example clearly shows the comparatively small amount of heat required for the solids, or 1[illegible] per cent, and the large amount required, or 81.3 per cent, to change the ice at 32° to water at 32°.

Taking the fuel value of crude oil at 18000 B.t.u., bituminous coal at 12000 B.t.u., lignite coal and dry spruce wood at 6000 B.t.u., and assuming the efficiency of the boiler and distributing plant at 50 per cent, there will be required to thaw one cubic yard of this frozen gravel: 8.365 pounds of crude oil; 12.55 pounds of bituminous coal and 16.82 pounds of lignite coal or dry spruce wood. When water at natural temperatures is used through points, the calculation involves different conditions. Accurate data is lacking as to the efficiency obtained from water so used and through what range of temperature the water is most efficient. To continue the example it will be considered that the water after dropping to 36 degrees above zero, is no longer efficient and with the initial temperature of the water at 50 degrees, the range of temperature is 14 degrees, or one pound of water between 36 to 50 degrees contains 14 B.t.u. of heat, which at 70 per cent efficiency is reduced to 9.8 B.t.u. Under these conditions, 7684 pounds, or 921 gallons, of this water will be required to thaw one cubic yard of this frozen gravel.

Thawing with hot rocks is no longer practised, but was practiced during the early days of the Klondike and some of the first interior Alaska districts. The rocks were heated in a fire at the surface and dropped to the bottom of the shaft, or piled against the frozen face in the drifts, and covered with sheet iron or steel plates to concentrate the heat. The heat from the rocks can be more easily controlled than that from wood fires, and so obviates much of the sloughing of the sides or roof.

Thawing with woodfires is now done only where other thawing equipment is lacking or as a temporary expedient. The use of wood fires at a few of the very small drifting operations in some of the more isolated interior districts has been briefly stated under "Drift

Mining". Wood fires are also sometimes used to thaw small areas of river bar placers which are frozen during the winter or at a few of the open cut mines where it may be more practical to thaw some occasional small frozen spot that is troublesome. In thawing with wood fires from the surface, an area is stripped of ice or of such material as can be removed. Kindling is placed, over which is piled dry wood. Green wood or brush is placed over this and all is covered with sheets of iron or steel to concentrate the heat. The fire is ignited and burns slowly. During the winter only enough ground is thawed as can be excavated before it freezes again, while during the open season this feature needs no consideration. The size and shape of fires and the rate of thawing vary with the conditions. One fire containing about 1-1/2 cord of wood thawed to the depth of 18 inches, thawing 6 cubic yards of gravel.

Thawing by Natural Means or Exposure to the Elements

This method of thawing with natural agencies, sometimes referred to as "solar thawing", involves the utilization of the heat from the air and the sun. The moss or sod blanket must first be removed and any muck or other frozen overburden is thawed and removed according to the methods described under "Stripping of Overburden", to expose the frozen gravels.

Where steam scraper, shovel-in and similar open-cut methods of mining are used, the rate of thawing from the surface down during average seasons will generally keep close pace with the mining, and as the thawed material is removed from time to time, depths of 6 inches to a foot or more may thaw each day. The conductivity of gravel and sand is relatively low and considering that the average temperature during the 3 or 4 summer months is generally not over 50 to 55 degrees Fahr., and as during practically each of these months there may be a frost, it can readily be seen that the rate of natural thawing is very slow. Gravel that is undisturbed and is without drainage, thaws especially slow and will ordinarily only thaw to depths of 2 to 4 feet during the season. Where there is natural drainage along bedrock or bedrock drains are opened so as to permit the water from the thawing gravels to seep down into them and flow away, the rate of thawing is greatly increased and the thawing during a season will continue to depths of 8 to 12 feet and sometimes deeper. However, after the gravels have once been stripped they will again freeze to depths of from 2 to 10 feet each winter, which may be to bedrock. Natural thawing has been successfully completed, but not on any very extensive scale where the gravels were not more than about 15 feet in depth, and where bedrock drainage was established. It then usually required one or two seasons. As seasonal frost handicaps most of the open-cut and all dredging operations, particularly during the earlier part of the season, sufficient gravel must generally be thawed of this frost by steam to get the mining under way.

Some of the large northern dredging companies, most of which were operating in the Yukon Territory, conducted large scale stripping operations followed by experiments in natural thawing. In most instances, ample water, grade, etc., were lacking to permit cheap stripping and such extensive operation as was necessary to keep ahead of the dredging. Even where the gravels, which ranged from 15 to 25 feet in depth, had been stripped several seasons ahead, they were found, when dredged, to be very incompletely thawed, the lower gravels and bedrock were still frozen, except those connected to a thawed bedrock channel. The results were, in general, too unsatisfactory to justify the adoption of this method over the well tried method of thawing by what was at that time steam, and now water, at natural temperatures.

McCarthy[30] in commenting on the experiments conducted by the

(30) McCarthy, E.E., Stripping Frozen Gravel: Min. Mag. Apr. 1914, p. 289.

Yukon Gold Co. states:

"The experiments of the Yukon Gold Co. above described were sufficient to demonstrate to our satisfaction that the method of stripping and so-called actual thawing could not be relied upon for any large-scale operation. The stripping work on claims Nos. 89 and 90 on Bonanza Creek was of no benefit to the dredging operation. Practically all of the ground had to be thawed by steam before the dredges could operate. The ground was stripped and exposed for an average of less than a season before dredging was attempted. On claims Nos. 78 and 79, opposite Trail Gulch, where main-ditch water was used for stripping, the ground was approximately 50 per cent thawed when reached by the dredge a season and a half later. On account of incomplete data, it is not possible to say positively how much of the thaw was due to stripping and how much of the ground was naturally thawed previously. It is my opinion, from the data available, that the proportion of complete thawing due to stripping was small and altogether disproportionate to the expense of doing the work. The same comments apply to the work on Nos. 62 and 63 Bonanza. In this case the stripping was more thorough and the ground was exposed for an average of over three seasons. The dredge reports show that 80 per cent of the ground was frozen and had to be thawed by steam."

In general, it can be stated that because of the restrictions imposed by Alaska conditions, the removal of overburden on a scale extensive enough for large dredging operations can seldom be accomplished, nor can its removal always be done cheaply enough to justify it as a means for thawing by natural agencies alone. When combined with the object to reduce the deposit to a more practical mining depth, this method holds wider application. The cost of natural thawing includes the cost of stripping, subsequent attention which is generally a small cost, and the interest on the sum expended on the work until the gravel thawed has been mined. The cost of stripping overburden has been stated under that heading.

Steam Thawing

Up to the time of the development of the method of thawing with water at natural temperatures, most of the frozen gravels were thawed with steam applied through thawing points. Steam under pressure of 100 to 150 pounds at the boiler is delivered to the main steam line from which it is distributed to the various headers or laterals. The main line and headers are wrapped in asbestos packing or other insulating material and encased in wooden boxes packed with saw dust to avoid as much condensation as possible. At intervals of 5 to 6 feet along the headers, short steam hose connections are made to the head of the steam points, or branch lines may be run from the headers to a battery supplying from 4 to 10 or more points. Each header, branch and connection to the points is equipped with a valve. Boiler plants of from 100 to 400 horsepower were required at the average single dredge operations for thawing alone, and one company operating eight large dredges in the Yukon used 2000 horsepower.

The steam points are made of 3/4 to 1 inch extra heavy hydraulic pipe cut into lengths of from 6 to 24 feet with some up to 40 feet. Special coupling connections may be used where the long lengths are required. A tool steel bit is welded to the lower end of the point and provided with an opening usually 3/16 inch in diameter, through which the steam escapes. A solid standard drop-forged head which will withstand the heavy blows of a hammer is welded to the upper end. There are various kinds of steam points, differing in the type of drive head, steam connection and form of the bit. The squared or rounded taper point is most generally used, and where boulders have to be drilled a chisel or a cross bit is provided. With the steam turned on, a point will quickly thaw its way through the muck to the gravel without driving. Where the hole starts in gravel, a steel bar is generally used to make a hole for starting the steam point. The short points or starters from 6 to 10 feet long are first used; they are then removed and the longer points driven through the gravel and into bedrock. As the gravel must thaw ahead before the point can be driven, two men are allotted a certain number of points to drive, working from one to the other. In average gravel the points can be sunk at the rate of about 2 feet per hour. The head of the steam point is pounded with a heavy hammer and the point is given an occasional twist to aid its sinking into the gravel. In coarse gravel the driving of the points is difficult. Some heavy gravel can be pushed to one side after sufficient space for it has been thawed. Boulders must generally be drilled through, or if the ground is not too deep, it may be more practical to withdraw the point and start a new hole. Anvils which can be attached to the point at a conven-

(22448) Steam thawing ahead of dredging. Candle Creek, Kuskokwim district.

(22453) Driving steam thawing points ahead of dredging.

ient height above the ground for driving are sometimes used. Their use dispenses with the high ladders otherwise required and reduces the breakage of the points.

The points are spaced from 4 to 10 feet apart in triangular, or less often rectangular, relation to each other. The spacing is governed mainly by the character and depth of the ground. The ground is thawed from 6 to 48 hours and sometimes more, depending on the character and depth of the ground, the amount of ice present, and the spacing of the points. After the steam is turned off the ground is "sweated" by the retained heat. The proper spacing, time of thawing and sweating are most important factors for efficient and economical thawing. A steam point will thaw its largest area at the top of the hole, so that the thawed portion will have a form somewhat similar to an inverted cone, so that frozen "horses" of gravel and bedrock may still remain between points after thawing ceases. The ground is generally prospected with a steel bar and should any unthawed areas be located, points are driven into them and the thaw completed.

Ground 40 feet deep has been steam thawed, but the steam thawing of such deep ground for dredging has not been very successful. The steam thawing of muck is often slow compared to gravel, as the fine thawed material forms a blanket of low conductivity around the point. Clay thaws very slowly and some clays are baked hard by the steam, making disintegration in the sluices most difficult.

The cost of steam thawing is governed principally by: (1) the character and depth of the deposit; (2) the amount of ice present; (3) the cost of labor and fuel; (4) steam loss due to condensation; (5) mining method or application; and (6) the scale of operation. The main item of cost is often the driving of the points to bedrock. The cost of thawing is generally less at the open-cut and dredging operations than at the drift mines as a better system is generally employed, the work is done on a larger scale, the points are longer, the spacing is greater, and the ground is permitted to stand or "sweat" longer.

Steam thawing ahead of dredges has been done for 12 cents per cubic yard, normally ranging up to 25 cents. In some instances it has been much higher. The Yukon Gold Co.[31] in the Yukon Territory

[31] Perry, O.C., Development of Dredging in the Yukon Territory: Trans. Canadian Min. Inst., Vol. 18, 1915, p. 26-44.

from 1909 - 1914 steam thawed 2,289,487 square yards of frozen ground, or 71.3 per cent of the area worked, averaging from 20 to 35 feet in depth, at a cost of from $1.43 to $1.77 per square yard, or an average cost of $1.57 per square yard. The total cost of steam thawing per cubic yard dredged was 12.18 to 17.62 cents, average 14.83 cents, and averaged 46.8 per cent of the total cost of dredging during this period of six years.

On Otter Creek in the Iditarod district, a 150 boiler horsepower plant handled 95 points, or a duty of 1.58 horsepower per point. The deposit was all gravel 14 feet deep. The cost of thawing ranged from 30 to 45 cents per cubic yard. At a nearby operation 200 boiler horsepower handled 110 points or 1.81 horsepower per point. About 100,000 cubic yards of gravel were thawed here one season at a cost of 33 cents per cubic yard. On Candle Creek in the Kuskokwim, where less than 50 per cent of the gravel is frozen, a 100 boiler horsepower plant handled 80 points. The gravel thawed averaged 15 to 18 feet deep, the muck and other overburden having been previously removed. The points were spaced at 6 foot centers. Twelve cords of wood costing $10 per cord were burned in 24 hours. With ten men per shift employed on the thawing operations, about 100,000 cubic yards were thawed in 1922, at a cost of 25 cents per cubic yard. On the basis of 50 per cent of the gravel having to be thawed, this amounts to 12-1/2 cents per cubic yard dredged. Steam thawing ahead of dredging operations has now given way to cold water thawing, except where it is used in a small way at the start of the season.

Thawing With Hot Water

The use of hot water, instead of steam, applied through points for thawing purposes has been tried at different times. The results indicated that the ground could be thoroughly thawed, but steam thawing was generally considered to be more effective at that time. Payne[32]

[32] Payne, F.L., The Development and Problem of the Yukon: Trans. Canadian Min. Inst., Vol. 16, 1913, p. 237.

reported that the results of his experiments with hot water thawing preparatory of dredging operations in the Yukon, showed that by the use of hot water, four times the amount of gravel could be thawed in two thirds of the time, with less than half the fuel necessary when steam was the medium employed. The points could be driven faster and thawing was more uniform. The great condensation losses that occur with steam, and the possibility of back pressure through the points with the consequent choking by mud, etc., were overcome. Hot water thawing has not been adopted, but bearing a close relationship to thawing with water at natural temperatures, its application and merits can be gauged through a study of that method.

Thawing with Water at Natural Temperatures

The use of water as a medium for thawing frozen gravels was recognized some years ago and was probably first applied through thawing points in the experiments conducted on hot water thawing. About 1918, different persons started experiments using water at natural temperatures with such satisfactory results that within a few years the Yukon Gold Co., and the Canadian Klondike Co., in the Yukon Territory;

John H. Miles of the Alaska Mines Co. at Nome, Edward Pierce on Candle Creek, C. Aarons of the Fairbanks Gold Dredging Co. in the Fairbanks district, and possibly others, conducted experiments which led to its use on a practical scale. John H. Miles was one of the first to put it to practical use and was the first to apply for a patent on the method of thawing he developed. United States Patent No. 1,339,036 was granted him on May 4, 1920. After his death these rights were purchased by the Hammon Consolidated Goldfields Co., operating at Nome. This company has not announced any definite policy concerning the use of this method by others.

The successful application of the method of thawing frozen ground with water at natural temperatures has made available for dredging many of the large areas of so-called low grade ground that were previously considered to be of little or no economic importance, in that it is not only much cheaper than the former steam methods, but the deeper deposits can be successfully thawed.

Two methods of thawing with water at natural temperatures have been developed and are in use. They differ in the way the water is applied to the ground, and its subsequent flow. One is known as the Pierce method and will be discussed later. The other method and the one which has been generally adopted by the dredging companies is based on the Miles method. This involves the use of water under pressure, delivered to the ground, through thawing points. The water may be obtained from ditches or by pumping. As the water leaves the points which are driven into bedrock or close to the bottom of a frozen stratum, it thaws and loosens the ground around the point. It is an interesting fact that as thawing proceeds and the cylinder of thawed ground enlarges, the water, instead of returning alongside of the point, works its way to the outer edge of the thawed cylinder, circulating upwards along its frozen rim. Therefore, by the proper placing of the points, and the regulation of the flow of water, a maximum efficiency of the water is obtainable. Experiments conducted by Miles, and subsequently by others, show that the cylinder thawed by the water in the gravel, has its greatest diameter around the outlet of the point, so that thawing is most thorough at bedrock, the place where it is most required. Thawed channels and strata may, however, be encountered or developed, and the water seeking the easiest line of flow will follow such courses. Water from one point may then work its way to other points before rising to the surface or escape by underground channels. This will leave intervening spots or "horses" of frozen ground which the water has not been able to reach during the average period of thawing and in the latter case will cause the loss of much water. Such unthawed areas require the placing of additional points.

The water for thawing is delivered under pressure from the ditch or pump, or from both, to the main pipe line, then to one or more branches or manifolds. From these manifolds it is conducted through the various headers or other branches and delivered to the points through hose connections. Each branch and point connection has a valve to control the flow of the water. The size of the pipe lines, headers, etc., is governed by the amount of water required. The spacing of the headers and their division is governed by the spacing of the points. The pressure of the water at the points generally ranges from 20 to 60 pounds per square inch, in most cases being governed by the available head. The loss in friction due to the many bends, angles and the small pipe is large. It has been found that in average gravel a high pressure is a necessary aid to driving the points, as this will eliminate much of the trouble caused by their plugging. It will more readily force thawed material away from the point, and establish a better circulation of the water. Miles reports better success in driving with a 60-pound pressure than with one at 40 pounds. High pressure may, however, cause the points to be forced up the hole and away from bedrock. After the points are once set, the pressure is controlled according to what is considered best and most efficient.

Water at 32 degrees Fahr. or at the freezing point, contains no available heat units for thawing, and as most of the water at natural temperatures in Alaska will be near this point or 4 to 6 degrees above freezing during the spring and fall months, there are practically only three months, June, July and August, and probably a part of September, when the temperature will be 50°F., or better. During adverse cold seasons, the water temperatures may not average over 40 degrees, while during others, temperatures of 65 to 70 degrees have been recorded over short periods. The temperature of the water at night may be 6 to 10 degrees lower than during the day. With a closer spacing of points or increasing the time of the thaw, water averaging 34° to 36° has done satisfactory but slow thawing. The most efficient and practical results are, however, generally obtained when the temperature of the water, on returning to the surface, does not fall below about 38°. Some operators have found this limit to be higher, but in practice this will be governed by the available initial temperature and the water supply. From 8 to 15 degrees of the water temperature is generally all the heat that can be efficiently removed. Wide flat ditches or shallow reservoirs on south slopes will appreciably warm the water supply. Water supplies from ditches are generally inadequate or too unreliable for thawing purposes, and the cost to obtain such supplies may be too great to permit thawing at low costs. In districts where such is the case and where fuel can be obtained at a reasonable cost, pumping may be the most practical means to provide the entire water supply or for supplementing the ditch supply. It also permits the re-use of water. Where pumping is resorted to, less water would be required and the thawing hastened if the water was warmed. This would result in a corresponding decrease in the cost of pumping.

The amount of water required depends on the many conditions. At Nome where the ground is being thawed to 60 feet in depth, from 1 to 1-3/4 miners inches of ditch water are used per point under pressures from 50 to 80 pounds. At one operation 1000 gallons of water were pumped per minute under 17-1/2 pounds pressure to supply 100 points. At the Yukon Gold Co., in the Yukon Territory, about 3500 gallons per minute were pumped for 1000 points.

The thawing points are made of extra strong pipe 1/2 to 1 inch in size. These may be fitted with the standard steel drive head, when they are similar to the regulation steam points. Where anvil attachments are used for driving, no drive head is necessary, the upper end of the point being fitted with a bent pipe, or "goose neck" for water connection. Pl. 28253. The lower end of the point generally has welded to it a steel bit with 3/8 to 1/2 inch opening. In difficult ground a chisel or a cross bit is used for drilling boulders. In easy driving, shallow ground a "tee" fitting with a light steel plug at the top for driving, with a nipple connection at the side for the water hose connection is used. A plain open-end point is often used in ground when driving is comparatively easy; however, this form of point plugs easily. A bit has recently been developed to overcome this. It has a pointed tip, tapering up to a broad shoulder. The water discharges through two holes set opposite each other and pointing downward at an angle. Deep flutes from the holes run out to the shoulder. When driving, this shoulder deflects the material, keeping the holes clear. On Fairbanks Creek, 1/2 inch water pipe equipped with a head made of a tee fitting and similar to the steam sweater, is used. They stand light driving and no unusual difficulty is experienced here in driving them to bedrock, although heavier points are often required. Thawing points are usually 10 to 20 feet long. Where greater lengths are required, several are joined together, special fitted shoulder joints, threads and sleeves being used.

Two men working together are allotted a certain number of points to drive. Water thaws slower than steam, so two men can generally look after twice as many points. As the ground ahead of the bit must be thawed before the point can be driven, the men work from one point to the other driving each as far as it will go at that time. Depending on the ground and water temperatures, two men do the driving of from 10 to 25 and more points. Under average conditions a point can be driven from 3/4 to 1-1/2 feet per hour and when the water is unusually warm a rate equalling that of driving with steam has been realized. In some light shallow ground points can sometimes be set with very little driving, while hard driving is generally necessary in deep deposits or heavy gravel. The procedure of driving the points is similar to that followed in steam thawing. At several of the operations where heavy driving is necessary, a slotted anvil weighing from 60 to 80 pounds is keyed on the thawing point at a convenient height. It is fitted with handles inserted on opposite sides for turning the point back and forth while working it down. Pl. 28282. The head of this anvil is pounded with an 8 or 12 pound hammer. The driving of the points to bedrock, especially in bouldery gravel, is a great item of the cost of the thawing operation. The progress is often very slow and it is sometimes impossible to get the points down to bedrock. On the Third Beach line at Nome, there are certain localities where the deposit is up to 60 feet and more in depth, the bedrock being overlain by slabby boulders. The best method developed so far has been to drill holes during the winter with a churn drill and inserting the points as soonas the water begins to flow in the spring. The cost of drilling these holes is, however, a considerable item against low cost thawing, although cheaper and more practical than if they had to be driven in this kind of ground by the usual methods. Machine drills with jointed steel were tried but were not successful.

The points are generally set in triangular relation to each

(28283) Water thawing ahead of dredges at Nome.

(28282) Driving water thawing points with anvil attachment, at Nome.

other and spaced from 8 to 16 feet apart. Short points may also be put down in between them. At Nome, where the churn drill holes are used, these holes are spaced 32 feet apart, and intermediate points which generally cannot be driven to bedrock are set half way between them. Where one or more horizons in the deposit are not frozen, the point is first driven fairly well to the bottom of a frozen one. After this is thawed, the point is then driven to a similar position in the next frozen bed or to bedrock, as the case may be.

The thawing scope of a point, when set in equilateral triangular relation, is generally considered to be a hexagonal prism, the long radius of which is one-half the distance between points. Thus with 16 foot spacing there would be four times as much ground thawed per point as when the spacing is 8 feet. Spacing, therefore, has a most important bearing on the cost of thawing, especially where the driving of the points is difficult.

The time required to complete a thaw is governed mainly by the temperature of the water, the spacing, and the character of the deposit. While no definite time can be stated, under average conditions thawing has been completed with 8 foot spacing in 4 to 8 days, with 10 foot spacing 8 to 12 days, and 16 foot spacing 10 to 14 days. Some of the thawing of the deep ground at Nome, where the churn drill holes were spaced 22 feet apart, required from 2 to 4 weeks. During a period of maximum water temperature, thawing has been completed in about half the time required with average temperatures.

The water boiling up to the surface of the ground makes the ground very soggy under foot and as the thaw continues and is completed the ground subsides, the subsidence depending upon the amount of ice that was present and the character of the ground. This is a point to consider in estimating the volume of material to be dug by the dredge. In some instances, the volume is reduced 25 per cent by the thawing, and is naturally greatest where much muck overburden is present. This subsidence often causes trouble by breaking the pipe lines. The question as to whether the ground that has been thawed will freeze back has often been asked. The operators state that the permanent frost is gone for good after the ground has once been thoroughly thawed, only the seasonal frost returning. If the moss and muck overburden is not removed, this seasonal frost is generally not deeper than 2 to 5 feet. The shallower gravels which have been stripped of overburden may, however, again freeze to bedrock during the winter. Gravel thawed by water will dig and sluice more readily than when thawed by natural or steam methods. This is especially true where clay is present, as the water aids in softening and disintegrating this material.

The Riley Investment Co. on Otter Creek in the Iditarod district, after several years of experimental work, installed a 700 point water thawing plant in 1923 and is very successfully thawing ahead of a 2-1/2 cubic foot dredge, which will dig about 1500 cubic yards or 3000 square feet of bedrock per day. The creek deposit is of medium size gravel with but few boulders. Some clay is present with the gravel, and the slate bedrock is overlain by sticky clay derived from its decomposition. Most of the gravel is covered with from 1 to 2 feet of sod, moss, or overburden, there being practically no muck. The average depth of the deposit as dredged is 15 feet. Approximately 50 per cent of the

(24500) Thawing with water on Otter Creek, Iditarod district.

(Cann photo) Water thawing ahead of dredge on Fairbanks Creek.

deposit is frozen to bedrock, there being thawed channels and patches. These are first located by driving steel bars to bedrock.

Water for thawing is obtained from a 4-mile ditch following the north slope of the hill. The flow varies from 150 to 400 miners inches. From the penstock to the Y. there are 1800 feet of pipe line from 16 to 12 inches in diameter. This line is then divided into two 9-inch branches connecting with the two [illegible]-inch manifolds. Each manifold is 300 feet long, tapped every 10 feet on both sides with connections opposite each other for 3-inch fittings to which the headers are connected. This connection consists of a nipple, valve, nipple and union to 40 feet of 3-inch pipe, then reduced to 40 feet of 2-1/2 inch pipe, then to 20 feet of 2-inch pipe, making each header 100 feet long. Usually only every other header connection is used, so their spacing along the manifold would be every 20 feet. Each side of the headers is tapped every 10 feet, but offset to provide a connection every 5 feet, and at the end, for 3/4 inch fittings and a valve, making connections for 21 points on each header. With this arrangement, the thawing points are spaced 10 feet between rows and 10 feet apart along the rows, each row being offset 5 feet, so that the holes are placed in isosceles triangular relation.

A regulation 16-foot, solid head, 3/4-inch point of the steam type with square tapered bit with 3/8 inch opening is driven in stages to bedrock with the water turned on under full pressure. The point is then removed, and a "sweater" inserted. Certain areas permit the sweater to be driven to bedrock without this preliminary procedure. These sweaters are 16 feet long and made of 1/2 inch extra strong pipe, and used with the full opening at the bottom. The lower 4 or 5 inches are case hardened. The head is fitted with a 3/4-inch tee to which is fitted 1-inch 4-ply water hose. These sweaters are not driven hard so a 3/4-inch plug at the top suffices for a drive head. The equipment contains 100 points and 700 of these sweaters.

Under the present system 8 men will drive about 40 points and set the sweaters in two 10-hour shifts and have the thawing underway for an area of 4000 square feet. One man is allotted 21 points to drive, which has been found to be about the average number for efficient driving. The average time required to complete a thaw is from 10 to 12 days, although during periods of higher water temperatures a thaw has been completed in 4 to 5 days. Pressures taken when the plant was in full operation were as follows:

At Y on main pipe line, 32 pounds per square inch.

On 9-inch line, upper end, at first header connection, 29 pounds.

On 9-inch line, lower end, at last header connection, 24 pounds.

At extreme end of headers, 19 to 23 pounds.

No pressures taken at end of points.

Temperatures taken at penstock during 1923 season, up to July 7, ranged from 36 to 68° Fahr. - the daily averages being 40° to 60°. On July 6 the highest was recorded at 68 degrees, and 69 degrees at the headers. The temperature of the water at night is considerably lower than during the day. Differences of from 6° to 8° have been recorded between 9 a.m. and 2 p.m. of an average summer day. In 1922 the temperature of the water averaged between 42° and 44°, 50° being the highest recorded. The coldest water used was in 1922, when the average temperature/was 26 degrees. With average summer conditions, the difference in the temperature of the water entering the ground and that returning was generally from 10 to 12 degrees. When the temperature of the water was only 42 to 44 degrees on entering, this difference dropped to about 6 degrees, while there were many times at lower ones when only 2 degrees could be utilized. According to the manager, Mr. ?. Donnelly, more heat units are removed from the water at the start of the thawing than after it has been under way for a while. There were no noticeable differences in the results when using 1/2 or 3/4 inch points. In the spring, steam is used to thaw the surface frost ahead of the dredge to get underway.

of some water used from another ditch

The cost of thawing with water over a long period at this operation cannot be definitely stated. The following is, however, the average daily labor cost from which a close approximation can be drawn. Wages are on a 10-hour basis and include board at $2 per day.

8 pointmen at $9.00	$72.00
1 day foreman at $12.00	12.00
1 night foreman at $10.00.............	10.00
1 ditchman at $9.00	9.00
Half time of blacksmith and helper ...	10.50
Per day	$113.50

From June 22 to July 2, 1923, or ten days, the above crew set 391 points and 39,100 square feet, 15 feet deep, or 21,722 cubic yards were thawed at a labor and repair cost of 3 cents per square foot or 5-1/4 cents per cubic yard. Former steam thawing costs were 35 to 45 cents per cubic yard. Considering the preparatory work, delays, etc., it appears safe to say that 7 cents per cubic yard should cover the operating cost. Approximately $10,000 is invested in the thawing equipment, exclusive of the ditch line which remains from former operations.

The reader is referred to the recently published U.S. Bureau of Mines Technical Paper No. 309 on "Recent Progress in the Thawing of Frozen Gravel in Placer Mining" by Chas. Janin, wherein he very ably treats the subject of thawing particularly with water at natural temperatures, and gives descriptions of the experiments and practical operations conducted by the persons mentioned and by the larger dredging companies.

The cost of thawing with water at natural temperatures is governed mainly by the cost of the water and the character of the ground. The latter governs mainly the cost of driving the points and the amount of water required. Therefore, for low thawing costs, an ample and cheap supply of water under pressure must be available and the deposit must be of such a nature as to permit easy driving of the points. The operating costs depend upon local conditions and the scale of the operation, and normally range from 7 to 15 cents per cubic yard. In the Nome district, it is estimated that water thawing on a large scale can be done for 4 cents or less per cubic yard, where large water supplies are available under pressure from ditches already constructed. As far as can be ascertained, this low cost has as yet not been realized. The Yukon Gold Co. with pumped water but with a large amount of power already available, thawed with water at natural temperatures for an operating cost of 10 to 14 cents per cubic yard. On Fairbanks Creek, using an erratic small water supply from a ditch, thawing was done for 12 cents per cubic yard. As only a part of the ground dredged has to be thawed at most of the operations, the cost of thawing per cubic yard dredged is often around 5 cents.

<u>The Pierce Method</u>

The principle of the Pierce method of thawing with water under natural temperatures involves the principles of natural or solar thawing supplemented by the thawing action of the water applied to the surface. The lowest point of bedrock within the area to be thawed is first located by prospecting with a steel bar or other means. A shaft about 5 feet square is sunk well into bedrock at this place. A series of shafts or a trench may be used. This shaft or trench is tightly timbered to within a few feet of the bottom and is also extended above the surface of the ground to keep out surface water, the purpose being to permit no water to enter the shaft or trench except from the bottom. Around the sides and at the bottom some coarse gravel is thrown in to keep the fine material from filling in. Water under natural flow usually from the creek, is then allowed to run over the area being sure that water is kept at the extreme edges of the block, as thawing will not be accomplished beyond the outer limits of such water. The water seeps into the gravel as it thaws, draining to the shaft or trench, from where it is pumped from time to time to establish a circulation and drainage. The suction pipe is kept close to the bottom of the shaft. Where natural conditions answer for similar drainage purposes, the shaft and pumping would not be necessary. As the gravel thaws, the water level lowers until the thaw is completed to and into bedrock. Where the gravel is covered with muck, thawing points are driven down to the gravel and water applied to the gravel only, the muck presumably being thawed by natural means. Where clay or other impervious strata are interbedded with the gravel, a similar use of thawing points would be required to thaw them and to deliver the water below such horizons.

Regarding the thawing operations conducted with this method by Mr. Pierce on Candle Creek in the Fairhaven district, he states:[33]

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[33] Pierce, E.E., Cold Water Thawing of Frozen Gravels: Min. and Sci. Press, Feb. 4, 1922, Vol. 124, pp. 154-156.

"In our operations last summer, we found on August 4 (the day we started to pump from the shaft) that the seasonal thaw had reached to a depth of 3-1/2 feet.......... On August 6 the frost line had moved downward to contour line N (about 1 foot deeper). On August 18 (the day we stopped pumping) the frost line had moved downward through the entire area to be thawed, passing through and thawing a layer of muck, till it had reached and thawed into bedrock. The entire area, 790 feet up-stream and 235 feet downstream from the shaft, with an average width of 60 feet (average depth 9 feet), had been completely thawed in a period of 15 days, with an actual pumping time of 80 hours. This ground was dredged during the same summer and no horses of frost were encountered. The ground thawed well and evenly. The cost per cubic yard to thaw this ground was 1.4 cents per yard, not including any overhead or equipment charges."

A 2-1/2-inch rotary pump with a rated discharge of 250 gallons of water per minute driven by a 4-horsepower Cushman gasoline engine was used for the pumping.

This method was tried in 1922 on Otter Creek on a block of frozen gravel 40,000 square feet in area and 15 feet deep. After 37 days had elapsed the thawing had gone to a depth of from 5 to 9 feet. The temperature of the water pumped from the shaft was always 32 degrees Fahr. (Probably not enough pumping.) The thawing being too slow and time not being available to complete the thaw, the experiment was abandoned. Had sufficient length of time been available, it was thought by the management that it would have been successful. The character of the deposit and the conditions on Otter Creek have been previously stated. Small blocks of shallow gravels have been successfully thawed by this method at some of the operations on Seward Peninsula. Where conditions are favorable for thawing by this method, some low costs should be realized. These principles applied where natural or solar thawing is practiced, would surely improve that method of thawing. A combination of the principles of both the Pierce and Miles methods would appear to be a most feasible way of overcoming some of the difficulties encountered, and of reducing the cost of thawing, at some of the operations where the Miles method is used.

Open-cut Mining

Open-cut mining properly embraces all forms of placer mining where the entire deposit is worked from the surface down. It therefore excludes drift mining, and while it would include hydraulic mining and dredging, these will be considered under separate headings. In its simplest form, open-cut mining involves mostly manual labor, and as such is now restricted to small operations. At the larger operations, machinery is used for excavating and transporting the gravel to the sluices. Prior to the excavation of the gold bearing gravels, the overburden may be removed by stripping, for which some form of hydraulicking is often used in conjunction with the operation.

Of the many methods of open-cut mining which were formerly used in Alaska, and some of which were well adapted to conditions at that time, a comparatively few remain. Derricking, horse scraping, track and incline systems, and most of the other methods of similar kind are methods of the past. The cumbersome, immobile excavating machinery with belt conveyors, bucket elevators, etc., proved impractical and too costly to operate under Alaskan conditions. Steam shovel methods met with but little financial success in placer mining and were generally failures when handicapped with the additional cost of steam thawing the frozen gravels. The steam shovel is, however, a very efficient digging machine and can handle heavier material than other mechanical excavators but lacks the important features necessary for efficient operation in placer mining. Mechanical excavators for open-cut methods of placer mining should possess mobility, a relatively large digging radius, and the ability to dump their load directly to the sluices. Most intermediate conveying systems cannot keep pace with the excavating machine and along with the additional cost for such equipment and the cost of their operation, generally prohibit the profitable mining of the lower grade gravels. While all mechanical operations have their limitations, the dragline excavator and the cable-way excavator answer these requirements better than other types, and when employed under suitable conditions, can be successfully operated with less labor, power and maintenance than the bottomless type of steam scraper.

The methods involving much manual labor, as beach mining, ground-sluicing and booming with shoveling-in, are gradually passing in many of the districts, but are still popular and will continue so with a considerable number of miners of small means. Such methods are often the most practical for mining areas of small extent where the water supply is small or intermittent, or other conditions are restrictive, as very little capital is invested.

The depth of deposit that can be mined by open-cut methods is governed principally by the depth of overburden that can be removed by stripping, thus reducing the depth of the material which is to be excavated by more costly methods. Mechanical excavation in open-cut placer mining is generally limited by Alaskan conditions to gravels not exceeding 8 or 10 feet in depth. One great advantage of open-cut mining is that it permits the natural thawing of the shallow exposed gravels.

Rockers and Longtoms

Rockers and longtoms are simple washing devices which were most extensively used during the early daysof beach mining, particularly at Nome. They are still used by a few lone beach miners and can occasionally be seen in use around the old camps for washing small quantities of gold bearing material "sniped" from bedrock crevices and old tailing dumps. They are also used in washing drill and other prospecting samples.

<u>Beach Mining</u>

Sea beach mining was in its prime during the early days following the discovery of gold on the beaches at Nome, Lituya Bay, Yakataga, Kodiak and elsewhere. The richer portions were soon exhausted by the simple hand methods and repeated attempts to mine them on a larger scale with mechanical equipment met with failure. This form of mining is an intermittent operation, usually following a storm when the high surf washes the overburden of beach material, leaving a new concentration of the heavier black or ruby sands containing the gold. These concentrates are washed in rockers, longtoms, surf washers, or small sluices. On the Nome beach small prospect holes are dug to locate the ruby sand concentrate which is usually covered with a foot or more of barren sand and gravel. This is removed by shoveling, and the 2 to 3 inch depth of concentrate is shoveled into buckets or wheelbarrows and transported to the washing device.

The longtom is a small sluice box with a grizzly or screen at the top end for removing the coarser material. For effective saving of the fine gold from the heavy concentrate, this washing device is set at a high gradient of 3 to 4 inches to the foot and the material passed over riffles and amalgam plates, the latter being protected from undue scouring by covering them with 1/2 inch mesh wire screen or punched plate. With the longtom, the water for sluicing is usually bailed with a large dipper. Pl. 22484. The surf washer can only be used when the surf is of proper height. It is somewhat similar to the longtom, but constructed wider and shorter. The incoming surf rushes up the sluice, washing material from the hopper and on retreating carries it over the plates. Pl. 22485. The average duty per man per 10 hours for longtom and rocker work is from 3 to 5 cubic yards. One man can attend to two surf washers and in one instance 8 cubic yards per 10 hours was handled.

(22455 Beach mining with surf washers at Nome.

(22454) Beach mining with long tom at Nome.

Ground-sluicing, Booming, Shoveling-in

Ground-sluicing

The stripping of overburden by ground-sluicing has been treated in a previous chapter. Ground-sluicing as a mining method, however, generally continues deeper than the average stripping operation, so that most of the gravels are removed, reducing to a minimum the amount to be subsequently excavated and conveyed to the sluices by more expensive methods. In this respect, ground-sluicing is best adapted to shallow gravel deposits, usually not over 10 feet in depth, containing coarse gold, and to such richer gravel deposits which may be overlain by an overburden of muck or other light material which can be cheaply removed by running water. To successfully ground-sluice gravel, more favorable grades are necessary than for the removal of muck or light material. The most favorable conditions are found on the benches and the higher reaches of the creeks. In several instances on benches affording exceptionally good dump room and grade, although usually small water supplies, gravel faces as high as 80 feet are ground-sluiced, and in numerous cases creek deposits up to 20 feet and more in depth, over half of which is muck overburden, are being successfully handled in this way.

As applied to creek deposits, a dam, equipped with gates and spillways for controlling the water, is constructed across the creek just above the ground to be worked, and a by-pass flume or ditch is constructed for diverting the excess water around the workings. When the ground-sluicing is to be followed by shoveling-in, the first cut along one side of the pay channel is made, confining all the water to a single cut 12 to 16 feet in width, and depending on conditions, from 100 to as much as 1000 feet in length. The overburden, and as much of the gravel as it is practical to remove, are sluiced through this cut, concentrating the gold in the remaining gravels. When boulders accumulate, they are stacked by hand alongside the cut. Where the grade and other conditions permit, and where the bedrock is rough and slabby and so affording a natural riffle, the sluicing may be carried to bedrock. Under average conditions, however, from 1 to 4 feet of gravel may remain to be shoveled into the sluice boxes or excavated by other means. Usually but one cut is ground-sluiced and shoveled in at a time, the operation being conducted by from one to four men and often only one cut is completed in a season. The ground sluicing is usually done in the earlier part of the season, when the spring floods can be taken advantage of; the balance of the season being spent in shoveling-in. After the first cut has been completed the water is deflected against the bank by the use of shear boards and wing dams, and another paralleling cut is ground-sluiced, etc., one dam answering for the entire width of the channel. At some operations, particularly those mining bench deposits, water is taken from a ditch and allowed to run over the banks, washing down the material which is then carried along with an additional supply of water. At other operations, especially if the gravels are excavated by methods other than shoveling-in, a comparatively large area is first ground-sluiced.

Booming

At most of these operations, especially in the interior districts, the water supply is small, or during the greater part of the season the flow may be too low for continuous use. Under such conditions, the water is impounded back of the dam, or in the ditch, and released at intervals by hand operated or automatic gates. The water being suddenly released in this way, rushes or booms down the cut carrying the material along with it. When water is so used for ground-sluicing, the operation is known as "booming".

Different types of automatic or self-dumping gates are in use, the swinging type being most common. This heavy wooden gate swings outward on a horizontal pivot set one-third of the height of the gate from the bottom. When the water back of the dam rises to a level over two thirds the height of the gate, the gate is automatically released by an ingenuous device and returned to its closed position when the reservoir is nearly empty. One objection to this type of gate is the heavy jar from its action which causes the dam and gate to leak. This is partly overcome by constructing the timber portion of the dam on each side of the gate independent of the main dam structure, filling these sections with clay and cushioning the gate seat with strips of canvas. Another type of gate used is the box gate, which works vertically, being held in position by a guide at each corner. It also has special releasing devices, but the action of the gate being more gradual, there is no undue strain on the dam. As the box rises, the water runs out through the bottom and on returning to position it slips over a cushioned shoulder, forming a tight connection. Pl. 22505. The sizes of the automatic swing gates vary from 4 to 10 feet in width. At some of the operations one or two gates 2 to 4 feet in width are used, generally being built into the side of the ditch. These small gates are of light construction, swinging from a horizontal pivot at the bottom of the gate and controlled by a counter balanced weight. Canvas is nailed to the gate and to the sides and bottom of the chute, to make it water tight. This canvas acts like a bellows when the gate opens and closes. When a gate is released it usually sounds an alarm to warn the men in the pit.

(22505) Automatic gate, box type. Rampart district.

(22504) Shoveling into boxes below automatic dam. Rampart district.

Shoveling-in

Shoveling-in is a method adapted to rich shallow gravels not over 6 or 8 feet in depth, where it is not practical to handle them by other means, but as such gravel deposits are now rare in Alaska, the method is generally restricted to the shallow gravels remaining after ground-sluicing or booming. It is a simple method and has the advantage that it allows the careful cleaning of bedrock. The dam at the head of the pit is necessary in creek deposits to keep out the excess water, and the seepage water is handled by open drain or by small enclosed timber or box drains. For favorable conditions for shoveling-in, the bedrock grade should be steeper than the required sluice grade and means should be available for the natural disposal of the tailing.

The sluice boxes are usually 12 to 14 inches in width, and of the telescoping kind, and where the bedrock grade is not adequate, they are mounted on low trestles or posts, and braced to bedrock or sides of the cut. The usual grade used is 6 inches to the 12 foot box, although more is preferred. Pole riffles are the customary kind.

A long string of tailing boxes to provide more dumproom are usually required. The bottoms of these are lined with an extra thickness of board or light sheet iron or steel, and set at a lower grade than the regular sluice boxes, usually at 4-1/2 to 5 inches. Water is conducted through a flume directly from the dam to the head of the boxes or through canvas flume hose or pipe. The width of cut most practical for shoveling directly into the sluices is 6 feet on either side of them, which has established the practical unit of the "box length", or an area 12 feet wide and the length of one box or 12 feet long. Only the lighter material is shoveled-in, the larger rocks generally 5 inches or over are piled on cleaned bedrock. From 1 to 3 feet of bedrock may be taken up and, if hard or creviced, requires much pick work.

The duty of labor in shoveling-in varies principally with the character of the gravel and bedrock, the height of lift and the shoveler's efficiency. A 6 to 8 foot lift is the maximum height to which it is practical for a man to shovel in one lift. Where the gravel and bedrock must be picked and many boulders thrown out and bedrock is difficult to clean, the duty becomes low. Under Alaskan conditions, one man will shovel from 2-1/2 to as much as 10 cubic yards in 10 hours with lifts from 3 to 7 feet and the depth of material shoveled is usually from 1 to 5 feet. An average day's work for a shoveler in the interior districts during the boom days was considered to be 7 to 8 cubic yards.

Costs

Ground-sluicing and booming are very closely allied at most of the small operations. The cost of ground-sluicing and booming varies from 15 to 35 cents per cubic yard, as a rule, although under most favorable conditions has been done for as little as 7 cents. The average ground-sluicing or booming operation followed by shoveling-in involves an expenditure of from $350 to $1500 in equipment, exclusive of any ditch which may be used. The average dam equipped with an automatic gate costs from $250 to $800. Some miners in estimating their costs add from $1 to $2 per day to the labor and mess cost for each man employed as a means of depreciating the equipment.

The cost of shoveling-in is most variable, being from $1.25

to as much as $4 per cubic yard. In easy digging gravel with other conditions favorable, as in one instance on Seward Peninsula, the cost of shoveling-in was $1 per cubic yard.

In the Hot Springs district, a cut 50 by 800 feet was boomed of frozen muck and gravel to a depth of 25 feet at a cost of 7 cents per cubic yard. Shoveling-in 2-1/2 feet of gravel and bedrock cost $2.80 per cubic yard. The combined cost was 30 cents per cubic yard.

On Little Minook Creek in the Rampart district, 18 feet of muck and gravel was boomed from a cut 12 by 600 feet at a cost of 18 cents per cubic yard. Two feet of gravel and bedrock requiring much picking and the throwing out of half of it as boulders was handled at a cost of $2.20 per cubic yard. Combined cost was 38 cents per cubic yard. This was the fourth cut and cost considerably less than the first. One mile down the creek, a booming operation taking out the first cut 1000 feet long and 12 feet wide removed 7-1/2 feet of muck and gravel for 22 cents per cubic yard and shoveled-in 2 feet of material, 60 per cent being boulders, at a cost of $2.80. The combined cost was

77 cents per cubic yard.

On Greenstone Creek in the Ruby district, sod was stripped by hand, and the muck and gravel ground-sluiced off to a depth of 6 feet, in a pit 60 by 200 feet for 55 cents per cubic yard; 2 feet of material was shoveled-in for $1.65; combined cost was 70 cents per cubic yard. On the same creek, but in a bench deposit with better grade, a 10-foot depth of muck and gravel was ground-sluiced off for 26 cents per cubic yard, and one foot of material shoveled-in for $2.56. Combined cost was 47 cents per cubic yard. The cost of $12 per man per 8-hour shift is here used and considered as covering depreciation. Combined costs for ground-sluicing and shoveling-in in other localities range from 20 cents to $1.00 per cubic yard.

Self Dumping Carriers

The method of shoveling the gravel into wheel barrows, wheeling to and dumping into a bucket which is hoisted to the carrier and conveyed up an inclined cableway and automatically dumped into the sluices, is now used only at a few small operations in the interior districts. Similar conditions are necessary as those required for the regular ground-sluicing and shovel-in methods, but some of the difficulties occasioned by lack of grade are overcome by removing the gravel from the pit to a place where the required grade for the sluices and dumproom can be obtained. The pits worked are not over 150 feet in greatest dimension, being limited to this size so that the wheeling distance to the centrally located bucket station will not exceed the practical limits. This station is fixed, the bucket setting in a timber crib, the top of which is level with the top of bedrock. The shoveler spends from 1/4 to 1/3 of his time wheeling, which along with the cost of the fuel, the engineer's wages, the wear and tear on equipment, would infer a greater cost than when the gravel is shoveled into the boxes. It, however, has the advantage of permitting a wider pit and speeding up the operation, particularly where the gravels are of a character permitting easy shoveling and which would otherwise be retarded by poor sluicing conditions.

The self-dumping bucket and carrier, steam hoist and other equipment is similar to those used at small drift mines. The buckets hold from 2 to 6 wheelbarrow loads and from 5 to 15 H.P. steam hoists are used. At three operations noted, a high shoveling and wheeling duty of from 7 to 9 cubic yards was obtained. The cost, exclusive of ground-sluicing, ranged from $1.75 to $2.50 per cubic yard with from 2 to 5 feet depths of gravel and bedrock being handled.

On Ophir Creek in the Innoko District, 18 feet of frozen muck and 4 feet of gravel was stripped at a cost of 16 cents per cubic yard. five feet of gravel and bedrock was mined by the method under consideration, for $1.75 per cubic yard. The combined cost for the 27 feet was 42 cents per cubic yard. At an adjoining operation a similar method was being started, there being 35 feet of frozen muck and 6 feet of gravel, the operators estimating it would cost 50 cents a cubic yard to mine it. On Chatham Creek in the Fairbanks district, 10 feet of overburden was ground-sluiced off at a cost of 16 cents per cubic yard and 4 feet of gravel and bedrock was handled for $1.25 per cubic yard. The combined cost for the 14-foot depth was 49 cents per cubic yard.

Steam Scrapers

Steam scrapers were up to recent years used by a large number of operations located principally in the interior districts, but have now been reduced to where only about twenty are still active. The profitable field for scraper operation is passing by reason of the depletion of the available areas adapted to this method, or in giving way to the less costly methods, mainly dredging. The small drag and wheel scrapers which were too light in weight and construction and too difficult to handle under power, were replaced by the heavy scrapers of the bottomless or Bagley type, and the slip-toothed type. The Bagley type has proved the more efficient scraper, while the slip type is still being used at some of the smaller operations, usually because it is the only equipment available. Both types are also used for stacking tailing at some of the hydraulic mines where the water supply is inadequate for this purpose.

Steam scrapers are adapted to the mining of comparatively wide areas of shallow creek gravels, containing no large boulders, where the bedrock is not hard or irregular, and where the low creek gradients necessitate the elevation of the gravels for sluicing. The gravels should also be unfrozen and the pit must be kept free of water. As a means of excavating gravels containing frost, the Bagley type of scraper has a decided advantage over other mechanical means, for because of its mobility it can be readily shifted about the pit, removing the material in shallow cuts as it naturally thaws. Usually the overburden is removed a season in advance of the scraping work, so as to permit the gravels to thaw, but even so, if proper drainage is not provided some frozen ground may still be encountered. During an average season the thawing will generally keep pace with the scraping, the rate of thawing under such conditions varying from 4 to 12 inches per day. If much frost must be contended with and especially during an adverse cold season when the rate of thawing is slow, the scraper operation is greatly handicapped.

The practice at steam scraper operations is to remove as much of the overburden as conditions will permit, so that the volume of material to be scraped and transported to the sluices is reduced to an economical minimum. After the overburden has been removed by the methods described in the chapter on "Stripping", any remaining barren or too low grade gravel is removed with the scraper and dumped on unprofitable or worked-out ground, and a part of it may be used in building up the incline or for a dump to support the upper sluice or dump box. Under average conditions there will then remain from 4 to 8 feet of pay gravel and from 2 to 4 feet of bedrock to be scraped and put through the sluices. Hard, irregular, or creviced bedrock cannot be properly cleaned with the scraper, but will require some hand work , and at some localities where the gold is distributed to irregular depths in the bedrock, further difficulties are encountered which increase the cost of operation.

The power plant is installed alongside the purposed pit and at a point from where two or more pits can be worked. The preparatory work and set-up for the pit is generally done in the fall after the close of the seasons mining or completed in the early spring. The scraping of the pay gravel is usually not started until the spring freezes are over or early in June and continues until the first heavy frosts about the latter part of September.

When the large power consumption, the large labor costs, the costly set-up, the excessive cable wear, and the repair costs, involved in the handling of such a comparatively small amount of material, is considered, it can readily be understood why steam scraper methods are becoming impractical for the mining of the present average low grade Alaskan gravels.

The operation and limitations of the two types of scrapers differ and will, therefore, be treated separately.

Bagley or Bottomless Type Scrapers

The Bagley type scraper is constructed with a curved back, so that no bottom is necessary and can be used with either side down. Fitted to the edges of the back are knives which cut and peal up the dirt, and for scraping the heavier gravel or the bedrock, the cutting edge is equipped with heavy teeth. Attached to the back of the scraper is a heavy haulback lift, giving added weight to the cutting edge. It stands vertical when loading, and when returning empty lies flat, raising the teeth and cutting edge to permit the scraper to be more readily handled. The scraper is so constructed that as it is pulled ahead, it fills itself, lifting the back slightly so the whole load slides on top of the ground. Unloading is accomplished by simply hauling back the scraper, leaving the load where it stopped.

In the following table are given the more important details of the Bagley scraper in the sizes used in Alaska. Larger scrapers have been used but have not proved satisfactory. By renewing the plates, teeth and other parts, the scraper has a long life, many being in use for 5 seasons and more. Because of its construction and method of operation, the scraper usually delivers a full load of loose material and can push considerable material ahead of it, making it most efficient for "yarding" or delivering the material to some place in the pit until such time that its removal can be completed.

Some of the operations are obliged to use whatever equipment is available and may, therefore, have a poorly balanced plant, but as the speed of the operation is governed principally by the scraper engine,

DETAILS OF HADLEY SCRAPER (1)

Size	3 1/2 foot	4 foot	5 foot
Capacity, Cu. yds. -	1 1/4	1 3/4	2 1/2
Prices, F.O.B., Seattle.- With teeth and haulback	$382.50	$446.25	$536.50
Without teeth & haulback	231.00	357.00	427.00
Weights- lbs.,- With teeth & haulback -	3100	3270	4125
Without teeth & Haulback	2150	2169	2580
Number of teeth -	5	6	7
Engine required (compound geared)-	8 x 10	9 1/4 x 10	10 x 12
Speed of main line at drum, per min.-	up to 175 feet.-	up to 250 feet.-	up to 250 feet.
" " haulback lines at drum, per min.	up to 350 feet.-	up to 500 feet.-	up to 550 feet.
Approx. pull on main line at drum	----	31500 lbs.	37,400 lbs.
Size cable recommended for lead.-	7/8 inch	1 inch	1 1/8 inch.
" " " for haulback-	3/4 "	7/8 "	1 "

(1) From manufacturers catalogue 1923.

it should be ample for all demands. Compound geared 3 drum, double cylinder scraper engines are used. The size of the pits vary according to the equipment and local conditions, the average pit at the large operations varying from 275 by 300 to 300 by 400 feet, while at the smaller ones the pits may be half this size. A typical arrangement for a Bagley scraper operation is shown in Fig.1. Short masts and deadmen, securely anchored, are installed around the edge of the pit, spacing them from 50 to 75 feet apart. These are for the sheaves and guide blocks. Two short masts or deadmen are placed in front of the main hoist, one on each side, which serve as anchors for the main lead sheaves. A 50 to 60 foot gin pole to carry the sheave for the car cable is installed back of the sluices in line with the track incline. All sheaves are of manganese steel, the usual diameters of the main lead or head sheave being 30 to 36 inches and 14 to 18 inches for the haulback sheaves and guide blocks. Cable wear is excessive, due principally to the abrasion by the sharp sand. The greatest wear is usually 100 feet or more ahead of the scraper and about the same distance ahead of

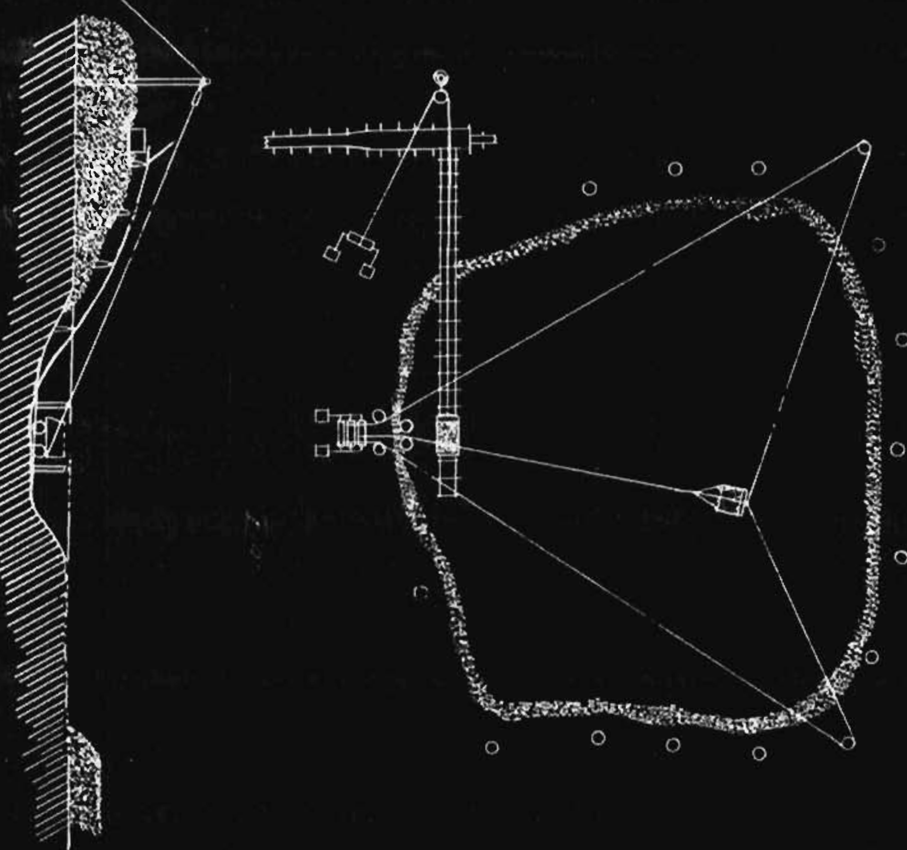

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Fig. 1 - Typical Sagley Scraping and Loading Operation.

the engine where it goes over several sheaves. Breakage of the individual wires due to sharp bends over the sheaves is slight and is seldom responsible for undue damage to the cables. Under steady use a set of cables often lasts only 4 to 6 weeks. A high grade, 6-strand, 19-wire steel cable with hemp center is used. By means of two haulback or tail lines which are guided from the shifted positions of the sheaves, the scraper can be dragged to any desired place in the pit. On being pulled ahead, the scraper takes a long shallow cut in filling itself and is then dragged to the underground loading station where the teeth engage a timber, the load dropping through an opening into the car below. This car which is self-dumping is used in different sizes, holding from 2-1/2 to 4 cubic yards of loose material. With each load from the scraper the car is hauled up an incline track by cable from an auxiliary 6 by 8 or 8-1/2 by 10 hoist and dumps into the dump box. The use of the car incline and auxiliary hoist, while requiring additional equipment and the services of an extra engineer, has proved a saving in fuel and speeds up the scraping.

It is used to advantage where the material has to be elevated about 40 feet or more above bedrock, or where other conditions may warrant it. A timber or pole incline up which the scraper drags its load all the way to the dump-box is generally used in the smaller pits or where the elevation is comparatively low. A loaded scraper, car on the track incline, sluices and general arrangement are shown in Pls. Nos. 24513, 24514, and 24515. Pl. 28301 shows the entire operation.

Where the material is dumped into the cars, with average digging conditions and everything running smoothly, 30 to 45 trips of the scraper are made per hour, while at some of the smaller operations where the scraper delivers to the sluice this speed is materially reduced. The speed of operation is, however, governed by the length of haul, frost and other conditions, so that the average number of trips made is considerably less, for the average yardage scraped into the boxes ranges from 15 to 40 cubic yards per hour.

For successful scraper work the pit must be kept well drained, and while this is usually accomplished by open bedrock drain, in

(24513) Bagley scraper delivering load to underground station.

(24514) Car taking load from underground station to the sluices.

(24815) Bagley scraper operation. Car delivering to sluices.

(28301) Bagley scraper operation on Goldstream Creek, Fairbanks District.

localities like the Fairbanks district, where the bedrock grade is low and drains are expensive to maintain, it has been found more practical to use a pulsometer or other type of pump for handling the seepage water, which is generally small in quantity, excepting during periods of heavy rain, and which can usually be handled by intermittent periods of pumping. At a number of the operations water for sluicing must be pumped. This insures a more reliable water supply and the operators at these places contend it is little, if any, more expensive than if it were possible to construct and maintain a ditch line under the existing conditions.

The largest Bagley operations are conducted alongside of the railroad on Goldstream and Gilmore creeks in the Fairbanks district. In 1924, five of these plants were in operation. The total depths of the deposits worked ranged from 15 to 35 feet, which, after being stripped of muck and waste gravel left from 6 to 8 feet of gravel and 2 to 4 feet of bedrock to scrape. The pits were from 80,000 to 120,000 square feet in area. Bagley scrapers from 1-3/4 to 2-1/2 cubic yard sizes were used. An average of 6 to 8 men were employed per shift.

The boiler horsepower at four of these plants ranged from 80 to 150; the wood consumed per 10-hour shift was from 3 to 6 cords, costing from $10 to $12 per cord. The cost of the wood consumed and the attendance of one fireman at a cost of $8.50 per shift, including board, averaged 4.8 cents per horsepower hour. On the basis of 500 cubic yards of material being scraped and sluiced in two shifts or 20 hours, this power cost amounts to 22-1/2 cents per cubic yard. At one operation with 180 boiler horsepower, 5-1/2 tons of coal, costing $6.25 per ton, were burned per shift, which, with the cost of attendance, amounts to 2.4 cents per horsepower hour. One operation burned 1-1/2 cords of wood per shift for pumping water for sluicing.

The cost of scraping and sluicing the gravel and bedrock ranged from 45 to 90 cents per cubic yard. At one operation where water was pumped for sluicing, this power cost and sluice attendance was 15 cents per cubic yard. The combined costs of stripping, scraping and sluicing ranged from 25 to 50 cents per square foot for ground 15 to 35 feet deep or 40 to 60 cents per cubic yard. The capital invested in equipment at these operations ranges from $15,000 to over $25,000. The smaller operations in other districts have from $4000 to $12,000 invested in equipment.

Practice and conditions, while varying at the different operations are well illustrated in the following description of a typical large Fairbanks mine. The average depth of ground mined was about 15 feet. The 5 feet of overburden was hydraulicked off, 3 feet of upper gravel scraped to waste and about 5 feet of gravel and 3 feet of schist bedrock was scraped and sluiced. The pit was 500 by 400 feet in size and drained by two 2-inch pumps. A 4-foot or 1-3/4 cu. yd. Bagley enlarged to hold 2 cubic yards, operated by a 10 by 12 hoist, was used with 1-inch cable for the haulage cable and 3/4-inch for the haulback lines. Three sets of cable were required for the season. The material was scraped and dumped into the car in the underground station and hauled up the track incline by a 6-1/2 by 10 engine and dumped into the dumpbox. Three boilers, for a total of 115 H.P., produced the power. With favorable conditions the scraper made 35 to 40 trips per hour.

although this was greatly reduced in the average due to frost conditions, so that the average yardage scraped to car was approximately 450 cubic yards per 20-hour day.

The dump box at the head of the sluices is 100 feet long and 4 feet wide. At the lower end this box narrows to 22 inches, where it is connected to the 22-inch sluice boxes, of which 6 to 10 lengths are used. The dumpbox and sluice are set on a grade of 16 inches to 12 feet and paved with block riffles. An undercurrent is used to catch fine gold. It is the same size as the sluice box and set on a 20-inch grade. It consists of a perforated steel plate with 1/2-inch holes, placed 3 inches above a burlap surface. As the burlap becomes covered with mud slime, it is taken up and cleaned every day. About 125 miners inches of water from the ditch are used for sluicing. A dump box man is kept busy forking out the larger rocks and keeping the sluices from clogging.

Twelve to 14 men constitute the average crew for 2 shifts, the labor and mess cost being $60 per shift. The boilers burn 4 cords of wood per shift, costing $12 per cord. This 16-foot depth of ground was worked for 35 cents per square foot or 59 cents per cubic yard. Detailed costs are not available, but it is estimated that the cost of scraping and sluicing the 8-foot depth of gravel and bedrock was about 25 cents per square foot or 85 cents per cubic yard. The operator stated that this 16-foot depth could be mined for 25 cents per square foot or 42 cents per cubic yard if average conditions had existed. The cost of rigging and setting up for one of these large pits is about $1000. About $25,000 is invested in the plant and equipment.

On Willow Creek, in the Iditarod district, Bagley operations were conducted for a period of 5 years by stripping about 9 feet of overburden by ground sluicing and 7 feet of gravel and soft slate bedrock was scraped into a car by a 1-1/4 cubic yard scraper, at an average cost of 30 cents per square foot or 51 cents per cubic yard. The cost of scraping the 7 feet of gravel and bedrock was 65 cents per cubic yard. With 8 or 9 men employed, working one shift only, an area of 40,000 to 50,000 square feet was mined in a season. A 60 H.P. boiler produced the power. No water was pumped. Wood cost $14 per cord and 3-1/2 cords were burned per shift. A plant of similar size on Flat Creek in ground averaging 10 feet in depth with soft slate bedrock and easy digging conditions, mined 200,000 square feet in a season, at an operating cost of 25 cents per square foot or 68 cents per cubic yard. The same operator in 1922 mined a 20-foot depth of ground from which 12 feet of overburden was stripped and the balance scraped to a car, at a cost of 50 cents per square foot or 68 cents per cubic yard.

Slip Scrapers

The operation of the slip scraper restricts it to the mining of shallower and richer deposits. The scraper is equipped with a full bottom, the cutting edge being fitted with heavy teeth of which there are generally five.

A typical arrangement for a slip scraper operation is shown in Fig. 2 The pit is kept free of water, usually by an open bed-rock drain. A 2 or 3 drum, 7 by 10 or 8-1/4 by 10, double cylinder hoist with a 3/4 to 7/8 inch lead cable, and one 5/8 or 3/4 inch tail or haulback cable, operates the scraper, for which a 40 to 60 H.P.

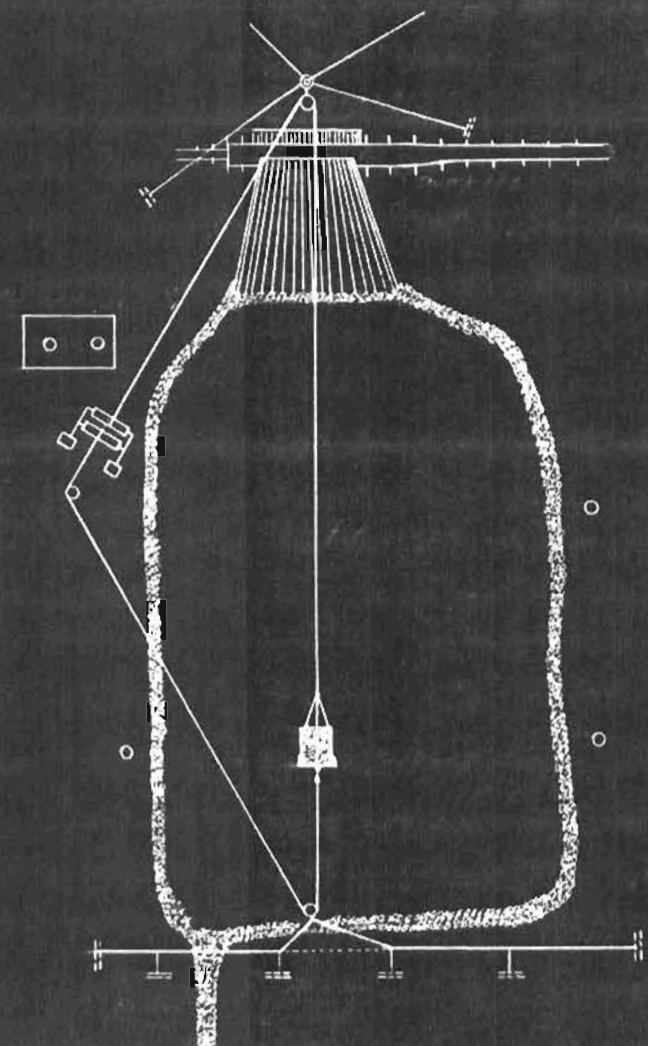

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Fig2 - Typical Slip Scraper Arrangement

boiler is used. A continuous cable system operated on a single drum has been used for dragging the scraper back and forth, but has little to recommend it. Two sizes of scrapers holding 3/4 and 1 cubic yard of loose material are in use. While the scraper must be fully loaded at the back to keep it from upending, the load delivered to the sluices is often but 1/2 to 3/4 of its capacity.

To assist the scraper in digging its load, the rear end must be raised so that the teeth can sink into the ground. Two men are required for this, one on each of the poles or long handles which fit into sockets at the upper rear corners. When the scraper is loaded these poles are withdrawn. Pl. 22481. The loaded scraper is then dragged to the far end of the pit and up a timber incline at the top of which the teeth engage a timber, upending the scraper and dumping its contents into the dump box where one man is usually required to see that the scraper empties properly and look after the sluicing. The scraper going up the incline and the usual sluicing arrangement are shown in Plate No. 22482. The scraper is then dragged back over the same path

(22481) Slip scraper operation. Scraper has just been loaded.

(22482) Slip scraper traveling up incline to sluices.

and the operation repeated until a cut about equal to its own width, 4-1/2 feet, and about 1 foot deep and the length of the pit has been completed. Sheave B is then shifted by hand along the anchor cable shown to the position for the adjoining cut. This can be improved by the use of a long bridal cable extending along the entire lower end of the pit and the shifting of the sheave accomplished by cables operated from the nigger head or extra drum on the hoist. There are various ways of anchoring and shifting this sheave, but as only one haulback cable is used, the scraper cannot be as readily shifted about the pit as the Bagley can. This governs the shape of the pit, so that they are usually about twice as long as the width. The largest pits scraped are about 300 feet long. With a haul of 150 to 300 feet, the 3/4 cubic yard scraper will make from 10 to 30 trips per hour, delivering to the dump box an average of 50 to 125 cubic yards per ten hour shift. In difficult digging ground, or in the scraping of bedrock, a heavy plow attached to the scraper is used to loosen the material so the scraper can pick it up. At the larger operations, where 40,000 to 65,000 square feet of a pit are mined in a season, the crew for each shift consists of an engineer, fireman, dump box man, two men in the pit and one or two roustabouts, while at some of the smaller operations the crew may be but 3 or 4 men.

In the Innoko district, a pit 65,000 square feet in area was mined, a 4-foot depth of overburden and upper gravel being first removed with water for 14 cents per cubic yard. Four feet of gravel and bedrock was then scraped into the boxes by a 3/4 cubic yard scraper, in 95 days, with a crew of 13 men, for 23 cents per square foot or $1.58 per cubic yard. The cost of mining the entire depth of 8 feet was 87 cents per cubic yard. A 40 H.P. boiler was used burning 1 cord of wood per shift. No water was pumped. The capital invested in the plant exclusive of the ditch is about $6500. In the same district, in ground 16 feet deep, 10 feet of muck was stripped for 7 cents per cubic yard and with a 3/4 cubic yard scraper, 6 feet of gravel and bed-rock was scraped in 74 10-hour shifts with a crew of 6 men at a cost of 30 cents per square foot or $1.35 per cubic yard. The cost of the entire operation was 32 cents per square foot or 54 cents per cubic yard. The pit was 150 by 230 feet in size. A 8-1/4 by 10, 2-drum hoist with a 50 H.P. boiler was used, about 500 square feet of bedrock being scraped per cord of wood. No water was pumped. The cost of the equipment is about $7000.

In the Hot Springs district, in ground 11 feet deep, 4 feet of muck and top gravel was ground-sluiced off for 15 cents per cubic yard. With a 1-cubic-yard scraper, 7 feet of gravel and bedrock, or 10,500 cubic yards, was scraped in and sluiced in 110 days, at a cost of 35 cents a square foot or $1.32 per cubic yard. With a crew of seven, only one 10-hour shift was worked per day. The cost of mining the entire 11 feet was 89 cents per cubic yard. The pit was 290 feet long and 140 feet wide. About 100 miners inches of water, supplementing the small supply from the ditch, was pumped. Two 40 H.P. boilers were used, which burned 4 cords of wood per shift. About $17,000 is invested in machinery and equipment.

Cableway Excavators

Cableway excavators for placer mining have been but little used in Alaska. One operation was recently conducted on Goldstream Creek in the Fairbanks district. At this operation, as at the several other places where the excavator was used, conditions adverse to cheap operation were encountered. Frozen ground and difficult slabby bedrock were the main handicaps, and as seepage water and water for the sluices had to be pumped at this operation, it is obvious that low costs could not be realized.

The operation combines some of the advantages of the steam scraper with the added advantage of conveying, elevating and automatically dumping the material into the sluices without the use of additional machinery. It lacks the mobility of the Bagley and cannot handle a pit of as large an area or of as favorable proportions. It, however, has the advantages of requiring less power, labor, and equipment with lower maintenance cost, than a steam scraper operated under similar conditions.

(22806 Cableway excavator operation

(22808) Cableway excavator dumping into sluices.

Several types of cableway excavators are on the market, the difference being mainly in the type of the bucket and its control. The 3/4 cubic yard bucket is used in Alaska, although it is made in various sizes. The bucket is somewhat similar to the toothed slip scraper and is attached to the carrier by a swinging bail. It is shown in Pl. No.22506, with the traveller block at the stop button and the chains being pulled through a block on the haulage cable, dumping the bucket. Another type is a combination affair, the upper side of the bucket being a bottomless scraper. This bucket is attached to the carrier by flexible chains which overcome some of the difficulties encountered with a bail connection.

A typical operation is shown in Fig. 3. The tension cable operates the tension or fall blocks at the gin pole, tightening or slackening the track cable. The track cable at the lower end is shifted, by hand, along a series of short bridal cables. Starting with the empty bucket near the top of the incline track cable which is now tight, the haulage cable is released, allowing the carrier and bucket

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Fig 3. Cableway Excavator Operation

to travel down the track cable by gravity. This saves power. When the excavator is over the point of excavation, the tension cable is released, lowering the track cable, carrier and bucket into the pit. The bucket is then pulled forward by the haulage cable and loaded, after which the tension blocks are drawn up tightening the track cable and lifting carrier and loaded bucket with it. As the bucket clears the ground, it is pulled forward and up at the same time the track cable is tightening, and conveyed and discharged into the dump box. The loaded bucket on its way to the sluices and other details are shown in Pl. No. 22506. While the speed of operation depends on the digging conditions and length of span, from 30 to 40 trips per hour can be made under average favorable conditions.

As the line of cut is governed by the position of the lower end of the track cable, the cuts radiate to a common center, which is the gin pole end. This results in a wedge shaped pit which is generally 2 to 3 times as long as the average width. The pits worked are seldom over 250 to 275 feet long, requiring a cable span of 325 to 400 feet. Longer spans have been found impractical.

The stripping of overburden, drainage of the pit and the sluicing of the gravel is done as in steam scraper mining.

At an operation on Goldstream Creek, 7 feet of overburden was stripped and 10 feet of material excavated. Frost in the ground and difficult bedrock of hard slabby schist alternating with strata of soft schist retarded the work and required men in the pit to attend the excavator, which is otherwise unnecessary. The pit was 240 feet long, 150 feet wide at the lower end and 75 feet wide at the upper. The cable span was 325 feet. Seepage water and water for sluicing had to be pumped. The excavator was operated by a 6 by 10 2-drum hoist. One inch track cable was used. While excavating this difficult bedrock 30 trips of the excavator were made per hour and as much as 40 trips while in the thawed gravel. The operating conditions were too irregular, however, to obtain definite data. Eleven men were engaged for the two 10-hour shifts.

On Twin Creek, 8 feet of gravel and about 2 feet of bedrock was excavated. The lower part of the gravel contained large angular slide material, and bedrock was mainly a blocky hard gneiss. The pit was 325 feet long, 120 feet wide at one end and 70 feet wide at the other. A cable span was 450 feet in length, which was found to be too long. A 3/4 cubic yard excavator was operated by a 7 x 10 hoist with 30 H.P. boiler burning only 1/2 cord of wood per shift. The lower end of the track cable was shifted by cable from the hoist. No water was pumped. Nine men were employed. Excavation required about 70 days or averaged about 200 cubic yards per day, the excavator delivering the material faster than the one dump box man could handle it, although the digging conditions in general were most unfavorable.

In the Yukon Territory, on Gold Bottom Creek, a 3/4 cubic yard combination bucket was successfully used. The ground was 18 feet deep, wet but partly frozen, with large quartz boulders lying close to bedrock, which was hard, tight and slabby. Four feet of overburden was scraped off, using the scraper side of the bucket as a bottomless scraper, piling the material on the sides of the cut. Eleven feet of gravel was then excavated and dumped to waste. Three feet of gravel and 1 to 2 feet of bedrock was then excavated and put through the sluices. The pit was 100 feet wide and 200 feet long. Working one shift per day the excavating took 56 days. From 30 to 60 trips, average 40, were made per hour or about 200 cubic yards, place measurement, was handled per shift. The crew consisted of an engineer, fireman and one man for general work. About 3/4 cords of wood per shift was burned for operating the excavator.

No reliable costs could be obtained on these operations, but with favorable conditions, the cableway excavator should do cheaper work than steam scrapers. The excavator with carrier costs about $1200. A new complete outfit would cost from $7000 to $10,000, which could be cut about one-half by using some second hand equipment.

Dragline Excavators

The dragline excavator is a self-contained digging machine mounted upon skids and rollers or equipped with caterpillar traction. The bucket is operated by cable from the main engine over a series of sheaves and hangs from the end of a long boom. The angle at which this boom sets is fixed, although readily adjustable, according to the required dumping height. By means of a turntable and swinging engine the machine can be rotated horizontally through a complete circle. The toothed dragline bucket is lowered into the cut, pulled forward by a haulage cable and filled, hoisted to the end of the boom, the machine rotated to the dumping point and the bucket dumped. The standard sizes of dragline excavators are built with booms from 40 to 125 feet long, and buckets holding from 1 to 4 cubic yards. While the dragline excavator is not able to dig as heavy material, it has many distinct advantages over the steam shovel. Having a wider digging radius fewer moves are necessary. Setting on the surface of the ground, it can deliver the material at a considerable elevation and dump directly into the sluice, dispensing with any intermediate device for conveyance or elevation. This is a feature of important consideration in open cut mining. The dragline is well adapted under certain conditions for placer mining in Alaska, where the gravel is unfrozen and free of an excess of large boulders, and bedrock is comparatively soft and regular. While it lacks the greater mobility of the Bagley scraper, it has many advantages over all types of scrapers and other excavators, having speed of operation, requiring comparatively little power and labor, and is low in maintenance costs. It can be quite readily moved about the country, more so when equipped with caterpillars, and requiring but very little time to set up for operation, it has a useful place in the mining of the isolated small areas of placer ground still remaining in many of the districts. The dragline bucket is tight and can be operated under water, but under average conditions it would not be practical to properly clean bedrock unless the pit is drained. Under favored conditions, however, its portability, and its lower cost, especially if a good used machine can be purchased, adapts it for mining small or isolated areas of creek placers which would not justify the cost of installing a dredge.

Two dragline excavators and one combination dragline-steam-shovel are operated in Alaska. Other dragline excavator installations are under consideration.

A "Class 14" Bucyrus dragline excavator has been operated for the past six years on a low bench on Willow Creek in the Iditarod district. It is equipped with a 60-foot boom and 1-1/2 cubic yard Page bucket. The bucket weighs about 3700 pounds. Power is produced by a 60 H.P. boiler. It has a 14-foot turn table and the entire machine is mounted on skids and rollers. The deposit consists of about 12-feet of moss covered muck and 6 feet of light gravel. Bedrock is a soft slate, the upper portion being decomposed to a blue sticky clay. The ground is practically all frozen before the muck and upper gravels are moved by ground sluicing and hydraulicking, the remaining gravel thawing naturally. From 4 to 5 feet of gravel and about 1 foot of bedrock is handled by the excavator. The pit has natural drainage.

The average pit is 110 to 120 feet wide and 150 feet long.

requiring five positions of the machine, the center of the machine being always kept 65 feet, or the dumping reach, from the center of the sluice hopper. From each position an arc out varying from 30 to 60 feet in width is made and the bucket can be thrown about 18 feet beyond the digging reach, which is 62 feet, to take out the corners or outlying areas of the pit. The system of making the various cuts is complicated for from each position there is an overlapping area which can be reached. After the area most practical from the position has been dug, heavy planks are placed on the ground ahead of the machine, the bucket is thrown out for an anchorage, and the machine is pulled ahead over rollers to the next position, the move requiring but a few minutes. Pl. 24478 shows the bucket being lowered into the cut, Pl. 24477 shows the bucket being loaded, and in Pl. 24479 the bucket has been dumped into the sluice hopper.

The sluice hopper is 14 feet long, 8 feet wide at the bottom, and 6 feet deep, to which is attached a 16-foot length of sluice diverging to 2 feet in width at the lower end. These set on a heavy timber frame, all

(24473) Dragline excavator operation in the Iditarod district.

(24477) Dragline excavator bucket loading.

mounted on wheels so they can be moved along a wooden track to the next pit. This track is 8 feet beyond the edge of the pit and parallels it, the sluice hopper being placed opposite the center of the pit. The grade of the hopper and following sluice is 20 inches. The balance of the sluice boxes, usually about 10 lengths, are 2 feet wide and set on timber trestles on a grade of 15 inches. The riffles are Hungarian, manganese cast steel.

An average of about 160 miners inches of water is supplied to the sluices under low head from two ditches. The dump box man, using a giant with a 2 to 3 inch nozzle "boils" out the material as much as possible before it passes out of the hopper. During periods of low water supply the operation may be reduced to half time, when the water is impounded and used intermittently for periods of 1-1/2 to 2 hours at a time. The clayey material lying on bedrock is difficult to sluice, much of it passing through to the dump in large chunks. This difficult sluicing also retards the speed of the excavator.

The excavator normally digs about 60 cubic yards or 40 buckets

(24479) Dragline excavator bucket dumping into sluice hopper

(Special) Locally constructed dragline excavator, Nome Creek, Fairbanks District.

per hour which must be cut down when sluicing with a reduced water supply. The clean-up can be made, the machine and boxes moved ahead and set up again in two shifts. From 15,000 to 20,000 square feet of pit are dug from one set-up in from 5 to 7 shifts. The excavator is operated only one shift, the average crew consisting of an engineer, a fireman, a dumpbox man and two roustabouts; the cost of labor and board for this crew is $57 per day. The boiler burns 1-1/4 cords of wood per 10-hour shift, costing $25. The cost of repairs and replacement is very little. A royalty of 25 per cent of the gross gold production is paid for the use of the equipment and the lease of the claims.

From 100,000 to 150,000 square feet of bedrock are mined in a season, the excavator operations being limited to the area which can be groundsluiced. In 1922, a season of good water supply, 130,000 square feet or 67,400 cubic yards of overburden was stripped at a cost of 4.7 cents per sq. ft. or 9 cents per cubic yard. In 52 days, working one 10-hour shift per day with 7 men, the excavator dug 24,100 cubic yards of gravel and bedrock averaging 5 feet in depth. The cost of excavating and sluicing this material was 28 cents per cubic yard. The combined cost for a total depth of 19 feet, exclusive of royalty, was 11 cents per square foot or 16 cents per cubic yard. Costs during previous years are stated to have fluctuated very little.

There are numerous ways in setting up and operating the excavator, and while the above system has given good results, the operation could be speeded up and simplified by mounting the entire sluice on a track so that with each move forward of excavator the sluices could be pulled along an equal distance. Caterpillar traction increases the mobility and gives other advantages which may, however, not be justified, because of the higher cost for such equipment.

The dragline used at this operation is of a size well adapted to Alaskan conditions. It was purchased in the States as a used machine. This size is regularly equipped with a 60-foot boom and a 2-cubic-yard bucket, and can be obtained to operate by any kind of power. The steam operated machine with skids and rollers costs $25,250 at the factory, weighing when packed for export 52 tons. With caterpillar traction the cost is about $34,000 and the weight is 88 tons. To adapt this size to a wider range of work, optional combinations are offered, as an 80 foot boom using a 1-1/4 cubic yard bucket.

A locally constructed dragline excavator was operated on Nome Creek in the Fairbanks district. It is equipped with an old 6 by 8 hoist, 20 H.P. boiler, timber gantry, 40 foot boom and a 1/2 cubic yard bucket, all mounted on a timber frame. It is moved over log rollers. Pl. (Special). Medium size gravel averaging 9 feet in depth and about 3 feet of schist bedrock is excavated, the bucket dumping into a car, which conveys the material up a low incline to the sluices. Three men are employed and about 100 cubic yards are handled in a shift. The cost of operation is stated to be about 80 cents per cubic yard. This machine recently collapsed and the operations have been suspended.

A "203" combination dragline-steam-shovel machine with 3/4 cubic yard bucket has recently started operations on Caribou Creek in the Salchaket district. The operation was not visited by the writer, but it is reported that about 15 feet of overburden and barren gravel are first stripped with the dragline attachment. The lower or pay gravels of about a similar depth are then dug by the steam shovel, dumping into a self-dumping bucket and hauled up an incline cable to the sluices. It is apparent that the cost of such mining is high, as it is impossible to economically handle such a depth of gravel by this means of excavation and conveyance. The digging radius of this size of machine is too small and the intermediate conveyance of the material to the sluice delays the operation and adds considerable to the cost.

Drift Mining

Drift mining is a term applied to the exploitation of placer deposits by underground methods and is a method used in mining rich pay-streaks of moderate thickness, which are overlain by a deep barren over-burden or one too low grade to justify its removal. In Alaska, the method is best applied to mining the deep permanently frozen creek and bench deposits, whose main gold content is distributed in the lower gravels overlying bedrock or in the upper few feet of bedrock, or where a similar gold distribution occurs in the deep unfrozen bench deposits under conditions prohibiting mining by other methods.

This method of mining, which was at one time of such importance in the Nome, Fairbanks, Hot Springs, Koyukuk, Ruby, Tolovana, and numerous other districts, is very rapidly passing with the depletion of the richer portions of the placer adapted to this form of mining, and many of the areas formerly so mined, are being or will subsequently be worked by dredge, hydraulic, or open cut methods. Drift mining is now restricted mainly to a comparatively few and small operations in the

Yukon-Tanana valley or interior districts. There are but few large blocks of virgin ground remaining which are adapted to profitable mining by this method. Most of the present drifting is being conducted in ground left by former operations where the lower grade side or marginal pay, or small isolated blocks and pillars, are mined. A large number of failures have resulted therefrom. New shafts have often been sunk on what was supposedly a suitable block to find on further development that a large portion of it had been previously removed or that the gravels which were available were too low grade or too small in quantity to repay the expense of the development or their mining. Live water may also be encountered in quantities which could be pumped only at a prohibitive cost. Old shafts and workings are sometimes used in connection with the mining of such small areas as may remain and while this may necessitate transporting the material for long distances, it saves the heavy cost of new development.

Under present conditions, most of the drift mines cannot follow any definite system of mining and with the old equipment which must by force of circumstances be used at most of these operations, there is very little opportunity for improvement. Some of the former large drift mines employed from 30 to 50 shovelers underground and were able to mine between 100,000 to 200,000 square feet of bedrock per season. At the present time there are less than a dozen operations which employ more than 15 to 20 men for the entire operation and will seldom mine over 50,000 square feet of bedrock per season. While there are numerous small mines operated with crews of from 2 to 6 men, the more typical average drift mine of the present, operates but one shift per day and employs one hoistman, who is usually also the fireman, one general surface man and from 6 to 8 men working underground, mining from 10,000 to 30,000 square feet of bedrock per season. Frozen deposits 15 to 18 feet in depth have been drifted in a small way, although in many instances conditions were more favorable for mining these shallow deposits by other methods. Alaskan drift mining has been conducted mostly in frozen deposits ranging from 25 to over 200 feet in depth under conditions, which in most cases require the ground to be opened by a shaft, so the following will pertain principally to such operations.

Many articles were written on Alaska drift mining by able writers at the time when it was at its height and conditions for making such studies were more propitious, and as there are many variations in the practice, only the more representative methods, and those of recent development, can here be briefly outlined.

Drift mining operations can be divided into summer and winter mines, the development in both cases being done in much the same way. At the winter operations the gravel is mined and stored on the surface in so-called "winter dumps" until water for sluicing becomes available in the spring. Winter mining usually requires very little or no timbering where the ground is permanently frozen and in some cases, is the best time for mining unfrozen ground often very wet during the summer months, or for the mining of the small irregular areas mentioned. The rethawing and rehandling of the material in the spring before it can be sluiced often adds considerable to the cost. The tying up of capital through the winter, the larger steam requirements, and the uncertainties connected with the possible sluicing recovery are disadvantageous features of winter mining.

Most of the drift mining is conducted during the summer, although some operations may continue mining throughout the year. The plant is erected, the shaft sunk and all development and preparatory work is usually done during the winter to have everything in readiness by spring.

The equipment in use at the drift mines is most varied in size and kind and while governed by the scale of operation, depth of ground, etc., it is to a large extent governed by the old machinery which is available in the district and the resources of the operator. These old boilers, hoists, pumps, etc., have in most instances seen many years of service at other operations, some having been moved from district to district following the gold rushes. With old and often worn-out equipment, a high degree of efficiency cannot be looked for, but it is mainly due to the fact that cheap second hand outfits can be obtained that many of the operations are possible. Under the conditions such outfits adapted themselves very well for the purpose, for there are but few instances where the installation of new and modern equipment for drift mining would now be justified.

The average smaller mine, as a rule, is equipped with a 12 to 30 H.P. vertical or a marine type of boiler with a 6 by 6 or 7 by 7 single cylinder vertical hoist. At the larger operations, the return flue type of boiler is mostly used in sizes ranging from 30 to 60 H.P. with a 7 by 7 vertical or a 5-1/2 by 8 double cylinder hoist. Larger boilers are now rarely used, and where necessary it is customary to use two small ones of equivalent size as they can be more readily moved about and also afford the advantages of separate units. At many of the mines where only one shift is worked, thawing, or the pumping of water for sluicing is done after shift, so that one small boiler is sufficient for all purposes.

The average outfits contain 10 to 50 steam points, or sweaters, hose and pipes, a self-dumping bucket and carrier, or cage for a car, a small pump for the sump, cars, wheelbarrows, tools, cable, blocks, blacksmith outfit, sluices, etc., with a small ditch or a pump for pumping water for sluicing. An outfit costing from $3500 to more than $10,000 when new can now be gathered together from old outfits at practically the buyers' own terms. A second hand 30 to 40 H.P. plant which when new cost from $7000 to $10,000 can now often be purchased for from $500 to $2500. Ditch lines from former operations are also at the service of many of the present mines.

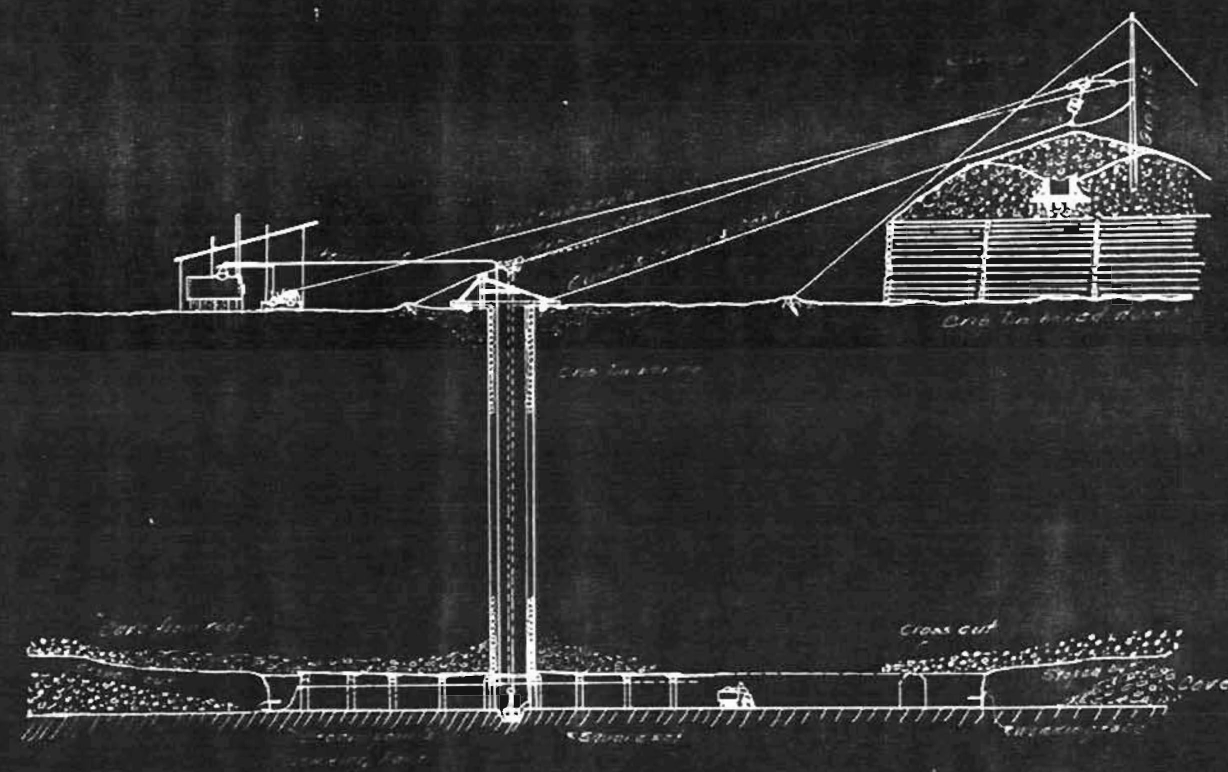
The neglect of insulating the boilers and steam lines at most of the plants is surprising. Insulation will quickly repay as evidenced in the smaller fuel consumption of the plants where it is done. While the operators are aware of this, many of them are indifferent about it. Partly due to lack of insulation, and more so because of the poor efficiency of the old equipment, steam costs are high. While the average present interior operation only burns from 1/2 to 1-1/2 cords of wood per shift, the cost of the fuel consumed varies from 2-1/2 to 7 cents per boiler horsepower hour. Around Nome crude oil was burned in the boilers.

The methods of opening up a drift mine which are quite similar to those employed in the underground development of flat vein or bedded deposits, are governed chiefly by the topography, the character, the thickness and the lateral dimensions of the paystreak to be drifted; the gold content and its distribution; the contour and grade of the bedrock; and in some instances by the resources of the operator. Most of these governing features must be known through previous prospecting or other work, before a block of ground can be properly opened up. The customary practice in Alaskan drift mining involves the sinking of a shaft; the development or opening up with drifts and cross cuts; the gravel and bedrock, if frozen, is thawed; excavated; transported to the shaft; hoisted to the surface; and conveyed to the sluices where the gold is recovered. Where the topography permits, as on some of the benches, the placer may be worked through an adit or tunnel.

Development

The shaft is generally sunk at a point about centrally located in the block of ground to be mined but keeping in consideration the grade of bedrock. These shafts are usually 6 by 6 or 7 by 7 feet in the clear or made about 2 feet larger to allow for the timbering. With two men working in the shaft from 5 to 8 feet per shift can be sunk through the muck. In most instances the muck is thawed before excavating, but in its frozen state is also excavated with a pick. When thawed, it can practically be bailed out of the shaft. The frozen gravel is always thawed before it can be dug. Depending on bedrock conditions, the system of mining and underground transport to be used, and to provide drainage, the shaft is sunk 6 to 14 feet and more in bedrock.

For a winter operation the shaft seldom requires timbering, except possibly a little cribbing at the surface. For summer work, in solidly frozen ground the shaft may require only a light crib timbering in the first 15 or 25 feet below the collar, with a square set at the bottom with a little cribbing above it, but in average ground and especially in the deeper deposits, the shaft is generally fully timbered. In the interior districts or where timber is available, round spruce poles 3 to 6 inches in diameter are used for cribbing the shaft. These timbers are cut to length and notched on one side at each end, and are placed

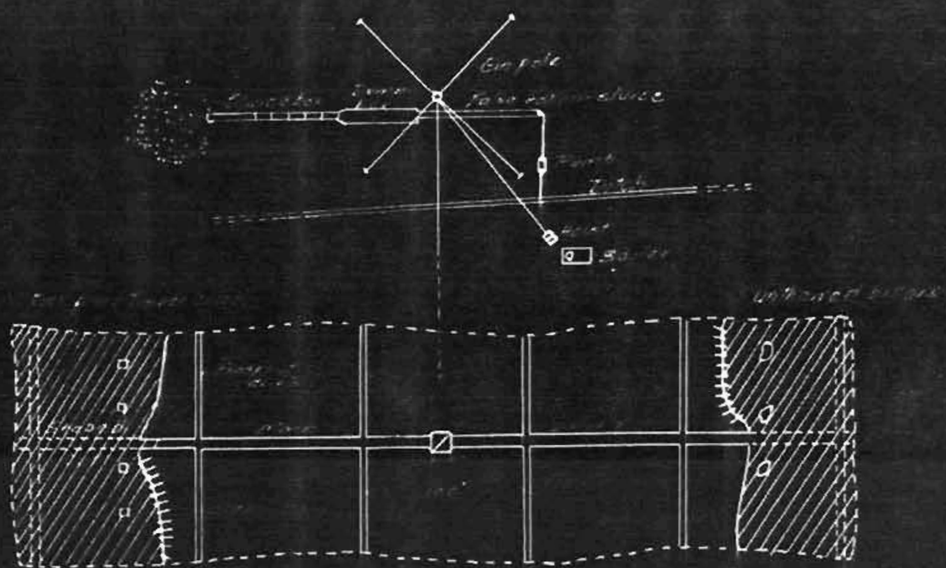


SECTION OF DRIFT MINE

To be reduced
to 1/2 size

Original sketch accompanies original
copy of report

Fig. - Section of Drift Mine.


Gin pole
Ditch

Original sketch accompanies original copy of report

Fig. 5. Underground and Surface Arrangement of Drift Mine.

one over the other and as the name implies, built up like a crib. The space between the crib and the frozen ground is then filled with gravel, or moss is generally used through the muck and tightly tamped into place. Care and experience is necessary to properly place the cribbing and tamp the material behind it so the timbering will keep plumb. Even when carefully done, any thawing of the gravel may cause settling and tend to shift the cribbing, causing it to "corkscrew" or "jackknife". The direct pressure on the cribbing is, however, usually very light. Deep shafts so timbered, have after a period of more than 15 years been brought back in service with little repair necessary, while in others retimbering was done although the old timbering was still in alignment. The bottom of the shaft or station is timbered with a square set. The average square set is made of 10 to 14 inch round timber, although at some of the deep mines timber 20 to 24 inches in diameter is sometimes used. One cord of 16-foot poles of the average size used will crib about 8 feet of shaft. On the Seward Peninsula, where timber and lumber must be imported, sawn material is used. One 63 foot shaft near Nome, 4 by 4 feet in the clear, was timbered at the bottom with a square set, using 10 by 10 inch posts and 10 by 14 caps; above this it was timbered with 2 by 4 inch lumber, notched and placed one above the other, like well timbering, and spiked together. Vertical pieces were placed in each corner and horizontally braced. This shaft cost about $500 to sink and about $700 to timber, with lumber costing $108 per thousand board feet at the mine.

The cost of sinking the average working shaft where little or no timbering is necessary ranges from $6 to $12 per foot, varying mainly according to the depth and the character of the deposit. Shafts fully crib timbered and with a square set at the station cost from $10 to $20 per foot, while some deep shafts sunk in difficult ground may cost $25 or more per foot.

Where conditions permit, drifts are driven from 250 to 300 feet up and down stream from the bottom of the shaft. This distance is governed chiefly by the bedrock grade and is more often restricted to 200 feet and less. Longer distances increase underground transportation costs and may not permit proper drainage of the workings. In a wide pay channel drifts may be driven in four directions from the shaft, while in narrow irregular deposits it is advisable to follow the pay in which case the drifts may have many bends. Cross cuts are driven every 50 to 100 feet from the main drifts to the limits of the pay. Fig. 4 shows a longitudinal section of a typical interior drift mine, Fig. 5 is a plan of underground workings, and a surface plan. The thawing of the ground in driving the drifts or cross cuts may in some instances be done with a single steam point, but it is more customary to use from 2 to 4. Long points may be used, but as the average advance made is from 6 to 10 feet per shift, it is better practice to use shorter points, thawing only the amount of ground that can be excavated by the shift.

In average frozen ground, only a few sets of timber each side of the shaft are ordinarily required, although in many instances the entire drift is timbered. Three piece sets of 2 posts and a cap are used, setting them from 5 to 8 feet apart. Round timbers 5 to 8 inches in diameter are generally as large as required for these sets.

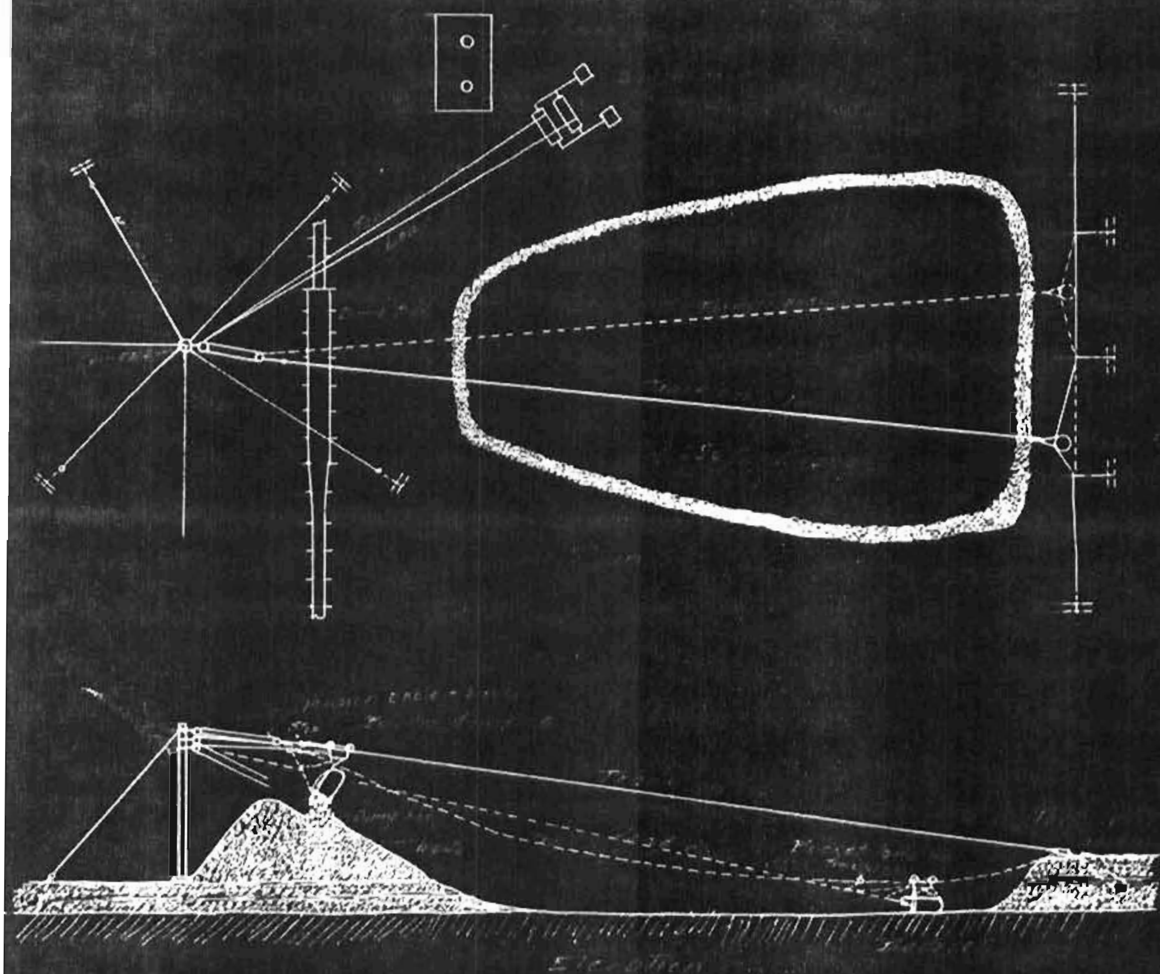
for the timbering usually has to carry only the weight of the gravel which may slough from overhead. To hold such sloughing, light pole lagging from 2 to 4 inches in diameter is placed on top and sides of the timber sets, although side lagging is usually not necessary. Mud sills or foot blocking are used only when bedrock is soft or mushy. In some mines, "swelling" ground causes the squeezing and breaking of the timbers. This is usually caused by the release of pressure on the ground and where wet thawed streaks are encountered. While impossible to entirely overcome its effect, it can often be lessened by giving the posts a wider spread at the base, removing the lower side lagging and releasing the pressure by picking down the material from behind the timbering. The average cost of untimbered drifts and cross cuts is $5 to $8 per foot; the cost for timbering being $2 to $4 per foot.

As mentioned, the shaft is sunk into bedrock and the development conducted so that the workings will drain to a common sump at or near the shaft, from where the water is pumped to the surface. In the solidly frozen ground, the water is produced from the thawing of the gravel, or some may seep down the shaft. It is generally small in quantity and can be easily handled with a 1 or 2 inch single or duplex pump. At most of the mines a few hours pumping per day is all that is required. Steam injectors are successfully used at some of the operations where the volume of water is small and the lift not too great. When thawed channels are encountered or wet unfrozen ground is mined, pumping requirements are greatly increased, so much so in some instances as to prohibit mining.

In the Fairbanks district on Dome Creek, a 138-foot shaft, 7 by 7 feet in the clear was sunk through 115 feet of muck, 15 feet of gravel and 8 feet of bedrock with an additional 6-foot sump below. The muck was picked without thawing for 75 feet, two men in the shaft averaging 6 feet per shift. The remaining muck and the gravel was thawed, using 9 9-foot steam points, the thaw in the muck requiring 10 hours and in the gravel 12 hours. The average sinking progress made in the gravel was 4-1/2 feet per shift. The entire shaft was timbered; 6 days labor of 6 men was required to put in the cribbing after it was cut. Sixteen cords of poles were used, costing $192. The cost of the timber for the square set, its framing and putting it in place, was about $100. The wood fuel burned cost $256. The entire cost of the timbered shaft, including the sump, was about $2000, or $14.50 per foot. There were 500 feet of timbered drifts costing $8 per foot, and 100 feet untimbered, costing $6 per foot. The total cost of development, erection of plant and all preparatory work was about $6500. One of the best records in shaft sinking was made some years ago at the mouth of Dome Creek, where a 171-foot shaft was sunk without timbering in 21 days with 3 men in the shaft and 2 on the surface for each 10-hour shift.

Mining and Transportation

In a few instances, the gravel has been mined by working away from the shaft, but the customary practice is to start at the farthest away faces and work back toward the shaft using a modified form of the "longwall" or retreating method. This keeps the men away from the stoped out areas and permits the waste to be piled behind. While thawing is being done at a face in one part of the mine, the gravel is being



Fg. [illegible] Cableway Excavator Operation excavated from another.

The height of the working face is governed chiefly by the distribution of the gold and generally ranges from 4 to 8 feet. A 5 or 6 foot working face is the average, from 1 to 2 feet of bedrock being included. Working faces less than 4 feet high are poor economy, as they produce cramped working conditions, a higher face more than repaying for the small cost of handling the additional gravel. Occasionally there may be two or more distinct strata of pay gravel and when separated by a thick stratum of barren gravel or muck, are mined separately. There are a few instances where a thickness of 20 feet and more has been mined from one level, but where such conditions exist, except it be a deep deposit, it is usually cheaper to mine by some other method.

Muck streaks may be intercalated in the gravel so that as the underlying gravel is being extracted this muck may slab off in large pieces. They usually come down slowly, giving ample warning, and are consequently of little danger. However, unless they are supported, they may bury the working faces. Where this threatens, a heavy post and short cap will generally hold it. Frozen pillars of gravel, or timber cribs or bulkheads filled with waste gravel, from 4 to 6 feet square and spaced from 25 to 50 feet apart, paralleling the face and about similar distances back from the face, are used when support of the ground is required. It is the general practice to keep the workings safe for a distance up to about 50 feet back from the face, but beyond this point the pillars or timbers in the worked out areas are withdrawn and the ground allowed to settle.

Very little drift mining is now being done in bench deposits which can be opened by adit. In frozen ground the methods of development and mining are practically the same as when shafts are used. The adit is driven to proper grade, generally deep in bedrock and cross cutting the pay channel; drifts are then run in both directions and the lateral cross cuts are driven. Mining from an adit saves hoisting, pumping and some of the heavy shaft costs otherwise incurred, although in thawed or wet ground the heavy timbering generally required often prohibits profitable mining.

In the Nizina and some of the other southwestern Alaska districts, some drift mining from adits has been done in the unfrozen bench gravels, requiring heavy three-piece sets and full lagging in the adits and drifts, and while some of the gravel was tightly packed and permitted its extraction with but little timbering, many of the faces had to be closely timbered. Under the conditions, only comparatively small areas could be mined from each side of the adit, or main cross cut. Square set timbering may be necessary in unfrozen wet channels of heavy gravel, as was the case at the early drift mining in the Valdez creek district.

In loose unfrozen ground, it becomes necessary to timber closely and hold it well against the face. One of the best systems for handling this kind of ground is one which has been used at the Hidden Treasure and other drift mines[34] in California. Heavy posts set on base blocks or

(34) Browne, R.E., The ancient river beds of the Forest Hill Divide, Tenth Ann. Rept. State Min. Cal., 1890, p. 452.

sills are placed in a line parallel to the face and support the caps, above which lagging is driven along the roof and into the face as the gravel is removed and when sufficiently advanced another set of timbers is placed. When the ground is unusually heavy, a false or intermediate set is used to guide and support the lagging until the regular set can be put in. Boulders and waste are piled behind in the breasted-out portion to assist in supporting the roof.

The mining or excavation of the gravel and bedrock is mostly done by manual labor in picking it down and shoveling it into wheelbarrows or cars. Scrapers have been repeatedly tried for scraping down the gravel and bedrock from the face, but the gravel has generally been too tightly packed or the bedrock has been too hard and irregular to make this a success. It should, however, work with proper equipment where conditions are favorable, but if the face must be picked down by hand and a scraper is used only for conveying it to the cars, there appears to be little to gain by such a method. This pick work is most difficult and tiring and but for the change and relief that the miners get by shoveling and wheeling, they could not continue for long. Pneumatic pick machines would be a great help in this respect. The blasting down of the gravel after it is thawed has been tried. It has not proven advantageous but does hold possibilities. A method of drilling and blasting down the face without thawing, and scraping the material to cars, has recently been successfully developed. It will be described later. Methods of hydraulicking down the face which combine thawing with the breaking down of the material, have under favorable conditions been quite successful as far as they went, but these methods have not been adopted, possibly because of the small field open to their application.

Tightly packed gravel is difficult to pick down, so it is undercut, usually by first removing the upper or softer part of the bedrock. The miner, known as the shoveler, picks down the material and shovels it into a wheelbarrow or a car. Heavy rocks are thrown behind him as waste. If the bedrock floor is rough, making shoveling difficult, the material may be broken down onto shoveling plates. Wheelbarrows are generally considered to be best adapted to the conditions at the smaller mines where the distance is not too long, and where there may be sharp turns to make and bedrock is irregular or has a high gradient. They require a minimum of space and hence the drifts need not be so large. Low built cars are generally preferred at the larger mines where systematic development and mining can be done and the grade is more uniform. At some of the former operations at Nome, these loaded cars were run onto a cage and hoisted to the surface. Most of the larger present operations use a combination of the two methods. The wheelbarrows being loaded at the face are wheeled to the main drift, where they are dumped into a waiting car. With this system the drift must be carried deeper in bedrock than the cross cut, so as to permit dumping into the car without wheeling up a steep grade. In all cases the material is transported to the shaft, and with the exception mentioned, is dumped into the bucket, hoisted and conveyed to the sluices.

The duty per man in picking, shoveling and wheeling varies chiefly with the character of the material, working conditions, length of trip and himself, and may be from 75 to 125 wheelbarrow loads per 8-hour shift. With the same considerations, he will mine from 30 to 40 square feet of of bedrock to a height of 5 or 6 feet, the average being about 25 square feet or about 5 cubic yards.

Several different types of buckets are used, but the one in most general use is the Fairbanks self-dumping type made in sizes holding from 3 to 8 wheelbarrow loads. Such a bucket with carrier is shown in Pl.22476. The bucket has a swinging bail to which a sheave is attached. The bucket is hoisted by a cable operating through this sheave and the sheaves on the carrier, the latter remaining at the surface on the incline track cable. A chain sling is attached to the bucket and to a ring which travels along the guide or trip cable. The bucket on reaching the carrier engages a catch and automatically locks itself to it. Both are then pulled up the incline track cable to a point over the dump where the ring guide encounters a stop on the trip cable, upsetting the bucket. This procedure is shown in Fig. 4 and Pl. 28296. Returning to the collar of the shaft by gravity, the carrier strikes a trip, releasing the bucket, which is then lowered down the shaft. Men and all supplies are also carried by these buckets. It is speedy in action and at many plants can make a complete trip in one minute, which is, however, considerably faster than the material is usually delivered to it.

(22476) Fairbanks self-dumping bucket and carrier.

(28296) Drift mining in interior Alaska. Surface arrangement.

Sluicing

At the summer mines, the material as hoisted is generally delivered directly to the sluices and sluiced at once. The time for sluicing may, however, be regulated by the water supply and, as at some of the mines, the small amount of material mined can be sluiced in a few hours after the shift is over. The sluicing arrangements at most of the operations, consist of a dumpbox followed by the regular sluice boxes, set on trestles at a sufficient height above the ground to provide the necessary grade and dump, or the dumpbox or head of the sluices are often set up on an old waste dump. The dumpbox is provided with a timber apron or the sides may be built up with waste dirt to form a chute to catch and guide the material as it falls from the bucket into the box. The dump box may be from 20 to 32 feet long and from 2-1/2 to 4 feet wide set on grades of 12 to 14 inches to 12 feet. The sluice boxes are from 12 to 16 inches in width and set on grades of 7 to 12 inches, sometimes more if available. Pole riffles set lengthwise are in most common use and may be shod with strips of iron or steel. Several sets of such riffles may sometimes be placed crosswise. Undercurrents of the same width as the sluices consisting of punched steel plate placed several inches above cocoa matting may be added at the end of the sluices, but refinements for saving fine gold are generally surprisingly lacking.

At many of the mines the gravel contains much clay or there may be a thick clay "sediment" on top of bedrock, which adds to the sluicing difficulties and often leads to poor gold recovery. The dumpbox man forks out the large rocks, puddles this clay and tries to disintegrate the material as much as possible before it is allowed to pass through the sluices. Most of the gold is generally recovered in the dump box and the first box or so below it, but much of this lumpy unwashed clay goes through the sluices and to the dump, carrying with it some of the gold. The most satisfactory method used for sluicing such clayey material is to store it on the dump, and by using water under pressure through a small nozzle, cut it up and wash it well before it is permitted to enter the sluice. Pl. 24507.

Water for sluicing is usually obtained from a small ditch, although at many of the mines the water must be pumped. While pumping may add materially to the sluicing cost, it has the advantage of providing a more steady water supply and save costly ditch construction and maintenance. The water supply regulates the period for sluicing and while attempts have been made to sluice during the winter by using pumped warm water, the added cost and the resulting poor gold saving do not make this advisable. Sufficient water for sluicing at the average drift mine is generally available from the latter part of April to the end of September. The quantity of water used for sluicing at the average drift mines varies from 30 to 100 miners inches. In seasons of protracted drought, the gravel is stored in piles or dumps, which are often crib timbered; or hoppers are sometimes used where it is necessary to store the gravels for periods of only a day or two.

In storing gravel in large dumps similar methods are used as for winter dumps. The sluices are placed on heavy timber supports and covered over with boards or poles and the gravel dumped on top. When water is available, these boards are withdrawn as the material over them

(28295) Drift mining dump and sluices.

(24507) Sluicing the dump by nozzling.

is caved, shoveled, scraped or nozzled into the boxes. Unless they are hydraulicked, the winter dumps must again be thawed before they can be sluiced.

When the gravels are comparatively free of clay and large boulders and a steady supply of water is available from a ditch line, the sluicing costs are comparatively small. Under average conditions a dumpbox man is necessary, when the cost of sluicing will range from about 15 to 45 cents per cubic yard, depending on the amount of gravel handled and the method used. At an operation in the Ruby district about 30 cubic yards of clayey gravel is mined per day of one shift. This is stored on the dump for 3 days, when one man hydraulicks it and puts it through the sluices in one shift at a cost of 20 cents per cubic yard. The water is pumped and used through a one-inch nozzle. In the Fairbanks district and other interior districts, the average cost for sluicing is considered by many of the operators to be about 10 per cent of the cost of drift mining.

Thawing

The thawing of frozen gravel was first accomplished with wood fires or hot rocks, and this method is still used at a few small isolated mines. Hot water was later used at a number of mines. With these few exceptions, the thawing in drift mines is done with steam under pressures of 90 to 110 pounds, at the boilers. The steam is conducted down the shaft and to the workings through pipes from which connections are made to the various crossheads or batteries with pipe and steam hose. Each crosshead delivers steam to 4 or 5 points, a valve and hose connecting to each point.

The steam points are made of extra heavy hydraulic steel pipe from 3/4 to 1 inch in outside diameter and from 6 to 20 feet long. Lengths over 12 feet are now seldom used at the face partly because of the greater ease with which the short points can be handled and the greater regularity of the thaw. There are many kinds of points, differing in the type of drive head, steam connection, and the form of the bit. The lighter points are fitted with a heavy "tee", with a tool steel plug for a drive head and a pipe nipple for the steam connections, but the standard point has a heavy tool steel head, with the nipple welded to it, or fastened by special attachments. A hole is usually drilled through the solid head for inserting a small bar for turning the point while driving. The points may have either round, pointed, diamond shaped, chisel, or cross bits, the kind used being governed by the character of the ground. The round, pointed or straight bit is most commonly used. With a small amount of steam turned on, the point is driven into the face, and where two men work together, one does the driving with a heavy hammer, while the other guides and rotates the point. In some ground, thawing is sufficiently rapid and other conditions are such that the point can be quickly advanced, although this cannot be faster than the gravel thaws, so that a number of points are generally under way at a time. Hard driving is generally necessary as the gravel ahead of the point must be pushed to one side or some of the larger rocks drilled through. When large rocks are encountered, it is generally advisable to pull and start a new hole. When steam is used for driving the points, there is a "blowing back" or escape of steam which fills the workings, rendering difficult vision and causing the gravel in the roof to thaw and slough. To overcome this, many of the miners use hot water instead of steam while driving. The water used is pumped from the sump, being heated with steam usually from the exhaust of the pump. This method, however, requires additional piping and tends to wash and slough off the face so that it is subsequently more difficult to plug the hole around the point and seal in the steam.

The points are set horizontally along the face, spacing them from 2 to 4 feet apart and at a horizon where they can be most easily driven. This is usually just on top of bedrock or a few inches below, providing bedrock is not hard or blocky. Irregularities of bedrock may, however, be so that the point may be in both gravel and bedrock. After the point has been driven home it may remain during the thaw, but it is more customary to withdraw the point and insert a "sweater". Sweaters are made of ordinary iron pipe from 3/8 to 1/2 inch in diameter, the head being fitted with a tee for steam connection and a plug for light driving. Their use makes a large saving in the cost of equipment and as the points cannot always be withdrawn after the thaw is completed, these light pipes can be bent back and out of the way of the workers. The collar of the hole is now carefully plugged by wrapping burlap or similar material around the point or sweater and ramming it tight, so that no steam will "blow back". The steam is then turned on, being regulated with the valves at each point and as much steam given as the ground will take. The regulation of the steam requires experience as some ground will take the full steam pressure while in other cases where the gravel is tight only a small amount can be used. Too much steam will cause it to "blow back" around or into the point, clogging it, and filling the workings with steam. Where thawing is underway there is a constant shower of gravel from the roof and the point man must be on a constant lookout for large falling rocks.

In easy ground, two men working separately can generally accomplish more than when working together. The rate of driving or setting the points varies according to the length of point and the character of the gravel. In average ground, two men working together can set from 10 to 30 nine-foot points per shift, while in some of the easy ground, one man may set 20 to 25 eight foot points. Where the gravel is tight and bouldery and bedrock is blocky, as at a number of mines in the Fairbanks district, it usually requires the good hard work of two men to set 4 to 6 nine-foot points in 8 hours.

The time required to complete a thaw and the duty of a steam point is governed by numerous factors, chief among which are the character of the ground, distance between points, length of point, height of face, steam pressure, etc. In favorable gravel and under average operation, the steam is turned on for 6 to 12 hours, while in tight gravel with much clay 45 hours may be required. Under average conditions 10 to 20 hours are necessary. After the steam is turned off the gravel retains heat for a considerable length of time and until dissipated further thawing continues. This "sweating" completes the thaw, so that gravel should not be excavated until several days have elapsed and the gravels are cool. Immediate demand for thawed gravel at most of the mines is, however, such that most of it is mined while still warm, often hot.

The steam point will normally thaw from 1 to 3 feet beyond the end of the bit. The average area thawed with a 9-foot point is from 30 to 45 square feet or from 7 to 8 cubic yards. The amount of steam required per point under average conditions is generally considered to be one boiler horsepower, although there are instances where 2 horsepower was required. High steam consumption is usually due to inefficiency and long, poorly insulated steam lines or to the usual character of the material thawed. Gibson[35] states that the horsepower per steam point

(35) Gibson, A., Drift Mining in the Frozen Gravel at Cape Nome. Min. and S.P., Mar. 7, 1914, p. 404.

at 5 operations at Nome ranged from 0.76 to 1.12, from 25 to 90 points averaging 7 feet in length being set per thaw and with steam turned on for from 8 to 12 hours and "sweating" from 1 to 2-1/2 days, from 2.28 to 7.11 cubic yards were thawed per point.

Under favorable conditions, ground has been thawed in drift mines for 2 cents per square foot or about 15 cents per cubic yard. Such low costs are however seldom attained, especially at the present operations. In the more difficult ground or at small operations the cost is often 10 to 12 cents per square foot or about 50 to 75 cents per cubic yard. Under average conditions 30 to 40 cents per cubic yard is about the usual figure. Ellis[36] estimated that the cost of steam

[36] Ellis, H.I., Thawing Methods at Fairbanks. E. and M.J., July 3, 1915, p. 1-6.

thawing in the Fairbanks district accounted for about 20% of the total cost of drift mining.

In tightly packed gravels or where the bedrock is irregular, hard and blocky, or overlain by heavy gravel, the driving of the points is slow and difficult. The use of machine drills for drilling holes in such ground for inserting the steam points or "sweaters" has proved successful at several drift mines. This method was also tried at other operations where, however, it was not satisfactory mainly because the wrong type of drill and equipment was used. The Idaho Mining Co., on Little Eldorado Creek in the Fairbanks district, has been very successful with this method, and it has been the one big determining factor for profitable operation.

The deposit here averages 165 feet in depth, and while it is solidly frozen, the average gravel seldom contains more than about 5 per cent of ice. The gravel is tightly packed, of medium size, but contains some large hard quartz and schist boulders, which lie on the bedrock. Bedrock is a mica schist, soft beds alternating with harder slabby ones. Up to the time of adopting the present method as later described, an average of 3-1/2 feet of gravel and 1-1/2 feet of the bedrock was mined. A 70-cubic-foot air brake locomotive compressor furnished the air and an old boiler was used for an air receiver. These were used to a good advantage, although better results could have been obtained with a larger compressor for the pressure at the receiver dropped from 80 lbs. to 55 lbs. and less when the drill was in operation. A BCRW 430 Jack hammer drill, equipped with the water attachment by which a small amount of cold water is delivered under low pressure through the hollow 7/8-inch drill steel to the bit, was used for drilling and was easily handled by one man. This use of water instead of air or steam accounts mainly for the successful drilling. Drill steels were used in lengths of 3, 6 and 9 feet and equipped with cross bits gauged from 1-1/2 inches down to 1-1/4 inches. The holes were usually drilled 3 feet apart in a horizontal line just on top of bedrock or a little above it in the gravel. Two boxes supporting a plank, placed at the proper inclination and at right angles to the face, acted as a support and guide for the drill. The hard boulders were quite easily drilled through, although when an unusually large one was struck, a new hole was generally started. A little caving or "ravelling" of the holes, at infrequent times caused the slight binding of the drill, but this was attributed mainly to the low air pressure. Very little trouble was experienced in the freezing of the air, as water traps were used in the steam line and dry air delivered to the drill. This could be further lessened by putting alcohol in the line.

An average of 5 nine-foot holes could be drilled with a set of steel before resharpening was necessary. With the old method of setting points by hand, it required 8 hours for 2 men to set 4 to 6 nine-foot points, while with this method one man would average 180 feet of drilling or 20 holes, insert the 3/8-inch sweaters, and get the thaw underway, in 8 hours. A 9-foot hole could be drilled in the average time of 20 minutes. It was estimated that the cost of drilling and setting the sweaters which included the labor and mess cost for one man, 1/4 cord of wood for running the compressor and wear and tear on the equipment, was $13 per shift or 65 cents per 9-foot hole.

From 40 to 45 hours were required for thawing as only a small amount of steam could be turned on. After the steam was turned off, the ground was sweated for about one day. Average thawing extended 18 inches beyond the end of the sweater, although 40 square feet of area was sometimes thawed per sweater. While the cost of thawing is not known, the entire cost of operation, exclusive of capital and royalty charges, in 1922, was 74 cents per square foot, 60,000 square feet being mined.

A new method of drift mining involving modern underground practices has recently been installed and developed at this same property by Mr. J.F.Foran, the engineer and manager for this company. The frozen gravel and bedrock is drilled and blasted down and delivered to the cars by an underground scraper and successfully sluiced on the surface, dispensing with the customary steam thawing methods. New equipment for this purpose was installed after the new shaft, 238 feet of main drifts and 30 foot station level had been completed by the former method. The present mechanical equipment consists of three 50-horsepower boilers, a 7 by 10 double cylinder hoist, a six wheelbarrow load self-dumping bucket and carrier, a No. 5 Sturtevant blower for ventilation, a 680 cubic foot Leyner air compressor, an 8 inch centrifugal pump for pumping the water for sluicing, three "BBRW 13" Jackhammer drills, one 6-1/2 horsepower "Turbinair" double drum air hoist, one 12 cubic foot Quincy box-type bottomless slush scraper, etc. The air drills are of the wet type, using 7/8 inch hollow hexagonal steel with a cross bit of 1-3/8 inch gage. Starters are seldom used, the drilling being done with 5-foot steels.

The shaft is 169 feet deep to bedrock and is 6 feet in bedrock. It is 7 by 7 feet in size in the clear, and is fully crib timbered down to the square set station at the bottom. The cost of moving and setting up the old plant, sinking and timbering the shaft, was $2500. The main drifts, continuing from where they stopped with the old method, were driven to a total distance of 275 feet upstream and 240 feet downstream. Cross cuts, 280 feet and 185 feet in total length, were then driven at the respective ends of these drifts to the side limits of the pay. The 6-1/2 by 6 foot drifts were driven under the new system of drilling and blasting at the rate of 7 feet per 6-hour shift, by one driller and two muckers working two faces, at the cost of $4.50 per foot. These drifts required no timbering, whereas those driven by the old method of thawing required three piece sets and top lagging. The cross cuts at the ends were driven 18 feet wide and 5 feet high by two drillers and four muckers working two faces a shift, advancing each face an average of 4 feet per shift. A block of ground containing about 120,000 bedrock square feet of pay was opened up.

Starting in the cross cuts at the extreme end of the block, mining is done along the wall nearest the shaft and advances toward the shaft. Two drills are used at the upstream end and the average height of face carried is 4-1/2 feet or 2 feet of gravel and 2-1/2 feet of bedrock. The back holes are drilled in the gravel and spaced 3 feet apart; the cut or breast holes are drilled in bedrock and spaced 2-1/2 feet; and the lifters in bedrock with 3-foot spacing. The holes are all drilled 5 feet deep and break to the bottom. With two drills working, a 130 foot face can be drilled, the holes loaded and shot in two 8-hour shifts. One man will drill on an average of 150 feet of hole, load and shoot them; or an average of 100 square feet or approximately 17 cubic yards is drilled and broken per man per shift. One steel will drill an average of three 5-foot holes. There is never any trouble with stuck steel and practically no trouble with the freezing of the drills. Shortly after drilling, the holes must be blown out with air to remove any water and so prevent any ice from forming and closing them. The holes are loaded with 40 per cent straight nitro glycerine dynamite, 4-1/2 sticks to the hole. No stemming is used. This powder has been found to be too fast for the gravel and too gassy under the ventilation provided. The average powder consumption has been 3.4 pound per bedrock square foot. The cost of the powder is 7-1/2 cents, fuse and caps 2-1/2 cents, or a total explosives cost of 10 cents per square foot, or about 60 cents per cubic yard.

From 12 to 24 hours after blasting, the material is scraped from along the face to the main drift, up a short incline and dumped into a car. The scraper is dragged back and forth by cables operated from the two-drum air hoist.

A great deal of trouble has been experienced and time lost through the freezing of the air in the rotary gears of the air hoist. The incline up which the scraper is dragged has also caused some delay and must be taken down and set up at a new place for about each 1300 square feet of bedrock scraped. This requires from 2 to 3 hours each time. It is planned to put the main drifts 6 feet lower in the bedrock, which will dispense with the incline. Some delays are also occasioned in tramming, as the two trammers cannot keep pace with the scraper when it is operating properly. Under the present arrangement the scraper operation averages but about 5 hours out of the eight, although an average of about 250 square feet of bedrock are scraped during that period. With the above mentioned difficulties corrected, permitting almost continuous scraping and with 3 drills busy at the face, it is expected that this can be increased to about 350 square feet per shift. Lacking equipment, only one drill is operated at the downstream face, where after the material has been blasted down, it is shoveled into wheelbarrows.

The workings are kept safe by putting in bulkheads about every 25 feet along the face. These are 4 by 8 foot timber cribs filled with waste gravel. With each advance of about 40 feet another row of bulkheads is put in. At intervening places where the roof may slab, as at the lower points, a post with cap is set. As the work advances, these are removed and the ground allowed to settle.

After the material has been scraped to the car, it is trammed to the shaft, dumped into the bucket, hoisted to the surface, conveyed over the incline cable and automatically dumped into the sluices.

The blasting down of frozen gravels in drift mines is not a new idea but has been tried on numerous occasions. It has not proved practical because of the character of the material which after being broken still required thawing. The success of this blasting at this operation is due to the unusual character of the material mined. This deep tightly packed frozen gravel contains an unusually small amount of ice, not more than about 5 per cent, which occurs as small crystals and to a lesser extent as small masses or seams. The shattering effect of the detonation is mainly responsible for preparing this material for sluicing without the necessity of the customary thawing. The heat liberated by the explosion plays but a comparatively small part. As this material strikes the water and passes through the sluices, it readily disintegrates and is satisfactorily sluiced.

This operation now employs 15 men and operates but one shift of 8 hours. The success of this method has been proven although the operation must still be considered to be in the experimental stage. When once properly equipped and developed so that 2 drills and a scraper can be kept busy at each face, it is the expectation of the management that from 1000 to 1400 bedrock square feet can be mined per day of two shifts by working a crew of about 40 men, at a cost of 50 cents per square foot, exclusive of capital charges and royalty.

The hydraulicking of frozen gravels in a drift mine has on different occasions been done on a small scale. With one method, the gravel face was nozzled down with water pumped from the underground sump and which was warmed by the steam exhaust of the pump. Both the thawing and breaking down of the gravels was accomplished with this water. The excess water was drained to the sump to be re-used and the broken down material was shoveled or scraped into wheelbarrows or car and conveyed to the surface for sluicing. The main difficulties encountered were that most of the bedrock had to be dug and cleaned up by hand and there was excessive wear on the pump lining. At another operation in a low lying bench where the paystreak was composed of small gravel containing only a small amount of porous frost, water was conducted down the shaft and to the working faces through hose and pipe and the gravel and bedrock nozzled down and sluiced to the sluice boxes in the main cross cut. Diagonal paralleling drifts had been driven from the main cross cut. Hydraulicking started at the innermost faces and retreated toward the main cross out, leaving narrow pillars between the drifts which were later removed. An adit on low grade and which by force of conditions could be made available for no other use, was used for carrying off the water and the light material in the tailing. The main bulk of the tailing was hoisted to the surface by way of the shaft. The average height of working face was 5 feet and about 4000 square feet of bedrock was so mined. Unless it may be in some bench deposit affording exceptionally favorable conditions for a method of this kind, underground hydraulicking in Alaska on anything but a very small scale presents many difficulties which greatly outweigh the advantages of the regulation methods of drift mining.

In the Circle, Forty Mile and some of the more isolated districts there are a number of miners who work alone, and with the most primitive of methods take out a small dump each winter. A small shaft is sunk to bedrock in the frozen ground which ranges from 12 to 25 feet in depth, and an area ranging from 500 to as much as 2000 square feet is opened up. The frozen gravel is thawed with wood fires. Kindling is placed along the face over which a layer of dry wood is placed and the pile built up to a height of about 2 feet. This is then covered over with coarse gravel or rocks, or with a layer of green wood covered with a sheet iron plate. The placing and handling of these fires require experience, for the heat must be retained and held against the face, otherwise the roof will slough badly. Sometimes a number of fires are placed. The fires usually burn from 3 to 5 hours, thawing from 12 to 16 inches back into the face. They are generally ignited in the early evening, so that the thaw is complete by morning. Practice varies, for at one operation three piles of wood 8 feet long and 2 feet wide and high burned for 10 hours, after which the ground was "sweated" for 24 hours, thawing into the face to an average depth of 16 inches, or thawing about 40 bedrock square feet. Two shafts are sometimes used, placing them from 50 to 75 feet apart, so that while the gravel is being mined from one the thawing is being done in the other. At one place, a 60-foot adit was driven on a bench deposit to the edge of the pay and a 25-foot raise made to the surface for ventilation. Drifts were then driven a short distance up and down stream and the gravel removed by working toward the portal of the adit. The working face varied from 2 to 4 feet in height. This lone miner mines on an average of 1000 wheelbarrow loads of gravel each winter, which return from $200 to $400 in gold when sluiced the following spring.

Costs

The present day conditions for drift mining in frozen gravels are, in general, adverse to low costs, mainly because of the less favorable ground remaining and the smaller areas which limit the scale of the operations. When drift mining was at its height, frozen gravels were drift mined at several mines in the Fairbanks district, for as low as 40 cents per square foot, and in a few cases near Nome, costs of 25 cents per square foot were reported. In 1915, Ellis[37] estimated that the

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[37] Ellis, H.I., Winter Drift Mining at Fairbanks, E. & M.J., Oct. 30, 1915, p. 710.

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cost of drift mining in the Fairbanks district was 50 cents to $1.25 per square foot of bedrock, the average being 75 cents, basing his estimate on the duty of the shovelers which was taken at 30 to 35 square feet of bedrock per 10 hours, or equivalent to about 7 cubic yards of gravel in place. Present costs in the Fairbanks district range from 50 cents to $1 per square foot with several instances where the cost is $1.50. The average, however, is about 75 cents. Drift mining in the Tolovana district costs from 60 cents to $1 per square foot with a cost of 50 cents being reported from one operation where the gravel is light and conditions are generally favorable. In the Ruby district where the pay channels are rarely more than 75 feet wide and conditions generally adverse to cheap mining, the operating costs at 6 mines in 1922 ranged from 60 cents in the more favorable instances to $1.25 where adverse, averaging 85 cents per square foot or about $5 per cubic yard. The average cost of steam thawing here was 45 cents per cubic yard and 35 cents for sluicing.

In 1914, Gibson[38] reported the operating cost per cubic yard,

[38] Gibson, A., op cit. p. 404.

exclusive of preparatory work, at 5 operations at Nome as follows: thawing from 27 to 50 cents; mining 94 cents to $1.25; sluicing 9 cents to 64 cents; the total operating cost, $1.40 to $2.41. The total height of the working faces varied from 4 to 5 feet; from 16 to 20 men being employed and from 60 to 158 cubic yards of pay gravel being hoisted per day of 2 ten-hour shifts from shafts 45 to 81 feet deep. Drift mining at Nome has now practically passed for most of the remaining ground is adverse for profitable drift mining. Lumber for timbering, and fuel oil for steam generation is used there, and most of the available ground has been acquired by dredging or hydraulic mining interests. There are but few places there now where ground containing less than $4 in gold per cubic yard will return an operating profit by drift mining.

Hydraulic Mining.

Hydraulic mining, as interpreted in this report consists in the washing down or excavation of the placer and the transportation of the material to the sluices by the use of water under pressure; followed by the sluicing of the material and the disposal of the tailing. To assist in the transportation and sluicing, an additional supply of water known as groundsluice, by-wash, or bankhead water is usually required. The most important requirements for hydraulic mining are -- an ample, steady and cheap supply of water under high pressure; and an adequate bed-rock grade for the sluices and to provide dump room for the tailing.

Hydraulic mining in Alaska is being conducted in the beds of the creeks, or in bench deposits most of which are only slightly elevated above the creek level, so that adequate grades are generally lacking. These creek deposits vary from a few feet to 25 feet in depth; while the benches containing similar depths of gravel are more often overlain by muck or barren overburden, so that total depths of 40 to 50 feet are not uncommon. The bench deposits in Alaska are not characterized by the great thicknesses or extent as some of those in California although in southern Alaska and the Upper Yukon country, there are some auriferous benches up to 100 feet or more thick containing mostly gravel but which in most instances are so situated that they will not support profitable hydraulicking. As a general rule, the Alaskan placers have the gold concentrated close to the bedrock surface. Therefore, if the pay gravel is overlain by great depths of barren gravel, profitable hydraulicking can only be conducted if other conditions are unusually favorable. There being less barren gravel overburden to handle in the case of the shallower placer and consequently the gold content per unit of volume being greater, it is natural that such placers are the principal ones now being hydraulicked. Shallow placers, however, necessitate frequent moves of the plants and sluices causing a loss of much valuable time when the water supply may be at its best, and adds to the cost. The presence of boulders is not such an important consideration as it would be in other methods of mining. Some boulders are found in most of the placers but if occurring in large numbers may prohibit mining. At many of the hydraulic mines in Southern Alaska, boulders are encountered in exceptionally large quantities which partly counteract some of the advantages that this part of Alaska may have over some of the interior and Seward Peninsula districts where the percentage of boulders present in the placers being hydraulicked, are generally less.

A soft regular bedrock which can be readily cleaned with the giant is also one of the requirements for low cost operation. While this feature is not unfavorable at many of the mines; at others, there are hard, blocky beds interbedded with the softer formation or the formation may be cut by numerous dikes, causing an irregular bedrock surface. Much of this irregular bedrock can be cleaned up with the giants or with small canvas hose and nozzle outfits but unless this piping is properly done, gold may be driven deeper into bedrock. A final cleaning by hand, especially if bedrock is creviced, is then generally necessary.

The presence of stiff clay is troublesome, being difficult to break down with the nozzle and may require blasting to aid in its disintegration. Sticky clay is most difficult to wash although in hydraulic mining such material can generally be well disintegrated by the giants before it is put into the sluices. Cemented gravels are of rare occurrence in Alaska.

With the exception of some of the relatively small placer districts in southern Alaska, the long continued conditions of erosion have produced very low stream gradients. Thus, the average fall of most of the streams where placer deposits are found on the Seward Peninsula and the interior districts, range from 25 to 150 feet per mile. The grades in southern Alaska are generally higher, more often being from 100 to 200 feet, and in some instances exceed this. Local irregularities in bedrock may provide steeper grades than the average, and the tributaries and the upper reaches of the main streams are generally steeper. A grade of 3 inches to 12 feet or 110 feet per mile is considered the minimum over which gravel can be economically moved through the sluice boxes without employing an excessive quantity of water. Hydraulicking in the stream beds or low lying benches adjacent to the stream, therefore, requires a plentiful supply of groundsluice or by-wash water to partly offset the low grades, and it may become necessary to adopt a special method for hydraulicking whereby a better sluice grade can be created. Natural dump facilities are also generally lacking, necessitating the stacking of the tailing.

Groundsluice or by-wash water is conducted over the bank or to the sluices through open channels and is generally the surplus creek water after the giants have been supplied. The quantity available is usually small, especially during the greater part of the average season. The amount of groundsluice water required is governed principally by the grade of bedrock, the character of the material and the size of the sluices. It is therefore customary under average Alaskan conditions, to use as much as is normally available so that from one to three times the quantity as that supplied by the field giants may be used at some of the operations. From [illegible] to 2000 miners inches of groundsluice water is used at the largest of the operations in southern Alaska.

The conditions governing water supply and the construction of dams, water conduits, pipe lines, etc. have been discussed in the chapter on water supply, and to which the reader is referred as it deals principally with the supply for hydraulic mining. In general, it can be stated that conditions are adverse for obtaining large supplies at high heads although a number of the operations in southern Alaska have such favorable supplies. Similar conditions are found on the Seward Peninsula, where however, it has required the construction of long expensive ditch lines which under present day conditions would not be justified. Fluctuations in the flow are pronounced, especially so, in the interior districts where the water supply is generally small and under low pressure. Favorable reservoir sites for impounding large quantities of water are very seldom available so that practically no operation escapes the handicap of a reduced water supply during a part of the season. Many have to discontinue hydraulicking entirely during low water periods while others continue only at greatly reduced capacity. Interior operations are especially characterized by the use of small quantities of water which have been impounded and released intermittently for short periods.

The season for hydraulicking is established by the climate which naturally affects the water supply. Besides the handicap occasioned by a drought, the supply is quickly reduced when the temperature drops to freezing. The hydraulicking of the gravels usually does not start until early in June and seldom continues after the first heavy freeze late in September. Most of the preparatory work is done in April and May or after the completion of mining in the fall. Varying climatic conditions may extend this period but the average season is from 90 to 120 days and in high elevations where snow water must often be relied upon, the season may not be over 20 days. Many of the operations realize but a small part of this short season. Disregarding the time that may be lost through lack of water, the time during which the actual hydraulicking of the gravels is done in most cases, amounts to only 50 to 70 per cent of the available season, the balance of the time being spent in moving, setting up, cleaning up, etc. It is, therefore, evident that usually less than half of the season is actually spent in moving the gravels and where only one shift is worked this may be less than a quarter of the time.

The smaller hydraulic mines predominate in Alaska, for having comparatively small amounts of capital invested and employing only from 2 to 8 men are best able to meet conditions. The many small operations have from 50 to 600 miners inches of water available under heads of from 30 to 200 feet and in an average season will mine from 2000 to 30,000 cubic yards of gravel. The larger mines most of which are situated on the Seward Peninsula and in Southern Alaska have from 600 to 2500 miners inches of water under heads of from 100 to 300 feet and mine from 30,000 to 150,000 cubic yards in an average season. There are very few instances where 1000 or more cubic yards of gravel are put through the sluices per day; or where the water supply is greater or at higher head than the limits mentioned. Several operations in Southern Alaska exceed this daily yardage if the average is taken only during the period of actual hydraulicking. Other exceptions in both daily yardage and water supply. are found at several of the hydraulic elevator plants on Seward Peninsula which will be discussed under separate heading.

The capital invested in the water supply, hydraulic equipment and for opening up the property is most variable because of the many differing conditions. The cost of bringing the water to the property under pressure is generally the main item. Some of the operations have the use of water conduits constructed by former operators, and some have been able to obtain used hydraulic equipment at a very nominal cost. Many of the small mines operating under low head and with small outfits have been equipped with pipe, giants, etc. at a cost of from $1000 to $3500. Hydraulic mines operated under average conditions and handling between 250 to about 750 cubic yards of gravel per day have from $3500 to $15,000 or more invested in equipment. Larger plants involve investments up to $100,000. Within these limits, the cost of the dam, ditch line, etc. may be included, excepting where the ditches are of large capacity and long length. There are numerous instances where from 1/4 to one million dollars, and a few where it has been more, have been spent in water supply, equipment, and opening up the property, so handicapping the operation that profitable results were impossible. The life of the average Alaskan hydraulic operation on creek or shallow bench ground, is from 5 to 10 years. There are a few hydraulic mines that have been active for longer periods while others are operated periodically by leasers or through changes in ownership.

In spite of the numerous adverse conditions which have been mentioned hydraulicking has an important place in Alaskan placer mining. At most of the operations where this method is used, it generally applies itself better than any other method that could be employed. There are, however, numerous creek placers being hydraulicked, or are being worked by other methods, where the volume of material mined each season is ridiculously small, especially when the investment in a water supply and equipment is considered. Conditions at some of these properties were favorable for dredging by which method the ground could have been worked out in easily one fifth of the time at a much less cost and no doubt with a better gold recovery.

Duty of Water:

The duty of water in hydraulic mining is usually stated as the number of cubic yards of material which can be broken down and put through the sluices by one miners inch (1 1/2 cubic feet per minute) in 24 hours. It varies with the depth and character of the material, the character and grade of bedrock, size and grade of the sluices, type of riffles, the quantity and pressure of the water, facility for disposal of tailing, and the skill of the operator. The duty of water must be at least approximately known before estimates can be made as to the possible scale of operation so that a properly balanced plant can be installed. It is also a most important factor in determining the efficiency of the operation. Unfortunately very few of the Alaskan operators measure the amount of water used or keep account of the time during which the water was turned on, consequently complete or accurate data is seldom available.

The table on the duty of the miners inch in Alaska, includes data of engineers to whom acknowledgment is made, and estimates based on the data obtained from the operators. As stated, some of this latter information was incomplete but where possible the missing data was closely calculated and the approximate duty of the water derived. These estimates are given mainly to show the generally low duty obtained

Duty of Miners Inch.

Locality	Height of bank ft.	Sluices Width Inches	Depth Inches	Grade Inches	Riffles	Head in ft. on field giants	Miners inches of water	Duty cu.yds. in 24 hrs.	Remarks.
Seward Peninsula.									
a Anvil Creek	30	33	18	4 1/2	Angle iron	-	500	1.4	Heavy partly frozen gravel; much flat schist
a Anvil Creek	4 1/2	-	-	-	-	-	100	3.0	Frozen muck stripping- 3 inch grade- ditch head water.
a Anvil Creek	20	-	-	-	-	-	400	10.0	Frozen muck stripping 4 1/2 in. grade.
a Anvil Creek	30	30	24	3-5	Blocks	150	543	2.63	Unfrozen, coarse, subangular, gravel. Hydraulic elevator.
Glacier Creek	15	30	30	4	Ungrate	30	(c) 700	1.00	Unfrozen, med. gravel, much flat schist. (f)
Big Hurrah Creek	6	36	18	6	Rails	-	(d) 900	1.20	Unfrozen med. gravel, much flat slate. (f)
Little Creek	15-35	48	24	5-7	A.1.. rails	300	-	1.25 -1.5	Partly frozen, med. gravel Hydraulic elevator.
Osborne Creek	9	36	24	7	Blocks,rails	170	750	1.2	Partly frozen, heavy gravel Hydraulic elevator.
Osborne Creek	2 1/2	-	-	-	-	160	600	5.4	Stripping, moss and muck with giant.
Ophir Creek	9	-	-	6	Blocks,rails	-	-	1.1 - 1.35	Partly frozen medium gravel.Hydraulic elevator
Mt. McKinley Dist.									
Moore Creek	10	24	20	6	(d)+(e)	-	(c) 300	1.6	Unfrozen medium round gravel. Stack tailing 2 hrs. a day.

Fairbanks Dist.

Fairbanks Dist.									
Pedro Creek	15	36	30	11	Blocks	-	350 [c]	1.2	Partly frozen heavy gravel. (f).
Pedro Creek	6	36	30	5	Rail	130	400 [c]	0.8	Partly frozen med. gravel. (f).
Goldstream Creek	8	-	-	-	-	-	200	3.5	Stripping muck with pumped water, 3% grade.
Circle Dist.									
Mastodon Creek	10	30	24	8	Blocks	100	500 [c]	0.7	Partly frozen round medium gravel. (f)
(b) Mastodon Creek	12	30	-	-	Blocks	100	240	2.5	Partly frozen gravel, [illegible] 10 hour inch. (f)
Seventy Mile Dist.									
Crooked Creek	7	30	24	8	Blocks	60	460 [c]	1.2	Partly frozen light gravel (f).
Yentna Dist.									
Falls Creek	3	36	30	8	(e)	100	300 [c]	0.9	Unfrozen medium gravel. Boulders. (f).
Nugget Creek	6	28	24	7	(e)	300	450 [c]	0.8	Unfrozen medium gravel. Boulders. (f).
Peters Creek	9	30	24	6	Rails + (e)	165	800 [c]	0.8	Unfrozen medium gravel. Boulders. (f).
Denali Region.									
Crow Creek	10	52	36	6"	Rails	145	2500 [d]	0.5	Very coarse wash. Many large boulders. Use much G.S. water. (f).
Nizina Dist.									
Dan Creek	10-18	48	44	5	Rails	275	-	0.25 -0.4	Unusually coarse wash and many boulders. Much G.S. water. (f).
Chititu Creek.	10	40	36	5 1/2-6	Rails	250	2100 [c]	0.35-0.5	Heavy gravel, many boulder Much G. S. water (f).

a Purington, C. W. b Mills, R. I.

c Includes groundsluice water.

d Punched plate over matting.

e Longitudinal steelshod riffles.

f Stack Tailing with a giant.

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

The general y low duty is accounted for mainly by the low bedrock and sluice box grades; by the general low water pressures; by the large amount of water used by the elevator or that used by the stacker giant, or the large amount of groundsluice water, as the case may apply. At some of the Nome operations much of the material is flat, while in the Southern Alaskan districts the gravels are unusually heavy and generally large amounts of groundsluice water are required. Frozen ground conditions at some of the operations may lower the duty materially, while at others the giants can pipe the frozen material as fast as it can be transported to the sluice boxes. Examples are unfortunately lacking on operations where it is not necessary to either elevate the material or stack the tailings. Under such conditions a duty of 3 to 4 cubic yards should not be uncommon. Tables on giants published by manufacturers usually show that the duty of a giant under average conditions is taken as being approximately 3 cubic yards. In hydraulicking the small rounded gravels of the "White Channel" bench in the Dawson country, the water duty ranged from 2 to 10 cubic yards with sluice grades of 12 to 14 inches.(39) The duty at the Yukon Gold Company's

(39) Purington, C.W., Gravel and Placer Mining in Alaska, U.S.Geol. Survey, Bull. 263, 1905, p. 139.

operations on Bonanza Creek ranged from 4.50 to 6.60 cubic yards.

Water under high pressure is more effective than under low pressure, and the duty of the water is apt to be low when the head is less than 200 feet. Purington(40) contends that an increase in head will

(40) Purington, C.W., op cit. p. 134.

not increase the amount of gravel which can be moved to the sluices, for the force of the water is entirely expended in piping against the face, while the sluice is the governing factor in moving the gravel after it leaves the face. While it is true that a given quantity of such spent water will only move a certain amount of gravel to and through the sluices, being dependent on the grade over which it runs, a high head delivers more water, and will more readily disintegrate the material than a lower one, provided other conditions are equal It is also customary Alaskan practice to get behind the material and drive it into the cut and to the sluices, where a high head will move it more readily and farther, thereby permitting the working of larger pits and requiring less frequent moves of the giants.

Hydraulic Mining Methods

The many differing conditions governing hydraulic mining have caused the development and adoption of various methods. While the general principle of all of the methods may be quite the same, there are different ways in piping down the material; in delivering it to the sluices; in placing the sluices; and in disposing of the boulders and the tailing. The methods used for removing the moss, the muck and in some instances the barren sand, gravel and other overburden, prior to the hydraulicking of the pay gravels, have been described in the chapter on "Stripping".

The hydraulicking of bench deposits elevated well about the stream levels, is a comparatively simple matter when a fair water supply is available, as adequate grades for sluicing requirements and dump room for the natural disposal of the tailing are generally provided. Where a deep bench deposit under such conditions is to be mined, the operation may be started at the rim or the exposed face of the deposit, or an adit may be driven in the bedrock, or a deep cut sluiced out, until the pay channel is encountered. In the case of an adit, a raise is driven from it to the surface, which is later enlarged by piping the surrounding material into it until a pit is opened. This was done in opening the lake bed deposit in the Silver Bow Basin back of Juneau, where a long tunnel was driven through solid rock tapping the deposit and through which the tailing was conducted to the dump. Similar means have been used in opening up some of the high bench gravels in California and elsewhere. The sluice boxes are then placed in the tunnel, or in the cut, as the case may be. The giants are set up in front of the bank, but at a safe distance away, and directed against the bank, which is undercut, caved and broken down and transported through bedrock sluices to the main sluice or sluice boxes. These bedrock sluices are kept well up to the face and if the formation is hard or irregular, they may be an item of considerable expense. Steel fluming or chutes are sometimes laid on bedrock to assist in moving the loose material to the sluices. It is more customary to get behind the material after it is broken down and clear of the face and drive it into the head of the boxes. Two or more working faces should be provided so as to permit continuous operation. A side swipe along the gravel bank with the nozzle will break down more gravel than where the water is permitted to pound "dead" against the face. For undercutting the smaller sized nozzle is generally the more efficient. When the deposit is frozen, undercutting is a slow and unsatisfactory operation for not only is it difficult to cave a frozen bank but on caving it will usually break off in large chunks which may be troublesome. Constant application of the pressure water against the frozen face is poor practice. Better results can generally be obtained by piping deep vertical cuts into the bank to expose a large area to the elements, and nozzling off the thawed material from time to time.

Where the shallower placers are hydraulicked, it is the more general practice to set the giants on top of the bank, getting behind the material and driving it into the pit and to the sluices. Advantage is so taken of the grade and the material is driven ahead in the desired direction as it is loosened, and in frozen ground permits a larger area to be exposed to the elements for thawing.

Before the mining of creek deposits can be undertaken, ample provision must be made for diverting the creek and all excess water around the workings as stated under "Water Supply". Special consideration must also be given toward safeguarding the operation from high floods which are of common occurrence in the narrower valleys.

Hydraulic mining methods as practiced in Alaska, excluding the bench method mentioned or where hydraulic elevators are used, can be divided into three general classes:

(a) Piping the material into the head of the boxes.

(b) Piping the material over the side of the boxes.

(c) A combination of both (a) and (b).

Methods (b) and (c) are special methods that have been developed to meet some of the adverse and limiting conditions encountered in mining the creek placers and are also applicable to some bench placers. Method (b) can be divided in three general classes based on the position of the sluice boxes in relation to the surface of the bedrock, as follows:

(1) The sluice boxes all set in bedrock, the tops being below the surface.

(2) The lower boxes in or on bedrock, the upper ones on or above bedrock surface.

(3) All ~~[crossed out]~~ or a part of the boxes on or elevated above bedrock.

There are naturally variations in practice, but only the more distinctive and important methods can be given consideration. The selection of the best method for a particular operation is dependent on many limiting factors, each method possessing certain advantages. The size of the pit that can be mined is governed principally by the head or pressure of the water and will therefore range through wide limits.

(a) Piping into the Head of the Boxes

This method is in most general use in Alaska and is best adapted for hydraulicking shallow benches, and comparatively narrow creek deposits where the bedrock gradient is 6 inches or more to 12 feet. Its application in connection with the mining of the deep benches has been mentioned. One of the principal advantages of this method is that all of the water used reaches and is available for the sluice boxes, so that a comparatively small volume of water will often suffice. For this reason it is the method most always adopted by those operations having small water supplies or where the water is used intermittently. A relatively short string of sluice boxes are generally set so they can usually be given a higher gradient than that of bedrock by taking advantage of local irregularities, or because of the shorter bedrock excavation necessary to obtain such grades. Lightly constructed sluice boxes are used and the installation for a pit can generally be quickly made, which is a big advantage where the placer is not over 6 or 8 feet deep and other conditions exist which necessitate the working of small pits and consequently frequent moving and setting up.

The sluice boxes are first installed at about the middle of the lower end of the purposed pit and depending on the character and grade of the bedrock, are placed on or in the bedrock, with the head of the boxes low enough in bedrock to permit proper entry. These same conditions and those governing the tailing disposal, limit the number of sluice boxes to be installed. Where the bedrock is hard and the natural gradient is low, but 3 or 4 boxes are generally used, while under more favorable conditions there may be 6 to 12 or more. Timber or board wings are erected at the head of the boxes, one on each side, and angling slightly upstream. These serve as backstops and a chute for the water and material. As a rule, the field giants are set on top of the bank, at a distance upstream from the wings dependent on the pressure. At the average operation one or two field giants are used; if only one, it is placed at the upper end in line with the sluices or shifted about as required; if two are used, one is placed near each upper corner of the purposed pit.

The material is then piped towards and into the head of the boxes. Pits from 300 to 450 feet long have been mined by this method, where the water pressure and other conditions are favorable. In pits of this size, however, intermediate or "booster" giants are used and the material moved along in stages. Where a satisfactory sluice box gradient can be procured, a succession of short pits can be mined by extending the sluices upstream after each pit has been piped in; but this practice may give little advantage if the tailing must be stacked. Pl. 2249 illustrates such an operation on a shallow bench in the Hot Springs district. Note the hose and nozzles. As much more material can be

(22494) Hydraulic mining. Piping into the head. Sluice box extension.

(24527) Hydraulic mining in Yentna district. Piping into the head.

moved through a sluice box than through the ground sluice or bedrock sluice, the giants should not be too far removed from the head of the boxes or the duty of the water will be greatly reduced. Some operators allow the head of the boxes to be above bedrock, or bedrock conditions sometimes make this necessary. The material must then be piped up a slope before entering the boxes and the water backs up in the pit. At most of the operations where there is an average bedrock, a sump or pothole is almost certain to develop ahead of the boxes. This impedes the flow of the water and material, requiring additional piping to move it on and into the boxes.

A typical operation of its kind is conducted on Falls Creek in the Yentna district. The creek deposit averages 6 feet in depth and consists of unfrozen, rounded gravel, 10 to 15 per cent of which is in boulders, the largest being about 3 feet in maximum dimension. Bedrock is a coal formation of clay, shale and sandstone, and easily cleaned with the giants. The average pit mined is 80 feet wide and 125 feet long. Two field giants with 3-inch nozzles working under a 100 foot head are set on top of the bank so that while one giant is piping into the head of the boxes on one side of the pit, the boulders are removed from the other side and piled by hand on cleaned bedrock. Pl. 24627 shows the general pit and sluice arrangements, the boulder removal, and giant stacker. Because of the low grade of bedrock from 42 to 54 feet of boxes are all that can generally be installed. These boxes are 36 inches wide and 20 inches deep, set on an 6-inch grade and provided with steel shod 2 by 4 riffles placed lengthwise. The tailing requires constant stacking by a giant with 5-inch nozzle. The water supply, including ground sluice water, varies from 250 to 700 miners inches. The average crew consists of 6 men divided into two 10-hour shifts. During periods of maximum water supply, an area of about 1000 square feet can be mined in two shifts, or the average pit completed in 8 to 9 days. A set-up for a new pit is made in one day. During one of the most favorable seasons, 70,000 square feet of ground, averaging 9 feet deep, which included one foot of bedrock, was mined in 75 days at a cost of 7-1/2 cents per square foot or 22 cents per cubic yard.

Average costs are from 30 to 35 cents per cubic yard. About $5000 is invested in the 1600-foot ditch and the hydraulic equipment.

A large hydraulic operation is conducted on Crow Creek in the Girdwood District, where the unfrozen creek deposit varies from 6 to 25 feet in depth, averaging 12 feet. The gravel is unusually heavy, about 50 per cent being over 6 inches in diameter with many large boulders. A false bedrock of tough clay is usually mined to, the true bedrock being a slate and graywacke, all being readily cleaned with the giants.

The usual practice has been to mine an area in two paralleling and adjoining pits, each from 100 to 150 feet in width and 400 to 450 feet long. Each pit is worked separately but kept abreast and each has its own sluice boxes. This permits the pits to be alternately used as a by-pass for the creek water and while the boulders are being handled in one pit, piping is done in the adjoining one, permitting practically continuous operation.

A No. 7 giant with 6-inch nozzle working under a 145 foot head is set on top of the bank of each pit and sometimes another giant of

(24552) Hydraulic mining on Crow Creek. Double sluices.

(24554) Hydraulic mining at Crow Creek. [illegible]ings and sluices.

similar size is set midway between them. The gravel from each pit is then piped down and driven into the head of the boxes, which are provided with the heavy timber wings. See Pls. 24554 and 24552. As the giants are moved up stream and the distance to the head of the sluices becomes too long for the giant to reach, a smaller "booster" giant is set on bedrock at one side of the pit and about half way down. The head giant then drives the gravel into the field of this booster giant, which in turn pipes it on and into the head of the boxes. After the gravel in both pits has been piped in, the gravel between the pits is removed and the bedrock is given a final cleaning with the giants. The boulders are drilled with air drills and blasted, and put through the sluices with the rest of the material. A No. 7 giant with 5-inch nozzle under 170-foot head stacks the tailings from both sluices. The boulder and tailing disposal will be more fully described under those headings.

The sluice boxes are 5 feet wide and 3 feet deep set on a 6-inch grade, from 6 to 12 lengths of boxes being generally provided for each line. Rail riffles of 40 lb. weight set transverse, are used in the first two boxes, the balance being 25 lb. rails set lengthwise. From 1000 to 1400 miners inches of ground-sluice water in addition to the giant water, passes through the boxes. Including the water for stacking the tailing, about 2600 miners inches are normally used, giving a water duty of about 3.5 cubic yards. In 1923, 66,000 cubic yards were mined, the crew ranging from 12 to 18 men. The cost of mining exclusive of royalty paid for the use of the equipment and for the claims, was 43 cents per cubic yard. This property was equipped and opened up over 15 years ago at an expense of about $250,000. Present equipment in use and the 1-1/4-mile ditch line would cost about $30,000 to replace.

(b) Piping over the side, the sluice boxes all set in bedrock, the tops being below the surface

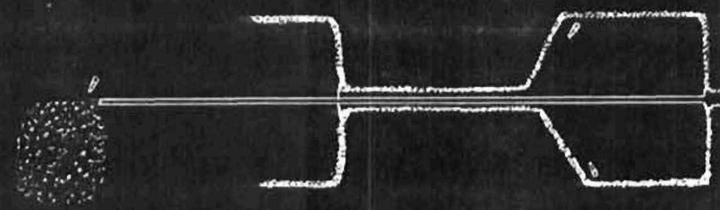
(1) This method is used in the Nizina district for the hydraulic mining of creek deposits and is especially well adapted for the conditions encountered there. The piping over the side is done in two ways; with one, it is started at the upper end of the purposed pit, working downstream; with the other, the start is made at the lower end working upstream. Each has its merits, which can be best shown in the

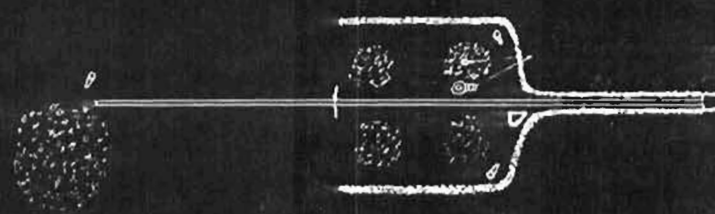
description of the operations where they are employed.

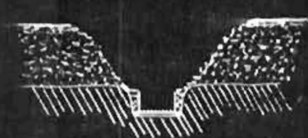
The Dan Creek Mining Co. on Dan Creek conducts one of the largest hydraulic operations in Alaska. The creek deposit mined by this method varies from 6 to 15 feet in depth. The gravel is rounded but unusually heavy, containing up to 75 per cent of material over 8 inches in diameter, some boulders being 6 to 10 feet in maximum dimension. The bedrock is a slate formation of varying character and hardness, and is cut by occasional hard porphyry dikes which form high ridges, although in general the bedrock is not hard and the average contour is quite regular. The gold is coarse and heavy and of the "pumpkin seed" variety, from 40 to 60 per cent will remain on a 1/4-inch screen. Large quantities of copper nuggets and some native silver are also present.

The size of the pits mined usually range from 500 to 700 and more feet in length and from 175 to 300 feet in width. After a pit has been completed a line of sluice boxes, 4 feet in width, are set in the upper end of the old rock sluice and just at the lower end of the proposed pit, and are paved with longitudinal rail riffles. While dependent on tailing requirements, usually from 16 to 20 of these boxes are installed but never less than eight. As soon as the water begins to run in the spring, short wings are constructed at the head of these boxes, and with a giant with 4-inch nozzle, a central cut running the full length of the purposed pit is piped through the gravel and into bedrock. The bedrock sluice is made about 6 feet wide and 5 to 6 feet deep or deep enough so that the tops of the boxes will be a foot or two below the surface of bedrock. Pick work is required in making this sluice, and while the harder portions must often be blasted, as little blasting as possible is done.

The maximum grade obtainable for the sluice boxes ranges from 5 to 5-1/2 inches, although grades as low as 3-1/2 inches have been used. The sluice boxes, which are 45 inches wide and 46-1/2 inches deep, inside dimensions, are then installed for the entire length of the bedrock sluice, connecting with the lower boxes. They are equipped with 20-pound rail riffles spaced at 4-inch centers, placed lengthwise and spiked to 6 by 6 inch ties. One and one-half inch boards are used to line the







Original sketches accompany original
copy of report

Fig. 6a - Plan showing hydraulic mining method of piping over side of boxes, advancing downstream.

Fig. 6b - Method of Piping over the Side
Advancing Upstream

Section across bedrock cut, showing position of sluice boxes in relation to bedrock inside of the boxes, while the outside is protected by nailing heavy slabs or old boards along the upper parts.

The general set-up and arrangement of the workings are shown in Fig. 6a. A large amount of ground sluice water is turned into the head of the sluices, generally about twice as much as that supplied by a field giant, so that the boxes run practically full when a field giant is operating. The initial cut is first made to bedrock at the upper end of the pit after which two No. 4 giants with 5-inch nozzles working with a head of 275 feet are placed on bedrock, one on either side of the sluice and well to the outer edge, as shown in the figure. While the giant on one side is piping the material along the diagonal face and over the side into the sluices, the boulder crew is preparing to blast the boulders by "bulldozing" on the other side. See boulder disposal, p. 340 Thus, the piping and boulder operations alternate from one side of the sluice to the other. As a rule, 2 to 3 periods of each are required to get to bedrock.

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

The upper boxes and rock sluice are sometimes cleaned up as the work advances to safeguard against theft or flood, but generally the entire pit is completed before the clean-up starts. The clean-up is made during the day shift only and is done by a well organized crew of ten men. Generally 10 boxes are cleaned up and removed at a time. With the water cut down to the proper point, the rails from the upper or first ten boxes are removed, the heavier material and the coarse copper nuggets are forked out, and the balance worked down the sluice and cleaned up. The timber guards and the sides of the boxes, except the lower board, are then removed and with the canvas hose outfits, one on each side of the sluice, the material alongside is piped in and another clean-up made. The remaining parts of the boxes are then removed and the material in the rock sluice hosed down as clean as possible to the boxes below. The next ten boxes are similarly handled and after the entire sluice has been cleaned, an average of 75 to 80 feet being so cleaned up in a day, a final clean-up of the rock sluice is made. This is done by the foreman and 4 men who pick out the crevices, and with a water syphon put all the material through two lengths of 12-inch riffled boxes which are placed across the rock sluice and moved along as the work proceeds. This final clean-up requires from 5 to 6 days under average conditions. Pl. 24537 and 24540 show the completed pit with the clean-up under way.

About 18 men are generally employed, the regular pit crew for each shift of 10 hours consisting of a foreman, nozzleman, stackerman, sluice tender, powder man, powderman's helper and 2 or 3 extras, with the shifts so arranged that the hydraulicking is practically continuous.

(24537) Hydraulic mining on Dan Creek. Completed pit showing bedrock sluice and removal of the boxes.

(24540) Dan Creek. Removing and cleaning up the sluices.

According to the manager, Mr. C. Howard Birch, the average water duty per miners inch is 0.25 cubic yards, the duty being more dependent on the volume of water used than on the pressure. This low duty is accounted for mainly because of the unusually heavy material and the low gradient, requiring large quantities of ground sluice water.

Two pits were completed in 1923, which was an exceptionally favorable season for hydraulicking. No. 1 pit was 528 feet long and averaged 165 feet wide; No. 2 pit was 480 feet long and averaged 170 feet wide. The No. 2 pit which averaged only 6 feet in depth, required 9 days for making the set-up, 17-1/2 days for hydraulicking and 10 days for the clean-up. For both pits, 22 days were taken to make the set-ups, 42 twenty-four-hour days for hydraulicking, and 26 ten-hour shifts for the clean-up. The expenses for the season were $34,124. About $100,000 has been invested in the water supply and equipment.

The entire operation is conducted in a most systematic and business-like manner and is one of the few hydraulic operations where accurate detailed accounts are kept of the operating data and the costs.

These are given in summarized form in the following table:

Hydraulic Mining Costs - Dan Creek Mining Co.

Costs per Cubic Yard	1916-1920 Average. a	1921	1922
Operation	$ 0.091	$0.141	$0.081
Deadwork	.087	.159	.104
Explosives only	.054	.108	.046
	0.232	0.408	0.231
Overhead, etc.	.103	.242	.102
Total	0.335	0.650	0.333
Operating Data			
Av. depth in feet	25.4	12	18
Sq. ft. of bedrock mined	131,294	140,218	154,786
Cu. yds. mined	113,843	62,318	103,190
Actual 24 hr. days operated	94.2	64	77.1
Av. no. of men employed	18.4	17.5	16.8
Av. wage per shift, mess incl.	6.04	6.57	6.39
Mess cost per man day	1.43	1.68	1.62

a Average per season over a period of five years, during which time 569,214 cubic yards of material were mined, the total costs ranging from 19 to 60 cents per cubic yard.

The above data includes a small yardage mined on the benches.

A similar method, but differing in the boulder disposal and the construction of the sluice boxes is used at the No. 1 operations of Jno. E. Andrews on Chititu Creek in the Nizina district, the operation being well illustrated in Pl. 24543 and 24544.

At the No. 9 operations on this Creek, while the set-up is made in a manner very similar to that on Dan Creek, the piping starts at the lower end of the pit and advances upstream. See Fig. By alternating from one side of the sluices to the other, the material is piped along a face at about right angles to the sluices or tending to point upstream a bit. A point of the bank next to the sluice is often left to the last as a protection to the men clearing boulders on the opposite side. In other respects the methods used at No. 1 and No. 9 Chititu are very much the same. The boulders are loaded onto a steel stone boat operated by donkey hoist and piled on cleaned bedrock. The tailings are stacked by giant.

A special type of sluice box is used. Ties are placed cross wise in the bedrock sluice to which are spiked 20-pound rails, placed

(24643) Hydraulic mining on Chititu Creek. Piping over the side.

(24644) Piping over the side on Chititu Creek.

longthwise and spaced at 4-inch centers. These serve as the bottom of the sluice, the sides then being boarded up as at Dan Creek. Caps are, however, used to keep the tops of the boxes from collapsing. The grade of the sluices at No. 1 is 5-1/2 inches; at No. 9 it is 6 inches. The boxes are 3 feet by 3 feet in dimension and those below the pit are constructed with the regular bottoms. The clean-up is conducted in much the same manner as at Dan Creek, but as bedrock is generally softer and permits the cutting of a smoother bedrock sluice, this sluice can be more easily cleaned up.

In 1923, the No. 1 operation made a set-up for a pit 900 feet long, averaging 150 feet in width, but about 150 feet remained unfinished at a lower end at the close of the season. The average depth of the deposit was 10 feet. There were 39,326 cubic yards mined in 64 twenty-hour days. The labor and mess cost only, for making the set-up, hydraulicking and cleaning up is reported to have been 22 cents per cubic yard. At the No. 9 operations a pit 460 feet long, averaging 140 feet wide and 11 feet deep was hydraulicked in 44 twenty-hour days, the total yardage handled being 23,323 cubic yards. The labor and mess cost only, for the entire operation, was 21 cents per cubic yard. In 1924, the two operations mined 99,180 cubic yards, the average depth being 9 feet at an operating cost of 51 cents per cubic yard. Thirty-five men were employed.

The method of piping over the site with the sluice boxes all set below bedrock as described, is particularly adapted to the mining of creek placers that are comparatively wide and not too shallow, containing unusually coarse wash, and where the stream gradients are low. An ample steady water supply under high pressure and a large quantity of ground sluice water is required. To insure good gold saving, the gold should be coarse and heavy. The placer should be at least 10 feet deep with other conditions favorable to provide a sufficient volume of material to justify making the extensive and costly set up. The bedrock should be fairly regular and not too hard. With this method, the set-up for the entire season's operation can be made at one time and further permits practically the continuous use of the water during the season. No backstops are required, the gravel faces serving for this purpose. The dip, strike and contour of bedrock rock are some of the determining factors in comparing the advantage of working upstream or down. Working downstream from the head of the pit has the advantage of the grade, and the material being in motion in the general direction of the flow in the sluices on reaching them, can be more readily transported than when it is piped straight across or angling upstream, as is the case when the work advances upstream. In this latter case the material may come to practically a dead stop on striking the sluice flow, and must again be put in motion. This has a tendency to block the sluices. However, where there is much fine material present, the boxes can be easily overloaded by either system. The downstream system permits the sluice boxes and rock sluice to be cleaned up at any time as far as the work has advanced, which is a valuable safeguard against possible theft and flood. It may, however, be impossible to complete the entire pit by the end of the season with this system and the following seasons work be thereby handicapped, whereas with the system of working upstream, it is a simple matter to extond the pit.

(b) Piping over the sides of the boxes, with the boxes set as stated under (2) and (3)

The procedure in piping the material involves practically the same principles in both (2) and (3) so they will be treated together. The chief benefit of setting the boxes in these positions is that a higher grade can be given than natural conditions afford. The material from the lower part of the pit must be piped upstream before it is piped over the side of the boxes in order that a sufficient length of sluice boxes will be below to insure good gold recovery. As the tops of the boxes above this point are generally always above bedrock, most of the material must be piped up the low incline of gravel alongside the boxes. Some of the pressure water does not reach the boxes, so any additional volume of ground sluice water must be turned in at the head. The height to which the boxes may be placed above bedrock is governed mainly by the size of the material and the pressure of the water. When the heads of the boxes are placed 8 to 10 feet above bedrock, it is generally better practice to drive the material from the upper part of the pit downstream to a point where the elevation is less. The pressure water should be under high head so that most of the material can be readily piped up over the side, and to permit the working of a pit large enough to justify the set-up. The material should be of a comparatively small size, otherwise an unusual amount of the coarser rocks may have to be removed and piled out of the way. The method is used principally in the Forty Mile, Circle and Seventy Mile districts and to a small extent in some of the other interior districts, where the creek placers are from 8 to 12 feet deep or are of that depth after having been stripped of overburden.

On Eagle Creek, in the Circle district, the frozen creek deposit averages 18 feet in depth and 150 feet in width, the central 60 feet having been previously drifted out. To help thaw the ground and also to get rid of troublesome sandy material, from 6 to 8 feet of overburden is stripped with the giants, usually a season in advance of actual hydraulicking. About 6 feet of medium sized pay gravel, 4 feet of sandy clay which wedges out at the edges of the channel, and 1 foot of schist bedrock is piped to the boxes. The gold is coarse. Most of the boulders encountered are from old rock piles from former drifting operations. Many old drift timbers are also present. The average grade of the creek is 125 feet to the mile.

The general pit arrangements and sluice box set-up is shown in Fig. 7. A trench is first piped into bedrock and into the bank ahead and 3 to 4 boxes are set on 9-inch grade and light wings erected at the head. A head giant then pipes out to grade a cut down the center of the purposed pit connecting with these boxes. From 10 to 12 more boxes are then installed on a 7 inch grade. Steel standards fastened to each side of the boxes and meeting 4 feet above over the center of the boxes, support steel plates 1/4 inch thick, 5 feet high and 8 feet long, and which hang from a 3/4-inch pipe running from one standard to the other. While it is the aim to pipe the gravel so it will just roll over the top of the boxes and into them, these plates are necessary to stop flying material and water from going beyond. When piping, the bottoms of these plates are fastened to the opposite side of the boxes, as the piping is generally done from only one side at a time. The boxes are

36 inches wide, excluding the 1-1/2-inch liners, and are 24 inches deep. The bottom and sides are made of 1-1/4-inch material. A heavy timber with a quarter section cut out, so as to fit over the top and upper outer side of the boxes, is nailed along each edge as a protection from the piping. The upper 10 boxes or those on 7-inch grade are paved with high carbon steel plates 1/2-inch thick and cut square so they can be turned. These plates are laid on 2 x 4's running crosswise of the boxes, with a special spacing block so as to leave a 2-inch space between plates which acts as a riffle. These plates are used to save grade. The lower boxes are paved with 12-pound rail riffles, set lengthwise, spaced 2-3/4 inch centers with cast iron spacers and bolted together in sets 4 feet long. Depending on conditions, the lower end of the boxes may be resting on bedrock, or a foot or so below, while the head of the boxes may be from 6 to 10 feet above bedrock, so that the tops at this point are generally only a few feet below the surface of the gravel. Small wings are erected at the head to guide the ground sluice water.

The average pit mined from a set-up is about 150 feet square.

Eight field giants, 4 on each side of the boxes, are placed about as shown in Fig. 7. These are equipped with 3-1/4-inch nozzles and operated under 120 foot head. The stacker has a 5-1/2-inch nozzle operating under 135 foot head. Normal water conditions permit the use of only one field giant and the stacker at a time, so the field giants not in use are "plugged". During low water periods, water is impounded in a ditch reservoir, and necessitates intermittent operation, or splashing, for periods of about 1 hour in duration, averaging 8 to 10 of these splashes in 24 hours.

Giants B, which are first set on bedrock below the pit, pipe the material upstream into the field of giants A, and also drive some of it over the sides. The giants A do most of the piping over the side. The upper giant A drives the material over the side at a point usually below the first or second upper boxes, and also drives into the field of the others. Giants B are, however, used mainly to take up the lower gravel, clay and bedrock, and for final cleaning, being advanced upstream in stages. Giant C does the stacking, and along with the inner

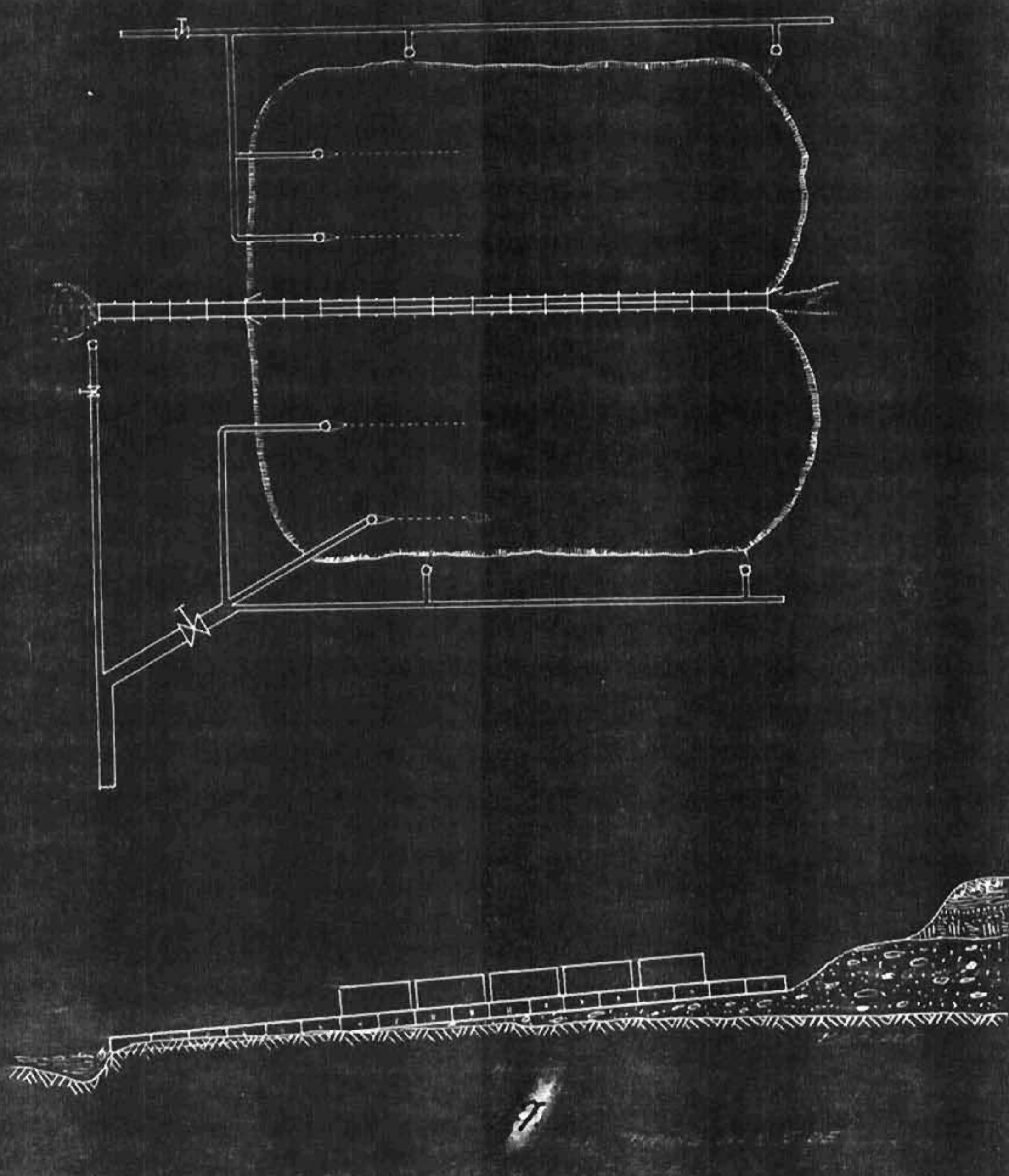


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Fig. 7
Hydraulic Mining Method "Piping Over Side" as used
on Eagle Creek, Circle District

giant B drives the material lying alongside the boxes to points upstream for piping over. Finally the boxes are cleaned up and removed, after which giants B and C drive ahead onto unworked ground, the remaining material which was left alongside and under the boxes and at points D, to be recovered in the next pit. Giant B finally pipes the short trench for the lower 3 or 4 boxes for starting the next pit.

The average crew consists of 6 men, two 12-hour shifts being worked when water is available. A complete set-up for a pit, exclusive of moving the pipe lines, can be made in 24 hours. One set-up of the main pipe lines serves for two pits. During an average season, from 2 to 3 pits are mined. In 1921, 20740 cubic yards were handled at an operating cost of 36.1 cents per cubic yard, and in 1922, 49860 cubic yards at a cost of 19.96 cents per cubic yard. During exceptionally dry seasons only stripping ahead can be done as the water supply is then too low to permit the regular hydraulicking. About $50,000 is invested in equipment and the 3 miles of ditch lines.

On Crooked Creek, in the Seventy Mile district, the creek deposit mined averages from 6 to 12 feet in depth. The gravel is of medium size with but few boulders. Bedrock formation is composed of alternating beds of sandstone, shale and conglomerate, some beds being harder and more resistant, forming occasional high ribs or reefs. A sticky clay sediment overlies all but the conglomerate formation. The average grade of the stream is 100 feet to the mile. The deposit is stripped with giants well ahead of mining, leaving from 5 to 6 feet of gravel and from 1 to 2 feet of bedrock to be mined. The average pit mined is generally 125 feet long and from 80 to 150 feet wide, depending on water pressure and width of the pay. The trench is piped out and the sluice boxes are placed in much the same manner as at Eagle Creek. Generally from 10 to 14 boxes are set, these on a grade of 8 inches to 12 feet. The lower end of the boxes are usually set just below bedrock, while the head is 1 to 3 feet above bedrock, although in one set-up this was 12 feet above, which was found to be much too high for good work. The boxes are 20 inches wide and 24 inches high, constructed according to regular design of 1-inch sides and bottom. These are paved with block riffles, made up in sets and held in place by special lining boards which are bolted to the sides of the boxes.

These liners are made up in sets 12 feet long. 2-inch boards being bolted together, making them high enough to come flush with the tops of the boxes. Old boards or slabs are nailed lengthwise to the side braces of the boxes and a 1-1/2-inch board strip is nailed lengthwise along the top edge, so that the boxes are fully protected from the force of the piping. Board aprons or backstops are hung centrally along the boxes from standards made of 2-inch pipe, being similar in principle and purpose to those used at Eagle Creek. Pl. 28278. At some of the other operations, board backstops are erected along one side of the boxes opposite to the piping, instead of hanging them from standards.

Four field giants are set, (a) two on the bank near each upper corner of the pit, and (b) two at the lower edge of the pit on bedrock. The field giants use 2-1/2 or 3-inch nozzles depending on the water supply. These now operate under only 60-foot of head, although 150 feet was available at the former work further down the Creek. This low head is handicapping the operation and a higher ditch is being constructed. The stacker giant (c) with 5-inch nozzle, operates under 70-foot head. The set up is very similar to that at Eagle Creek, and the piping is done in much the same way. During low water periods, the water is stored in the ditch reservoir and used intermittently for short periods at a time. The average water supply permits the use of but one field giant, and the stacker giant at a time, when the practice is to complete one side of the pit before the other side is piped. When a full head of water is available, piping is sometimes done from both sides at one time. The lower giant b pipes the material diagonally upstream, and as far to the head of the boxes as practical before it is put over the side by this giant and giant a, and the pit is piped well into bedrock. The material alongside of the boxes at the lower end is then piped to the upper end by giant b and the stacker giant c, and piped over the side. Bedrock is then given final cleaning with a fire hose and nozzle outfit. From 6 inches to 3 or 4 feet of bedrock is piped up. Boxes are then cleaned up and removed and material remaining alongside and underneath is piped ahead on virgin ground for the next pit. Under normal operation the flow of material through the sluice boxes is about 6 inches deep. The boulders are removed and piled by hand on cleaned bedrock, the larger ones being broken with a sledge. Six men are employed, shifts of 12 hours being worked.

One pit of 18,750 sq. ft., or about 4170 cu. yds., was piped over the side in 8 days with a full head of water available. About 220 inches of groundsluice water was used or about twice as much as the one field giant with 3-inch nozzle under 60 foot head. The total water used, including that used by the stacker giant, was 455 inches, giving an approximate water duty of 1.2 cu. yds. Twelve boxes are installed, the giants set, the bedrock drain fixed up, and everything is made ready for a new pit, 125 feet long, by 3 men in 8 shifts. The average clean-up of the boxes is done by 4 men in 1 shift. In 1922, with a good steady water supply under a head of 120 feet, 34,000 square feet of ground 6 feet deep, or 7555 cu. yds. were piped over the side in 10-1/2 days of steady piping. Including the setting-up, clean-up, and all, 15 days were required. This is the best work that has been done here. Where the water is used intermittently, it generally requires from 25 to 27 days to pipe over a pit 125 by 150 feet and 6 feet deep, or 4160 cubic yards. During an average season, May 10 to Sept. 15, about 5 pits, or from 75000 to 80000 square feet are completed, when the operating cost ranges from 5 to 7 cents per square foot or 23 to 32 cents per cubic yard. About $8000 is invested in the equipment and $5000 in the ditch line.

A method of piping over but one side of the boxes, the boxes all being elevated above bedrock and running across or at angles with the channel, was used on Moose Creek in the Kantishna district for a while. The creek deposit averages 10 feet in depth, containing unfrozen medium sized round gravel. Bedrock is a tough clay. A trench is first piped to grade in the gravel, crosswise or at an angle with the channel. From 9 to 10 lengths of sluice boxes, 40 inches wide, are then installed in this cut on a grade of 9 inches. This usually brings the top of the head box about 2 feet below the surface of the ground and the bottom of the last box, a foot or so above bedrock. These boxes are heavily constructed and have timber guards on the lower side as a protection from the battering of the gravel. A heavy board apron or side about 8 feet high is erected along the upper side of the boxes. Two giants with 3-1/2-inch nozzles, under 250 foot head, are set up about 200 feet or so downstream from the sluices, so that each can cover its field to the best advantage and a third giant is placed so that it can pipe the material into the field of the central giant and also stack the tailing. A large quantity of water is turned into the head of the boxes as considerable of the giant water does not enter them. The material is then piped upstream against the slight grade and towards the upper half of the sluice, then up the incline of gravel lying alongside of the boxes and over their side, striking the apron and falling into them. As piping advances upstream, boulders are piled behind or to one side on cleaned bedrock. When all the material has been put through the boxes, except that directly alongside and under them, which is later driven on to the next set-up, the boxes are cleaned up and removed.

While this hydraulicking has been underway, another line of boxes has been installed about 200 feet farther upstream. Giants are then re-set and the next pit mined, there being very little time lost between pits.

At an operation in the Yontma district, the boxes were elevated above the ground but placed lengthwise with the channel and the material piped over the side, alternating from one side to the other. No hanging plates or backstops were used. This method as applied and followed here did not prove advantageous.

<u>(c) The combination method of piping over the side of the boxes and into the head of the boxes.</u>

This method, often termed the "Circle" system of hydraulic mining, affords some of the advantages of both methods (a) and (b), which in combination make it particularly applicable to hydraulicking average gravels up to medium depths where the gradient is not steep enough for good practice for piping into the head, or where the bedrock and other conditions are unfavorable for piping over the side, so that a pit of practical size can be mined. With the combination method, a longer pit can be mined than would otherwise be practical under similar conditions by other hydraulic methods. The method is very successfully applied where such conditions are encountered and where the water supply is comparatively small or must be intermittently used.

On Mastodon Creek in the Circle district, the frozen creek deposit ranges from 15 to 20 feet in depth, a part of the deposit had been previously drift mined. The overburden is stripped with the giants well ahead of actual mining to aid in thawing and to reduce the depth to an average of 10 to 12 feet of gravel. The gravel is of medium size and contains an average number of medium sized boulders. Bedrock is a schist, much of it being slabby but most of which can be piped up and cleaned with a giant, the more creviced requiring some hand cleaning. The average stream grade at the lower ground is 5 inches to 12 feet, increasing to 6 inches at the present operation farther up the Creek.

The water supply is erratic, and with full head is usually only sufficient to operate one field giant and the stacker at a time. During low water period the water must be used in splashes averaging about 8 to 12 ten-minute splashes in 12 hours, when the field giant and the stacker giant are generally operated alternately. The pressure water is obtained from two ditch lines, at different elevations, the average head being about 100 feet. The crew employed varies with the water conditions, during a favorable season being 10 to 12, working two 12-hour shifts, and during an unfavorable season only one shift may be worked with from 2 to 4 men.

The general plan of set up is shown in Fig. 8. The pits mined at the lower operation are usually about 200 feet long and 150 to 200 feet wide. On the upper ground they are generally 80 to 100 feet in width, mainly because of the narrower channel. From 3 to 4 boxes are first installed on grade below the purposed pit, as deep in bedrock as conditions will permit and small wings are erected at the head. The trench down the center is then piped out, the material going through these boxes. While dependent on bedrock conditions, usually from 8 to 10 more boxes are installed in this trench and heavier wings erected at the head. The boxes are 32 inches wide and 24 inches deep, set on a grade of 7 or 8 inches. Block riffles are used. The head

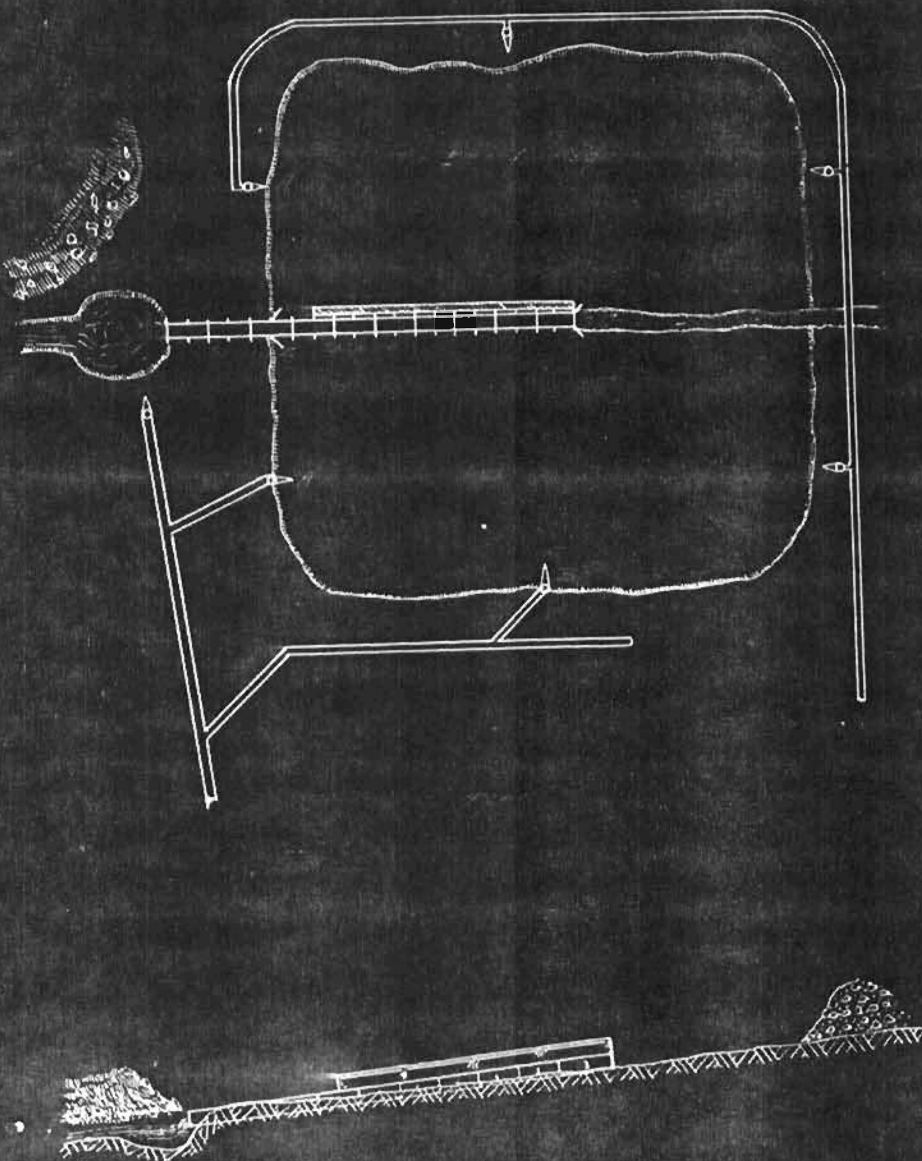

Fig 8

Combination Method of Hydraulic Mining
"Circle System" as used on [illegible] Creek

Original sketch accompanies original copy of report

Fig. 8
Combination Method of Hydraulic Mining
"Circle System" as Used on Mastodon Creek

of the boxes in the average pit are usually about the center of the pit and setting on bedrock. Sometimes here, as well as at other operations, the head of the boxes are placed above bedrock a foot or more. This is, however, objectionable and should be avoided for reasons stated under "piping into the head." After the gravel has been piped down to the level of the tops of the boxes, a board back stop about 6 feet high is erected along the side of the boxes, opposite to the side being piped. The field giants are first placed as shown, being later moved to more advantageous positions. In shorter pits the b giants may be omitted. When the water supply permits, 3-1/4-inch nozzles are used on all of the giants and the amount of ground sluice water is about twice that provided by one field giant. The c giants pipe the material upstream, which with the aid of the b giants is driven over the side of the boxes. The a giants drive some material into the field of b, also driving a little over the side, but they are used mainly for piping the material within their field into the head of the boxes. The a and b giants may later be moved down into the pit, especially if the bank is too high for efficient operation from the initial set-up. The material lying alongside of the boxes at the last is driven ahead by c and d and put over the side or driven into the field of a and the upper part of the pit completed. The boxes are removed, and any material which remains alongside the boxes or in the bedrock trench is piped ahead to be put in from the next cut. Where this method is used on some creeks affording lower grades, the greater part of the pit is piped into the head of the boxes, especially during a period of low water supply. With a full head of water, operating one field giant and the stacker steadily, one pit on the upper ground, 100 ft. wide, 200 feet long, and averaging 10 feet deep,was piped to the boxes in 21 days, working 4 men to the 12-hour shift, at a cost of 10 cents per square foot or about 27 cents per cubic yard. This area was stripped of 6 to 6 feet of overburden for 5 cents per square foot. With average splash water conditions, it would have required about 50 days to pipe in the 10 feet of gravel and bedrock in this pit. The average time required for installing 12 to 14 boxes, setting up the giants, etc., is 2 shifts with 6 men. The average clean-up requires one shift. With an exceptionally good water supply, the operating cost for hydraulicking, exclusive of the stripping, has been as low as 15 cents per cubic yard. This operating cost, however, usually ranges from 25 to 50 cents per cubic yard.

Boulder Disposal

The generally low gradients and small water supplies which most of the operations have to contend with, materially increase the amount of heavy material which cannot be passed through the sluices and the disposal of which adds considerably to the cost of mining. There are but few instances where all of the material can be passed through the sluice boxes, even after the larger boulders have been broken up. All rocks too heavy to be so disposed of are therefore piled to one side on cleaned bedrock or removed entirely from the pit. At the small operations this is generally done by strictly manual means. Stiff leg derricks, usually operated by hand have been found very useful where there are many large boulders and the pit is confined to a small area. The bouldersmaybe loaded onto a sled or stone boat which may be horsedrawn or operated by some mechanical power. The removal of the boulders and their stacking on cleaned bedrock with a steel stone boat operated by cables from a donkey hoist, as practiced on Chititu Creek is shown in Pl. 24547. "Sky lines" or over-head cables stretched across the pit over which traveling carriers are operated by steam or water power are used at several of the mines. In this case, after the wire nets or stone boats are loaded with boulders, the traction cable is tightened, the load of boulders hoisted to the carrier, hauled over the traction cable and automatically dumped at the desired place. The installation of large derricks and "sky line" outfits, especially when operated by steam, have a very restricted field in Alaska.

The large boulders are generally broken up to facilitate their handling. The flat soft or friable ones can be readily broken by hand with a sledge. The more rounded hard and tough boulders are blasted, generally by "bulldozing" or "mud capping" them, the dynamite being placed on top of the boulder and covered with sand or mud. At several of the larger hydraulic mines, hard rounded boulders are drilled before

(24547) /Boulder disposal with donkey hoist and stone boat.

(24548) Boulder disposal. Loading the steel stone boat.

they are blasted. "Bulldozing" requires much heavier charges of dynamite than if they are drilled and the holes loaded and shot, consequently the latter method makes a great saving in the cost of explosives.

In the Nizina district on Dan Creek an unusually large number of rounded boulders, chiefly of greenstone, limestone and slate, must be contended with. With the exception of the very largest ones which are from 6 to 10 feet in size, and which are undercut with the giants, rolled over and left there, all over 15 inches are broken up and put through the sluice. The more friable and flat ones are broken with a sledge; the hard ones, which greatly predominate, are "bulldozed".

A total of 27,415 shots were fired during the season of 1922, or 257 per day. There were 14,075 pounds of 60 per cent straight dynamite used, costing 20.3 cents per pound. Including the 8 x caps costing $1.80 per box and the triple taped waterproof fuse, costing 92 cents per 100 feet, the total cost for explosives was $4,512, or 4.6 cents per cubic yard of ground mined. There was 0.59 pound of dynamite used per shot, or 0.13 pound per cubic yard mined; 0.26 shots were fired per cubic yard mined or 3.8 cubic yards of ground mined per shot fired. Two men per shift are employed for this work.

In the Girdwood district on Crow Creek, about 15 per cent of the deposit consists of hard rounded granite and graywacke boulders. While some of these can be broken with a sledge, and some are "bulldozed", most of them are drilled before blasting. See Pl. 24556. The usual boulder crew consists of four men to the shift, generally only one shift being worked. Three "Clipper" air drills equipped with 7/8-inch hexagon steel with Carr bits are available for drilling. The depth of the holes range from 5 to 30 inches; from 40 to 50 steels being used per shift. About 300 shots are averaged per day. In 1923, 1-1/2 tons of 60% dynamite, costing $11 per box, 25,000 caps and 72,000 feet of fuse were used for the work. All the material is put through the sluices. The air for operating the drills is produced by a 12 by 10 single stage compressor, belt driven by a 20-inch Pelton water wheel operating under a 150 foot head.

Tailing Disposal

The tailings from operations in well elevated bench deposits

(24534) Bo lder disposal by stone boat and horse.

(24556) Drilling boulders preparatory to blasting. Crow Creek can in most instances be dumped over the edge into the stream below. Where the topography affords gradients not less than 12 inches in 12 feet, the tailing can be disposed of by extending the tail boxes from time to time and spreading them over the surface of worked out or barren ground. The grade of the surface must be considerable more than that of the sluice, in order that there will be ample vertical space for the tailing below the end of the lowest box. Creek deposits, and benches only slightly elevated above the stream bed seldom afford these required conditions, so that means must be provided to create dump room.

This is accomplished by stacking the tailing with a giant or where the water supply is small and this method is not practical, scrapers of the Bagley or slip tooth type operated by steam power are used. It may be practical to use a part of the water otherwise required by the giant stacker to provide water power for operating a scraper. Horsedrawn scrapers were at one time used for tailing disposal, but their use has been discontinued for the cheaper methods.

The stacking of the tailing with water under pressure is the

(24549 Stacking tailing with the giant.

(24490) Difficult hydraulic mining in the Iditarod district. Derrick for handling boulders.

method most commonly employed. The giant is set to one side of the end of the sluice and the heavier material is piped into a pile, the lighter material being carried down the bedrock sluice to the creek. On very low grades, another giant set further downstream is often required to boost along this lighter material and keep the channel open. See Pl. 24549. Where there is much sand or fine material in the tailing to be stacked, the efficiency of this method is reduced as such material tends to run back into the sump. Depending on conditions, the stacking may have to be conducted continuously while in some cases, an hour or two each shift may be sufficient. The quantity of water required is, therefore, very variable and may range from 1/8 to as much as that required by the field giant. Where much heavy material is stacked or tailing room is limited, the stacker giant may require even more water than a field giant.

On Dan Creek, where the tailing contains many boulders, 15 inches in size, it has been stacked to a height of 52 feet by a giant with 4-inch nozzle under 310 foot head.

At one operation on Mastodon Creek in the Circle district, tailing was stacked to a height of 35 feet without difficulty by a 3-inch nozzle under 100 foot head, the largest rocks being about 12 inches in largest dimension. The tailing at this operation was at one time piped up an inclined chute 4 feet wide and 2 feet deep, the bottom of which was fitted with beveled steel shod riffles set at an angle to keep the sand and fine material from running back into the sump. As a general rule, the tailing can be stacked to a height of one-third the head on the giant and at a distance from the giant of one-half the head. The height and length of the tailing pile is, however, also governed by the character of the material, so for efficient giant stacking under average conditions the face of the pile should be kept as long as practical and at an angle of slope not exceeding 25 degrees.

Former practice of tailing disposal at Crow Creek was to extend the sluices as the tailing accumulated. This required an addition of from one to two boxes per day, so that the sluice eventually contained from 60 to 90 boxes. Having sufficient water under pressure, 8 to 10 boxes set on 6-inch grade are now used and the tailing stacked with a giant, a practice which has been found to be more practical and cheaper than the old method.

While there are no debris laws in Alaska, tailing should not be dumped indiscriminately into the stream beds, but preventive measures should be taken to impound them so they will not be eventually deposited over workable ground, the property of another, or pollute his water supply. Fortunately there are now but few instances where this involves a serious problem or expense. The proper stacking partly overcomes this although in narrow valleys subject to high floods exceptionally strong dams may be required.

Hydraulic Mining Costs

The cost of hydraulic mining in Alaska normally ranges from 25 to 50 cents per cubic yard, which includes seasonal preparatory work, labor and mess, ditch maintenance, general supplies and other costs of operation, but is exclusive of any overhead or capital charge. Labor and its found constitutes from 85% to 95% of the operating cost. The many varying conditions under which placer mining is conducted in

Alaska have been stated, so it can readily be understood that if an ample water supply is available and other conditions are generally favorable, that it is possible to mine for less than 25 cents, while under adverse conditions the cost may reach 75 cents to $1 per cubic yard. There are several instances known where it has cost over a dollar during an adverse season.

Some hydraulicking has been done, particularly on the deep benches, for around 10 cents per cubic yard, but conditions were exceptional. Years ago the deep lake bed deposit near Juneau was hydraulicked at an operating cost of around 6 cents per cubic yard under the best of operating conditions. In general it can be stated that the operating cost over a period of years will rarely average less than 20 cents per cubic yard for the hydraulicking of bench deposits and 25 to 30 cents per cubic yard at the creek operations, and only then when conditions are more favorable than the average. The cost of hydraulic mining at any particular operation varies mainly with the water supply. Therefore, a comparatively low cost may be realized during a favorable season while during a dry one the cost may be two or three times higher.

Some costs have already been given of typical operations. Near Nome, one operation in creek gravel 16 feet deep cost 30 cents per cubic yard, another in 6 foot ground, 26 cents. Both stacked the tailings with a giant. In the Iditarod district, on the Upgrade Assn., almost unlimited grade is available but other conditons are adverse for hydraulicking. Pl. 24490. The cost there ranges from 50 cents to $1 per cubic yard, and in some of the creeks nearby 35 to 50 cents. In the Yentna district, where the water supply is fairly reliable, unfrozen medium sized creek gravels 5 to 9 feet deep are mined for 5 to 7-1/2 cents per square foot or 25 to 35 cents per cubic yard. During unusually dry seasons, this may be 40 to 50 cents or more. In the Hot Springs district in 1922, four small operations on shallow high bench deposits, averaging from 5 to 10 feet deep, were hydraulicked with water under heads of 20 to 60 feet and mostly used in splashes, at costs from 3-1/2 to 7-1/2 cents per square foot or 19 to 27 cents per cubic yard. A total of about 200,000 square feet, or 45,000 cubic yards were mined at these four operations during the season. No stacking of tailing was necessary. Another, but better equipped plant nearby under similar conditions mined 40,000 cubic yards, averaging 7 feet in depth for 15 cents per cubic yard. During a previous year with steady water, a somewhat larger area, averaging 6 feet deep was mined at this place at a cost stated to have been 12 cents per cubic yard.

In the Fairbanks district, 18 feet of frozen creek ground was mined for 54 cents per cubic yard. Gravel was heavy and the creviced blocky bedrock required hand cleaning. Tailing was stacked by giant. In the Rampart district, a low lying sloping bench 10 to 40 feet deep, composed of 8 to 10 feet of gravel overlain by muck, all being frozen, cost 20 cents per cubic yard. All the material went through the boxes. The tailing was stacked. One operation on the Kenai Peninsula, hydraulicked creek gravels 6 feet deep during one season, with a large water supply available under 300 foot head, for 20 cents a cubic yard.

Hydraulic Elevators

Hydraulic elevators are used in connection with the hydraulic mining of flat lying placers where it becomes necessary to elevate the material to provide satisfactory sluice gradients and dumproom, and where bedrock lies below the drainage level so that the workings cannot be naturally drained. While elevators are inefficient machines they are well adapted to the mining of placers under such conditions which otherwise prohibit dredging or are generally unfavorable to ordinary hydraulicking, but where an abundance of cheap water under high pressure is available.

The gravel should be comparatively small in size, otherwise it may be necessary to throw out and dispose of an excessive amount of the larger rock, as the size of the material that can be put through the elevator must be smaller than the throat. Elevator practice has special advantages in placers containing considerable stiff, sticky clay, which is difficult to wash, as it receives the additional disintegration and washing as it is sucked up the elevator, strikes the hood and falls into the sluices.

The principle of the hydraulic elevator is similar to that of a steam injector in that a jet of water under pressure causes a vacuum or suction which draws in the inflowing water and gravel through the intake opening and forces it up an inclined pipe, discharging into the sluice. There are a considerable number of well known makes of hydraulic elevators all acting on this principle, but differing in details of construction. One make in particular has an auxiliary suction on each side of the main intake, so as to allow air, water, and solid matter to enter there if the main intake chokes and also by extending these suctions the low places in bedrock can be drained. Its general construction produces a higher efficiency and tends to reduce the wear and tear on the machine. The admission of air with the material is a necessary aid in the operation of the elevator, so that this feature and the proper adjustment of the dimensions of the elevator, more especially the nozzle, throat and upraise pipe are of main consideration in elevator construction. Hydraulic elevators are made in various sizes with throats from 5 to 16 inches in diameter, upcast pipes from 6 to 30 inches, and for nozzles from 2 to 8 inches in diameter.

The importance of an abundant water supply under pressure is explained by the fact that from 1/2 to 2/3 of the available pressure water (generally the higher figure) is required by the elevator, leaving only the smaller portion for the breaking down, and the driving of the material to the elevator. The capacity of an elevator varies with the ratio of the pressure head to the height of lift; the effective head and volume of the water; the regularity of the flow of water and material to the elevator; and also with the duty of the water from the giants. The duty of the giant water is one of the main factors in determining the size of an elevator. The weight of solid material that the elevator will lift under ordinary conditions is usually about 2 to 3 per cent of the total weight lifted, at the most 5 per cent. Where there is much seepage water, the capacity of the elevator is reduced and causes the elevator to choke. A water lift, which is practically a small elevator with a suction pipe instead of an open intake, must often be installed to handle this excess water.

The proper inclination at which the elevator is set is governed by the exigencies of the ground and by the friction to which the material must be submitted. The angle may vary from 42 degrees to nearly vertical, but is generally 60 to 70 degrees. One make of elevator is said to work best at an angle of 80 degrees. The height to which the material can be elevated ordinarily ranges from 10 to 20 per cent of the effective pressure on the elevator nozzle, although by the use of compound lifts, the height of lift may be nearly doubled. The depth of ground that can be mined depends on the available head of the pressure water, and also on the size of the material, the inclination of the upcast pipe, and the height above the surface at which the sluices must be placed to obtain the necessary grade. The depth should however be sufficient to allow a large yardage to be mined from one set-up of the elevator, but not so deep as to require excessive lifts. Depths from 18 to 25 feet are generally considered as being most favorable under average conditions.

Hydraulic elevators are operated principally on the forward the giants, is usually protected by fastening a board covering around it. After the elevator has been installed and securely braced, the sluice boxes are set. The upcast pipe enters at the bottom of the head box. This head box is enclosed at the back and top and the striking plate or a heavy curved manganese hood is attached to the top to receive the force of the material. Pl. 22465. The head box is given a grade of 4 to 5 inches, the grade of the boxes below being increased 1 inch to 12 feet after every 2 or 3 boxes. Even though the material is elevated to the sluices, conditions often prohibit the natural disposal of the tailing, which is generally dumped into a worked out pit and must be removed from the end of the sluice and stacked by a giant as occasion demands. The field giants, at first set on top of the bank, pipe the material to the elevator and as the pit is opened are moved down into it. Pl. 28262. In large pits, the material is piped along to the "booster" giants, which drive it on to the elevator. The system of piping is similar to that of "piping into the head". The material may be piped to bedrock sluices leading to the elevator and often steel

Peninsula, where in most instances the more favorable water supplies are available. For opposite reasons, they are but little used in the interior districts, where some half dozen operations have small elevators working with lifts from 6 to 15 feet. There are, however, some creek deposits being hydraulicked and the tailing stacked where the use of an elevator would be more practical, although in general the useful field for the elevator in Alaska is very limited.

The hydraulic elevator pits, as mined in Alaska, generally range from about 1 to 5 acres in area. On opening up an area, a pit 10 to 15 feet square is sunk from the surface to 6 to 10 feet in bedrock. The elevator is installed in this pit, which should be located at the lowest point of bedrock to allow all water to drain to it. In wet ground, a water lift may be required in sinking this pit and some timbering may be necessary. Some elevators are so constructed that they can be set up on the surface and will sink their way to bedrock. After the operation is underway and much seepage water must be handled, another sump is dug several feet deeper in bedrock and a water lift installed. That part of the elevator exposed to the battering of the material from

(22465) Installing hydraulic elevator and sluice boxes near Nome.

(22487) Hydraulic elevator operation. Hot Springs district.

chutes are laid on bedrock and the material piped to them to aid in its transportation. As only those rocks about a half inch smaller than the diameter of the throat can be safely handled by the elevator, the oversize must be removed and disposed of. As a precaution, a grizzly or grating to keep out the oversize is often placed ahead of the intake.

To keep out as much seepage water as possible, it may be necessary to leave a strip of ground between pits or between the pit and the creek. At one operation, the elevator was installed with its back to a completed pit and when the elevator started operation, a dam was built up between the elevator and the old pit, with brush, and with the tailing as it left the sluices.

The largest elevator operations in Alaska have been conducted back of Nome on Little Creek and near vicinity, although since the starting of the large dredges there, they have been greatly reduced in scale and will soon be entirely discontinued. The deposit mined varies from 15 to 40 feet in depth, and with the exception of some small irregular thawed areas, is frozen. The moss and from 2 to 10 feet or more of muck is first removed with giants, much of which goes to the elevator. The gravel is variable in depth and character, but in average, is of medium size with an average amount of boulders. Mixed with much of the gravel and overlying some of the bedrock is a clay. Bedrock is slate, schist, and limestone, the latter being very slabby, creviced and irregular.

Up to 1923, elevator operations were seasonally conducted in 4 pits, each ranging from 3 to 5 acres in area. A total of from 100 to 125 men were employed. The average operating season was from about June 10 to Oct. 15. Operations in all of the pits could not be conducted throughout this entire season, but depending on the water supply from 350,000 to 550,000 cubic yards were generally mined per season or from 1000 to 1500 cubic yards a day per pit. Two 11-hour shifts were worked in the pits, there being from 10 to 15 men and one or two teams of horses in each pit on the day shift. The available head of the pressure water in the pits is from 290 to 310 feet. Six or more field giants are eventually set up in a pit, but as a rule only two giants and the elevator are operated at a time.

The field giants are equipped with 3 to 3-1/2-inch nozzles, 2-1/2 inch when the water is low. In each pit is a Campbell elevator with 10-inch throat and 18-inch upcast pipe. The elevator nozzles are generally 4-1/4 inches for lifts up to 40 feet, a larger size being used for higher lifts. The elevator is set on an angle of 62-1/2 degrees, the height of the lifts ranging from 30 feet to the highest which is 55 feet. Each elevator uses from 450 to 550 miners inches of water or a total of from 750 to 1000 inches are used at each pit. The tailing is stacked at intervals by a giant with 3-inch nozzle. Booster giants are used and where bedrock is rough, steel sluices aid in moving the material across the pit. All oversize rocks are picked up and loaded onto stone boats, and then hauled to one side or out of the pit by a team of horses.

The hood or head box is 12 feet long, 4 feet wide and 4 feet high, set on 5-inch grade and paved with block riffles. The other boxes, which are of steel, are 6 feet long, 4 feet wide and 2 feet high.

the upper 4 to 6 boxes having a 6-inch grade and those below 7 inches. From 150 to 180 feet of these sluice boxes are set and equipped with some angle iron riffles set crosswise, but mostly with 16-pound rail riffles placed lengthwise. These rails are bolted together in sets with 1-1/2-inch spaces. The corner of each set is fitted with a cast iron block constructed so they fit together and so a square steel bar can be fitted into them and keyed under a steel shoulder running lengthwise along each side of the boxes to hold the riffles in place. There is considerable fine rusty gold that will not amalgamate and is difficult to save, so on some of the sluices the lower 24 feet are made 8 feet wide and given a little higher grade.

About 3 days are generally required to sink a pit down to 8 or 10 feet in bedrock, and one day to install the elevator. The elevator throats are of manganese steel and replaceable. When handling sand, gravel and bedrock, they last about 3 months or handle about 100,000 cubic yards, by which time they have enlarged to 13 to 14 inches. Most of the gold is heavy and while very little is recovered in the head box, most of it is recovered in the 2 or 3 boxes just below it. Practically no gold is recovered in the elevator sump. One season's clean-up recovered only 7 ounces from the sump. The creviced limestone and the potholes in bedrock are cleaned by hand, from 10 to 25 men doing this work. The gold goes deep into the crevices which are picked and cleaned out and the material wheeled or shoveled in to small sluice boxes set up for this purpose. Unless this material contains from 2-1/2 to 3 cents worth of gold to the pan, it generally does not pay to recover it.

In 1921, when 4 pits were in operation, 550,000 cubic yards were mined at an average operating cost of 35 cents per cubic yard, which included ditch maintenance amounting on this yardage basis to about 3-1/2 cents per cubic yard. The average operating cost has been from 45 to 50 cents per cubic yard. The average duty of all the water used in frozen ground is from 1 to 1-1/4 cubic yards; in partly frozen ground from 1-1/4 to 1.75 cubic yards.

On the Inmachuck River, a Campbell elevator, with 9-inch throat, 4-inch nozzle, with a lift of 37 feet. and set on a 62 degree angle, is used under a 350-foot head. From 2 to 3 field giants and one stacker giant are used with 3-inch nozzles. Pls. 28233 and 28234. Two shifts of 10 hours each are worked, there being 6 men on the day shift, 3 at night, and 6 on the ditch. The deposit is frozen and averages from 20 to 25 feet in depth, about half of which is muck overburden and which is first removed. In 1924 a pit 315 by 460 feet was mined at a cost of 17.2 cents per square foot. About 53,000 cubic yards of gravel and bedrock were put through the elevator in 64 days at a cost of 47 cents per cubic yard. The cost in 1923 was about 35 cents per cubic yard. The average operating season is 65 to 90 days. On Osborne Creek, a Campbell elevator with 10-inch throat, 4-inch nozzle, and operating under 170 foot head is set on a 72 degree angle, and lifts 15 feet. The deposit, which is partly frozen, averages 9 feet in depth and contains heavy gravel. Bedrock is a clay and is easily cleaned with the giants. Two giants with 3-1/2-inch nozzles are used in the pit and tailing is stacked at intervals with a 3-inch nozzle. From 65 to

72 feet of sluice boxes, 3 feet wide, set on grades from 7 to 8 inches, are used in the set-up. The head boxes are paved with rail riffles set both crosswise and lengthwise with the bottoms up. Block riffles are used in the other boxes. Usually about 2-1/2 feet of sod and light overburden is stripped off before the elevator is operated. The pits are from 200 to 250 feet wide by 175 to 200 feet long. With average water, a pit is completed in three weeks time. Ten men are employed. Excepting the heavy wash, operating conditions are favorable. The operating cost ranges from 20 to 35 cents per cubic yard.

The Wild Goose Mining and Trading Co. formerly conducted large elevator operations on Ophir Creek in the Council district, and from 1908 to 1910 handled from 96,000 to over 150,000 cubic yards per season in gravel averaging from 6 to 11 feet in depth. The working costs which included all operating costs, depreciation on equipment, and management were from 11.82 to 18.41 cents per square foot, or 39.6 to 46.2 cents per cubic yard.[41]

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[41] Munroe, C.E., and Lanagan, W.E., Mining Engineers' Handbook, Peele, R., p. 792.

(28262)
Opening elevator pit, driving to elevator

(28234)
Elevator and sluices.

(28233)
Hydraulic elevator operation on Inmachuck River.

More recent elevator work conducted at this property was in ground ranging from 4 to 10 feet in depth, most of the bedrock being a slabby limestone, very irregular and difficult to clean up. The elevator is operated only during a part of the season, depending on the surplus water supply in the ditch, and the length of time that could be spared from the dredging operations, by the hydraulic crew of 5 men. From 1918 to 1921, inclusive, a total of 96,685 cubic yards were elevated at an average operating cost of 21.27 cents per cubic yard, which is exclusive of depreciation, management, etc., but including the proportional charge for ditch maintenance. It is customary at this operation to charge depreciation on equipment only at $1000 per year, which is, however, excluded in the following detailed data:

Hydraulic Elevator Mining Costs

Wild Goose Mining and Trading Company, Ophir Creek

	1918	1919	1920	1921
Labor	3648.50	4339.70	5281.10	
Mess	1351.60	1545.46	1744.80	
Supplies	89.55	10.25	71.25	
Freight & team	683.09	780.85	482.77	
Ditch maintenance	1968.43	1017.35	756.75	
Melting & Transport	84.56	35.30	53.04	
General expense	450.61	337.98	233.80	
	8276.34	8066.89	8623.51	5327.39
Area mined, sq. ft.			84125	65660
Av. depth, ft.			9.34	7.7
Cu. yds. mined	38040	11050	29111	18684
Cost per cu. yd., cents	21.76	73.00	29.62	28.52

Two small elevator operations are conducted in the Iditarod district. The deposits are from 12 to 16 feet in depth, the overburden being removed, leaving from 4 to 6 feet of material to be elevated. From 20,000 to 35,000 square feet of bedrock are mined per season at each operation with a crew of 4 to 6 men. The elevators are made out of a heavy pipe, 6 inches in inside diameter with a 2-1/2 or 3-inch nozzle fitted to the bottom. The material enters through an opening cut out of the side of the pipe. The elevators are set at angles of 75 degrees and operate under 45 to 55 feet of head, with lifts of 6 to 8 feet. From 36 to 72 feet of 24-inch sluice boxes are used in the set-up. One giant with a 1-1/2 to 2-1/2-inch nozzle pipes the material to the elevator. During the greater part of the season, water is only available for intermittent use. The tailing is periodically stacked with a Bagley scraper. The operating costs average from 45 to 55 cents per cubic yard.

Ruble Elevators

Ruble or grizzly elevators may be used under similar conditions as those required for hydraulic elevator operation, but where conditions will permit the pit to be naturally drained. The advantages of the Ruble are: its comparatively low first cost as it can be constructed at the property; it can be readily moved and set up, unless bedrock is unusually rough and irregular; and its capacity for handling heavy boulders. The Ruble has been used at an operation on the Kenai Peninsula and at several operations on Seward Peninsula. Haley[42] reports its very successful operation in California. Only one Ruble elevator is now being operated in Alaska; this is on Candle Creek on the Seward Peninsula.

(42) Haley, C.S., Elevating 10 cent gravel at a profit; Min. & Sci. Press, Vol. 104, Apr. 13, 1912, p. 530

The Ruble elevator on Candle Creek consists of an inclined chute 8-1/2 feet wide and 52 feet long with 10-foot sides at the lower end and 6 feet at the upper. It is all set on a slope giving a 17-foot elevation at the top or discharge end. Including the detachable apron which runs from bedrock to the elevator proper, the bottom is solid up to 22 feet; above this and continuing to the top or for 30 feet are the grizzly bars. These are set transverse, spaced 1-1/4 inches apart and are made of 2-1/2 by 6-1/2 inch timbers, the tops being shod with strips of steel. Underneath the grizzly is a bottom or box sloping from the upper end down to the sluice boxes. All parts subjected to the scouring of the material are lined with steel plates 3/16 of an inch thick. The sluice boxes are set at right angles to the elevator. Fig. 28237, 28240, 28242. The total length of sluice boxes installed is 36 feet. They are 4 feet wide, set on a 1-inch to 1-foot grade and paved with steel-shod Hungarian riffles. Excepting the detachable apron, the elevator is supported on heavy framework resting on two heavy sills. It is all mounted on rollers so that four men with a capstan and cable can move it upstream to another set-up. The total weight is about 15 tons and its entire cost constructed and set up at the property was about $3000.

The deposit mined is frozen and of variable depth, but averages

(28237)
Ruble elevator on
Candle Creek, Fair-
haven district.

(28240)
Ruble elevator on
Candle Creek, Fair-
haven district.

(28242)
Ruble elevator on
Candle Creek, Fair-
haven district.

about 30 feet of muck and 7 feet of gravel. The gravel is of medium size, with but few boulders over one foot in maximum thickness. Most of the gold is coarse. Bedrock is a schist, a foot or two being mined. The grade of bedrock is 1.6 feet to 100 feet. The muck is first removed by hydraulicking to permit thawing, at a cost of about 5 cents per cubic yard. The average depth mined with the elevator is 9 feet.

The elevator is set in position at the center of the lower end of the proposed cut, the lower end of the apron being set one foot in bedrock. Two-inch board wings are erected on each side of the elevator and the sluice boxes are placed.

The average pit mined with the elevator from one set up is from 75 to 100 feet wide and 200 feet long. A giant with 4-inch nozzle is set up about 50 feet back from and in line with the elevator. Two or more field giants depending on the water supply are used in the pit. They have 3 to 3-1/2-inch nozzles. The average head available at the giants is 200 feet. The field giants drive the material to the elevator giant which picks it up and pipes small quantities of it at a time up the solid bottomed portion of the elevator, carefully washing or "boiling out" the fine material before putting it over the grizzly. Unless the fine material containing the gold is carefully washed out from the heavy rocks, much of the gold may be driven over the grizzly onto the dump. To aid in keeping the gold from being driven over the top a swinging gate or apron is placed near the upper end of the grizzly. The heavier rocks, when washed clean, are driven up and over the top of the grizzly. The fine material goes through the grizzly and into the sluice boxes. When the rock dump builds up, planks are laid on the dump, thereby really extending the length of the elevator, and permits the heavy material to be piled considerably higher than the elevator. When this exceeds practical limits, these piles are piped down with the stacker giant. The tailing from the sluice boxes is stacked as occasion demands. With 400 inches of water available under 200 foot head an average of 600 cubic yards can be mined in 24 hours, giving an average water duty of 1-1/2 cubic yards. From 3 to 4 shifts are required to move the elevator, install it and the sluices and get it in readiness for a new pit. Three to 4 men are engaged per shift in the elevator pit. While the working season in this district is from about May 15 to Sept. 15, there are usually but about 50 days of this season during which sufficient water is available for the elevator operation. From 20,000 to 40,000 cubic yards of gravel and bedrock are elevated during a season and from 75,000 to 100,000 cubic yards of muck are stripped.

Dredging.

The first gold dredge in the North was operated on the Lewes River in the Yukon Territory in 1899 and during the same year the first Alaskan dredge started operation on Snake River at Nome, although this method of placer mining did not reach a real operating stage in Alaska until 1903 when two small dredges were operated on the Seward Peninsula. Gold dredging started in the Forty Mile district in 1907 and in the Iditarod, Circle and Fairbanks districts in 1912. The number of dredges rapidly increased, and in 1914 there were 42 dredges operated, producing 22 per cent of the Alaska placer gold output for that year. While there were more than 60 bucket dredges in Alaska in 1916, only 34 were active. In spite of the smaller number of dredges operated since 1914, the gold produced by them has each year shown an increased percentage. In 1923, 25 dredges produced 51 per cent of the annual placer gold output. In 1924, 28 dredges were operated, 18 being on the Seward Peninsula and 10 in the interior districts, although four of the Seward Peninsula dredges ran for only about one month. Statistics on the number of gold dredges operated, the production, the average gold content recovered from the gravels dredged, etc., by years, are given in the chapter on "Production".

While many gold dredges have been operated in Alaska and the value of the gold so won has been large, the operations have been conducted on a comparatively small scale which in a general way reflects the average character and extent of the deposits. The more favorable and richer shallower deposits have naturally been among the first to be dredged, the permanently frozen areas being avoided as much as possible. The recent development of the method of thawing frozen gravels with water at natural temperatures has been of greatest importance to Alaska gold dredging in that it has greatly extended the field, by making possible the dredging of large areas of so-called low grade ground formerly considered to be of little economic importance or formerly considered too deep to be successfully thawed. Other developments that have helped to reduce dredging costs and thereby extend the field, have been the development of the deisel engine and other means of reducing power costs and improved transportation facilities to the interior districts served by the Alaska Railroad. Placer mining has also reached a stage in most of the known placer fields whereby conditions have become more satisfactory for acquiring the many holdings necessary for dredging. The two large dredging fields in Alaska have now been made available for large scale operations. The year 1923, witnessed the beginning of such operations at Nome and all indications point to the early development of very extensive dredging operations in the Fairbanks district.

The Alaska dredging possibilities lie mainly in those creek, low bench, elevated beach lines and gravel plain deposits formerly mined by other methods. In these known fields, there remain the lower grade gravels, and the wet ground that these former operations could not mine successfully. Gold was lost in the tailings, and where creviced slabby bedrock was encountered, much gold may have been passed over. It has become almost an axiom among many of the dredge operators on the Seward Peninsula to consider the conditions right for dredging any ground that has paid to work by hand methods, even if the ground has been worked over several times. While this is indicative and would justify prospecting, it is most hazardous to install a dredge, without first prospecting the ground in a proper and thorough manner. Numerous failures have resulted through lack of prospecting and it is especially necessary in ground that has been cut up by former mining. Placers that have not been the scene of some former mining, seldom contain sufficient gold to permit profitable dredging. Former mining may, however, have been prohibited if the area was thawed and water soaked; or the property may have been acquired by dredging interests soon after its discovery.

Alaska gold dredging is entering a new era. There has been much prospecting of possible dredging ground during the past few years, and the results indicate that 6 or 8 new dredges will be erected and start operations within the next 2 or 3 years. Some of the small dredges that have been idle are to soon resume operations, although 5 or 6 of the present active dredges will have shortly depleted their ground. The future for gold dredging is most favorable, when judged by the encouraging results of the prospecting and the new developments, particularly around Nome and in the Fairbanks and Kuskokwim districts.

Experience and sound judgment are essential in determining the dredging possibilities of a deposit. All the physical and economic features affecting dredging must be determined before a dredge best suited to a particular deposit can be selected. A suitable volume of gravel must be assured which will repay all costs and return all invested capital and leave a net profit commensurable with the undertaking. The surficial conditions, the depth and character of any overburden; the value, character and distribution of the gold or any other valuable content; the depth, character and extent of the deposit to be dredged; the occurrence and nature of the frost; the character and contour of bedrock; the water level; are all to be determined by prospecting. The available water supply; the accessibility and transportation; the climate and length of the operating season; the cost of labor, supplies, fuel or power; the cost of the property or royalties; taxes, titles, etc., must all be investigated. All of these features have a direct bearing on the merits of the property. Of the physical conditions, the occurrence of both seasonal and permanent frost; the presence of stiff or sticky clays; boulders; slabby or hard bedrock; high bedrock gradients, etc., reduce the digging capacity of a dredge and consequently increase the operating cost and may therefore, prohibit dredging.

The following table on Alaskan gold dredges and the physical conditions of the placers dredged, and the table on the Details of Alaskan Dredges, have been compiled from data obtained in the field, and from the operators. Each season shows a change in the number of dredges operated, with some changes in location, management or mechanical detail. Some 8 or 10 dredges that have been idle for a number of years and show no intimation for future operation, have been omitted. The tables require but little explanation and are as complete and accurate as it is practical to make them. The daily yardage dug by the dredges fluctuates, the figures given are mostly averages derived from operating data. The amount of water used for sluicing can only be approximately stated. The table giving the physical conditions of the placer dredged by the different dredges, explains in a general way, the application of the

ALASKAN GOLD DREDGES. 1924.

AND PHYSICAL CONDITIONS OF PLA

		Operator	Location	Type	Size of bucket in cu.ft.	Type bucket line	H. P. and make of
		Seward Peninsula.					
1	b	Alaska Dredging Assn.	Candle Cr.	Flume	1 3/4,	open	
2	a	Alaska Inv. & Dev. Co.	Osborne Cr.	Stacker	2 3/4,	open	1 - 50; Weston
3	a	Alaska Kougarok Co.	Taylor Cr.	Stacker	2 1/2,	open	1- 50; 1-30; Sta
4	a	Alaska Mines Corpn.	Snake R.	Stacker	3 1/2,	close	1- 60; 1-20; Sta
5	a	Bangor Dredging Co.	Anvil Cr.	Stacker	3 1/2,	close	1- 100; 1-24; Wet
6	a	Bering Dredging Corpn.	Kougarok R.	(e)	2 1/2,	close	1- 80; 1-60; Bol
7	b	Candle Cr. Dredging Co.	Candle Cr.	Flume	3 1/2,	close	2- 50; Western
8	a	Casadepaga Mg. Synd.	Canyon Cr.	Flume	2 1/2,	open	2- 50; Western
9	a	Crooked Cr. Dredge	Crooked Cr.	Flume	2 1/2,	open	1- 60; Western
10	a	Dexter Cr. Dredging Co.	Dexter Cr.	Stacker	2 3/4,	open	1- 40; 1-25; Wes
11	a	Dime Cr. Dredging Co.	Dime Cr.	Flume	1 1/2,	open	1- 60; 1-35; Wes
12	a	Eskimo Gold Mg. Co.	Solomon R.	Stacker (d)	5,	close	1- 25; Western
13	a	Hammon Consol. Goldfds. Co. #1	Little Cr.	Stacker	9,	close	1- 200; Dow Willa
14	a	" " " " #2	"	"	9,	"	592 H.P. electric
15	a	" " " " #3	"	"	9,	"	" " "
16	a	Iverson & Johnson	Big Hurrah	Flume	1 1/4,	open	" " "
17	a	Lather Gold Dredging Co.	Budd Cr.	Stacker	2 3/4,	open	1-35; Western
18	a	Northern Light Mg. Co.	Ophir Cr.	Flume	2 1/2,	open	1-50; 1-40; Standa
19	a	Shovel Cr. Dredging Co.	Shovel Cr.	Flume	2 1/2,	close	2-35; Western
20	b	Swanson Cr. Mg. Co.	Swanson Cr.	Flume	2,	open	2-35; Scandia [illegible]
21	a	Wild Goose Mg. & Trdg. Co. #1	Ophir Cr.	Stacker	3 1/2,	open	
22	b	" " " " #2	" "	" (d)	3,	close	160 H.P. electric
		Yentna District.					2-60; Atlas D.D.
23	a	Cache Cr. Dredging Co.	Cache Cr.	(e)	6 1/2,	close	310 H.P. electric
		Circle District.					
24	a	Berry Dredging Co.	Mammoth Cr.	(f)	3 1/2,	close	2-75; Wolf Locomo
		Fairbanks District.					
25	a	Fairbanks Gold Dredging Co. #1	Fairbanks Cr.	Stacker	4,	close	2- 110; Scandia [illegible]
26	a	" " " #2	"	"	3 1/2,	open	2-75; Werkspoor
27	a	Chatham Gold Dredging Co.	Cleary Cr.	Flume	1 1/2,	close	2-32; Doman Tract
		Iditarod District.					
28	a	Riley Inv. Co.	Otter Cr.	(c)	3 1/2,	close	1-120; Atlas dies
29	a	Northern Alaska Dredging Co.	Otter Cr.	(c)	3,	close	1-110; Atlas dies
		Innoko District.					
30	a	Flume Dredge Co.	Yankee Cr.	Flume	2 1/2,	open	1-60; Western (h)
31	b	" " "	Little Cr.	Flume	2 1/2,	open	1-60; Western (h)
32	b	Innoko Dredging Co.	Ganes Cr.	(f)	3 1/2,	close	2-75; Morris Cond
33	a	Guinan & Ames Dredging Corpn.	Ganes Cr.	(c)	2,	open	1-60; Scandia [illegible]
		Mt. McKinley District.					
34	a	Kuskokwim Dredging Co.	Candle Cr.	Stacker	3 1/2,	close	1-60; 1-80; Bolind

a. Operated during 1924.

b. Idle during 1924.

c. Combination rev. screen, one flume & conveyor.

d. Shaking screens.

e. Revolving screen, one flume.

f. Revolving screen, two flumes & conveyor.

g. Auxiliary 160 H.P. Washburn distillate engine.

h. Installing hydro-electric plant.

i. Shore diesel electric plant.

j. Power from 6-625 H.P. Werkspoor diesel unit plan

k. Depth of gravel after stripping of overburden.

l. Relative conditions for- regardless of any frost difficulties.

A. Average. B. Many boulders.

F. Favorable. D. Difficult. S. Seasonal frost only.

DREDGES. 1924.

CONDITIONS OF PLACER DREDGED.

H. P. and make of engines	Kind of fuel or power	Fuel consumption per operating day	Digging depth below low water ft.	Cu. yds. dug. per day average.	Manager or Supt.
1 - 50; Weston	Distillate	50 gals	12	600	E.M.Pierce
1- 60; 1-30; Standard	Distillate	140 gals.	15	1000	D.M.Webb
1- 20; 1-20; Standard	Distillate	120 gals.	12	600	J.Kelliher
1- 100; 1-24; Bets & Weiss	Diesel oil	-	30	-	J.J.Keenan
1- 60; 1-60; Bolinder S.D.	Diesel oil	160 gals.	25	2000	O. Olson
2- 50; Western	Distillate	200 gals.	15	1500	J. Matthews
2- 50; Western	Distillate	-	15	-	E.E. Pierce
1- 60; Western	Distillate	100 gals.	12	900	C.L. Peck
1- 40; 1-25; Western	Distillate	110 gals.	12	800	F. Mebes
1- 60; 1-35; Western	Gasoline	130 gals.	16	1000	A.M.Kittleson
1- 25; Western (1)	Distillate	60 gals.	15	600	A. Garrod
1- 200; Dow Willans diesel	Diesel electric	220 gals.	20	3000	R.S. Oglesby
592 H.P. electric (1)	Diesel electric	-	60	5000	H.R.Edwards
" " " (1)	" "	-	40	5000	"
" " " (1)	" "	-	60	5000	"
1-35; Western	Distillate	70 gals	10	500	F. Iverson
1-60;1-40; Standard	Distillate	-	15	1000	M. Luther
2-35; Western	Distillate	120 gals.	15	1000	G. Russell
2-35; Scandia S.D.	Diesel oil	110 gals.	15	1000	A. Hylan
--	Distillate	-	12	-	C. Rise
140 H.P. electric (2)	Hydro electric	-	21	2200	F. Ayer
2-60; Atlas S.D.	Diesel oil	180 gals.	20	1800	" "
310 H.P. electric	Hydro electric	-	20	3000	R. Humphries
2-75; Wolf Locomobile	Wood	4 cords	18	2200	Wm. Heitman
2- 110; Scandia S.D.	Diesel oil	250 gals.	35	2500	C. Aarons
2-75; Werkspoor diesel	Diesel oil	150 gals.	28	1000	" "
2-32; Doman Tractor	Gasoline	110 gals.	14	1000	E.H.Holbrook
1-120; Atlas diesel	Diesel oil	110 gals.	15	1800	H. Donnelly
1-110; Atlas diesel	Diesel oil	110 gals.	15	1800	A. Matheson
1-60; Western (h)	Gasoline (h)	100 gals.	12	1000	J. Sampe
1-60; Western (h)	(h)	-	12	-	"
2-75; Morris condensing	Wood	8 cords	15	1500	-
1-60; Scandia S.D.	Diesel oil	100 gals.	18	900	J. Gulnan
1-60; 1-60; Bolinder S.D	Diesel oil	150 gals.	35	1200	T. Aitken

es & conveyor.

n distillate engine.

Day	Manager or Supt.	Physical Conditions of Placer. Depth of deposit dredged, ft.	Character of gravel.	Frost conditions	General relative conditions.(1) Dredging.	Sluicing.	
	M.M. Pierce	6-10	A-light	P.F.P.	A.	F.	1
	D. E. Webb	6-12	A- B	S	A.	A	2
	J. Kelliher	6-8 (K)	A	P.F.	F.	F.	3
	J.J. Keenan	20-35	A.	P.F.	A.	A.	4
	O. Olson	9-15	A.	S.	A.	A.	5
	J. Matthews	3-8	A.	S.	A.	A.	6
	H.E. Pierce	8-12 (K)	A. light	P.F.	A.	F.	7
	C.L. Peck	4-12	Light	S.	A.	F.	8
	F. Mebes	4-14	A.	S.	D.	A.	9
	A.M. Kittleson	9-14	A.	S	A.	A.	10
	A. Garrod	10-15 (K)	Light	P.F.F.	A.	A.	11
	R.E. Oglesby	8-14	A.	P.F.P.	F.	F.	12
	H.R. Edwards	35-70	A.	P.F.	A.	A.	13
	"	" "	A.	P.F.	A.	A.	14
	"	" "	A.	P.F.	A.	A.	15
	F. Iverson	5-10	Light	S.	F.	F.	16
	M. Luther	16	Light	S.	F.	F.	17
	G. Russell	5-15	A.	P.F.F.	A.	A.	18
	A. Nylan	6-10	Light	S.	F.	F.	19
	C. Rice	-	-	-	-	-	20
	F. Ayer	7-24	A.	P.F.F.	D.	A.	21
	" "	11-20	A.	S.	A.	A.	22
	H. Humphries	3-10	A.-B.	none	A.	A.	23
	Wm. Heitman	9-18 (K)	A. B.	S.	D.	F.	24
	G. Aarons	16-22	A.	P.F.F.	A.	A.	25
	" "	12-20	A.	P.F.F.	A.	A.	26
	E.M. Holbrook	12-23	A.	S.	F.	A.	27
	H. Donnelly	12-15	A.	P.F.F.	A.	A.	28
	A. Matheson	12-15	A.	P.F.F.-S.	A.	A.	29
	J. Saupe	6-10	A	S.	F.	D.	30
	"	-	-	-	-	-	31
	"	6-10	A.-light	S.	F.	A.	32
	J. Guinan	-	A.	S.	A.	A.	33
	T. Aitken	15-20 (K)	A.	P.F.F.	D.	D.	34

Dredge No. See table preceding	Bucket line No. of buckets In line	Bucket line No. of buckets Dumping per min.	Anchorage	Revolving screens Dimensions in ft.	Revolving screens Perforations inches.	Size di in inch
1. Alaska Dredging Assn.	31	18	Lines	none	-	10"
2. Alaska Inv. & Dev. Co.	32	14	Spuds	4x21	3/8;1/2;2.	8"
3. Alaska Kougarok Co.	31	15	Lines	4x24	3/8; 1".	10"
4. Alaska Mines Corpn.	74	27	Spuds	6x30	1/4;5/8.	12"
5. Bangor Dredging Co.	86	22	Spuds	5x23	3/8;5/8;1 1/4	10"
6. Bering Dredging Corpn.	54	24	Lines	4x21	2 1/2.	7" +10
7. Candle Cr. Dredging Co.	82	27	Spuds.	none	-	14"
8. Casadepaga Mg. Synd.	30	-	Spuds	none	-	12"
9. Crooked Cr. Dredge	29	16	Spud	none	-	10"
10. Dexter Cr. Dredging Co.	34	12	Spuds	4x24	3/8; 1"	10"
11. Dime Cr. Dredging Co.	29	19	Spud.	none	-	5"
12. Eskimo Gold Mg. Co.	64	21	Spuds	shaking 1-7x12;1-7 1/2x12	3/8; 1 1/2	5" +10 2-12";
13. Hammon Consol. Goldfds. Co. #1.	103	22	Spuds	7x40	3/8;1/2;1 1/2	" 1- "
14. " " " " #2	82	22	Spuds	7x40	3/8;1/2;1 1/2	" "
15. " " " " #3	103	-	Spuds	7x40	3/8;1/2;1 1/2	
16. Iverson & Johnson	27	18	Lines	none	-	8"
17. Luther Gold Dredging Co.	-	16	Spuds	4x21	-	12"
18. Northern Light Mg. Co.	30	16	Spuds	none	-	5"+ 10
19. Shovel Cr. Dredging Co.	52	21	Spuds	none	-	8"
20. Swanson Cr. Mg. Co.	-	-	-	none	-	
21. Wild Goose Mg. & Trdg. Co. #1.	63	22	Spuds	4 1/2x22 1/2.	3/8 to 1 1/8	10"
22. " " " " " #2	55	21	Spud	Shaking	3/8; 1/2	5+10"
23. Cache Cr. Dredging Co.	66	18	Spud	6x12	8"	5+ 15'
24. Berry Dredging Co.	57	25	Spuds	4x16	2"	8 +12'
25. Fairbanks Gold Dredging Co. #1.	78	24	Spuds	5x26	1/2;3/4;1	6 +10'
26. " " " " #2(c)	38	13	Lines	5x22	1/2;5/8;1	12
27. Chatham Gold Dredging Co.	60	33	Lines	none	-	8
28. Riley Investment Co.	64	22	Spuds	4x14	2 1/2	5+ 12'
29. Northern Alaska Dredging Co.	64	24	Spud-lines	4x14	2 1/2	8+ 10'
30. Flume Dredge Co.	29	12	Spuds	none	-	12
31. " " " .	-	-	"	"	-	12
32. Innoko Dredging Co.	59	28	Spuds	4 1/2x19	1;2 1/2	6 + 1
33. Guinan & Ames Dredging Corpn.	31	15	Spud	4x 16	1 1/4	8"
34. Kuskokwim Dredging Co. (d)	72	17	Spud	6x20	1/2;3/4	3 + 1

a. Riffled area exclusive of save-all or undercurrent.
b. Dredge reconstructed.
c. Sand elevator.
d. 10 in. sand pump.
U.C. Undercurrent.

DETAILS OF ALASKAN GOLD DREDGES.

	Pumps.		Stacker or Conveyor.		Table & Sluice Data.			
	Size disch. in inches.	Normal-Gals. water per min.	Length ft.	Belt width inches.	Flume dimensions ft.	Gold saving area sq.ft.(a)	Grade of Flume or main tables.	Riffles
	10"	3000	none	-	5x70	210	10" to 12'	Rail
	8"	1750	-	24	-	525	1 1/4" to 1'	Rail & S.H.
	10"	3000	68	24	-	-	-	-
	12"	4500	70	22	-	580	1 1/4" to 1'	A. I
1/4	10"	3000	-	-	-	500	1 1/2" to 1'	A.I.
	7" +10"	3600	45	24	3 x80	-	3/4" to 1'	Rail
	14"	4000	none	-	3 1/2x72.	248	10" to 12'	Rail
	12"	4500	none	-	3 x 70	210U.C.	-	Rail
	10"	3000	none	-	2 1/2x60	-	10" to 12'	Rail
	10"	3000	-	-	-	200	1 1/4" to 1'	S.H.
	6"	900	none	-	1 1/2x54	81	9" to 12'	Rail
2	6" +10"	-	80	30	-	755	1 3/4" to 1'	S.H.
	2-12";2-6"	12000	160	36	-	4000	1 1/4" to 1'	
1/2	" " "	12000	142	36	-	4000	" "	S.H.
1/2	" " "	12000	160	36	-	4000	" "	S.H.
1/2								S.H.
	8"	1600	none		2x60	-U.C.	12" to 12'	Rail
	12"	36000	-	-	-	-"U.C.	-	-
	6"+ 10"	5600	none	-	3 x80	240	12" to 12'	Rail
	8"	-	none	-	2 2/3x78-	208	12" to 12'	Rail
		-	-	-	-	-	-	-
1/8	10"	3000	60	28	-	612	1" to 1'	S.H.
	8+10"(d)	3600	60	28	4 x 20	492	1" to 1'	S.H. + A.I
	6+ 15"	6000	none	-	4 x108	452	10" to 12'	Rail + Mn.
	8 +12"	4200	68	24	2(2 1/2x56)	340	10" to 12'	A.I. + Mn.
1	6 +10"	4000	90	24	-	730	1 1/4" to 1'	A.I.
1	12	3600	72	24	-	298	1 1/2" to 1'	A.I.+ S.H.
	8	1500	none	-	2 1/2x 60	150U.C.	1" to 1'	Rail
	6+ 12"	4500	68	24	3 1/2x75	264	1" to 1'	Mn.G., Rail
	8+ 10"	-	42	24	3 x 75	225	1" to 1'	Rail + A.I
	12	4000	none	- -	2 1/2x74	185U.C.	10" to 12'	Rail
	12	4000	"	-	2 1/2 x74	185U.C.	10" to 12'	"
	8 + 12"	8000	60	16	2(2 1/2x75)	466	18" to 12'	
	8"	1800	75	14	2 1/2 x75	197	10" to 12'	A.I. + C.I
	5 + 10"	3600	80	24	none	560	1+1 1/8"to 1'	C. I
								A.I.

S.H. Steel or iron shod hungarian riffles.
A.I. Angle iron hungarian riffles.
Mn.L. Manganese plate shod longitudinal riffles.
Mn.G. Manganese grate riffles.
C.I. - Cast iron riffles.

Riffles	Save all area sq. ft.	Approx. Total Wt. of dredge tons.	Size of Hull. ft.	Original builder.	
Rail	-	68	24 x 44 x 4 1/3	Union Const. Co.	1
Rail & S.H.	17	145	30 x 60 x 5 1/2	" " "	2
-	-	-	34 x 60 x 5 1/2	Risdon Iron Works	3
A. I	20	-	28 x 74 x 5 1/2	(b)	4
A.I.	36	325	36 x 92 x 6 1/4	Union Const. Co.	5
Rail	-	135	30 x 60 x 5 1/2	Union Const. Co.	6
Rail	-	-	30 x 62 x 5	" " "	7
Rail	-	125	28 x 60 x 5	Kimball & Saupe	8
Rail	20	-	28 x 50 x 3 1/2	(b)	9
S.H.	32	-	30 x 60	Union Const. Co.	10
Rail	-	55	18 x 37 x 3	(b)	11
S.H.	40	-	44 1/2x 86 x7	Western Eng. Co.	12.
S.H.	-	1750	56x140x11 1/2	Yuba Mfr. Co.	13.
S.H.	-	1500	56x115 x11 1/2	" "	14
S.H.	-	1750	- -	" "	15.
Rail	-	55	25 x 50 x 3	(b)	16.
-	-	-	30 x 60 x5 1/2	Union Const. Co.	17.
Rail	-	160	25 x 60 x 5 1/2	Union Iron Works	18.
Rail	-	-	30 x 60 x 5	Yuba Mfr. Co. (b)	19.
-	-	-	30 x 60	B. Bernard	20.
S.H.	36	360	36 x 75 x 6 1/2	Yuba Mfg. Co.	21.
S.H. + A.I.	-	-	32 x 96	I.B. Hammond (b)	22
Rail + Mn.L.	90	-	58 x 87 x 7 2/3	Bucyrus. (b)	23.
A.I. + Mn.C.	28	250	40 x 86 x 5 1/2	Union Const. Co.	24.
A.I.	21	350	40 x 90 x 6	Union Const. Co.	25.
A.I.+ S.H.	26	-	38 x 90 x 5	Risdon Iron Wks.(b)	26.
Rail	-	75	22 1/2 x 46 x 4	Holbrook et al	27.
Mn.C., Rail, A.I.	26	140	30 x 62 1/2 x 5 1/2	Union Const. Co.	28.
Rail + A.I.	25	-	30 x 80 x 5 1/2	Union Const. Co.	29.
Rail	-	125	28 x 60 x 4	Kimball & Saube	30.
"	-	125	28 x 60 x 4	" "	31.
A.I. + C.I.	45	260	38 x 73 1/2 x 5	Union Const. Co.	32.
C. I	30	115	25 x 50 x 4 1/3	" " "	33.
A.I.	30	350	36 x 90 x 6 1/3	" " "	34.

different sizes and types of dredges, the daily yardage handled and some of the difficulties that may be encountered.

During the early days of dredging around Nome, many so-called land dredges, often of freakish construction, were operated for short periods, dipper and suction dredges were also tried, but none of these can be credited with any real success. There were also numerous failures among the earlier bucket dredges but the bucket dredge of the single lift type is now the only kind in use.

The selection of a dredge is a matter for important consideration. The choice of the wrong type of dredge or a size not adapted for the conditions has led to failure where success might otherwise have been possible. A number of the dredges now operated are too large for the shallow deposits they dig, necessitating the digging of much additional bedrock or the construction of dams to provide their flotation. In general, large dredges are not to be considered for Alaska except in the more easily accessible districts, where the gravels are about 25-feet or more in depth and a large volume of gravel is assured.. Thus at Nome and in the Fairbanks districts, certain deposits justify the larger dredges. This consideration is otherwise governed by the operating conditions and the amount of capital that can be consistently invested in the dredge and its equipment. The 2-1/2 to 4-cubic feet bucket dredges are in general the most practical sizes for average Alaskan conditions.

Being far removed from the source of replacements, a dredge should be strongly constructed so as to lessen the possibility of a serious break down. The dredge is put in repair before starting the season and is expected to give a maximum operating time, through the entire season. One serious break down may cause a large loss of time and money. A large stock of additional parts must be kept on hand and in isolated districts a machine shop must be included. An oxyacetylene welding outfit is indispensible around a dredge for repairing broken parts, building up tumbler plates, buckets, etc.

The flume or single sluice type of dredge has been developed for dredging the relatively narrow, shallow, rich creek placers containing coarse gold in loose washed gravel, free of stiff sticky clay, and boulders

(22438) Glacier ice on Shovel Creek.

(22440) The 2-1/2 cu. ft. flume dredge on Ophir Creek.

and having a favorable bedrock. They are of light draught and construction, and are operated mostly by distillate engines. The buckets discharge directly into the head of the flume, the tailing being dumped astern of the dredge. The disposal of the tailing regulates the depth of ground that can be dredged, the usual depths ranging up to 12 and 15 feet. For satisfactory and economical operation, the gravels, and bedrock must permit easy digging and free sluicing. Being of lighter weight and less expensive than other types, the flume dredge is well adapted for dredging small areas particularly in isolated districts, and where conditions are otherwise favorable to its operation. See Pl. 22460, 24457, 22430 and Fig. 9.

The revolving screen and flume type dredge such as the Cache Creek dredge No. 23, see table and Pl. 24520, is an improvement over the straight flume dredge. In this instance, the use of this type of dredge is made possible because of the shallow depth of the gravels, and necessary because of the occurrence of many large boulders and some clay. The buckets deliver to a revolving screen at the lower end of which are set three 1-3/4 inch nozzles, operating under high pressure. The material is thoroughly

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Fig. 9 - Plan of 2-1/2 cu. ft. distillate driven flume dredge with undercurrent.

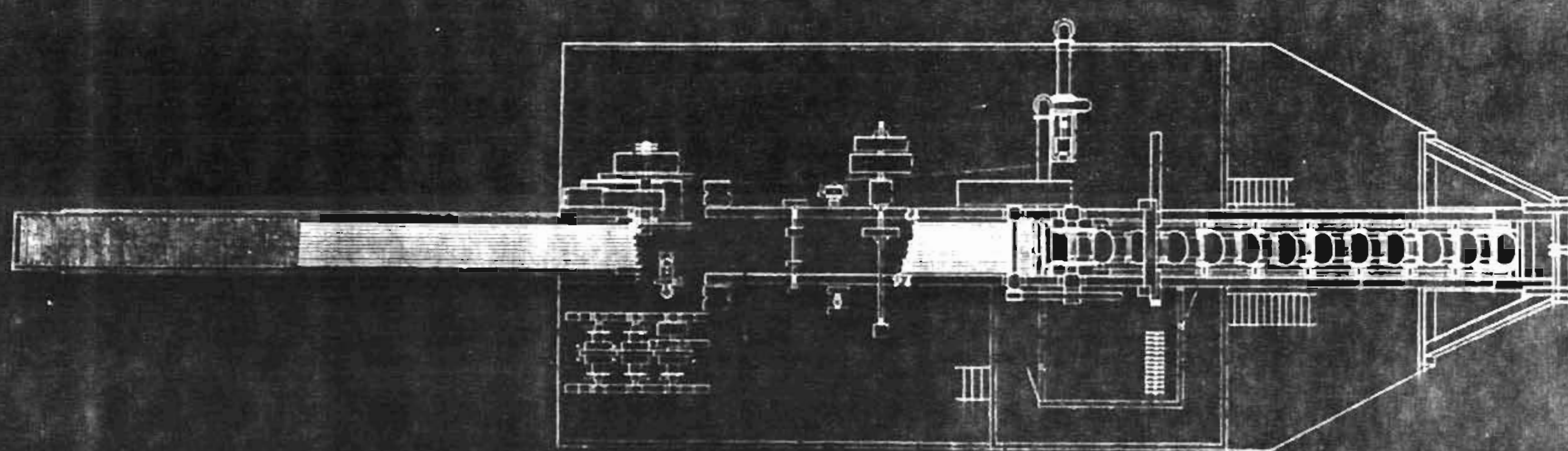

Fig. 9 . Plan of 2 1/2 cu. ft. distillate driven flume dredge with undercurrent.

(24467) The [illegible]-1/2 cu. ft. distillate driven, flume dredge on Yankee Creek.

(22439) [illegible] [illegible]-1/4 cu. ft. flume dredge, formerly on Warm Creek.

disintegrated and washed. The oversize, or material over 6 inches in size, then passes through a chute where it is divided, passed through the two rock chutes and dumped 10 feet astern of the dredge. The undersize goes to the head of the riffled flume. The lower 20 feet of this flume is divided into three branches and by shifting the flow from one to the other, the tailing is dumped level across the series of cuts. With these arrangements, the gold saving is greatly improved, the sands are prevented from running back under the dredge and the water level in the pond can be better maintained. Pl. 24523.

The combination type of dredge with a revolving screen, flume and conveyor is, in general, better adapted for the average Alaskan dredging conditions than other types where the gravels are not more than about 20-feet in depth or too shallow for proper flotation. These dredges are equipped with a coarse mesh screen, wherein the material is disintegrated and washed with water under high pressure delivered from nozzles or jets, the oversize going to a belt conveyor, the undersize to the flume. This conveyor which is really a stacker, but lacks the adjustable feature, is permanently affixed

(24523) The flume of the Cache Creek dredge.

(28283) Conveyor and two flumes on the Perry dredge.

to the dredge at a slope best suiting the conditions. Pl. 28281 and Fig. 10.

The combination type of dredge is lighter in weight and is less expensive than a table stacker dredge of similar capacity. Two dredges of this type, Nos. 24 and 32, have two flumes, one at either side of the screen and conveyor. Pl. 28283. The undersize on these two dredges goes over a short, wide riffled sluice, set on a high grade just below the screen and in the same direction as the flow in the screen, then onto another sluice below in a reverse direction and is distributed to the head of the two flumes. These two dredges have more than double the gold saving area of the dredges with single flumes and in many respects are quite similar to the table-stacker dredge.

The conveyor on the combination dredge not only disposes of the heavy material but stacks it where most required. Thus, where the deposit contains much fine material, the flume is extended beyond the end of the conveyor, the heavy material from the conveyor then prevents the fine material from the flume from running back into the pond and

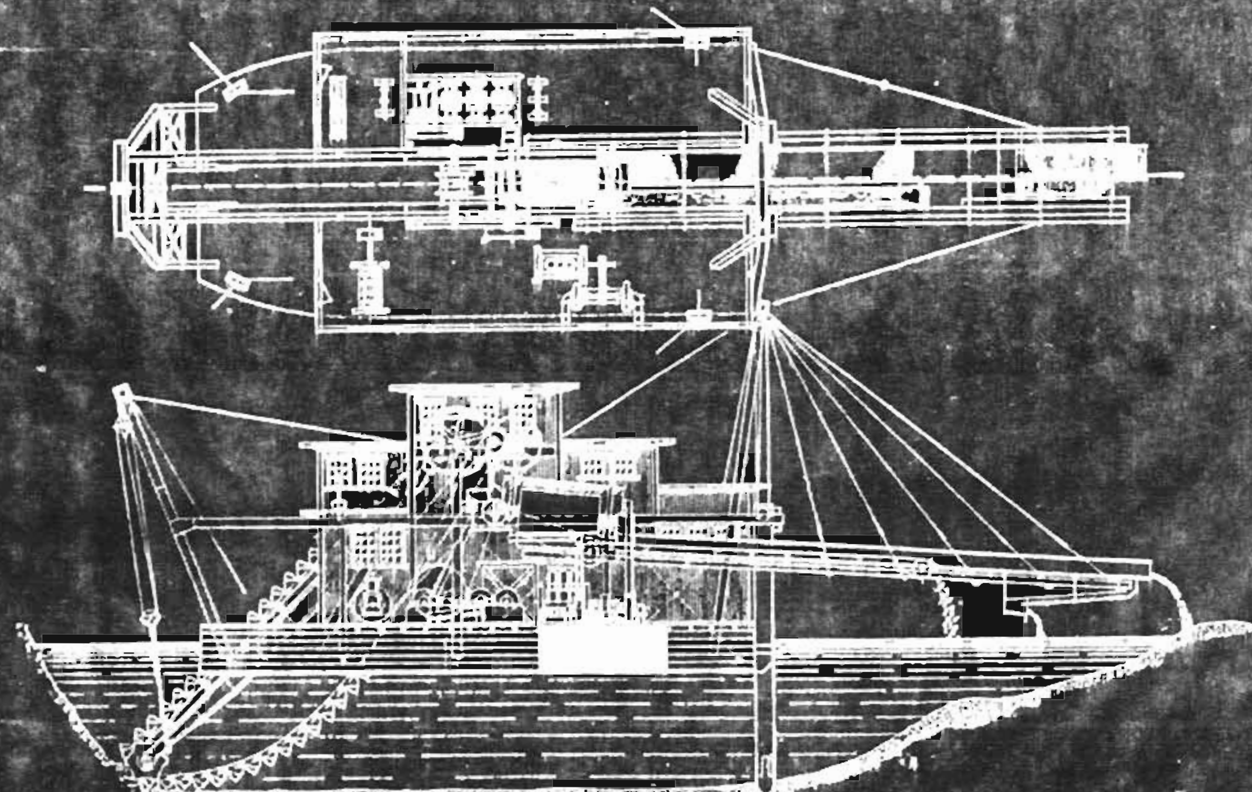

Fig. 16. Plan and elevation of a 3 1/2 cu.ft. combination type of dredge with revolving screen, flume and conveyor and equipped with undercurrent.

Taken from page 106, Fig. 14, Gold dredgingn in the United States, by Chas. Janin, U.S.Bureau of mines bulletin No.127.

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Fig. 10 - Plan and elevation of a 3-1/2 cu. ft. combination type of dredge with revolving screen, flume and conveyor and equipped with undercurrent.

Taken from page 106, Fig. 14, Gold dredging in the United States, by Chas. Janin, U. S. Bureau of Mines bulletin No. 127.

(24520) Electrically driven 6-1/2 cu. ft. screen-flume dredge on Cache Creek.

(28201) Steam driven, combination type dredge on Mammoth Creek.

under the stern of the boat. Should the dredge have only one flume, the conveyor is installed to one side of it. Difficulty is sometimes encountered where the gravel contains very little clay or fine material, in retaining sufficient water in the pond. This has been remedied by extending the conveyor which then dumps the heavy material beyond the end of the flume against which the fine material from the flume is deposited.

The stacker or California type of dredge has the widest useful field of any of the dredges. It is the best kind of dredge for ground containing gold that is difficult to save and is the only kind to satisfactorily dredge the more difficult and deeper deposits. The buckets deliver to a revolving screen, the largest perforations used in these screens being 1 to 1-1/2 inches in diameter. After disintegration and washing, the oversize material goes to the stacker and is piled behind the dredge. The undersize is distributed to the gold saving tables and sluices and the tailing discharged astern. [illegible] Pl. 24446 and Pl. Lomen Photo.

Two dredges of this type, No. 12 and 22, are equipped with shaking screens. The material is delivered by the buckets to a riffled flume or sluice, then going to the shaking screens. These screens are in two sections, timed to work in opposite directions. The screens are equipped with retarding bars and cast iron "fingers" are suspended over the screens to retard the flow of material and help disintegrate the clay. Jets of water under high pressure wash the material. The screens are operated by eccentrics and on the No. 12 dredge made 124 three-inch strokes per minute. The oversize, which may include some unwashed clayey material, goes to the stacker, the undersize passes over riffled chutes underneath the screen and is distributed to the tables, the tailing discharging through sluices astern of the dredge. An extra man must be employed as a screen and flume tender.

Dredges Nos. 26 and 34 are both digging downstream and to keep the sand from filling in at the stern of the dredge, they are equipped with sand elevators. The tailing from the tables are delivered to a sump from where the sand buckets elevate the material and dump it into a chute which delivers it to the stacker. No. 26 has but one elevator, No. 34 has two, one for

(24446) The 3-1/2 cu. ft. semi-diesel driven, stacker dredge, on Candle Creek in the Kuskokwim.

(Lomen Photo) No. 1 dredge of Hammon Consolidated Goldfields Co., at Nome. A 9 cu.ft. electrically operated stacker dredge.

each set of tables. Unless a dredge is digging downstream, very few of the dredges on the creeks experience difficulty with the sand, in fact several of the dredges have to deliver tailing to the stern of the dredge to provide anchorage for the spuds.

In addition to the water which may be required for stripping or thawing operations, an ample supply of [redacted] water must be available for flotation and sluicing. For the average Alaskan dredge not less than 35 to 50 miners inches of clear water should flow constantly into the pond, otherwise the pond water will become too thick, causing excessive wear of the pumps and interfere with the gold saving. Depending on the flotation necessary and the character of the material dredged, larger quantities may be required. The straight flume dredges require more water for sluicing than dredges with screens. The local creek supply is generally ample for this purpose although during very dry seasons, a number of the dredges have been shut down due to lack of water for flotation.

The reader must be referred to the many books and articles on the operation of dredges, details of design and their construction for it is not practical to cover them in this report. Special reference is made to "Gold Dredging in the United States" by Chas. Janin, U. S. Bureau of Mines Bulletin 127. There are however, numerous features along this line which apply directly to Alaska operations and of which a brief mention must be made.

The small size of many of the hulls is forcibly shown by the fact that many of the dredges have had to extend and widen their hulls, or add pontoons to keep the decks from being awash or to lessen the draught to aid flotation. A number of the smaller dredges have utilized empty oil drums for this purpose. Wooden hulls are used exclusively, the recently constructed large dredges at Nome have wooden hulls but with a steel frame work. Native timber makes very poor hull material. With reasonable treatment, a hull should last the life time of the property. One dredge has the same hull still in fair condition, after 20 seasons of operation.

Most of the smaller dredges have open link connected bucket lines. Pl. 24459. Their main advantages are their lighter weight and the lower power requirements which adapts them for certain dredges and conditions.

They were at one time considered more favorable for digging difficult bedrock and some of the operators contend that the open link connected line permits the boulders to be handled more readily. The advantages of the modern close connected line are so marked that a comparison is hardly necessary. The shape and weight of the buckets are determined by the character and depth of the ground and the size of the gravel. For tight, difficult digging ground a small and strongly built bucket should be used. Bouldery ground requires larger buckets and a line, of special design. Pl. 24&24. For clayey ground, the buckets should be wide and shallow and free from inside projections so their load can be dumped as readily as possible. With a strong manganese steel bucket line and sufficient power, practically any of the bedrock encountered in the Alaskan dredging fields, if unfrozen, can be satisfactorily dug. Dredge No. 21., on Ophir Creek has dug 10 feet of slabby limestone bedrock, with no undue difficulty. Excepting some of the smaller flume dredges most of the ladder trusses, are equipped with chutes or pans to catch the spill from the buckets and return it to the digging face. During freezing weather, steam or hot water run

(24459) A light 2-1/2 cu. ft. open link connected, bucket line, etc., on flume dredge.

(24524) A 6-1/2 cu. ft., close connected bucket line of special design.

down this chute helps to keep the material from freezing to the ladder, etc. The buckets in discharging into the screen hopper or flume also spill some material. This falls onto a steeply inclined grizzly in the well hole, the undersize going to the save-all sluices.

Upper and lower tumblers of all standard shapes are used on the older dredges. On the newer dredges and those that have been modernized, the round lower tumbler is used almost entirely, with a 5 or 6 faced upper tumbler. With the exception of the larger dredges and several of the other stacker dredges, the main bucket line drive has a single bull gear drive. This subjects the shaft to severe strains and has been the cause of many breaks of the shaft or gear. The double gear drive equalizes this strain and improves the operation of the bucket line.

Inadequate power, especially for the bucket line, is the predicament of some of the dredges. This is sometimes caused by making the engine driving the bucket line, also drive too much other equipment. One interior dredge has recently increased its daily digging capacity by about 300 cubic yards by changing a pump drive over to the other engine. The speed of the bucket line must be readily adjustable to the different digging conditions. A low speed must be used where there is frost or heavy gravel or difficult bedrock is dug, and arrangments should be such that the speed can be quickly increased when digging conditions improve. The variable speed motor drive on the electric dredges, most successfully answers this requirement.

As a general rule, the buckets and lips last from 3 to 5 or more seasons of average operation, for the yardage handled during a season is relatively small. Frozen ground when encountered causes the greatest amount of wear and requires much additional power. In a recent instance at Nome, the entire bucket line on one of the large dredges had to be replaced after one season's digging in ground, the lower portion of which, had not been successfully thawed.

High bedrock gradients increase the difficulties of operation and seriously affect the cost. Dams must be constructed to raise the level of the water in the pond and in the shallower ground much additional bedrock must be dug, to provide ample flotation. A dredge should not dig downstream unless there is some great necessity for it, or conditions are such that they do not handicap the operation. It generally necessitates the building of dams unless the gradient is very low, complicates the tailing disposal, and makes the digging more difficult, for it generally means working against the general "lay" or gravel flow. This last condition is especially true when the gravel is flat and shingled. One interior operation started dredging at the head of the creek, working downstream on a 7-1/2 per cent grade. In addition to the numerous boulders encountered there and the generally bad digging conditions, dams had to be constructed across the narrow channel about every 40 feet of advance. The cost of the dams alone is stated to have amounted to about 60 cents for every cubic yard of ground dredged. While the grade has now decreased to about 2 per cent and dam construction is no longer necessary, the dredge must continue to dig downstream in gravel more difficult to dig from that direction, and averages only about 60 per cent of the yardage that a dredge of this size will normally handle. However, all of this difference cannot be laid to digging downstream for much clay is also present which increases the difficulties of washing and slows down the operation.

The normal Alaskan dredging season ranges from 3 to 5 months, varying according to the locality and the peculiarities of any particular season and the deposit. On the Seward Peninsula, the average season for most of the dredges starts in June and closes about the middle or latter part of October, the average operating season being about 100 days. A number of the dredges there realize from 130 to 145 days during a favorable season, while there are others which operate but about half this time. One of the large dredges at Nome started its first season on July 6, 1923, and operated until December 2, or for 149 days. Toward the close of that season, the temperature at one time dropped to 36 degrees, below zero. One of these dredges resumed digging in 1924 on May 1, continuing to December 7, or 220 days, which establishes a new record for Alaska. This company expects to be able to average a season of from 6 to 7 months. In 1912 and 1915, the Blue Goose dredge on Ophir Creek, which was then steam operated, ran for 152 days. The start of the season is generally greatly delayed on creeks fed by springs for after the creek has frozen over, the water from these springs break out causing successive overflows which build up unusual thickness of ice known as "glacier" and which generally covers the entire valley. Shovel Creek is probably the worst offender in this respect. In the early spring of 1922, this ice was over 15 feet thick. It practically covered the dredge and caused serious damage to it. On July 13, there was still 5 feet of this ice. Pl. 22433, so that dredging could not get underway, until August when further difficulties were encountered because of the seasonal frost. The average season on this Creek is about 75 days.

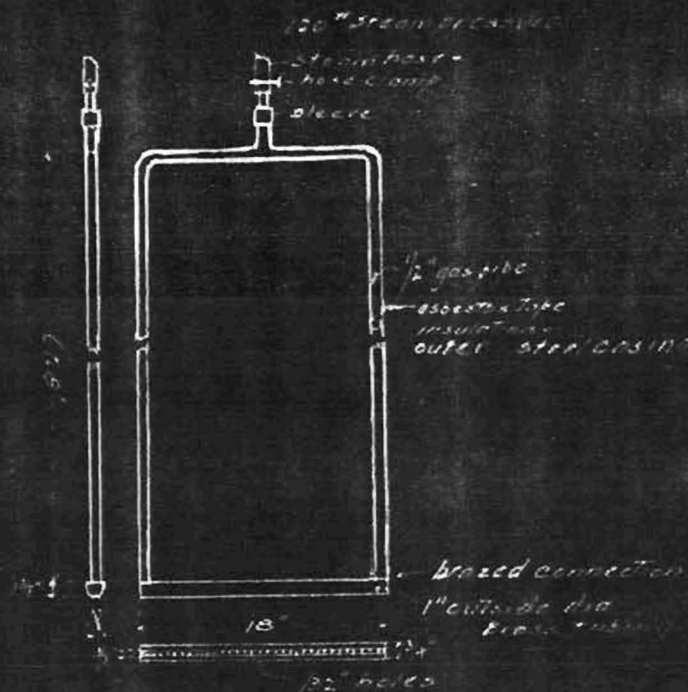
The average dredging season in the interior districts is generally longer than on the Seward Peninsula, ranging from 130 to 165 days, dredging starting early in May or June and continuing until late in October or early in November. The longest season recorded for any interior Alaskan dredge was for 194 days, being attained by one of the Otter Creek dredges in 1916. In 1923, the Kuskokwim dredge operated from May 2 to October 23, or 174 days. The Cacho Creek dredge which is operating outside of the severe cold belt, operated its longest season of 174 days in 1923.

Surface ice forming in the dredge pond in the fall is broken up while forming and pushed to one side by the dredge or the cakes are removed from the pond. Slush and anchor ice, however, quickly closes in on the dredge and soon has it tightly frozen in. There is no practical way of combating this kind of ice although the hulls are often heated with steam or in a few cases attempts have been made to warm the pond water. The experienced operator has learned that when the ice once starts to bother, that the practical end of the season has been reached and the dredge should be put into winter quarters. Some dredges, however, continue to operate until they are frozen in, where they are left until the next spring. This may, however, leave the dredge where it is unprotected from the early spring floods and other dangers. A safer method, which is employed, is to stop early enough for the dredge to dig itself a level bench to one side of the pond at some protected place, the water then being lowered allowing the dredge to settle on an even bottom. The dredges are only removed from the ponds when hull repairs become necessary.

In the spring, the dredge is cut loose from the ice, water is run into the pond and the dredge floated. The cutting of the ice around the boat and in the pond is done with saws and axes, but more often with steam points or steam ice cutters. Fig. 11 shows one of these ice cutters. The pond ice may also be blasted. For early operation, the ice cakes are removed from the pond, and the ground ahead of the dredge is stripped of its snow and ice covering. Where the seasonal frost is not deep, some good results have been obtained by scattering ashes over the ground. Sufficient ground is generally thawed ahead of the dredging with steam, and at several operations with water, to get the dredge well underway. Experience has shown that the best practice is generally to start dredging as early as may be practical in the Spring and stop earlier in the Fall, and not to fight the freezing weather.

The dredges are heated with steam, a boiler being generally supplied just for this purpose. During freezing weather, the stackers and sometimes the flumes are housed in canvas and steam heated. Hot water or steam is applied to the ladder chute or the line is relieved of the accumulating frozen material from time to time with a steam jet.

The dredges are practically all lighted by electricity. There



STEAM ICE CUTTER
Fig No. 11

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Steam Ice Cutter
Fig. No. 11

being continuous daylight for several months during the summer, the power for driving the electric generator for lighting is generally supplied by a small auxiliary internal combustion engine, excepting on the electric and steam driven dredges.

Alaskan dredges average from 20 to 60 per cent of their theoretical 24 hour digging capacity, the wide range being due mainly to the differing efficiencies of the dredges and their operation, the digging conditions and the time lost. Therefore, a mean derived from the performance of all the dredges would be of no practical value. However, most of the normally operated dredges working under average conditions realize from 40 to 45 per cent of their theoretical capacity.

The dredging season includes all the time from the start of dredging in the spring to its close in the fall. The operating or running time includes only the time the dredge was actually digging. All time spent in stepping ahead, changing lines, cleaning up, making repairs, delays due to accidents, engine or power trouble, floods, frost conditions, the handling of boulders or any of the numerous causes for stopping the digging must be charged to lost time. It is a part of the winchman's duty to record the cause of all lost time during his shift for which a printed form is supplied. The short dredging season makes it especially imperative that the greatest possible operating time be realized. The dredge should, therefore, be thoroughly overhauled and put in the best condition for operating before dredging starts in the spring and all safeguards should be taken to protect the dredge from any possible accidents.

Many of the dredges do operate for 22 hours out of the 24 hours and sometimes a little longer, for days at a time. The flume dredges generally average higher than the dredges of other types, some claiming an average operating time of 90 per cent which would, however, be possible only under exceptional conditions. Excepting any unusual long delays, the operating or running time of the Alaskan dredges generally averages from 75 to 85 per cent of the total time available. The greatest portion of time lost may be due to engine or power trouble, mechanical accidents, floods, lack of water, stopping ahead or moving especially in shallow ground, the clean up, etc.

The following table is given to show the causes and the amount of time lost by two dredges operated under widely differing physical conditions, further data being given under dredging costs.

Most of the dredges are operated on twelve hour shifts, the shoremen, stripping, thawing crews, and others that may be required, working 10 hours. Several of the companies have adopted the 8 hour shift because of the generally higher efficiency. The supply of capable dredge men must, however, be considered and because of the short season, the proportionately increased wages, and the many hours which would otherwise be put to little use, the men usually prefer the longer shift. The average dredge crew per shift consists of one winchman, one engineer, and an oiler with one or two shoremen or roustabouts on the day shift. Most of the companies employ a dredgemaster or superintendent. On the distillate driven flume dredges, the engineer spends about half his time with the engines, and also handles the duties of an oiler, but a flume tender who is sometimes also the roustabout is employed. Five men constitute the entire crew for steady operation on the smallest of the flume dredges.

LOST TIME IN PERCENT OF TOTAL TIME.

Cause of delay.	Wild Goose Dredge No. 1.[a] 1919.	1920.[b]	Cache Creek Dredge. 1922.
Step ahead.	2.57%	2.84%	—
Moving to cuts	0.91	0.96	1.72
Moving lines	1.47	2.12	0.56
Rocks	1.52	2.93	0.25
Clean up	0.04	0.02	1.09
Sluices	0.05	0.02	0.19
Stacker	0.52	0.21	—
Repairs machinery	1.47	1.42	—
Engine trouble	0.32.	0.22	—
Bucket line, ladder,	1.57	1.55	1.18
Screen	0.12	0.09	0.35
Winches	0.25	0.23	0.26
Pumps	0.03	0.10	0.15
Electric equipment	0.35	1.27	0.42
Spuds	0.05	0.11	0.08
Frost	—	0.48	—
Pond and dam	2.65	1.03	—
Miscellaneous	0.65	0.36	(c) 16.80
Lower tumbler-oiling			0.07
Upper tumbler, repairs			0.21
Power plant, ditch etc.			0.71
Hopper			0.16
Lost time, percent	15.53	15.94	25.60
" " hours	335.42	409.25	1063.03
Running time, hours	1824.58	2158.75	3088.97
Total time, hours	2160.	2568.	4152.

a. Digging down stream.
b. Time lost in 1917 was 34.9%
c. Time lost account of floods, pond and ditch trouble.

There is considerable variation in the wages paid by the dredges, even among those in the same districts. This difference is often due to personal reasons. A reliable and capable man deserves the higher wage. The following is the average scale, in addition to which board and lodging is provided. The shoremen and other labor are paid the prevailing wages, as given in the chapter on Labor.

Dredge wages.

	Winchmen	Engineers	Oilers	Dredgemaster
Seward Peninsula.	$7.50 - $9.00	$8. - $9.	$6.- $7.50	$10. - $12.
Interior.				
Iditarod - Innoko	$8. - $9.	$7.50.	$7.- $7.50	$12.-$13.
Innoko (8 hours)	$7.50	$7.50.	$6.50	------
Fairbanks	$8.	$8.	$7.	$275-$300. per mo.
Circle	$9.	$9.	$6.50	-----
Yentna (8 hours)	$6.	(a) $225. month	$5.00	$225.

a Electrician.

Dredgemasters, winchmen, and engineers living in the States or elsewhere out of the district are generally provided transportation and travelling expenses both ways, receiving wages only when on the property.

Reference to the table on Alaskan dredges will show the varied kind of power used and the amount of gasoline, distillate, fuel oil, diesel oil or wood consumed for power by the dredges in an average operating day. The cost of power on the distillate driven dredges and the dredges located in the more isolated and inaccessible districts where cheap fuel or hydro-electric power is not obtainable, is generally the greatest single item of the operating cost. Two companies operate their electric shore plants with diesel engines, both being located close to tide water. Two dredges are operated by hydro-electric power and one of the companies in the Innoko district is now installing a hydro-electric plant. The opportunities for a reliable and economical water power development in most of the dredging districts are, however, very limited, due to the difficulties generally encountered in obtaining favorable supplies, early freezing weather, and lack of ample reservoir sites. The Wild Goose Co. had available for power use the ditch and pipe line from former hydraulic operations. This water power is available for about 100 days each season, an auxiliary distillate engine being available when the water fails. Climatic conditions at Cache Creek permit the use of water for power during the entire season, where however, topographic features necessitate its use at a low head so that during unusual dry seasons, there is a lack of water during a month or so, which seriously handicaps the operation.

The diesel engine has made possible a great reduction of power costs and unless conditions are most favorable for other power development, will receive more general adoption for dredge power.

Steam is the ideal power for the average Alaskan dredge but should not be considered unless there is an abundant supply of good wood close at hand. Former steam dredges were equipped with the old and less efficient steam equipment which consumed large amounts of fuel. The wood supply soon had to be hauled long distances and the power costs became prohibitive necessitating a change of power. The satisfactory and economical operation of the locomobile type of steam equipment, makes it a most practical power in those isolated districts where wood or coal can be obtained at a reasonable cost.

The Berry dredge is equipped with two 75 H.P. Wolf locomobiles which have given most satisfactory service. For power purposes they consumed on an average of 4 cords of wood per operating day. An additional one-half cord of wood is consumed during the spring and fall when the heating of the dredge becomes necessary. The cost of the wood is now $15 per cord on the dredge. At a cost of $60 per day for wood and $23 for the wages and board of two engineers, one on each shift, this daily power cost is $83 or $0.554 per H.P. day. On a basis of 2200 cubic yards dredged per day, this amounts to $0.038 cents per cubic yard.

The following table has been compiled from data on 11 dredges operated on the Seward Peninsula in 1921 and shows the cost of power as being exceptionally high on the distillate and semi-diesel dredges.

Dredge Power Cost. Seward Peninsula, 1921

No. of dredges	Kind of Power	Cu.Yds Dredged in Season	Total H.P.	Cost of power (a)		
				Per day	Per Cu.yd. Dredged	Percentage of operating cost
5	Distillate	309,700	320	$441.00	$0.142	48.6
4	Semi-diesel	475,250	342	331.50	0.069	33.1
1	Diesel-electric	278,000	200	87.75	0.034	20.0
1	Hydro-electric	2020 per day	140	50.00	0.025	12.9
11	-	-	1002	910.25	-	-
Average	-	12,470 per day	-	-	0.73	33.8

(a) Includes only cost of fuel, lubricating oil, and labor in attendance. At most of the distillate driven dredges, the engineer devotes only a portion of his time to the engines.

The average cost of fuel delivered to the above distillate dredges was 63 cents per gallon, at the semi-diesel dredges, 24° diesel oil cost 36 cents per gallon, and at the diesel-electric plant the cost of the 24° oil was 30 cents per gallon. The cost of this distillate at Seattle was 17 cents per gallon, and for 24° diesel oil, 6-3/8 cents per gallon. The charge of $50 per day at the hydro-electric plant includes only the proportional cost of the ditch maintenance, and attendance at the plant the latter being mainly a portion of the dredge-master wages, all prorated on the basis of 100 days for the season.

The Cache Creek dredge, up to 1921, was steam operated, a poor grade lignite coal mined close by being used for fuel. The use of this coal was unsatisfactory, the steam power was too costly and with the heavy steam equipment aboard, the dredge drew too much water for satisfactory flotation. Hydro-electric power was then developed, a 1-mile ditch being constructed to deliver the water through a double pipe line, 1600 feet in length and 34 inches in diameter, to a 23-inch double discharge Leffel turbine water wheel, under 85 foot head. The 300 K.V.A. General Electric Co. belt-driven generator produces the alternating current which is transmitted at 11000 volts to the transformer near the dredge, where it is stepped down to 2300 volts, and transformed to 440 volts aboard the dredge. An average of 3800 K.W. hours are used per operating day. In 1922 the average cost of power which included the ditch and pipe line maintenance and the cost of labor, supplies, and power plant repairs, was $0.0168 per K.W. hour or $0.0283 per cubic yard dredged. The average cost of this power for a period of 3 seasons has been $52.43 per day, or $0.0258 per cubic yard dredged. The pipeline, turbine and most of the electrical equipment was second hand. The entire power installation cost $52,654. including $19.473 for the ditch and pipe line and $10,078 for the dredge electrical equipment.

The largest dredging company in Alaska, and operating at Nome, has a diesel plant consisting of 6 525-H.P. full diesel Werkspoor engines. These are operated on 14° - 16° fuel oil delivered to the Nome anchorage in tank steamers. The fuel consumption under average load is approximately 25 gallons per hour per engine. The engines are directly connected to 2300 volt alternating current generators. This current is transformed to 11,000 volts and transmitted 3-1/2 miles to the dredges. While the cost of power is not known, it is estimated to be little if any over 2 cents per K.W. hour. Conditions for developing comparatively cheap power, from coal or diesel oil, are also favorable in the Fairbanks districts, where the plant can be located close to the Alaska Railroad.

The loss of gold in dredge tailing is as a rule comparatively small, provided the material is thoroughly washed and disintegrated before it is put over the tables or sluices. The same principles for gold saving hold on dredges as for other methods of placer mining, but can in general be better applied on a dredge. While numerous physical conditions enter into the saving of gold, the recovery also depends upon the winchman. Bedrock may not be dug clean or the sluices may be overloaded. Unless the gold is coarse or heavy, and the gravel is free of clay which is difficult to disintegrate, a large loss of gold may result on the flume dredges. A deposit containing much sticky clay is being worked by one of the flume dredges, and great chunks of unwashed material pass over the end of the flume and according to the operator, about 40 per cent of the gold is being lost. Another feature adverse to good gold saving on flume dredges is the excessive amount of water generally required to carry the heavy material through the flume. The resulting high velocity or deep flow of material does not permit the lighter gold to sink and be caught in the riffles. The flumes of these dredges are paved with rail riffles, usually set lengthwise. Some of the rails should be set transverse, particularly in the upper part of the flume and especially so if clay is present or the gravel is flat. Transverse riffles will roll over the material and subject it to better disintegration than longitudinal riffles along which the material tends to slide more than roll. On the screen flume dredges this is more generally practiced, and special manganese shod, or manganese or cast iron grate riffles may be used alone or along with rails.

Some of the flume dredges are provided with undercurrents when a closely spaced bar, or plate, grizzly with small openings, is installed in the bottom of the flume near its lower end. The material passing through this grizzly is conducted back onto the dredge or underneath the flume and passed over short tables or sluices, paved with screen, expanded metal or punched plate over cocoa matting or burlap; or small special transverse riffles and sometimes an amalgamate plate may be used in conjunction. The practical use of these undercurrents is governed by the character of the deposit, the character and size of the gold and to their construction and operation.

One flume dredge, formerly operated in the Council District, reported that 20 per cent of the gold was recovered by the undercurrent. It is usually much less and in some cases they have been discarded due to the low recovery. On the Northern Light flume dredge, a test made during one clean-up showed that 82.54 per cent of the gold recovered was saved in the upper 25 feet of the flume, 10.93 per cent in the next 30 feet, 3.73 per cent by the undercurrent and 2.8 per cent in the tail sluice beyond the undercurrent grizzly. This tail sluice was paved with punched screen with 5/8" holes laid over burlap.

Dredges provided with screens not only have the advantage of being better adapted for washing and disintegrating the material, but by removing the heavier rocks, conditions for gold saving become more ideal and especially so on the table stacker dredges having the finer mesh screens, and on those screen flume dredges having additional gold saving area just underneath the screen. Stiff, sticky clay is always a bugbear to efficient gold saving, not only because of its difficult disintegration but also due to its sluice robbing propensities. The best practical means of treating such material on a dredge is to retain it in the revolving screen and subject it to attrition and the force of high pressure water from nozzles. Bars and rings are fitted to the screen to turn over the material and retard its flow. The material is further retarded by high pressure water forced against the flow from nozzles set at the lower end of the screen. Additional pressure water is forced directly down upon the material from nozzles projecting from a pipe running lengthwise through the screen. The action is quite similar to a ball mill, the material being worked over by the gravel until it will pass through the perforations.. In general, most of the gold recovered by the Alaskan dredges is recovered in the upper 25 feet of flume, or directly under the screens, or on the upper half of the tables.

The time of cleaning up on dredges varies according to the condition of the riffles. Some dredges clean up once a week, others once a month, at which time only the upper half of the flume, or the main portions of the tables are cleaned up. The lower portions are generally cleaned up only at the end of the season. Many operators state that only a few dollars worth of gold have been recovered from the last 5 feet of flume or riffled sluice and feel satisfied that very little gold is being lost. While no figures are available as to the amount of gold that goes over with the tailing, numerous colors of fine gold can, however, often be panned from the washed tailing and both coarse and fine gold from the unwashed clayey material. The regular clean-up requires from a few hours to a shift and during this period, advantage is taken to make minor repairs, adjust the engines, etc. The Wild Goose Company has its dredge arranged so that all of the material can be distributed to one set of tables, while the tables on the opposite side are being cleaned up without necessitating a shut down of the dredge. The saving of this time at the expense of attending to repairs, etc., and the gold saving, is open to question.

If nugget gold is present, a portion of the lower plate in the screen is given larger perforations. The material passing through these goes to a seperate coarse gold or "nugget" sluice for recovery.

The recovery from a nugget sluice will on some dredges average from 5 to 25 per cent of the total gold recovered.

The use of save-alls have in practically all cases more than repaid for their installation and attention. Faulty dredge design may cause excessive spilling from the buckets as they dump, although all dredges spill more or less material in this way, the gold therein being lost unless a save-all is provided. A number of the dredges report a saving of from $2500 to $5000 by the save-alls during a season's operation.

Amalgamation is practiced by all the dredges except several small flume dredges where the gold is coarse. The use of mercury applied to the riffles is imperative for good gold saving, especially if fine clean gold is present.

A number of the table stacker dredges were originally equipped with jigs or other special appliances for recovering fine gold and concentrates, particularly where such gold was coated with iron oxide or other compounds and could not be amalgamated. All of these, excepting the undercurrents mentioned, have been discarded.

On the table stacker dredges the standard dredge Hungarian steel-shod wood riffles and angle iron riffles are mostly used. The grades of the main tables average from 1 to 1-1/2 inches to the foot. Space does not permit a detailed discussion of gold saving and the arrangement of the tables or sluices. This is covered in a general way in the tables. The principles of gold saving, as practiced at Alaskan placer mines will be treated under a separate heading.

The methods used for determining the area or volume of ground dredged and the degree of accuracy of such measurements, are variable. A number of the smaller operations make only a rough measurement of the area dredged at the end of the season, and knowing, in a general way, the average depth dredged can calculate the approximate yardage. Several of the operations dredging shallow deposits of relatively uniform depth, use the unit of "square feet of bedrock dredged" but also state the average depth dug during the season. The more systematic operations generally make a close survey every two weeks, or each month, recording both the area in square feet, the average depth in feet, and the volume in cubic yards. Due allowance must be made for the slope of the banks and any irregularities in the shape or depth of the cut, especially in the deeper ground.

A method used by a number of the companies is to survey a base line along one or both sides of the course to be dredged, setting stakes at stations every 100 feet or more. A transit is set up at a station and the determining points along the edges of the cut located. The survey is then plotted and the area obtained with a planometer, or calculated. The average depth of the ground dug is derived from the daily dredge reports, and the yardage is calculated. The area ahead of the dredge is often staked out in 100 foot or other size squares. The base line, or the square system establishes the course of the dredge, its progress and location can be readily determined and the cut measurements can be quickly made. In deposits containing an irregular gold distribution or where the ground has not been thoroughly prospected, close drilling may be done ahead of the dredge. The course of the dredge and the depth of the bedrock to be dug is further determined by panning the material dug from time to time. Unprofitable areas are then avoided.

The cost of gold dredges has increased 45 to 60 per cent in the past 8 or 10 years. Some of the earlier Alaska dredges were originally erected and placed in operation at costs which could not now be duplicated for twice the amount. While it is impossible to estimate the cost of a dredge, its capacity, etc., unless all conditions are known, the following table, compiled from data obtained from several of the dredge builders, gives the weight, approximate average monthly capacity, etc., of different sizes and types of dredges, and their approximate cost, f.o.b. Pacific Coast.

Approximate Cost and Weight of Gold Dredges

Size Bucket Cu.Ft.	Av. Monthly Capacity Cu.Yds.	Approx. H.P.	Digging Depth Ft.	Lumber in Hull B.Ft.	Total wt. Dredge Tons	Approx. Cost f.o.b. S.F.
(a) 1-1/4open	17,500	50 (1)	12	17,000	52	$ 15,000 (d)
(b) 2-close con.	36,000	80 (2)	30	75,000	210	46,000
(b) 2-close	36,000	75 (2)	20			45,000
(b) 2-1/2-open	30,000	60 (1)	18	60,000	125	24,500
(c) 3-close	45,000	100 (3)	20	80,000	-	62,000
(c) 3-1/2-close	52,000	150 (3)	35	105,000	325	85,000
(c) 3-1/2-close	52,000	150 (3)	20	-	-	75,000
(b) 4-close	60,000	150 (2)	35	105,000	345	82,000
(c) 4-close	60,000	220 (3)	35			100,000
(c) 5-close	85,000	250 (4)	40	200,000	670	200,000
(c) 6-close	100,000	300 (4)	40	220,000	875 (5)	215,000
(c) 7-1/2-close	120,000	400 (4)	40	250,000	825	235,000

(1) - Distillate power
(2) - Steam power-locomobile
(3) - Diesel engines
(4) - Steam-electric
(5) - Includes steam shore plant

(a) - Flume dredge
(b) - Combination flume screen and conveyor dredge
(c) - Screen and stacker dredge
(d) - Cost of machinery only.

Full diesel engine power costs from $1000 to $1500 more than steam locomobile power on 3 to 3-1/2 cu. ft. dredges.

With the above table and the tables on ocean and inland freighting costs given under that chapter, an approximate estimate can be derived on the cost of a dredge landed at the property. Under average conditions, the 2-1/2 cubic foot flume dredges have been erected for $7000 to $9000; the combination 3-1/2 cubic foot dredges, from $12,000 to $18,000 and the 3-1/2 to 4 cubic foot stacker dredges from $18,000 to $25,000. Dredge No. 32 (see table on Alaskan dredges) was recently erected in 43 days at a cost of $15,000.

Dredge No. 2 ready to operate cost $50,000 in 1911. Dredge No. 5 as originally erected on Bangor Creek in 1914, cost $127,000. It cost $90,000 in Oakland. Dredge No. 6 cost $85,000 erected, in 1915. About 10 years ago, a 2-1/2 foot flume dredge similar to Dredge No. 8 erected in the Council and Solomon districts, cost around $27,500. These dredges erected in districts of average accessibility, now cost from $45,000 to $50,000. While the cost of the large dredges is not definitely known, Dredge No. 13 cost about $500,000 erected and Dredge No. 14 about $600,000. Their erection was completed during the winter when the extremely cold weather conditions added considerable to the cost. Dredge No. 21, as now constructed, cost about $125,000. Dredge No. 24 cost $86,000 erected in 1915. Dredge No. 25 cost $135,000 at Oakland in 1917, and erected at the property $180,000. Dredge No. 26 cost $80,000 erected. Dredge No. 30 cost $50,000 in 1921. Dredge No. 33, as originally erected on Glacier Creek, cost $28,000 in 1915. Dredge No. 34 cost $112,000 erected, in 1918, but an additional sum has been spent in changes made later. Many of the dredges on Seward Peninsula have changed ownership at least once or twice and have often been acquired for very nominal costs, either through direct sale, bankruptcy proceedings, etc. Others have been constructed with parts from older dredges.

Dredges which have proved unprofitable in their original localities or have completed the dredging of their ground, have been moved to new locations. These dredges having been acquired at a small part of their original cost or having been amortized during their former period of operation, have made it possible to dredge lower grade gravels or smaller areas which would otherwise prohibit profitable operation. This has been true of many of the dredging operations, particularly on the Seward Peninsula. Dredges have been moved to new localities on the same creek, to distant creeks and often to districts far removed. A freighting contractor at Nome gives the general figure for hauling intact over the snow the small dredges weighing from 125 to 200 tons, as $2500 per mile. Dredges weighing from 250 to 400 tons must be dismantled and the hull cut in half for hauling. These larger dredges are moved for $1500 per mile. Some dredges have, however, been moved for much less than this. Dredge No. 5 was moved during the winter of 1921, from Bangor Creek to Anvil Creek, a distance of 14 miles. The dredge was dismantled and the hull cut in two, lengthwise. The dismantling cost $4500, the hauling $11,000. The entire job, including the re-erection of the dredge, was contracted for $28,000. Dredge N o. 18 was moved in 1916, from Mystery Creek to Ophir Creek, a distance of 12 miles. The dredge was dismantled and the hull cut in half. The contract cost of dismantling and rebuilding the dredge was $3000, and the cost of moving was $3000. The dredge ready to operate on Ophir Creek cost the company $28,500. Dredge No. 24 was dismantled and hauled 2-1/2 miles down the creek for $3500 and reconstructed. The entire cost was about $15,000, which included additional material. Several dredges have dug their way for several miles downstream through old tailing to a new area, the gold recovery by the dredge paying a considerable part of the moving cost.

The average value of the gold recovered per cubic yard dredged from 1911 to 1922, incl., ranged from 51 to 77 cents per cubic yard, according to Brooks.[43] In 1923, this average dropped to 40 cents, the

(43) Brooks, A.H., The Alaskan Mining Industry in 1922, U.S.Geol. Surv. Bull. No. 755, p. 15.

lowest in history. Most of the deposits now being dredged yield from 20 to 50 cents worth of gold per cubic yard. About 1/3 of the operations are dredging gravels averaging around 50 cents per cubic yard. Three dredges report gold recoveries from 60 to 75 cents per cubic yard, and one over $1.25 per cubic yard. The opportunity of still acquiring dredgable ground which will contain an average gold content exceeding

40 or 50 cents per cubic yard appears to be very slight, unless new virgin fields should be discovered.

The cost of dredging in Alaska is high in most instances, and as the operations vary in scale and efficiency and are conducted under widely differing physical and economic conditions, the costs range through wide limits. The cost for the same dredge may also vary greatly from season to season. The cost of dredging as herein considered is the operating cost, which, unless otherwise noted, includes practically everything excepting charges made for depreciation, depletion or royalty, interest, or other charges which must be made against all capital invested in the dredge and other equipment, land, etc.. These capital charges are in some cases so great that profitable operation is impossible. While it is not practical or permissible to go into the details of other than operating costs, the capital account is one which must be given very serious thought, when operation in Alaska is considered.

The operating cost of dredging in Alaska ranges from 15 to 45 cents per cubic yard. There are instances where this cost has been exceeded but can generally be accounted for by unusually adverse ground conditions, serious accidents or delays, poor management, etc. Costs of 15 to 18 cents are only realized by a few operations in the more accessible districts, where conditions in general are favorable and the operation is efficiently and economically handled. Many of the low costs claimed can often be explained by the system employed in keeping the books or by the fact that office expense, management, etc., is not included or employed. Frozen ground not only adds the cost of thawing but may delay the operation or cause excessive wear and tear on the dredge. From more or less incomplete data obtained from the operators of 11 dredges on the Seward Peninsula in 1921, an attempt has been made to estimate the cost of dredging for that year. Each operation was checked or separately estimated and the average dredging cost derived. The data includes 4 dredges in the Nome districts, 3 in the Solomon district, and 4 in the Council district. These dredges operated under widely differing conditions. With the exception of a very small yardage which was artificially thawed at two of the operations, the ground dredged was unfrozen but for some seasonal frost. Of these 11 dredges, which dug 1,323,500 cubic yards, three, however, dug 740,000 cubic yards.

The operating costs ranged from 15 to 38 cents per cubic yard, the average being 21.6 cents. The total amount of capital invested in these dredges and dredging equipment was estimated at $590,000, which is low, as a number of these dredges were acquired for very nominal sums and could not now be replaced for twice this amount. While the probable life of the property could not be definitely determined in most cases, the depreciation of the amount invested in dredges and equipment averaged 4.64 cents and interest at simple 6 per cent, averaged 2.67 cents or in total averaging 7.31 cents per cubic yard, ranging from 2 to 20 cents. The cost of land, royalties, etc., could not be considered in the estimate. The season of 1921 was longer and operating conditions were, in general, more favorable than the average season. The number of days operated by the dredges varied from 75 to 129, the average being about 100.

One prominent engineer estimates that the frozen ground on the Nome tundra can be dredged at an operating cost of 9 to 10 cents per cubic yard, but exclusive of thawing costs. The total cost, including thawing and all capital charges are estimated at 23 cents per cubic yard. The estimate is based on the assumption that four dredges be operated for a season of 7 months and capable of digging 800,000 cubic yards per month.

Detailed operating data and costs of operations conducted by dredges of different sizes and types under differing conditions, follow. Much data concerning the production, capital charges, etc., and in some instances the operating costs, are held confidential and must be omitted. The data on the Wild Goose Mining and Trading Company No. 1 dredge is of particular interest, for it contains detailed accounts of its very successful operation from its start in 1910 to its close in 1924. This dredge was formerly driven by distillate engines. In 1918, it was electrically equipped and operated by hydro-electric power, excepting during the late fall or during short periods of water shortage, when power was supplied by the auxiliary distillate engine.

WILD GOOSE DREDGE NO. 1 - OPERATIONS.

Year	Length of season Days	Operating Time percent	Cu. yds. per season	Dredged per day	Av. value recovered per cu. yd. Dollars.	Operating Cost Per cu. yd. Cents.
1910	-	-	12,550	-	$1.7013	53.67)
1911	135.6	68.4	223,719	1649.	0.8573	20.90)
1912	128.5	72.4	224,490	1917.	0.3992	21.25)
1913	125.5	75.0	197,793	1565.	0.6207	31.77) a
1914	124.5	89.2	272,403	2188.	0.7666	15.34)
1915	123.2	84.9	265,393	2154.	0.7189	15.75)
1916	-	-	229,876	-	-	15.81)
1917	143.	65.1	215,730	1509.	0.5659	24.00
1918	-	-	149,503	-	0.7517	29.45 b
1919	90	84.6	164,224	1825	0.8164	29.31 b
1920	107	84.1	217,347	2031	0.6938	21.81
1921	129	-	260,648	2020	0.7146	19.34
1922	111	87.7	229,984	2072	0.5390	17.47
1923	108	84.7	201,465	1865	0.6718	18.48
1924						

a Exclusive of management which amounts from 2.2 to 4 cents per cu yd.
b Difficulty with frozen ground conditions. Retarded digging.

Previous to 1920 some small areas were thawed. Ground usually contains only seasonal frost. Depth dug varies from 7 to 24 feet. Bedrock - schist and thin bedded limestone. Gravel-medium size with some boulders.

Dredge digging downstream.

WILD GOOSE DREDGE NO. 1 OPERATIONS.

OPERATING COSTS.

	1917	1918	1919	1920.
Labor & Mess	$13,725.10	$7,660.37	$8,081.50	$10,746.00
Repairs & Renewals	12,561.75	14,438.62	11,188.52	9,777.56
Distillate and oil	9,455.47	4,357.32	2,151.20	1,866.96
Supplies	1,925.92	2,549.98	4,009.67	1,645.32
Freight on supplies	1,525.32	1,326.26	1,712.12	1,385.27
General expense	1,914.25	1,802.45	1,915.19	2,104.16
Stable	4,031.92	2,645.58	4,424.62	3,444.91
Ditch	1,402.66	2,087.01	3,052.05	4,288.25
Dams	-	-	2,382.39	1,230.80
Camp installation	-	-	721.60	1,292.66
Bullion charges	215.66	297.21	346.65	416.38
Insurance	-	1,750.00	3,361.91	2,456.93
Management, etc.	4,654.95	4,900.83	5,037.80	6,196.96
Travelling expense	315.25	408.55	744.40	1,057.01
Total	$51,784.28	$44,024.13	$49,129.82	$47,409.48
Per cu.yd.	0.240	0.2946	0.2991	0.2181

Capital invested in dredge and its equipment - $125,000. In power plant - $15,000. Depreciation, and interest - 6% - Amounts to $18875. per season, or $0.07 to $0.125 per cu. yd.

WILD GOOSE DREDGE NO. 2 OPERATIONS.

Year.	Length of season days	Cu. Yds. Dredged Per season	Per day.	Av. value per cu.yd. cents	Operating Cost Per Cu.Yd. Cents.
1921	137	202,257	1479	36.81	21.01
1922	100	213,797	2138	24.47	17.79
1923	91	150,305	1652	53.66	17.74

Cost includes management, etc.
Former Blue Goose dredge purchased by W.G.Co. for $15,000. Operated by them for 3 years only. Broke shaft late in 1923. Operation finished. Ground condition similar to No. 1 dredge but digging upstream.

RILEY INV. CO. DREDGING COSTS & DATA, OTTER CR.

	1921	1922
Operating Costs.		
Dredge operation, renewals & repairs	$35,851.79	(a) $40,066.27
Ground sluicing, brushing, etc.	6,441.49	1,249.90
Insurance	768.00	768.00
Expense acct. including management	7,827.47	6,638.55
Thawing	59,572.10	32,651.92
	$110,460.85	
b Credit- Profit from machine shop	7,542.00	
Total	$102,918.85	$ 81,374.64
Per square foot of bedrock, in cents	33.2	17.4
c " cubic yard in cents	61.8	33.6
Square feet of bedrock dug	309,475	465,950
Average depth dug in feet	14.5	14.0
c Cubic yards dug	166,200	241,504
d Square feet of bedrock thawed	260,000	255,000
Thawing Cost-cents per sq.ft.thawed	23.0	12.8
c " " " " cu.yd. "	42.5	23.7
Thawing cost-cents per sq.ft.dredged	19.2	7.0
c " " " " cu.yd.dredged	36.0	13.5
c Av. value of gold recovered per cu.yd.	61.4	54.2
No. of operating days	e 161	163
	(May 25 - Oct. 28)	(May 26- Nov.4)

a Cost of raising sunken dredge- $7,475, not included. Includes $6,372.84 for new buckets, lips, etc.
b Overcharge made against dredge and thawing- credited later.
c Cubic yard value cost, and other data calculated from square foot data
d Of ground thawed. Approximately half was thawed with steam and half with water.
e Includes about 20 days lost, by labor strike.

Dredge constructed in 1914.

In 1923, this dredge operated a season of 162 days digging 488,675 sq. ft. of bedrock or 271,486 cu. yds. The average depth dug was 15 feet. About 2/3 of the ground dredged was frozen and was thawed with water at natural temperature. The operating cost was 25.1 cents per cubic yard.

a

Beaton & Donnelly Dredge Operations - Otter Creek.

Operating cost. b	1920	1921	1922.
Dredge preliminary,	$ 6,328.53	$ 9,646.88	$ 4,442.71
Dredge operation,	29,441.44	32,768.74	31,858.96
Expense account	2,163.55	2,566.29	2,188.41
Preliminary stripping,	3,595.00	1,947.15	7,417.00
Mess account loss.	-	-	2,301.93
Ditch repair	1,622.50	-	-
Dredge repairs	-	-	1,108.85
Preliminary thawing	644.31	698.40	-
Thawing operations,	32,371.79	6,419.05	330.90
	$ 76,066.82	54,045.48	49,648.78
Cost per sq. ft. of bedrock in cents,	14.5	11.8	11.3
Cost per cu. yard., in cents	28.9	23.7	21.8
Sq. ft. of bedrock dug.	525,000	486,300	439, 200
Av. depth dug in feet	13.5	13.5	14.0
Cu. yds. dug	262,500	228,150	227, 733
Sq. ft. of bedrock thawed	235,000 c	small area	very little
No. of operating days	187	142	161 d
	(May 7-Nov. 9)	(June 15- Nov.3)	(May 21-Oct.28)

a Dredge constructed in 1918. Since 1923, operated by Northern Alaska Dredging Co.

b No management charged. Would add 1.5 to 2. cents per cu. yd.

c In 1920, about 1/2 of ground thawed was thawed by steam, balance with water.

d Lost 8 days due to broken shaft.

Cubic yard data calculated from square foot data.

Cache Creek Dredge Operation.

Operating Cost.	1921.	1922.	1923.	1924.
Labor, salaries, management, etc.	$15,653.08	$49,656.07	$ 37,639.78	$40,794.37
Dredge & power supplies	7,167.34	12,543.20	8,038.81	23,118.39
Miscellaneous a	3,994.34	8,830.19	12,632.13	9,100.62
San Francisco Office, etc.	908.06	645.00	875.62	b
Total	$27,722.82	$71,674.46	$59,086.84	$ 73,013.38
Per cubic yard	0.1458	0.1799	0.1924	0.3246

Operating data.

	1921.	1922.	1923.	1924.
Working days	94	173	174	151
	July 24- Oct.26.	May 17- Nov.6.	May 13-Nov.3.	May 13-Oct. 11.
Digging time, per cent.	73.0	74.4	76.0	83.0
Lost time, per cent.	27.0	25.6 c	24.0 d	17.0 e
Cu. yds. dug.	190,155	398,323	307,044	224,897.
Av. depth dug in feet	9.0	8.6	9.4	8.7

a Includes bullion charges, insurance, travelling expense, sundries, etc.
b Office expense, etc., included above.
c Floods caused four shutdowns causing loss of 31-1/2 days.
d During August operated only half of time due to water shortage for hydro-electric power. Also 9 days lost through floods.
e Broken spud caused loss of 12 days.

Unfrozen shallow creek deposit, gravels medium size with numerous boulders in certain areas. Must dig up to about 6 feet of easy digging coal formation bedrock to provide dredge flotation. Digging upstream over average grade of about 2-1/2 per cent.

BERRY DREDGE OPERATION.

Operating Cost.		1922		1923.	1924.
Labor & Supt.	a	20,903.08	b	25,733.42	
Supplies, etc.	a	15,062.66	b	13,709.57	
Office expense		562.61		474.44	
General expense		2,138.99		773.94	
Travelling expense		1,324.97		1,153.83	
Insurance & Taxes		2,652.05		2,541.66	
	$	42,644.36		44,386.86	
Per cu. yd.		0.2279		0.1764	

Operating data.

	1922	1923
Days operated c	92 July 2-18; July 30-Oct.12.	125. June 20-Oct.23.
Operating time, percent	84.4	90.2
Cu. yds. dug	187,132	251,692.

a Includes stripping and thawing, labor, $3,091.15, and supplies, cost not segregated. Steam thawed 40,000 cu. yds.

b Includes stripping and thawing, labor $6750.74; supplies $571.05. Stripped 76,000 cu.yds of overburden for natural thawing.

c Shut down July 19-29; to thaw ahead of dredge.

Cost of prospecting labor & supplies in 1923 - $1904.76 not included in above cost.
Moving and reconstruction of dredge completed June 1922, cost 13,267.42 and charged to capital account.

Steam operated dredge. Ground partly frozen, mostly seasonal frost. From 5 to 18 feet deep after stripping off 4 feet of overburden. Av. depth 10 ft. Bedrock schist and granite. Some high, hard reefs. Large granite boulders now.

Alaska Mines Co. Dredging Costs, 1920.

		Cost per cu.yd. Dredged Cents	Per Cent of Operating Cost.
Labor, dredge only	$ 9,525.89		
Material, dredge	383.89		
Repairs, labor & material	1,914.51		
Miscellaneous	1,362.65		
	$ 13,186.94	6.73	24.4
Thawing	10,195.00	5.20	19.0
Power	30,598.00	15.61	56.6
Total operating	$ 53,979.94	27.54	100.0
Overhead,	11,423.00	5.83	-
Total	65,402.94	33.37	-

This 8 cu. ft. electric driven dredge was formerly operated at Nome. It dug 196,000 cu. yds. in 1920 of which 25,290 cu. yds. were old tailing. During the 100 days the dredge operated the actual running time was 79 per cent, the greatest loss of time being due to lack of oil for power. Power produced by 650 K. W. shore plant at cost of 6.5 cents per K. W. hour, which was excessive. Of the ground dredged, 88,807 cubic yards were thawed with water at natural temperature at a cost of 11.49 cents per cubic yard.

The following will illustrate the operation of a 2- 1/2 cu. ft. distillate engine driven flume dredge in an isolated interior district. In 1922, the second season of its operation, this dredge dug 136,000 cubic yards from June 3 to Oct. 22, or 142 days, averaging about 20 hours of digging time each day. The average depth dug was 11 feet. The ground is unfrozen but for some seasonal frost and affords favorable digging conditions. The operating costs for 1922 were:

	Total	Per cu. yd.
Labor	$ 14,973.84	
Mess	3,807.41	
Mining material	540.40	
Distillate & oil	10,769.65	
Express & postage	800.50	
Travelling expense & miscellaneous	866.50	
	$ 31,757.91	$0.2335
Management, S. F. office expense, etc.	6,081.16	0.0447
	$ 37,839.07	$0.2782

The capital invested in dredge is $42,706. which depreciated in 8 years plus 6 per cent simple interest amounts to 5.8 cents per cu. yd. dredged in 1922. Dredges of this type and size were formerly operated on the Seward Peninsula at an operating cost of about 15 cents per cubic yard.

The Sluices and Gold Saving, Excluding Dredging.

The high cost of placer mining in Alaska and the lower average gold content of the gravels being mined, makes it especially necessary to save as much of the gold from the material put through the sluices as is possible, within practical limits. At most of the operations, the gold is coarse or heavy and while there is generally some fine gold present, or all of the gold may be fine, most of it can usually be saved with but few refinements in gold saving practice provided the material containing the gold is thoroughly washed and disintegrated. Quite often the gold is coated with a film of iron oxide, or with some compound of sulphur, arsenic, etc., and when this gold is fine, it is most difficult to save in the sluices. Light flaky or flour gold is of rare occurrence in any appreciable quantity and only a very small portion of it can be saved by the average methods.

The loss of gold in the tailing cannot be accurately determined, for the gold content of the material put through the sluices is not known except within certain limits and there is no practical way to accurately sample it or the tailing. The average placer miner however, does not like to admit that gold is being lost. Many of the dumps contain chunks of unwashed material which contain gold and sometimes amalgam, and the drops just off the end of the sluices often show appreciable losses. Gold loss in tailing is further evidenced in the number of "snipers" working over old dumps and from the results of drilling, or subsequent mining by following operations. Losses due to not thoroughly cleaning bedrock, etc. are not considered here.

Gold losses in the earlier days were no doubt greater than at present for as the deposits contained a higher gold content, a loss was not considered so serious. The sluices were often poorly adapted for the work. They were often overloaded, and the recovery suffered. Purington[44] estimated that in the interior, where two to five boxes with

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(44) Purington, C. W., Gravel and Placer Mining in Alaska, U. S. Geol. Survey Bull. 263, 1905, p. 191.

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no drop offs were used in saving the gold, from 10 to 20 per cent of the gold lifted into the boxes was allowed to return to the creek bed. There were instances reported where fully 50 per cent of the gold was lost during those days and there still are a few where it is safe to say that only 60 per cent of the gold put into the sluices, is recovered. With free washing gravel, i.e., free of difficult clay, and where other conditions are average, a high percentage of the gold can usually be saved by the customary methods.

The presence of stiff sticky clay, which is difficult to wash and disintegrate, further tends to rob the riffles of gold or amalgam as it rolls along, and the lack of suitable sluice gradients, account mostly for the loss of gold. A considerable loss may also result through the lack of sufficient water for sluicing or where the water must be used intermittently, or in splashes. In the latter case, each "splash" of water booms through the boxes, disturbs the riffles, dislodges gold, and carries it along until it eventually goes onto the dump. Lack of grade may prohibit the use of added refinements in gold saving at most of the hydraulic operations and some of the open cut mines; however, at the drift mines where only the richer portion of the deposit is mined, and at the mechanical and other operations where large amounts of barren or low grade material are first removed at considerable cost to get to the "pay", there is every reason why refinements in gold saving should be practiced, and the opportunity is generally there, as the gold bearing material is elevated and grade provided. There are, however, practically no instances, where the gold loss is large enough to justify special washing and gold saving plants requiring power for their operation or the costly labor for their attendance.

In the discussion of the various methods of placer mining and the operations described in connection with them, the sluices, riffles, and the conditions under which they are used, have been stated. It is not practical to further discuss their construction, etc., but in the following, some of the principles of gold saving and the methods as generally used in Alaska will be briefly mentioned.

Long sluices can seldom be used in Alaska as lack of grade generally permits the use of but 5 to 10 lengths of boxes. Excepting where special hydraulic methods of mining are employed, sluices over 200 feet in length are generally only used to aid in the tailing disposal.

The longer the sluice, the greater the opportunity of thoroughly disintegrating the material. Narrow sluices and a deep flow of material through them generally cause heavy gold losses. The depth of flow through the sluices should be deep enough to cover the largest rocks but under average conditions should not be over 6 or 8 inches deep. The tendency for the riffles to pack increases with the depth of the flow. Many of the sluices are too narrow and sometimes made so, in order that the scant water supply will better carry the heavy material over the low gradients.

The creek hydraulic operations must usually content themselves with grades of from 4 to 6 inches to the 12 foot box, although higher grades are often created by using special methods of mining as explained. In hydraulic mining, however, the material is generally pretty well disintegrated before it is put into the sluices so that shorter lengths of sluices may make satisfactory recovery, nevertheless, would conditions permit their use, longer sluices and the adoption of undercurrents, would improve it. A grade of 6 inches to 12 feet is considered the minimum over which gravel can be economically moved through sluice boxes without employing the use of excessive quantities of water, and where higher grades are available they are usually used. The sluices are given grades from 8 to 12 inches, and sometimes more, when permissable, but such high gradients are seldom available except where the material is elevated. The grade must be sufficient to keep the sluices from blocking without forcing it through with excessive amounts of water. Excessive amounts of water must be used at many of the mines, and at some of the hydraulic mines where the gold is coarse, the sluices are run almost full, yet a very satisfactory recovery is made. In these few instances, however, the sluices are 250 to 1000 feet long. Fine gold, whether it be bright or coated gold requires special consideration. The sluices should be wide so that the flow may be shallow and set on steeper grades to keep the sluices and riffles from packing. The saving of fine gold is best accomplished by removing the heavier material and passing the finer material over gold tables or undercurrents. In general,

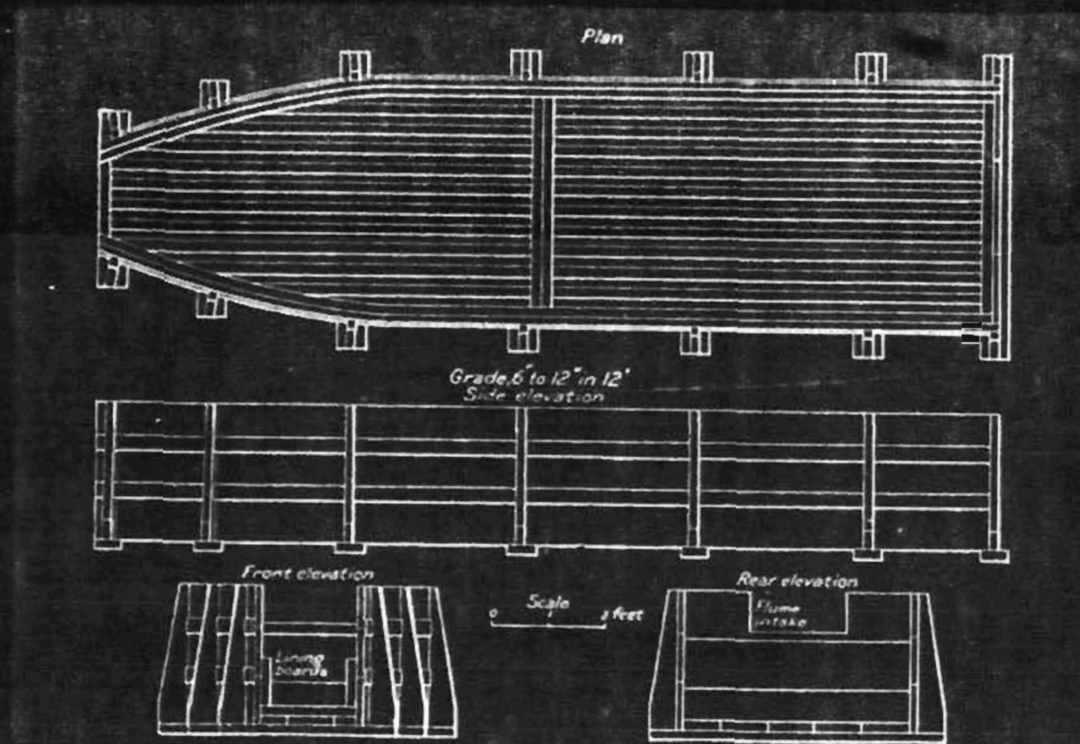

Fig. . Dump or mud box.

Original sketch accompanies
original copy of report

Fig. 12   Dump or mud box.

60 to 90 per cent of the average gold recovered is retained either in the dump box, if one is used, or in the head box and the 3 or 4 boxes below it. The lower end of the sluices seldom contain but a very small percentage of the total gold recovered.

The use of "drops" in the sluices are a great aid in disintegrating the material but the opportunity to employ them is generally lacking. They are a series of small vertical falls or breaks in the sluice, over which the material drops and is churned about at the bottom before continuing on. While a few inches of drop will help, they are more efficient when made from 1 to 5 or more feet high when the material is first passed onto a grizzly or inclined grating, the water and fine material passing through and falling into the sluice below, the washed oversize being dumped outside of the sluice.

Mud or dump-boxes are characteristic of the sluicing practice at many of the Alaskan operations where the material contains clay or mud and is difficult to wash. A small mud box is used at some of the shovel-in operations, but the larger dump boxes are used mainly at the drift mines and at the mechanical operations. A sketch of a dump box is shown in Fig. 12. They are merely a wide sluice tapering at the lower end to the width of the regular sluice box, set on grades of 7 to 14 inches which are generally higher than those given the sluices. They are paved with pole riffles usually set lengthwise, or with block riffles, and in a few cases with steel rails. They require the services of an extra man, or sometimes two at the larger operations, who puddles the clayey material as much as it is practical to do so, forks out the large rocks and sees that the sluices keep from clogging. The dump boxes used at some of the mechanical operations may be up to 100 feet or more in length, and as at the drift mines, the material is delivered intermittently to them, in relatively large loads. Unless the dump box is of ample size to readily handle this material, the box may become dammed, and on being released, the material is boomed through the box and sluices, escapes the attendant, and carries unwashed material and gold to the dump. At some of the operations, particularly at the drift mines, the material is conveyed and dumped into a hopper from which the flow to the dump box is regulated. The use of dump boxes, the delivery of the material to them, etc., at the drift mines, and steam scraper operations, has been described under those mining methods.

Riffles are used to retard the flow of material sufficient to give it a chance to settle but not too much to cause blocking or interfere with their proper functioning; to provide a place for the gold to lodge which requires the forming of dead spaces, or eddies where the material can be roughly classified or "boiled." This "boil" is affected by the shape and spacing of the riffles, the position in which they are placed in respect to the direction of flow, and the strength or velocity of the flow. This "boil" must be sufficient to prevent the riffles from filling up and packing hard with heavy sand but not too strong to prevent the gold to lodge and remain there.

The principal requirements of riffles for Alaskan practice are that they be efficient gold savers, at the same time cheap but durable, and not too heavy and bulky to be unwieldy. Riffles which may be efficient under one set of conditions may, however, not prove so under others. The Hungarian type, or the transverse riffle, is generally considered to be the best gold saver, although they retard the flow more than the longitudinal. It is generally good practice to use both, placing the transverse riffles in the upper boxes with the longitudinal below, or alternating with short sets of the transverse. The transverse riffle will tend to roll over the material, and disintegrate it more readily than the longitudinal ones over which the material tends to slide, especially if set too closely together. With wide spacing many of the longitudinal riffles act merely as a lodging place for the smaller rocks where, however, they become tightly wedged and provide a large area of riffled surface for retaining the gold. The spacing between riffles is regulated by the conditions and the results obtained. At the Alaskan operations, it generally ranges from 1-1/2 to 3 inches, the longitudinal riffles sometimes being given wider spacing.

The pole riffle is more generally used in Alaska than any other type, especially for the smaller sluices. Their principal merits are their cheapness and easy handling, but should not be used except where the gold is coarse. They are placed longitudinally in the sluices, being made up in sets from 3 to 8 feet long, consisting of from 3 to 8 small, green spruce poles which are peeled of their bark and held together atn varying spacing by cross pieces, nailed at each end. Small sawn timbers are also used instead of the poles and this riffle is sometimes made up in the Hungarian or transverse type. The poles or timbers are usually shod with strips of iron or steel, to prolong their otherwise very short life. Many instances were seen where the poles used were too large and too closely spaced, so that the intervening space was like chute, affording very little opportunity for the gold to find a place to lodge, the greater part of the riffled area being almost useless, in fact, detrimental.

Wood block riffles are used more at the hydraulic and mechanical operations. They are generally made up in sets, a number of blocks being held together and spaced by nailing strips of wood along the two opposite sides. These sets are then placed, crosswise in the sluice, so that the longitudinal spaces between the blocks are offset or staggered. Pl.28278.

(28278) Sluice showing block riffles and special liners. Also showing hangers for backstop as used for hydraulicking.

(22464) Widened tail sluice for recovering rusty gold.

Some operators "toe-nail" the blocks to the boxes but by making up these sets and allowing the strips to extend beyond the end blocks, and the liners made to fit down upon them, they are easily held in place. Wood blocks are giving way to steel rail riffles in most of the more accessible districts. Spruce and cottonwood blocks are used in Alaska. Cottonwood makes a poor block. An instance was noted at an interior hydraulic operation where the upper 3 boxes were paved with blocks, with longitudinal rail riffles below. On cleaning up, the operator was greatly disappointed to find very little gold in the upper boxes. Upon reaching the rail riffles, it was found that the gold had been retained by them. The failure of the block riffles was apparent, as they had been closely spaced and had "broomed" over.

Steel rail riffles are greatly increasing in use, especially in the interior district where a large supply of old rails were obtainable from the railroad and other sources at a comparatively low cost. In all cases, they have proven to be efficient gold savers and answer all the requirements, except being too costly to transport to many of the operations in the more inaccessible localities. Steel rails are used in weights from 12 to 40 pounds per yard, being placed both transverse and longitudinal, with either the ball or the bottom side up. When used with the bottom side up, which is in the minority of cases, they are usually given a spacing of 1/2 to one inch between edges. The operators contend that by using the bottom side up. the riffles do not pack as they often do when otherwise used. They create the proper "boil" and the gold finds ready lodgment and protection beneath the broad flanges. The wide surface of steel exposed lessens the frictional resistance to the flow, which is of advantage where the grade is low. There are numerous kinds of spacers, flanges, and methods of fastening the rails together in sets and for holding them in place in the sluices. Bouery[45] made an

(45) Bouery, P., A Study of Riffles for Hydraulicking. E. & M.J., Vol.95, May 24, 1913, p. 1055-1060.

extensive study of riffles at the La Grange hydraulic mine in California. He found that in general, rail riffles were better suited at this operation than others, and the transverse being superior to the longitudinal riffle. He also found that rails alone do not form sufficiently deep pockets for saving the gold and, furthermore, allow eddies to be formed which might wear the bottom of the sluices. He, therefore, covered the bottom of the sluices with a series of wooden riffles, made of 2 by 6 inch pieces, with blocks nailed to them to provide spaces for gathering the gold, and on these the transverse rail riffles were set. This arrangement proved very efficient.

Angle iron riffles are set transverse with the point of the angle, usually facing the flow. At several operations in the interior, the angle iron was set at a small inclination, which created a better "boil" and proved very successful, but when tried at other operations, they packed hard and failed, possibly because of spacing them too closely together. These riffles should not be used where heavy material is sluiced. They are mainly used on dredges, in some hydraulic elevator sluices and to a very small extent at some of the small open-cut and hydraulic operations. Under favorable conditions, they are good fine gold savers.

Cast iron or manganese grate riffles, some of which are of patented design, are generally constructed so they can be set either transverse or longitudinal. They are easily handled, are excellent gold savers, and are long lived, but are too expensive for the average operation. The shoulder or rim extending around the top of each slot or pocket tends to keep the riffle from packing and affords good lodgment for the gold. Old plates from dredge screens, boiler tubes, etc., are used at several operations for riffles.

Plates of high carbon steel are sometimes used. These are elevated above the bottom of the sluice and a transverse space is left between plates, forming a pocket where gold is recovered. This type of riffle is used mainly to save grade and is generally followed by other kinds set on higher grades. The smaller sluices often have the bottoms lined with boards, leaving a space between the ends and the sides of the boards where gold can lodge. These are known as "false bottoms" and as they reduce frictional resistance, permit them to be set on lower grades, in the same manner as sheet iron or steel is used to line the bottom of unriffled sluices or tail sluices. Rock or cobble riffles are rarely used. They require steeper grades, and being difficult to lay and take up, are more adapted for tail sluices or others which are cleaned up only after long periods of use.

Undercurrents and gold tables are used for saving fine or coated gold. At many of the operations their use has been discounted, often for the reason that the small amount of gold recovered by them did not justify the additional attention. This may not have been due entirely to the undercurrent for when properly designed and operated, and cleaned up often enough, they do good work.

The material should be as thoroughly washed and disintegrated as practical before it reaches the grizzly or screen. Undercurrents are, therefore, generally placed well toward or at the end of the sluice, and for ideal operation, all of the water and undersize material should pass through the grizzly to the undercurrent, only the clean oversize being retained and dumped to waste. This is, however, seldom practical. Lack of sufficient grade, prohibits the use of most undercurrents in Alaska, but a sluice box type is used to good advantage at many of the smaller interior operations. A sketch of this undercurrent is shown in Fig. 13.

The regular size and type of sluice box is used for this, the last box or two being equipped as shown and usually set at a slightly higher grade than the others. The oversize from the grizzly or plate goes to the dump, the undersize passing through, and goes over the gold saving surface, the material and arrangement of which depends on the character of the fine gold to be saved. These undercurrents require cleaning every day or two, as the burlap, matting, etc., may become slimy with mud. It is removed and washed out in a tub and returned. These undercurrents have been credited with from 5 to 20 per cent of the total gold recovered, recovering much fine rusty gold. Even better results should be obtainable if conditions would permit these undercurrents to be made wider than the regular sluice and placed on higher grades.

On the Upgrade Assn. in the Iditarod district, the gold is both coarse and fine, sharp and bright, with considerable that is at-

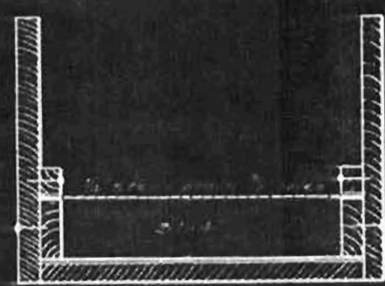

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Fig. 13

Sluice Box Undercurrent

tached to quartz. Being located on the side of the mountain, plenty of grade is available. There are no difficulties with clay. The deposit is hydraulicked, usually with a small intermittent water supply. From 8 to 12 boxes, 24 inches wide, are set on 17-inch grade and paved with longitudinal riffles made of 2 by 6 inch timbers shod with pieces of manganese steel, 5/8 inches thick and 1-1/2 inches wide. These riffles are spaced 1-1/2 inches apart and held together by a cross piece similarly shod, making the sets 6 feet long. One or two of the boxes may be paved with special solid cast manganese steel grid riffles set transverse. At the end of these boxes is a grizzly of manganese steel bars set transverse with 3/8-inch spacing, the undersize from it going through a chute to an undercurrent 4 feet wide and 12 feet long set on a 3½-inch grade. The surface of this undercurrent is covered with cocoa matting, in turn covered with wire screen of 1/4-inch mesh. Strips of wood 1 inch thick and 1-1/2 inches wide are fastened transversely to this at 30-inch centers. No mercury is used. The material which continues over the grizzly goes to one box equipped with a sluice box undercurrent similar to the kind described. The undercurrents at this property have recovered from 5 to 20 per cent of the total clean-up.

At some operations, the bottoms of several of the sluice boxes, usually the end ones, are equipped similarly to the gold saving surface of the sluice-box type of undercurrent, but no grizzly being provided for removing the heavier material, they wear out quickly, although they do save considerable fine gold. If the fine gold is not coated, mercury is generally used in these sluices. At several of the hydraulic elevator mines, where considerable rusty gold is present, the last box or two of the sluice has been doubled in width, given an inch or two more grade and equipped as above, and make an appreciable saving. Pl. 22464.

Mercury is generally not required for the saving of coarse gold and is of no value if the gold is rusty or coated as this kind of gold will not amalgamate. The use of mercury in the riffles and undercurrent where fine clean gold is present will be found most beneficial, in fact its use is then imperative. It has a strong affinity for clean gold and the amalgam formed is more readily retained by the riffles and is easier to handle in cleaning up the sluices. Practically all of the dredges and many of the other operators practice amalgamation, but there are many instances, particularly in the interior, where it is not used and at many of these it should be. While much of the gold there is coarse or often coated, there is generally some fine clean gold present that could be saved by using mercury. Many of the miners, however, want their gold in dust, or wish to avoid the small additional trouble of retorting, and its subsequent handling. Not being the customary practice in the interior, there are some miners who are unfamiliar with its use.

After the sluicing has been in progress long enough to stop all leakage and the depressions have been filled with material, the flow is shut off and the riffles in the upper part of the sluice and the undercurrents are charged with mercury. If much coarse gold is present, the mercury may be omitted from the upper boxes but added to the boxes below. The amount of mercury used varies with the richness of the gravel and the size of the operation, and is added from time to time in quantities sufficient to keep the amalgam dissolved. Some mercury will work down from the upper boxes, especially if they should be charged too heavily. The proper charging can only be learned by performance and experience. The mercury must be clean and in charging should not be splashed or spattered, otherwise it will break up in very minute globules, which will float away and cause a heavy mercury loss. There is always some mercury loss, and carelessness in its use may result in increasing rather than diminishing the loss of fine gold, but when properly handled and the sluices are tight and long, this mercury loss is of little consequence. One flask (76.5 lbs.) of mercury is generally ample for the needs of the average operation.

Amalgamated copper plates are sometimes used in undercurrents or other small sluices where only fine material often containing much black, ruby or other heavy sands with fine gold, is passed over them. Their greatest fault is that they scour too easily.

The Clean-up, Treatment and Marketing of the Gold.

The cleaning up of the sluice boxes consists in removing the riffles and collecting the gold as dust, or as amalgam, and the heavy concentrates containing more or less gold or other valuable content. The interval between clean-ups is generally made as long as practical to reduce the delay caused by them and is governed mainly by the richness of the gravels, the method of mining, the resources of the operator, the condition of the riffles, etc. Dangers from theft or floods also influence it. At most of the hydraulic mines the clean-up is made after the pit has been completed, while the shovel-in miner may clean up the head box each shift. With the richer gravels, the dump box or the first few upper boxes may be cleaned up every few days, the lower boxes generally being left until the final clean up. Other operations may have regular periods for cleaning up, which may be once a week, once a month, or may be done but once at the completion of the pit or season.

After the sluicing stops, the flow of water is cut down to the proper point and the clean-up crew consisting usually of from 2 to 4 men, including the operator, start cleaning up the boxes. The larger material, which may still remain in the boxes, is forked out or otherwise first removed. Beginning at the head box, the riffles are taken up and thoroughly scrubbed and cleaned before being removed from the boxes. Depending on the length of sluice and the crew, from 2 to 8 boxes are generally cleaned up at a time, always leaving some riffles or a stop of some kind below to keep the valuable material from going beyond. The material is then worked along the bottom of the boxes keeping it stirred up with shovels, rakes or scoops, as the flowing water concentrates it. The gold, or the amalgam if mercury is used, lags behind the heavy sands and is scooped up into pans or buckets. The concentrates are worked over some more to remove as much of the lighter or foreign material as practical and are then shoveled into separate receptacles. The process is then repeated until the next lower section is cleaned- up, etc. All nail holes, cracks, etc., are picked out and the bottom of the boxes swept clean. Worn out wooden riffles, lining boards, sluice boxes, etc., are burned and the ashes are panned.

The time required for cleaning up generally ranges from a few hours to a shift or two. Special methods of cleaning up are practiced at some of the operations and in some of these instances where the sluices are long, the clean up may require a week or so. Special methods of cleaning up have been mentioned in the description of the operations under the different methods of mining.

The gold dust or the amalgam as it is removed from the sluices has mixed with it more or less base material as sand, iron scrap, bullets, coins, etc., and will require further cleaning. The larger pieces can be picked out by hand and the iron and magnetic sand removed with a magnet. At those operations not using mercury in the sluices, the dust is panned as clean as practical and dried. It is then customary to pass it through a nest of screens of different mesh, coarse enough so that the foreign material can be picked out. The finer dust is cleaned by tossing it into the air with a pan or scoop and blowing off the sand.

Where amalgamation is practiced the amalgam is softened with an excess of mercury and stirred and worked up in buckets or ground in a mortar to bring the base material to the top for removal. This material may still contain considerable amalgam or fine rusty gold, when it is given further treatment. The excess mercury is then removed from the cleaned amalgam by straining and squeezing it through drilling or other strong cotton cloth.

The heavy sands or concentrates from the sluices and from the cleaning of the gold dust and the amalgam, besides containing gold and amalgam may contain native copper and silver, platinum, iridosmine, monazite, pyrite, marcasite, hematite, chromite, galena, cinnabar, cassiterite, wolframite, scheelite, barite, stibnite, or other minerals, along with magnetite, ilmenite, rutile, garnet, zircon, tourmaline and other rock forming minerals. The specific gravity of some of these minerals is almost as high as that of gold, so that their clean separation by water is most difficult, if not impossible by the ordinary methods. Where they occur in commercial quantities, the larger bits are usually picked out by hand or may permit rough water concentration. Some of these minerals have been a valuable by-product of gold placer mining and in the case of cassiterite has been the main product of several dredges. Platinum will not amalgamate and generally having a specific gravity equalling or exceeding that of gold, will, when present, be closely mixed with the gold. Although it is a heavy metal, the thin flakes float easily on running water and may not settle with the gold. The black sands from the sluices and from the cleaning of the amalgam should therefore be carefully panned in a tub or vat. Some of the platinum may spill over the pan, but as it settles to the bottom of the tub it can be panned out later. The gold, and the platinum particles are dried when the platinum can be separated by the blowing process. At some of the California gold dredges platinum is recovered and removed from the tables with the amalgam and the blacksands and as the amalgam is cleaned, the platinum is separated and sinks to the bottom of the soft amalgam. This is then cleaned by careful panning or blowing and the sands are passed repeatedly over special pocket or auger hole riffles and carpet or cocoa matting surfaces.

All the heavy sands are panned, rocked or put over special small sluices. As a general rule considerable fine gold or amalgam still remains, especially rusty or coated gold. It is more customary to put the sands in a tub or vat, add cyanide and stir it up, or put them into a clean-up barrel, add cyanide, lye or wood ashes, rotate the barrel and subject the contents to both abrasion and chemical action to brighten the gold. Usually some mercury is added and the gold amalgamated in the barrel. Depending on the conditions, the treatment takes from 20 minutes to several hours, after which the sands are panned or passed over special riffles or amalgamated plates. Even after this treatment, the sands may still contain high values in gold. While there are different processes for recovering gold from placer concentrates by roasting, fine grinding, cyanidation, chlorination, etc., such refinements at the placer property are not justified in view of the comparatively small quantity of such material recovered in the sluices. All placer concentrates should be analyzed and assayed, for they very often contain large quantities of gold or other valuable minerals or metals that cannot be recovered by ordinary methods but may justify their shipment to a smelter.

Cyanide is often very carelessly used, and when used in solutions of certain strengths will dissolve considerable gold.

Maclaurin[46] states that the maximum solubility of gold in

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(46) Maclaurin, J., J. Chem. Soc. Vol. 63, p. 724, 1893, Vol. 67, p. 199 1895.

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potassium cyanide is reached at a strength of 0.25 per cent and is very slight in solutions containing less than 0.005 per cent, but increases rapidly as the strength rises to 0.01 per cent, when the rate of dissolution is ten times as great as in the 0.005 per cent solution and about one half as great as the 0.25 per cent solution. A safe means of using it is to make up a stock solution of one ounce of 98 per cent potassium cyanide to one half gallon of water and then use 4 ounces or about 1/2 tea cup of this solution to 10 gallons of water. One operator in the interior puts his sands, which are mainly garnet and magnetite, into a tub or box, adds cyanide and mercury, and stirs it well for one hour. The sands are then passed over amalgamate plates and about 80 per cent of the contained gold is recovered by this first treatment. A diluted solution of commercial sulphuric acid, about 10 per cent, is then added to the previously heated sands and further heated to partly dissolve and break them up. They are then treated as before, after which but little value remains. Instead of the acid treatment, a similar "cracking" can be accomplished by heating such sands to a red heat and pouring water over them.

The amalgam is retorted to drive off the mercury. It is broken up and loosely packed into a pot retort, the interior of which has been coated with a thin wash of clay or chalk to prevent the sponge from sticking. Some operators line the retort with paper. The retort should not be filled more than three quarters full. The cover is then put on and keyed down, the joint having previously been provided with an asbestos cloth gasket or a lute of clay or similar material to assure a tight fit. It is then placed on the retort stand and the fire ignited. Wood or coal fires, or gasoline retort furnaces are used for retorting. The heat should be very gradually raised and the safest and best results are accomplished if the volatilization of the mercury does not start for about an hour. The mercury fumes escape through the iron pipe at the top of the retort and are condensed on passing through this pipe, which is fitted with a condenser through which water is continuously running. The mercury is recovered in a vessel containing water. If no condensor is provided, the pipe should be covered with gunny sacking kept well wetted. The retort should be kept at a dark red heat until toward the end of the operation, when the heat is raised to a cherry red color. This heat is maintained for 15 minutes or so after the last of the mercury has been driven off. The pipe is usually tapped with a hammer to see if the volatilization has been complete. The retort is allowed to cool gradually and should not be opened until cold. Care must be taken to do all retorting in a well ventilated place, with the outlet of the retort kept out doors. The retort should always be opened out doors for mercury fumes are very dangerous. The lower end of the retort pipe should not be allowed to get under water for a vacuum may be created by a drop in the heat drawing water into the retort and causing an explosion. It is safer to hang a piece of sacking over the end and keep it well wetted. Small balls of amalgam as obtained by the lone miner are often placed on a shovel and held over a fire to drive off the mercury. This should only be done out doors and the miner should keep on the side away from the fumes.

The retort from clean amalgam, if properly done, should be spongy permitting it to be readily broken up and show a clean golden color. An incompleted retort will be a light to dark gray in color due to the mercury still present. Too high a heat will form a tough dense mass. Sulphur, arsenic and other compounds may cause a black discolored retort sponge.

The retort sponge is often shipped to the banks for melting. The larger producers, particularly those located in isolated districts, melt it into bullion as it then permits better and safer shipment. A gasoline bullion furnace is used for melting the gold. A graphite crucible is gradually heated and tested, and borax glass is added for a flux and melted down. The gold is then added and as it melts down more may be added, the crucible should, however, not be too heavily loaded. The borax glass unites with any iron present and carries it into the slag. If considerable iron pyrite is present some metallic iron may be added to unite with the sulphur, forming an iron sulphide which comes off with the slag. If much silica is present, soda is added usually in the proportion of one part soda to two parts borax glass. Toward the end of the melt the slag is skimmed off with an iron rod and ~~some~~ more borax glass may again be added. When the melt is completed, the crucible is lifted from the furnace, the gold stirred with a graphite rod and poured into heated bullion molds which have been previously coated, by holding them over oil smoke or with lard oil. These molds should not be too hot, but should be at a temperature that oil will burn when applied to them. The bullion bricks are then plunged in cold water to loosen the slag or may be plunged into a pickling bath of one part nitric acid to three parts of water which removes any stain. With a hammer and a steel slag brush the bricks are cleaned up and then stamped, weighed and made ready for shipment.

The fineness of Alaskan placer gold normally ranges from about $14. to $19. per ounce and while there may sometimes be several "runs" of gold on the same creek which differ in fineness and other characteristics, the gold from any particular creek or deposit can usually be easily identified by the expert. The great difference in the fineness of gold is due mainly to the amount of silver that is always alloyed with it. Some copper may be present and also some platinum or other metals. The copper and silver content may be further increased, should these metals be present in the native state and not removed in the cleaning of the dust or, as both will amalgamate, they would be included in the amalgam. Lead and other metals from babbit, bullets, coins, etc., may be similarly included in the amalgam. Where base material is present, closer assay checks and better settlements will be obtained, if the product is divided in one containing the cleaner gold, and one containing impurities that cannot be readily removed in the final cleaning. This base material is later melted in base bullion.

Some of the highest grade placer gold has come from the Koyukuk district where gold of 978-1/2 fineness or $20.23 per ounce was found on Fay Creek, and 973.4 fine or $20.12 per ounce on Swift Creek. Some peculiar medallion shaped nuggets were found on Little Minook Creek in the Rampart district, which it is claimed assayed $20.42 per ounce, although this has not been definitely confirmed. Gold found on Little Moose Creek in the Kantishna district assayed 550 fine or $11.37 per ounce. This low fineness is, however, accounted for by the native silver occurring with the gold. On Tenderfoot Creek in the Richardson district the gold has a fineness of 640 at the upper end while at the lower end the fineness is 720. This wide difference may be due to the gold coming from different sources. Fine gold that has been transported relatively long distances from its source, usually has a higher fineness than the coarser, or that which has not been far removed from the same source.

During the earlier days, gold dust was used in place of money at most of the camps. The quality of the gold from the nearby creeks was well known and money was scarce and little in evidence. This custom has now passed except among a few of the older prospectors, mostly in the Forty Mile and Koyukuk districts. Gold dust is, however, purchased by all merchants near the mining camps at a reduction of $1. to $1.50 from its actual value per ounce. Most of the gold dust, retort sponge and bullion is sent direct to the banks at Nome, Iditarod, Fairbanks or Anchorage.

The banks conducted their own assay offices, melting all gold received and settle on the basis of the assay less a certain deduction for melting, assaying, insurance, express, refining and marketing. This charge is 2-1/2 per cent of the gross on amounts under $25,000 and 2 per cent if the amount is $25,000 or more. One bank charges 3 per cent, being in an isolated district from where the insurance rates are higher and the shipping out of the gold and the bringing in of currency requires considerable more time.

The banks ship by express to their representatives in the States and the operators not dealing with the local banks ship direct by express or mail. Practically all of the gold eventually reaches the U. S. Assay office at Seattle or the U. S. Mint at San Francisco. A little goes to the smelters, as does the base bullion. Shipments can be made by express from practically any of the camps to Seattle, San Francisco, and other Pacific Coast cities in the United States, during the open shipping season, at a rate normally ranging from $3.75 to $6.00 per $1000.00 in amounts of $25,000 or more and $4.50 to $6.00 in amounts less than $25,000. These charges include marine insurance, allowance being made if the shipper provides it. In amounts of $1000. or less, a special graduated tariff holds, the rates then being slightly higher. Winter express shipments from districts requiring dog or horse team transportation are practically double the summer rates. Shipments sent by registered first or fourth class mail are limited in weight to 11 pounds. The rate of postage between points in Alaska and to any point in United States for registered mail is two cents per ounce or fraction thereof in addition to the 10 cents per package for registration fee. As registration on first class mail provides indemnity for loss to the extent of its value up to $50. the packages can contain but around three ounces of gold to be fully covered. Insured fourth class mail in addition to the regular postage can be insured up to $100. upon payment of 25 cents.

To enable shipments by registered mail, in packages up to 11 pounds in weight, the operator carries a special open insurance policy, which he fills in to cover the shipment and advises the insurance company of the same.

Alaska Placer Mining Law and Taxation

An act to supplement the mining laws of the United States in the Territory of Alaska and to repeal an act entitled, "An Act to supplement the mining laws of the United States in their application to the Territory of Alaska; providing for the location and possession of mining claims in Alaska and repealing all acts and parts of acts in conflict herewith to the extent of such conflicts," approved April 30, 1913, was enacted by the Legislature of Alaska and approved on April 20, 1915. It is stated in H.B. No. 48, in Chapter 10 of the Session Laws of Alaska, 1915, as concerning placer mining, as follows:

Section 1. Any person qualified under the laws of the United States, who discovers upon the public domain within the Territory of Alaska, a placer deposit of gold or other mineral which is subject to entry and patent under the mining laws of the United States, may locate a mining claim thereon in the following manner, to-wit:

1st. He shall post, or write upon the initial post, stake, or monument on the claim, a notice of location containing:

a. The name or number of the claim.
b. The name of the locator or locators
c. The date of discovery and of posting notice on the claim.
d. The number of feet in length and width of the claim.

This notice shall be known as the location notice.

2nd. He shall distinctly mark the location on the ground so that its boundaries can be readily traced, by placing at each corner or angle thereof substantial stakes, or posts, not less than three feet high above the ground and three inches in diameter, hewed on four sides; or by placing at each corner or angle thereof mounds of earth or rock not less than three feet high and three feet in diameter and the stakes, posts or monuments so used must be marked with the name or number of the claim and the designation, by number, of the corner or angle. The initial stake or monument shall be one of the corner stakes, posts or monuments of the claim located.

If the claim is located on ground that is covered wholly or in part with brush or trees, such brush or trees shall be cut or blazed along the lines of such claim, so as to be readily traced.

If located in an open country, the boundary lines shall be located by placing line stakes or line monuments so as to be readily traced from corner to corner of said claim.

Section 2. Within ninety days after the discovery and posting of the notice aforesaid, the locator shall record with the Recorder of the District wherein such claim is situated, a certificate of location. Such certificate shall contain:

(a) The name or number of the claim.
(b) The name of the locator or locators.
(c) The date of discovery and of posting of the location notice.
(d) The number of feet in length and width of claim.
(e) It shall set forth the description with reference to some natural object, permanent monument, or well known mining claim, together with a description of the boundaries thereof so far as applied to the numbering of stakes or monuments.

A failure to record a certificate of location of claim as herein provided shall operate as and be deemed abandonment thereof, and the ground so located shall be open to re-location; provided, that if a full compliance with the preceding provisions of this act shall have been made before any location by another, such compliance shall operate to prevent the abandonment or forfeiture of such claim and save the rights of the original locator.

Section 3. No association placer mining claim shall hereafter be located in Alaska in excess of forty acres, and on every individual or association placer mining claim located in Alaska after August 1st, 1912, and until patent has been issued therefor, not less than One Hundred ($100.00) Dollars worth of labor shall be performed or improvements made during each calendar year, including the year of location for each and every twenty acres or fraction thereof and where the title of two or more contiguous placer claims has become vested in the same person or persons, or corporation, the said annual assessment work or improvements may be done or made at any place or places on said contiguous placer claims, provided that such work or improvements inures to, and is for the benefit of the entire area of such placer claims. In computing the value of assessment work or improvements, the rate of wages paid in the vicinity for similar work, shall be allowed.

Section 4. And it is further provided, that a survey of the claim or claims by a United States Mineral Surveyor may be credited to annual assessment work, but in no case shall the credit for such survey and its attendant expense, exceed the required assessment for one year on the claim or claims surveyed. When credit is sought for such work or improvement, the claimant must file in the Recorder's office in the district in which the claim is situated the field notes of the survey, together with a voucher showing the cost of such survey, properly attested by the surveyor, incorporated into the proof of annual labor as in case of other class of labor or improvements, as provided for in Section Seven (7) of this Act.

Section 5. That no individual placer mining location hereafter made shall be more than thirteen hundred twenty (1320) feet in its greatest length; and no association placer mining claim hereafter located shall be more than two thousand six hundred forty (2640) feet in its greatest length.

Any location made containing an excess of ground beyond the limits prescribed in this Act, either in area or length, may be re-located as to such excess, but such re-location shall be upon that end of the claim farthest from the initial stake, post or monument.

Section 6. That no power of attorney for the location of placer mining claims in Alaska shall be valid or have any force or effect whatsoever, nor shall any locations made thereunder be valid or have any force or effect unless such power of attorney be duly executed and acknowledged before an officer authorized to administer oaths and recorded in the office of the Recorder for the district in which such claim is located, prior to the date of the filing for record of any location thereunder. And no person shall be authorized to act as agent or attorney for the location of placer mining claims except under written power of attorney duly executed and acknowledged, and no person shall be competent to act as agent or attorney in fact for the location of placer mining claims for more than one individual in any one Recording District during the same calendar month. That no person shall hereafter locate or cause to be located for himself, more than two placer mining claims in any one calendar month, in any one Recording District, one or both of which locations may be included in association claims.

Section 7. In order to hold a claim or claims after the annual assessment work has been done thereon, the owner of such claim or claims, or some other person having knowledge of the facts, shall make and file an affidavit of the performance of such assessment work with the Recorder of the district in which such claim or claims is or are located, not later than ninety (90) days after the close of the calendar year in which such work was done, or the improvements made, which affidavit shall set forth the following:

(a) The name and number of the claim and where situated.

(b) The number of the days work and the character and value of the improvements made thereon.

(c) The date of the performance of such labor and the making of such improvements.

(d) The place where such work was done and improvements made with reference to the boundaries of such claim.
(e) At whose instance the work was done and improvements made.
(f) The actual amount paid for such work and improvements and by whom paid, when such work was not done or improvements made by the owner.

The failure to file for record the proof of assessment work as herein provided, shall be deemed an abandonment of the location and the claim shall be subject to relocation by any other person, provided, however, that a compliance with the provisions of this section before any relocation, shall operate to save the rights of the original locator, and further provided, that if said placer claim or claims have not been relocated by any other person or persons within one year after such forfeiture, the last locator, claimant or owner of such forfeited claim may return to said forfeited claim or claims and re-locate the same as though the same had never been located.

Section 8. Any personwho shall make or subscribe any affidavit required to be made under the provisions of this act, knowing the statements therein contained, or any of them, to be false, in whole or in part, or without knowing the statements therein contained to be true, shall be deemed guilty of perjury, and upon conviction thereof shall be punished by imprisonment in the penitentiary not less than one year nor more than five years. Any person who shall induce or procure, or shall aid in inducing or procuring another to commit perjury as herein defined, shall be guilty of subornation of perjury and upon conviction thereof shall be punished as herein provided for perjury.

Section 9. That any placer mining claim located or attempted to be located in violation of any of the provisions of this act, shall be null and void and revert to the public domain and may be located by any qualified locator as if no such prior attempt had been made.

The Federal and Territorial Mine Inspectors are empowered by law to have access at all times to any mine and all parts thereof for the purpose of inspecting the workings, timbering, ventilation, means of ingress and egress, and the means adopted and in use for the preservation of the lives and safety of the men employed under ground or on the surface, etc. All mine owners, lessees, agents, operators, managers, or superintendents must render such assistance as may be necessary to enable the inspector to make the examination. Should any mine or portion thereof be found to be in an unsafe or insecure condition, or if proper first aid measures have not been adopted, the inspector shall serve notice in writing, setting forth the nature and place of these defects and requiring them to be remedied within a specified time. The mine inspector must be immediately notified by the person in charge, in the quickest manner possible, of any serious or fatal accident. If the inspector cannot be immediately present, written statements concerning the accident made by those witnessing the same, and sworn to, must be procured, and along with a written report must be forwarded to the Inspector. Written report of all minor accidents shall be made promptly to the Inspector, which shall briefly describe the accidents and state the number of days the injured was incapacitated from performing his regular duties.

The Territorial Mine Inspector shall distribute blank forms, requiring statistics of accidents, labor, production or such other information as the Governor may require, which shall be filled in and returned to the mine Inspector's office by the person in charge of the mine, on or before the 31st day of December each year. The duties and powers of the Territorial Mine Inspector, the provisions of the Acts, etc., are stated in Chapter 51, Session Laws of Alaska, 1917; Chapter 59, Session Laws of 1919; and Chapters 82 and 96 of the Session Laws of 1923.

A compilation of Chapter 31, Session Laws of Alaska, 1921, entitled "An act to establish a system of license taxation, to provide for the collection thereof, and to provide punishment for doing business without a license, and declaring an emergency, as amended by Act of May 5, 1923 (Chapter 101, Session Laws of 1923)" enacted by the Legislature of the Territory of Alaska, states in part as pertaining to mining as follows:

> Section 1. Any person, firm, or corporation prosecuting, or attempting to prosecute, any of the following lines of business, or who shall employ any of the following appliances, in the Territory of Alaska, shall apply for and obtain a license and pay for said license, for the respective lines of business and appliances, as follows:
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> ....
>
> 15th: MINING: One per cent of the net income in excess of ten thousand ($10,000) dollars and not in excess of five hundred thousand ($500,000) dollars, and on all net income in excess of five hundred thousand ($500,000) dollars and not in excess of one million

($1,000,000) dollars, one and one-half per cent (1-1/2%); and on all net income in excess of one million ($1,000,000) dollars, one and three-fourths (1-3/4%) per cent.

By "net income" is meant the cash value of the output of the mine less operating expenses, repairs and betterments actually made, and royalties actually paid, and all taxes paid under Section 2569 of the Compiled Laws of Alaska; Provided, that the lessor of any mine operated under a lease shall be deemed to be engaged in mining within the provisions of this act and the royalties, less the cost of collecting the same, received by him, shall be deemed to be the net income within the provisions of this act; but where he receives royalties from more than one mining property he shall pay the tax on the aggregate income over five thousand dollars ($5,000.00). No deduction shall be made on account of depreciation of machinery, interest on bonds or money borrowed, or other taxes paid.

....

Section 2. Every person, firm or corporation desiring to engage in any of the lines of business.....as specified in Section 1 shall first apply for and obtain from the Territorial Treasurer a license so to do.........If the amount of the tax is not a fixed sum (as in placer mining), the applicant shall state in his application that he agrees to pay the license tax and will make a true return and will pay to the Treasurer such tax on or before the fifteenth of the next ensuing January.

Incomes from placer mining operations, the sale of placer mining property, etc., are taxable under the Federal Income Tax law, the provisions of which are so generally made known as to require no further mention here.

SELECTED BIBLIOGRAPHY.

Australia, Annual report, dredging and hydraulic sluicing in Australia in 1914. Gov. Printer, Melbourne, 1915.

Bowery, F., Study of riffles for hydraulicking. Engineering and Mining Journal, May 24, 1913. P. 1055-1060.

Bowie, A. T., Jr. A practical treatise on hydraulic mining, 10th ed. D. Van Nostrand Co., 1908. 313 pages.

Brigham, H. A. Examining and fitting up a hydraulic mine. Eng. & Min. Jour., Dec. 26, 1908 et seq.

British Columbia, Annual Reports of Minister of Mines, Victoria, B. C.

Brooks, A. H. Placer Mining on Seward Peninsula, Methods and Costs. U. S. Geol. Survey, Water Supply Paper 314, 1913; p. 269.303
Genesis and classification of placers, U. S. Geol. Survey Bull. 328. 1908, p. 111.
Formation and classification of placers, U. S. Geol. Survey Bull. 592, 1914, p. 27.
The Alaska Mining Industry, annual reports, U. S. Geol. Survey Bull. Mineral Resources of Alaska.
The Geography and Geology of Alaska. U. S. Geol. Survey. Prof. Paper 45, 1906, 327 p.

Brown, R. E., Ancient river beds of the Forest Hill divide: Tenth Ann. Rept. State Mineralogist, California Bureau Mines, 1890, p. 452.

Dennis, F. J., Modern Methods of Gravel Excavation. Steam shovel and dragline excavators. Min. & Sci. Press. Aug. 3, 1922, p. 136-140

Dunn, R. L. Drift Mining in California, 8th An. Report State Mineralogist, Cal. 1888.

Eddy, L. H., Bagley Scraper for Gravel Mining in Alaska, Eng. & Min. Jour. Aug. 14,1915. p. 287.

Edwards, W. W., Klondike Pipe Line, Siphon, Survey Construction of, Eng. & Min. Jour., Sept. 19, 1914, P. 531 - 533.

Ellis, E. E., Prospecting Methods at Fairbanks, Eng. & Min. Jour., May 8, 1915, p. 805.
Development Methods at Fairbanks, Eng. & Min. Jour., June 12,1915,p.1023.

Thawing Methods at Fairbanks, Eng. & Min. Jour., July 3, 1915, p. 1.

Stoping Methods at Fairbanks, Eng. & Min. Jour., Sept. 25, 1915, p. 503.

Sluicing Methods at Fairbanks, Eng. & Min. Jour. Dec. 18,1915, p. 993.

Winter Mining at Fairbanks, Eng. & Min. Jour., Oct. 30,1915, p. 707.

Handling Gold Dust at Fairbanks, Eng. & Min. Jour., Nov. 7, 1914, p. 817.

Hydraulic Mining at Circle, Eng. & Min., Jour., Dec. 19,1914, p. 1104, and Dec. 11, 1915, p. 952.

Ellsworth, C. E. and Davenport, R. W., Surface Water Supply of the Yukon-Tanana Region, U. S. Geol. Survey Water Supply Paper 342, 1915, 343 pages.

Evans, Geo. H., Practical Notes on Hydraulic Mining, 1897, 48 pages.

Gardner, W. E., Gold Dredging- Actual Recovery Compared with Estimates, Eng. & Min. Jour., Sept. 11, 1920, p. 515.

Geological Survey, U. S., Bulletins, papers and maps, various mining districts of Alaska.

Gibson, A., Drift Mining in Frozen Gravel at Cape Nome, Min. & Sci. Press, Mar. 7,1914, p. 405.

Third Beach Line at Nome, Min. & Sci. Press. Apr. 15, 1914, p. 687.

Thawing Frozen Ground for Placer Mining. Steam Thawing. Min. & Sci. Press, Jan. 17, 1914, p. 143.

Haley, Charles, Elevating 10 cent Gravel at a Profit. Bubble Elevator Operation, Min. & Sci. Press, Apr. 13, 1912, p. 530.

Gold Placers of California, Mining methods. Bull. 92, California State Mining Bureau, 1924.

Hall, E. E., Water Supply for Klondike Hydraulic Mines, Min., & Sci. Press, Aug. 28, 1916, p. 321. 324.

Hazzard, F. H., The Saving of Fine Placer Gold, Eng. & Min. Jour., Aug. 26, 1911. P. 394 - 396.

Henshaw, F. F. and Parker, G. L., Surface Water Supply of Seward Peninsula Ditch, Flume and Pipe Line Construction, Seepage Losses, U. S., Geol. Survey Water Supply Paper 314, 1913, pp. 51-249; 255- 269.

Horner, H. R., Notes on Black Sand Deposits of Southern Oregon and Northern California, U. S. Bureau of Mines Tech. Paper 196,1918.

Hubbard, J. D., Drift Mining in California; Eng. & Min. Jour., Nov. 17, 1917, p. 863 - 868.

Hutchins, J. P., Dredging in the Russian Empire; Eng. & Min. Jour., vol. 98, Nov. 14, 1914, p. 857.

Drift Gravel Mining in Eastern Siberia: Eng. & Min. Jour. May 11, 1920, p. 859.

Prospecting and Mining Gold Placers in Alaska: U. S. Geol. Survey Bull. 345, 1908, p. 56-68.

Janin, Charles, Placer Mining methods and operating costs: U. S. Bureau of Mines Bull. 121, 1916, p. 42.

Gold dredging in the United States: U. S. Bureau of Mines,Bull. 127, 1918, 216 pages. Treatise on the history, topography and geology of dredging areas, prospecting, details of dredge construction, operation, costs, etc.

Gold dredging in United States and Alaska: Min. & Sci. Press. Jan. 10, 1914, p. 93.

Gold Dredging on Seward Peninsula: Min. & Sci. Press, Sept. 28, 1912, p. 394.

Recovery of gold in dredging: Min. & Sci. Press, Nov. 7,1914, p. 717.

Recent progress in thawing of frozen gravels in placer mining: U. S. Bureau of Mines, Tech.Paper 309, 1922.

Janin, Charles, and Winston, W. B., Gold dredging in California: Cal. State Min. Bureau Bull. 57, 1910, 300 pages.

Jenning, H. J.,History and development of gold dredging in Montana; U. S. Bureau of Mines Bull. 121, 1916, 34 pages.

Katz, F. J.,Methods of placer mining in the Fairbanks district: U. S. Geol. Survey Bull. 525, 1913, pp. 115- 131.

Knox, N. B., and Haley, Charles, Mining of alluvial deposits: Min. Mag. 3 parts, Feb., March and April, 1915, 31 pages.

Longridge, C. C., Gold and tin dredging, 3rd ed. Mining Journal, London, 1916, 425 pages.

Hydraulic mining: Mining Journal, London, 1910, 335 pages.

McCarthy, E. E., Stripping frozen gravel in the Yukon: Mining Magazine, Vol. 10, Apr. 1914, p. 289-296.

Merriman, M., Treatise of hydraulics: Jno. Wiley & Sons, Inc., 1903.

Molino, A. H. P., Australian practice in pump dredging: Min. Magazine, July, 1917, P. 12-24.

New Zealand, Mining handbook, 1906, New Zealand Minister of Mines.
Report of New Zealand Minister of Mines 1902.

Nichol, J. M., Metallurgy of alluvial mining: Min. & Sci. Press, May 29,1915 P. 837 - 840. On black sand and fine gold.

Payne, H. M., Siberian drift mine timbering: Eng. & Min. Jour., June 9, 1917, p. 1019, 3 1/2 cols.

Development problem in the Yukon: Trans. Canadian Min. Inst., Vol. 16, 1913, p. 228.

Notes on Yukon Mining Problems: Trans. Canadian Min. Inst., Mar. 1917. P. 188- 206. Steam Thawing.

Peele, Robert and others, Mining engineers handbook: Jno. Wiley & Sons, Inc., 1918.

Perret, Leon, Prospecting frozen ground in Siberia: Min. & Sci. Press, June 22, 1912, p. 866.

Perry, O. B., Development of dredging in Yukon Territory: Eng. & Min. Jour., Vol. 100, Dec. 25, 1915, p. 1039 - 1044. Account of operation and steam thawing.

Power, H. T., Timbering in deep placer mining: Min. & Sci. Press, Aug. 11, 1917. Page 191- 194.

Purington, C. W., Methods and costs of gravel and placer mining in Alaska: U. S. Geol. Survey Bull. 263, 1905, 262 pages.

Hydraulic elevator work on Anvil Creek, Nome, Alaska: Min. & Sci. Press, Apr. 26, 1913, p. 615.

Cleaning up at Nome hydraulic mine: Min. & Sci. Press, May 3,1913, P. 653.

The Saward Peninsula exploration and mining of gravel deposits: Min. Mag., Mar. 1913, p. 203.

Radford, W. J., Methods of testing placer gravels: Min. & Sci. Press, July 4, 1914, p. 6.

Rocker for washing gravel: Min.& Sci.Press, June 8, 1912, p. 801.

Rickard, T. A., Dredging on Seward Peninsula: Min. & Sci. Press, Nov. 28, 1908, p. 734.

Dredging on the Yukon: Min. & Sci. Press, Aug. 29, 1908, p. 290 and Sept. 12, 1908, p. 354. Also steam thawing methods.

Mining methods in Far North; Min. & Sci. Press, Dec. 12, 1908, p. 810.

Rose, T. K., The Metallurgy of Gold. London, 1898, 514 pages.

Van Wagenen, T. F., Manual of hydraulic mining: D. Van Nostrand Co., 1913.

Wilson, E. B., Hydraulic and placer mining, 3d ed. 1918, Jno. Wiley & Sons, Inc., 412 pages.

Wimmler, N. L., Placer mining in Alaska in 1922, 1923, 1924: In Stewart, B. D., Annual Report of Mine Inspector to Governor of Alaska 1923, 1924, 1925.

Young, Geo. J., Elements of mining: McGraw Hill Co., 1916.

Yukon Territory, its history and resources: Minister of Interior, Ottawa, 1916.