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DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 739

MINERAL RESOURCES OF ALASKA

REPORT ON PROGRESS OF INVESTIGATIONS IN

1921

BY

A. H. BROOKS AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
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MINERAL RESOURCES OF ALASKA, 1921.

By Alfred H. Brooks and others.

PREFACE.

By Alfred H. Brooks.

This volume is the eighteenth of a series of annual bulletins [1] summarizing the results achieved during the year in the investigation of the mineral resources of Alaska and treating of the mining industry of the Territory, especially of the statistics of mineral production, with the collection of which the Geological Survey is charged by law.

The reports included in this volume are primarily intended to give prompt publication of the more important economic results of the work of the year. The time available for their preparation does not permit full office study of the field notes and specimens, and some of the statements made here may require modification when the study has been completed. Those who are interested in any particular district should therefore procure a copy of the complete report on that district as soon as it is available.

Again, as for many years in the past, the Geological Survey is under great obligation to residents of the Territory for valuable data. Those who have thus aided include the many mine operators who have made reports on production as well as developments. There are still some Alaskan mineral producers, though a constantly decreasing number, who fail to respond to the request for information. Therefore, it is still necessary to supplement the figures obtained from mine operators by estimates from other reliable sources. In this work the writer has received invaluable aid from many prospectors and miners, Federal and Territorial officials, engineers, and officers of banks and transportation and commercial companies.

[1] The preceding volumes in this series are U. S. Geol. Survey Bulls. 259, 284, 314, 345, 379, 442, 480, 520, 542, 592, 622, 642, 662, 692, 712, 714, and 722.

It is impracticable to mention by name all who have aided in this work, but it should be stated that without the assistance of these public-spirited citizens the preparation of this report would have been impossible. Special acknowledgments should be made to B. D. Stewart, Territorial mine inspector, and B. W. Dyer, Federal mine inspector; [2] the Director and other officers of the Bureau of the Mint; the Director and other officers of the Bureau of Mines; officers of the Alaska Customs Service; the officers of the Alaskan Engineering Commission; the American Railway Express Co.; Stephen Birch, Kennecott Copper Corporation; Sumner S. Smith, resident engineer of the Alaskan Naval Coal Commission; George Parks, of the General Land Office; E. H. Bartholf, of Hyder; R. L. Cline, of the United States Forest Service, Ketchikan; Thomas Vogel, of Porcupine; G. Howard Birch, of Nizina; M. J. Knowles, of McCarty; J. M. Elmer, of Chistochina; Charles A. Spongberg, of Valdez; F. E. Youngs, of Seward; Sidney Anderson, N. O. Anderson, and A. G. Thompson, of Anchorage; Edw. McConnell and Jos. Krumenacher, of Talkeetna; Z. T. Halferty, of Kodiak; Fred Phillips, of Iliamna; Paul Buckley, of Unalaska; W. F. Green, Peter McMullen, and Thomas Aitken, of McGrath; D. E. Stubbs and Joseph Lewis, of Aniak; G. A. Stecker, John Haroldson, A. Gabrielson, and J. L. Jean, of Kwinak; E. Larsen and Charles Zielke, of Nenana; A. W. Amero and James Funchion, of Caro; William Yanert, of Purgatory; D. P. Thornton, of Chisana; J. J. Hilliard, of Eagle; K. T. Sparks, of the Bureau of Mines, Luther C. Hess, First National Bank, and T. H. Deal, of Fairbanks; J. F. Zimmerman, of Fox; E. Chesworth and J. H. Elden, of Steel Creek; Charles M. Cole, of Jack Wade; Ronald Campbell, of Hot Springs; B. B. Smith, Frank Speljack, and J. E. Nollet, of Ophir; A. V. Thorn, of Tacotna; Harry Madison, of Tolstoi; R. C. Button, of Iditarod; Daniel Webster and H. S. Wanamaker, of Nolan; A. J. Griffin and Paul Solka, of Richardson; George M. Pilcher, of Marshall; Rev. John Chapman and Charles D. Wulf, of Anvik; George W. Ledger, of Rampart; John Minook, of Tanana; T. A. Parsons, of Ruby; B. J. Bower, of Long; Henry Willeke, of Poorman; A. M. Bainbridge and H. J. Patterson, of Livengood; R. W. J. Reed and Robert B. Benson, of Nome; William N. Marx, of Teller; H. L. Stull, of Deering; E. A. Fox, of Candle; Lewis Lloyd and James C. Cross, of Shungnak; and George L. Stanley, of Kiana.

[2] A manuscript copy of Messrs. Stewart and Dyer's annual report was received in advance of publication.

THE ALASKAN MINING INDUSTRY IN 1921.

By Alfred H. Brooks.

GENERAL FEATURES.

The value of the total mineral production of Alaska in 1920 was $23,303,757; the value in 1921 was $17,004,124. Yet in spite of this tremendous falling off, the mining industry as a whole can be said to have been more prosperous in 1921 than in 1920. The decrease in value is due to the low price of copper, and no advance of the Alaska copper-mining industry can be expected until there is a better market for the metal. Coal mining shows some growth, though it remains to be proved that Alaska high-grade coal will in the near future be mined for export. The search for Alaska oil fields was vigorously continued in 1921, though except at Katalla there has yet been no drilling. As will be shown, the placer-mining industry in 1921 had a prosperous growth, compared with that of previous years. The most important event of the year to the future of the mining industry was the practical completion of the Alaska Railroad (the Government line). There only remains to be built the bridge across Tanana River. The building of roads in Alaska was expedited during the year, so far as the funds available permitted. There is good reason to believe that the ocean transportation service to Alaska is soon to be improved. These betterments of means of communication are the most valuable local factors in promoting the revival of Alaska mining.

The dominant features of the year's mining are (1) the decrease of both copper production and development, owing to the low price of the metal; (2) the closing of the Perseverance mine, one of the three large auriferous lode mines at Juneau; (3) continuation of activity in auriferous quartz development in the Sitka, Juneau, Salmon River, and Willow Creek districts; (4) a revival of placer mining; (5) continuation of systematic prospecting for coal in the Matanuska field by the Naval Coal Commission; (6) the many examinations made in Alaska petroleum fields by oil companies, with the purpose of drilling. The discovery of a new locality of galena and other sulphide deposits in the Kantishna district is also worthy of special note.

The number of men engaged each year in productive mining gives a rough measure of the prosperity of the industry, but unfortunately complete statistics are not available. A careful study of all the facts at hand appears to justify the following estimates, which include only the men employed at mines that made some mineral output during the year.

Estimates of number of men employed at productive mines of Alaska, 1911–1921.

Year.	Placer mines.		Lode mines and reduction plants.	All other mining and quarrying.	Total men engaged in mining, not including winter placer mines.
	Summer.	Winter (omitted from total).			
1911	4,900	670	2,360	150	7,410
1912	4,500	900	2,560	150	7,210
1913	4,500	800	3,450	140	8,090
1914	4,400	800	3,500	140	8,040
1915	4,400	700	3,850	160	8,410
1916	4,050	880	4,570	340	8,960
1917	3,550	950	3,220	270	7,040
1918	3,000	610	2,000	400	5,400
1919	2,180	320	1,900	310	4,390
1920	1,990	340	1,880	360	4,230
1921	2,150	555	1,450	400	4,000

In considering the above table it should be remembered that the summer placer mines are operated for an average period of less than 100 days in a year. A comparison of the first two columns shows that only a small percentage of the men engaged in summer placer mining can find similar employment in the winter. As the winter placer mining is all done through shafts and drifts it is closely related to lode mining. Some of the deep placer mines are operated for nearly the entire year and hence are included in the total summer mines also. The lode mines include copper and gold and a few other metal mines, and the figures for these include only the average number employed during the year. The fourth column shows the number of men engaged in all other forms of mining and quarrying, including the exploitation of coal, petroleum, marble, tin, gypsum, and other products.

Mineral output of Alaska, 1920 and 1921.

	1920		1921		Decrease or increase in 1921.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold.........fine ounces..	404,683	$8,365,560	390,558	$8,073,540	− 14,126	− $292,020
Copper...........pounds..	70,435,363	12,960,106	57,011,597	7,354,496	−13,423,766	−5,605,610
Silver.........fine ounces..	953,546	1,039,364	761,085	761,085	− 192,461	−278,279
Coal...........short tons..	61,111	355,668	76,817	496,394	+ 15,706	+ 140,726
Tin, metallic.........do....	16	16,112	4	2,400	− 12	− 13,712
Lead.................do....	875	140,000	759	68,279	− 116	− 71,721
Platinum metals ....fine ounces..	1,478.97	160,117	40	2,670	− 1,438.97	− 157,447
Miscellaneous nonmetallic products, including petroleum, marble, gypsum, and quicksilver....	....	266,830	....	245,260	....	− 21,570
	....	23,303,757	....	17,004,124	....	−6,299,633

Value of total mineral production of Alaska, 1880–1921.

By years.				By substances.	
1880–1890	$4,686,714	1907	$20,850,235	Gold	$328,104,093
1891	916,920	1908	20,145,632	Copper	134,840,698
1892	1,098,400	1909	21,146,953	Silver	8,103,977
1893	1,051,610	1910	16,887,244	Coal	2,292,522
1894	1,312,567	1911	20,691,241	Tin	936,664
1895	2,388,042	1912	22,536,849	Lead	730,537
1896	2,981,877	1913	19,476,356	Antimony	237,500
1897	2,540,401	1914	19,065,666	Marble, gypsum, petroleum, platinum, etc	3,232,922
1898	2,587,815	1915	32,854,229		478,478,913
1899	5,706,226	1916	48,632,212		
1900	8,241,734	1917	40,710,205		
1901	7,010,838	1918	28,253,961		
1902	8,403,153	1919	19,620,913		
1903	8,944,134	1920	23,303,757		
1904	9,569,715	1921	17,004,124		
1905	16,480,762		478,478,913		
1906	23,378,428				

GOLD AND SILVER.

TOTAL PRODUCTION.

The total production of gold and silver since the beginning of mining in 1880 is given in the following table. For the earlier years the figures, especially those for silver, are probably far from correct, but they are based on the best information now available.

Gold and silver produced in Alaska, 1880–1921.

Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Commercial value.
1880	967	$20,000		
1881	1,935	40,000		
1882	7,256	150,000		
1883	14,561	301,000	10,320	$11,146
1884	9,724	201,000		
1885	14,512	300,000		
1886	21,575	446,000		
1887	32,653	675,000		
1888	41,119	850,000	2,320	2,181
1889	43,538	900,000	8,000	7,490
1890	36,862	762,000	7,500	6,071
1891	43,538	900,000	8,000	7,920
1892	52,245	1,080,000	8,000	7,000
1893	50,213	1,038,000	8,400	6,570
1894	62,017	1,282,000	22,261	14,257
1895	112,642	2,328,500	67,200	44,222
1896	138,401	2,861,000	145,300	99,087
1897	118,011	2,439,500	116,400	70,741
1898	121,760	2,517,000	92,400	54,575
1899	270,997	5,602,000	140,100	84,276
1900	395,030	8,166,000	73,300	45,494
1901	335,369	6,932,700	47,900	28,598
1902	400,709	8,283,400	92,000	48,590
1903	420,069	8,683,600	143,600	77,843
1904	443,115	9,160,000	198,700	114,934
1905	756,101	15,630,000	132,174	80,165
1906	1,066,030	22,036,794	203,500	136,345
1907	936,043	19,349,743	149,784	98,857
1908	933,290	19,292,818	135,672	71,906
1909	987,417	20,411,716	147,950	76,934
1910	780,131	16,126,749	157,850	85,239
1911	815,276	16,853,256	460,231	243,923
1912	829,436	17,145,951	515,186	316,839
1913	755,947	15,626,813	362,563	218,988
1914	762,596	15,764,259	394,805	218,327
1915	807,966	16,702,144	1,071,782	543,393
1916	834,068	17,241,713	1,379,171	907,495
1917	709,049	14,657,353	1,239,150	1,021,060
1918	458,641	9,480,952	847,789	847,789
1919	455,984	9,426,032	629,708	705,273
1920	404,683	8,365,560	953,546	1,039,364
1921	390,558	8,073,540	761,085	761,085
	15,872,034	328,104,093	10,733,647	8,103,977

Gold and silver produced in Alaska, 1921, by sources.

	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
Siliceous ores (2,894,813 short tons)	184,707	$3,818,226	99,515	$99,515
Copper ores (477,121 short tons)	1,329	27,471	545,229	545,229
Lead ores (727 short tons)	89	1,843	93,766	93,776
Placers (4,812,721 cubic yards of gravel)	204,433	4,226,000	22,565	22,565
	390,558	8,073,540	761,085	761,085

Gold and silver produced in Alaska from different sources, 1880–1921.

	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
Siliceous ores [a]	4,847,738	$100,211,663	1,868,163	$1,514,879
Copper ores	86,128	1,780,438	7,043,148	5,502,063
Placers	10,938,168	226,111,992	1,822,336	1,087,035
	15,872,034	328,104,093	10,733,647	8,103,977

[a] Including small amounts of lead ore.

LODE MINING.

Nineteen gold and silver lode mines and thirteen prospects [1] were operated in 1921 and produced gold, silver, and some lead and copper to a total value of $4,082,741; in 1920 seventeen gold and silver lode mines and five prospects were operated and produced metals to a total value of $4,886,547. This decrease in metallic output of the Alaska lode mines is due to the closing in June of the Perseverance mine, in the Juneau district. In general the lode-mining industry of 1921 showed progress during the year, but developments of ore bodies are not yet sufficient to give any assurance that output of gold from this source will increase in the immediate future. At the end of the year there were only three large productive mines in southeastern Alaska, and for the present the maintenance of Alaska's gold-lode production depends on these three mines. On the other hand, some progress was made during 1921 in lode mining in the Willow Creek district, where the gold output was nearly double that of 1920. It must be noted, however, that no noteworthy reserves of gold ore have yet been developed in the Willow Creek district, though the outlook for finding them is encouraging. The silver-lead deposits of the Kantishna region are promising. Lode mining at Fairbanks has increased in a small way, and the present accessibility of the district by rail will undoubtedly stimulate further search for commercial ore bodies.

[1] Lode properties the value of whose total metallic output is less than $1,000 are here classed as prospects. These include some mines on which considerable development work has been done, but which have not yet been put on a regular productive basis.

Though the developed gold-ore reserves in Alaska are small, the discovery of promising auriferous lodes in so many widely separated localities and the known widespread favorable geologic conditions for the bedrock occurrence of gold are auspicious for a large lode gold-mining development. Silver-bearing galena ores are also widespread in Alaska. Thus far mining of such deposits has been confined to the extraction of small but very rich ore shoots. There is good hope, though as yet no positive evidence, that larger galena ore bodies will be found and that the exploitation of such bodies may become a more permanent feature of Alaska metal mining than at present. Meanwhile the small shipments of galena ores rich in silver have greatly swelled the silver output derived from Alaska lode deposits, as shown in the following table:

Gold and silver produced from gold lode mines in Alaska in 1921, by districts.

District.	Ore mined (short tons).	Gold.		Silver.		Average value per ton of ore in gold and silver.
		Fine ounces.	Value.	Fine ounces.	Value.	
Southeastern Alaska	2,889,752	176,158.62	$3,641,522	102,070	$102,070	$1.29
Willow Creek	3,591	5,721.50	118,273	1,029	1,029	33.22
Fairbanks district	944	1,858.27	38,414	279	279	40.99
Other districts	1,253	1,057.53	21,860	89,913	89,913	89.20
	2,895,540	184,795.92	3,820,069	193,291	193,291	1.39

In the above table are included the silver-lead ores, as well as auriferous quartz. The ore hoisted from the auriferous quartz mines yielded on the average $1.39 worth of gold and silver to the ton. In 1920 the average recovery was $1.39, and in 1919 it was $1.38. It is needless to state that this low recovery is caused by the large percentage of the total tonnage mined that is to be credited to the mines of the Juneau district.

PLACER MINING.

During 42 years of mining Alaska has produced gold to the value of $328,104,093, and of this amount $226,112,000 is to be credited to her placer mines. Because of the high cost of all mining operations and the relatively low purchasing value of gold that have existed since the war gold placer mining has been on the decline. During this period of stagnation Alaska placer mining has been maintained chiefly by those who had large plants, such as dredges and hydraulic mines, and could not afford to let them rest idle. A very large percentage of the mines were operated by the owners, who had no other means of livelihood and were loath to leave the country and take up a new vocation. In 1921 there was a marked improvement in the placer-mining industry, which was expressed not only by an increase of about 9 per cent in the gold output but also in the number of large placer-mining projects that are under way. This revival is due to a general lowering of costs in the more accessible districts, though the costs are still very high. A considerable number of the smaller placer mines are being operated at a loss. Costs will undoubtedly be lowered in the region served by the Alaska Railroad, and when water transportation on Yukon River is adjusted to the new conditions produced by the railroad to Fairbanks, operating costs will also decline in some of the more isolated Yukon camps. The transportation furnished by the Alaska Railroad can not, however, be made available to the inland mining industry unless a very liberal policy of wagon-road construction is adopted. The construction of roads and trails is to-day the greatest need of the Alaska mining industry. The Alaska Road Commission is fully aware of this need and has accomplished much with the funds at its disposal.

The quantity of incoming freight required for placer mining varies greatly according to methods of mining and sources of fuel and lumber, but precise figures on this subject are not available. It is evident that in districts where placer mining is the only industry all the incoming freight is chargeable to this industry. The facts at hand indicate a more or less constant relation between the amount of annual incoming freight and the annual gold output, though manifestly the richer the ground the more gold will be produced to the ton of incoming freight. At Fairbanks the average of eight years showed that about $380 worth of placer gold was produced for each ton of incoming freight. This freight included, however, practically no fuel or lumber. The average of the Yukon camps was about $530 worth of placer gold for each ton of freight. In the smaller districts like Koyukuk, Iditarod, and Hot Springs, where very rich placer deposits were being exploited, from $500 to $1,000 worth of gold was produced for each ton of freight. The mining of the low-grade placers of Seward Peninsula, where it is necessary to import all fuel and lumber, in the two years 1919 and 1920 produced only $130 worth of gold for every ton of freight brought in. The figures given above, though only approximately accurate, clearly show how the cost of transportation is the dominating factor in placer mining.

A number of new finds of placer gold were made during 1921, but they were all in known fields of auriferous alluvium. One of these discoveries was made on Wilbur Creek, a tributary of Tolovana River, about 7 miles due east of Livengood Creek. The finding of coarse gold on this creek indicates that there may be a second belt of mineralization in the Tolovana area. Another deposit of placer gold was found on Kokomo Creek, a southerly tributary of Chatanika River, 10 miles east of Cleary. This discovery is significant chiefly because it indicates an eastern extension of the auriferous area. In 1921 placer mining was begun on gold prospects that had been found in 1918 on Stuyahok Creek, a tributary of Bonasila River, which flows into the Yukon 10 miles below Anvik. Prospecting in the Chandalar district has given specially encouraging results, and the output from this camp will probably increase. In general the outlook is favorable for an increase of placer-gold output in 1922.

Statistics of Alaska placer mining in 1920 and 1921.

Region.	Number of mines.				Number of miners.				Value of gold produced.		
	Summer.		Winter.		Summer.		Winter.		1920	1921	Decrease or increase, 1921.
	1920	1921	1920	1921	1920	1921	1920	1921			
Southeastern and southwestern Alaska	18	7	......	3	18	11	......	3	$10,000	$4,000	−$6,000
Copper River region	19	7	......	2	94	130	......	14	200,000	220,000	+20,000
Cook Inlet and Susitna region	27	34	......	2	70	144	......	29	55,000	165,000	+110,000
Yukon Basin	273	334	69	79	1,130	1,131	271	335	1,995,000	1,860,000	−135,000
Kuskokwim region	32	28	......	3	125	98	......	8	305,000	520,000	+215,000
Seward Peninsula	112	126	8	13	540	622	61	61	1,300,000	1,450,000	+150,000
Kobuk region	7	9	5	4	10	15	9	10	8,000	7,000	−1,000
	488	545	82	106	1,987	2,151	341	460	3,873,000	4,226,000	+353,000

Gold and silver produced from placer mines in Alaska in 1921, by regions.

Region.	Gold.		Silver.		Gravel mined (cubic yards).	Recovery per cubic yard.
	Fine ounces.	Value.	Fine ounces.	Value.		
Southeastern and southwestern Alaska	193.50	$4,000	33	$33	2,283	$1.75
Copper River region	10,642.50	220,000	1,110	1,110	341,183	.64
Cook Inlet and Susitna region	7,981.87	165,000	1,164	1,164	347,423	.47
Yukon Basin	89,977.50	1,860,000	11,952	11,952	1,574,546	1.18
Kuskokwim region	25,155.00	520,000	2,959	2,959	195,529	2.66
Seward Peninsula	70,143.75	1,450,000	5,307	5,307	2,347,418	.62
Kobuk region	338.63	7,000	40	40	4,339	1.61
	204,432.75	4,226,000	22,565	22,565	4,812,721	.88

Hydraulic mining is becoming of constantly increasing importance in the Alaska placer industry, and this accounts in part for the lowering of the average value of the gold recovery to the cubic yard from the gravel sluiced annually. As yet there are but few large hydraulic plants in operation. Conditions favorable for hydraulic mining on a large scale, such as proper stream gradients, water supply under sufficient head, and large bodies of auriferous gravel, are found in the mountainous belt that borders the Pacific Ocean and extends inland for 150 to 200 miles. The Porcupine, Nizina, Chistochina, Valdez Creek, Yentna, Kantishna, Bonnifield, and Chisna placer districts lie within or on the border of this mountainous belt. As yet no considerable tests of the larger bodies of auriferous gravel lying within this belt have been made to determine their gold content. Some of these deposits are well worth thorough prospecting.

The following table is based in part on returns made by operators of placer mines and in part on known facts or assumptions concerning the richness of the gravel in the several districts. Although the table is thus in part an estimate it is probably nearly correct.

The decline in the average gold content of the gravels mined from 1908 to 1914 reflects the gradual exhaustion of bonanza placers, the improvement of methods of placer mining, and the increased use of dredges.

Gravel sluiced in Alaskan placer mines and value of gold recovered, 1908–1920.

Year.	Total quantity of gravel (cubic yards).	Value of gold recovered per cubic yard.	Year.	Total quantity of gravel (cubic yards).	Value of gold recovered per cubic yard.
1908	4,275,000	$3.74	1915	8,100,000	$1.29
1909	4,418,000	3.66	1916	7,100,000	1.57
1910	4,036,000	2.97	1917	7,000,000	1.40
1911	5,790,000	2.17	1918	4,931,000	1.20
1912	7,050,000	1.70	1919	4,548,000	1.10
1913	6,800,000	1.57	1920	3,439,900	1.13
1914	8,500,000	1.26	1921	4,812,700	.88

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	18	.65	2.68	1.70
1913	21	.54	3.11	1.57
1914	22	.53	2.07	1.26
1915	22	.51	2.33	1.29
1916	24	.69	2.64	1.57
1917	26	.68	2.21	1.40
1918	24	.57	1.84	1.20
1919	27	.77	1.31	1.10
1920	29	.69	1.53	1.13
1921	37	.57	1.31	.88

As shown in the subjoined list, 24 dredges were operated in Alaska in 1921, as compared with 22 in 1920. Three of these machines were operated less than a month and therefore should not be classed with the normal producers. The Seward Peninsula dredges were in commission 90 to 121 days, averaging about 100 days of productive mining. The dredges of the Yukon and Kuskokwim region worked from 90 to 145 days. The average gold recovery for all Alaska dredges was 57 cents a cubic yard; for the Yukon and Kuskokwim dredges, 90 cents; and for Seward Peninsula, 39 cents. There is good reason to believe that two or three additional dredges will be in operation in 1922.

Gold dredges operated in Alaska in 1921.

Seward Peninsula:
- Council district:
  - Crooked Creek Dredge Co., Crooked Creek.
  - Garrod & Pfaffle, Warm Creek (?).
  - Northern Light Mining Co., Ophir Creek.
  - Wild Goose Mining & Trading Co. (2 dredges), Ophir Creek.
- Kougarok district:
  - Behring Dredging Corporation, Kougarok River.
  - Kougarok Mining Co., Kougarok River (?).
- Nome district:
  - Ames & Guinan, Glacier Creek.
  - Center Creek Dredging Co., Snake River.
  - Dexter Creek Dredging Co., Dexter Creek.
  - Dry Creek Dredging Co., Dry Creek.
  - Julien Dredging Co., Osborn Creek.
- Port Clarence district:
  - C. F. & F. L. Rice, Swanson Creek.
- Solomon district:
  - Eskimo Gold Dredging Co., Solomon River.
  - Iverson & Johnson, Big Hurrah Creek.
  - Shovel Creek Dredging Co., Shovel Creek.

Yukon basin:
- Circle district:
  - Berry Dredging Co., Mastodon Creek.
- Fraibanks district:
  - Fairbanks Gold Dredging Co. (2 dredges), Fairbanks Creek.
- Iditarod district:
  - Beatson & Donnelly, Otter Creek.
  - J. E. Riley Investment Co., Otter Creek.
- Innoko district:
  - Flume Dredge Co., Yankee Creek.

Kuskokwim region:
- Mount McKinley district:
  - Kuskokwim Dredging Co., Candle Creek.

Cook Inlet and Susitna region:
- Yentna district:
  - Cache Creek Dredging Co., Cache Creek.

Gold produced by dredge mining in Alaska, 1903–1921.

Year.	Number of dredges operated.	Value of gold output.	Gravel handled (cubic yards).	Value of gold recovered per cubic yard.
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	35	2,200,000	4,100,000	.54
1914	42	2,350,000	4,450,000	.53
1915	35	2,330,000	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	1,633,861	.69
1921	24	1,582,520	2,799,519	.57
		23,107,452		

COPPER.

The total copper output of Alaska in 1921 was 57,011,597 pounds, valued at $7,354,496; in 1920 it was 70,435,363 pounds, valued at $12,960,106. This decrease in output was the result of curtailment of production at the four large Alaska copper mines—the Kennecott-Bonanza, Jumbo, and Mother Lode, in the Chitina basin, and the Beatson-Bonanza, on Prince William Sound—and was but a reflection of the world-wide depression in the copper-mining industry. The Rush & Brown mine, in the Ketchikan district, is the only other Alaska copper mine that was operated on a productive basis throughout the year. There was, however, a small copper output from half a dozen other localities in Alaska during 1921.

Besides the copper the 477,121 tons of ore from the copper mines yielded 1,328.91 fine ounces of gold, valued at $27,471, and 545,229 fine ounces of silver, valued at $545,229.

The average copper content of the ore mined in 1921 was 5.8 per cent; in 1920 it was 4.6 per cent. The gold and silver content of the Alaska copper ores varies so greatly that the average is not significant. Of the total copper ore mined 448,236 tons was concentrated, yielding 47,571 tons of concentrates, which averaged 35 per cent of copper. Most of the copper concentrates and crude ore were shipped to the smelter at Tacoma, Wash.

Copper produced in Alaska, 1880–1921.

Year.	Mines operated.	Ore mined (tons).	Copper produced.	
			Pounds.	Value.
1880	1		3,393	$826
1901	2		250,000	40,000
1902	3	a 40,000	360,000	41,400
1903	4		1,200,000	156,000
1904	5		2,043,586	275,676
1905	8	52,199	4,805,236	749,617
1906	15	105,729	5,871,811	1,133,260
1907	13	98,927	6,308,786	1,261,757
1908	9	51,509	4,585,362	605,267
1909	7	34,669	4,124,705	536,211
1910	7	39,365	4,241,689	538,695
1911	8	68,975	27,267,878	3,408,485
1912	7	93,452	29,230,491	4,823,031
1913	6	135,756	21,659,958	3,357,293
1914	6	153,605	21,450,628	2,852,934
1915	14	369,600	86,509,312	15,139,129
1916	18	617,264	119,854,839	29,484,291
1917	17	659,957	88,793,400	24,240,598
1918	17	722,047	69,224,951	17,098,563
1919	8	492,644	47,220,771	8,783,063
1920	8	766,095	70,435,363	12,960,106
1921	6	477,121	57,011,597	7,354,496
	....	4,978,914	672,454,296	134,840,698

a Estimated.

Though underground exploration of copper lodes continued in a small way in all the Alaska copper districts no important advances can be recorded. At no time in its history has the Alaska copper-mining industry been so stagnant as it was in 1921. Most of the copper properties are in the hands of those who have not sufficient capital to permit systematic underground exploration. Their activities are usually limited to the required assessment work or to the search for and development of rich ore shoots that can be exploited at a profit, even by those of small financial resources. Such small activities can not lead to profitable mining unless the ore body is close to railroads or ocean transportation.

The record that there were only six productive copper mines in all Alaska in 1921, on its face, would certainly lead to dismay, yet some other facts in regard to the occurrence of copper are encouraging. The wide distribution of copper ores in Alaska has already been fully described.[2] There are in Alaska some 28 mines which have in the past produced copper on a commercial scale. The suspension of operations at some of these mines is due to the apparent exhaustion of the ore bodies, but in much the larger number it is due to other factors. The reopening of many of these mines is dependent on the availability of capital, notably for concentrating plants, on cheap transportation, and, above all, on a higher price of copper.

Copper mineralization has occurred at hundreds of localities, and the location of claims on very small showings is a common practice. The number of copper claims that have been staked therefore affords no measure of the number of commercial deposits. A careful weighing of the information at hand indicates that there are in Alaska within 25 miles of a railroad or of tidewater at least 65 copper prospects that give hope of containing commercial ore bodies. Therefore, although the evidence in hand is far from being conclusive, it appears that, including mines and accessible prospects, there are about 100 localities where there are copper ore bodies that have some promise of being of commercial size. These do not include the deposits of copper at localities now too remote to permit development without large investments in railroad construction.

LEAD.

The lead produced in Alaska in 1921 came from the gold ores of the Juneau district and from galena ores mined for their high silver content, chiefly in the Kantishna and Ruby districts of the Yukon and the Fairhaven district of Seward Peninsula. A total of 727 tons of these silver-lead ores was shipped in 1921 and yielded on the average 129 ounces of silver to the ton and 35 per cent of lead. In-

[2] Brooks, A. H., The future of Alaska mining: U. S. Geol. Survey Bull. 714, pp. 12-36, 1921.

cluding the small content of gold and copper, the average value of these silver-lead ores was $164 a ton.

All this mining was limited to the extraction of rich ore shoots, for the cost of transportation has thus far prohibited the exploitation of ore of lesser metallic content. The search for such valuable silver-lead deposits has brought additional evidence of the widespread occurrence of galena ores in Alaska. In the Kantishna district some indications have been found of the presence of larger ore bodies than have thus far been exploited.

Lead produced in Alaska, 1892–1921.

Year.	Tons.	Value.	Year.	Tons.	Value.
1892	30	$2,400	1908	40	$3,360
1893	40	3,040	1909	69	5,934
1894	35	2,310	1910	75	6,600
1895	20	1,320	1911	51	4,590
1896	30	1,800	1912	45	4,050
1897	30	2,160	1913	6	528
1898	30	2,240	1914	28	1,344
1899	35	3,150	1915	437	41,118
1900	40	3,440	1916	820	113,160
1901	40	3,440	1917	852	146,584
1902	30	2,460	1918	564	80,088
1903	30	2,520	1919	687	72,822
1904	30	2,580	1920	875	140,000
1905	30	2,620	1921	759	68,279
1906	30	3,420			
1907	30	3,180		5,818	730,537

TIN.

On account of the low price of tin, operations in the York district of Seward Peninsula, the only region in Alaska where commercial deposits of this metal have been found, were suspended in 1920. The only tin produced during the year was a few tons won from gold placer-mining operations in the Hot Springs district of the Yukon basin. No tin was shipped from Alaska in 1921.

Tin produced in Alaska, 1902–1921.

Year.	Ore (tons).	Metal (tons).	Value.	Year.	Ore (tons).	Metal (tons).	Value.
1902	25	15	$8,000	1913	98	50	$44,103
1903	41	25	14,000	1914	157.5	104	66,560
1904	23	14	8,000	1915	167	102	78,846
1905	10	6	4,000	1916	232	139	121,000
1906	57	34	38,640	1917	171	100	123,300
1907	37.5	22	16,752	1918	104.5	68	118,000
1908	42.5	25	15,180	1919	86	56	73,400
1909	19	11	7,638	1920	26	16	16,112
1910	16.5	10	8,335	1921	7	4	2,400
1911	92.5	61	52,798				
1912	194	130	119,600		1,607.0	992	936,664

PLATINUM METALS.

The output of platinum minerals in Alaska in 1921 showed a large falling off, owing to the suspension of operations at the Salt Chuck mine, which in the past has been the principal producer of palladium in Alaska. The platinum produced in 1921 was won entirely as a by-product of gold placer mining. The producers include one mine on Slate Creek, in the Chistochina district of the Copper River basin; three on Dime Creek and one on Sweepstake Creek, both in the Koyuk district of Seward Peninsula; and one on Bear Creek, in the Fairhaven district of Seward Peninsula. This record shows that the mining of placer platinum is not yet an established industry in Alaska, for its continuance is dependent on the recovery of placer gold. The total production of platinum metals in Alaska since they were first saved in 1916 is shown in the following table:

Platinum metals produced in Alaska, 1916–1921.

Year.	Crude ounces.	Fine ounces.	Value.	Year.	Crude ounces.	Fine ounces.	Value.
1916	12.0	8.33	$700	1920	1,493.4	1,478.97	$160,117
1917	81.2	53.40	5,500	1921	57.0	40.0	2,670
1918	301.0	284.00	36,600				
1919	579.3	569.52	73,663		2,523.9	2,434.22	279,250

QUICKSILVER.

The only quicksilver deposits thus far developed in Alaska occur in the lower Kuskokwim region and in the adjacent part of the basin of Iditarod River, which flows into the Yukon. For many years the Parks mine, on the banks of Kuskokwim River, was the only producer of quicksilver in Alaska. This mine was not productively operated in 1921, but some underground work was done. Developments were also continued on the adjacent Willis & Fuller's quicksilver claim. More important operations were conducted by the Thrift Mining Co. on cinnabar-bearing lodes on Montana Creek, a tributary of the upper Iditarod. This property has not been visited by the Geological Survey. The company reports that the vein on which work is being done is 3 feet 8 inches wide and that other promising cinnabar veins occur on the property. The cinnabar is now being treated in a four-tube retort, but a larger reduction plant is planned. This is the only property in Alaska on which quicksilver was produced in 1921.

MISCELLANEOUS METALS.

Antimony, tungsten, and chromite deposits in Alaska were mined during the World War, but this work ceased with the coming of peace. Only assessment work is now being done on lodes carrying these metals. In 1921 no development work, except that required by law, was done on Alaska deposits of nickel, molybdenite, and bismuth.

COAL.

Of the output of coal in Alaska during 1921, 53,088 tons came from the three Government mines in the Matanuska field. The total production of bituminous coal in 1921 was 58,078 tons; of lignitic coal, 18,739 tons. As shown by the subjoined table, Alaska coal mines do not yet supply the local consumption.

In 1921 there were 15 localities in Alaska where some coal was produced, but at only 7 of these did the total output exceed 1,000 tons, and of these 3 were Government mines. Of the 4 private mines producing more than 1,000 tons, 3 produced lignitic coal and 1, the Evan Jones, in the Matanuska field, subbituminous coal. The 15 mines, large and small, employed 401 men for an average of 231 days of the year. Of these men, about 150 were employed by the Naval Coal Commission, and a large part of these were engaged in development work and not in productive mining.

The most important events in the Alaska coal-mining industry in 1921 were the building of a Government coal washery and the opening of the Coal Creek mine, in the Matanuska field, by the Naval Coal Commission, and the systematic development of the Evan Jones mine, in the same field, and of the Healy mine, in the Nenana lignitic field. The last two, though operated only on a small scale, are the first private enterprises that have reached the stage of systematic production of Alaska coal. Their success brings the final proof that the Alaska coal can be utilized to supply the needs of the Territory. As Alaska is still using some 58,000 tons of imported coal, there is room for expansion on the basis of the present local market. Moreover, the lower cost of the local coal will undoubtedly lead to industrial developments that will produce a still larger demand. It should be noted, however, that in supplying such regions as Nome and Seward Peninsula the Alaska fields thus far opened up have no advantage in transportation over those that furnish the imported coals. In 1921 about 19,000 tons of coal was shipped to Nome.

Coal produced and consumed in Alaska, 1888–1921, in short tons.

Year.	Produced in Alaska, chiefly subbituminous and lignite.		Imported from States, chiefly bituminous from Washington.[a]	Total foreign coal, chiefly bituminous from British Columbia.[a]	Total coal consumed.
	Short tons.	Value.			
1888–1896	6,000	$84,000	.....	.....	.....
1897	2,000	28,000	.....	.....	.....
1898	1,000	14,000	.....	.....	.....
1899	1,200	16,800	10,000	[b] 50,120	61,320
1900	1,200	16,800	15,048	[b] 56,623	72,871
1901	1,300	15,600	24,000	[b] 77,674	102,974
1902	2,212	19,048	40,000	[b] 68,363	110,575
1903	1,447	9,782	64,626	[b] 60,605	126,678
1904	1,694	7,225	36,689	[b] 76,815	115,198
1905	3,774	13,250	67,713	[b] 72,612	144,099
1906	5,541	17,974	69,493	[b] 47,590	122,624
1907	10,139	53,600	46,246	[b] 93,262	149,647
1908	3,107	14,810	23,893	[b] 86,404	113,404
1909	2,800	12,300	33,112	69,046	104,958
1910	1,000	15,000	32,098	58,420	91,518
1911	900	9,300	32,255	61,845	95,000
1912	355	2,840	27,767	68,316	96,438
1913	2,300	13,800	69,066	56,430	127,796
1914	.....	.....	41,509	46,153	87,662
1915	1,400	3,300	46,329	29,457	77,186
1916	13,073	52,317	44,934	53,672	111,679
1917	53,955	265,317	58,116	56,589	168,660
1918	75,606	411,850	51,520	37,986	165,112
1919	60,674	343,547	57,166	48,708	166,548
1920	61,111	355,668	38,128	45,264	144,503
1921	76,817	496,394	24,278	33,776	134,871
	390,605	2,292,522	953,986	1,355,730	2,691,321

[a] No figures on imports before 1899 are available.
[b] By fiscal year ending June 30.

The Matanuska coal field is now the center of interest for the development of a coal-mining industry, because it is accessible to the Alaska Railroad. Its high-grade coals are of the same quality as those of Bering River, which is not yet served by a railroad. In their mode of occurrence, with reference to folding and faulting, the coal beds of the two fields are, so far as now known, very similar.

The lower part of the Matanuska field, however, also contains subbituminous coals of about the same quality as the coals of Vancouver Island, British Columbia. It is these subbituminous coals that have now been developed on a commercial scale. They are far less disturbed than the high-grade coals of the upper half of the field and on this account are far cheaper to mine. These high-grade coals have not yet been mined commercially, but they have been extensively explored by the Naval Coal Commission. The local market for the subbituminous coals is constantly increasing, but it is yet to be determined how far they can at present compete, in southeastern Alaska, with the Vancouver Island coals, which lie close to tidewater and are cheaper to mine than those in the Matanuska field.

Though the actual coal reserve of Vancouver Island is estimated to be over 1,000,000,000 tons,[3] the record of mining suggests that

[3] Clapp, C. H., Coal fields of Vancouver Island: Coal Resources of the World, vol. 2, pp. 509–513, Toronto, Canada, 1913.

much of this reserve is not readily available, for there has been no increase in the output of the collieries of Vancouver Island during the last decade, in spite of a growing market for coal. If the Vancouver Island fields are reaching their maximum annual output, the future industrial demands of the Pacific seaboard will force the use of the Alaska coal. Therefore, the possibility of a market for the subbituminous coal of Alaska on the west coast is by no means shut out. The export market for the Alaska high-grade bituminous coal depends on the cost of producing it. Those bituminous coals, because of their higher fuel value, are roughly 25 to 30 per cent more valuable than the subbituminous coals of Alaska and British Columbia. The cost of mining them is greatly increased by the friable condition of the coal beds and walls, the high angle of pitch of the beds, and the gaseous condition of the coal, but above all by the irregularity in occurrence of the beds,[4] which adds to mining costs by the expenditures made for dead work in searching out the coal beds that have been lost by displacements or other irregularities. It is not yet known how much this dead work will add to the cost of the coal mined, but the extra expense may be as much as $4 a ton. It will therefore probably not be safe on present information to estimate the cost of production at less than $10 a ton for the high-grade bituminous coal. Even at such a mining cost, and adding reasonable charges for transportation, there should be an export market for the coal. Of course, there is also a good prospect that systematic development in the Matanuska and Bering River fields will lead to the discovery of areas where the coal is less disturbed than that now developed. If so, a very great reduction in cost is to be expected, but in any event the average cost of recovery for these two coal fields as a whole must be placed at a high figure.

It may therefore be concluded that at present the subbituminous coal of Alaska can be mined and marketed at a profit for local use but can not be marketed at distant ports where it comes into competition with Vancouver Island coal. The high-grade bituminous coal and anthracite of Alaska have not yet been produced for the market. The commercial possibility of their finding an export market will depend on mining costs, as yet unknown. Of their eventual necessity to Pacific coast industries, however, there can be no doubt. It should also be noted that if Alaska becomes a large producer of fuel oil, the market for her coal will be curtailed.

In the Matanuska field[5] coal was mined in 1921 only at the Eska and Evan Jones mines, but considerable coal was recovered incidentally to underground exploration at the two mines of the Naval Coal Commission, at Chickaloon and Coal Creek. Some development

[4] Brooks, A. H., The Alaskan mining industry in 1920: U. S. Geol. Survey Bull. 722, pp. 27-30, 1921.

[5] Information on developments in the Matanuska field furnished by B. W. Dyer, Federal mine inspector.

work was also done on other private leasing units, but no coal was produced.

At the Eska mine productive mining was continued by the Alaskan Engineering Commission until October. During this time 44,630 tons of coal was mined and 3,260 feet of development work was completed. The mine was closed in accordance with a policy of leaving to private initiative the production of coal for the railroad as well as for private use.

The Evan Jones Coal Co., working under a lease, started productive mining in October, when a railroad spur was completed to the mine, in large part at its own expense. Over 3,000 feet of underground work was done.

The Naval Coal Commission completed some 9,605 feet of underground work at the Chickaloon mine and 1,957 feet of underground work and 3,559 feet of diamond drilling at the Coal Creek mine. Incidentally to this work 7,121 tons of high-grade bituminous coal was produced at Chickaloon and 1,337 tons at Coal Creek. The coal washery was completed in 1921 and will be of very material aid to the coal operators of the field. A 5,000-ton sample of coal is to be washed and given a naval test.

The Baxter mine, in the lower, subbituminous part of the field, was reopened late in 1921 and promises to be a coal producer in 1922. Work was started on leasing unit No. 4 by Murphy & Ramson, who drove an entry about 100 feet long and a crosscut about 60 feet long.

No productive mining was done in the Bering River field. The Bering River Coal Co. continued its development work until April, 1921, and later was granted a permit for the suspension of work for one year. A sample of coal is to be taken from this mine for a naval test. Two other leases were granted in the Bering River field during 1921, but no developments were started.

Some 2,500 tons of lignitic coal was mined in the Chulitna-Broad Pass field at three different mines. The facts at hand indicate that there is in this field a large area of coal land adjacent to the railroad. Some high-grade bituminous float coal was found on Riley Creek, but so far as known its source was not discovered.

The Healy River Coal Mining Co. operated its lignite mines in the Nenana field throughout the year. Here a coal bed 8 feet thick without partings is mined from an entry at river level. The coal is hoisted to a tipple on the top of the bluff, which is on the railroad. The Broad Pass Development Co. mined some coal from a shallow opening on Lignite Creek during the winter of 1920–21.

The McNally & Maitland lignite mine, at Bluff Point, Cook Inlet, was operated as usual during the summer. A little lignite was also obtained from the beach near Seldovia. Some lignite was obtained from the Kugruk mine, on Seward Peninsula, from the Bureau of Education mine, at Wainwright Inlet, and from other localities.

PETROLEUM.

No drilling has yet been done on the lands granted by the oil leasing act of 1920, and therefore the Chilkat Oil Co., in the Katalla field, continues to be the only producing oil company in Alaska. This company drilled one well in 1921. Its drilling has all been on one tract of 151 acres, to which patent had been earned before the oil-land withdrawal of 1910. In all 32 holes have been drilled in the Katalla field, of which about 14 found oil and 12 have been made productive. The wells are all small, the maximum daily output, all gained by pumping, being about 25 barrels. On the other hand, some of the wells have produced some oil for nearly 20 years. So far as can be judged from present information, the future of the field will rest on an output from many rather closely spaced shallow wells each with a relatively small production. The facts in hand suggest that a long life for the field is probable. Though no drilling was done in any other field, a number of oil companies had examinations made, and so far as can be learned the reports are satisfactory. The Geological Survey completed the mapping of the Iniskin Bay field and made a reconnaissance of a part of the Cold Bay field. The reports of this work are summarized in a later chapter of this volume, but the conclusions may be summarized as follows:

F. H. Moffit found that the Iniskin Bay region includes a number of long, narrow anticlines which are joined on the seaward side by a great monocline. This monoclinal structure affords a considerable drainage area and may have resulted in the accumulation of pools of oil. S. R. Capps reports that in the Cold Bay district and probably in other parts of the Alaska Peninsula there are structural features favorable to the accumulation of oil and that these are worth drilling and their dimensions suggest the possibility that they may contain large oil pools. In a later section of this report the writer briefly summarizes the geologic information about the possible occurrence of oil pools near Anchorage, where a small seepage was found in 1920.

During 1921 an oil seepage was found on Aniakchak River, about 60 miles southwest of the Cold Bay field. Petroleum is also reported to occur near Chignik, 70 miles southwest of Aniakchak. These discoveries or reported discoveries open up the hope of a much larger area of prospective oil land. The oil seepage at Douglas River, at the base of the Alaska Peninsula, where, so far as known, the geologic conditions are favorable, indicates another possible oil field. The area between the Douglas River and Cold Bay seepages is but little known. Oil seepages have been reported to occur in this unexplored area, which measures about 100 miles from northeast to southwest, but these reports have not been verified. If oil pools are developed at Cold Bay by drilling it is fair to classify much of the region lying between Chignik and Douglas River as at least promising wildcat territory. This region is about 250 miles long and 5 to 25 miles wide and is unsurveyed. Therefore, it is not known in what percentage of this vast area the structure is favorable. There is no a priori reason for believing that the structural features found in Cold Bay region should not be duplicated in other parts of the peninsula. Clearly, however, the oil resources of this region are entirely unproved and must await drilling. The volcanic region lying near Mount Katmai can not be classed as a favorable field for the oil prospector. The occurrence of oil in the extreme northern part of Alaska, notably near Smith Bay, was further verified in 1921 by examinations made by private individuals. The high cost of surveying this inaccessible region makes it impossible for the Geological Survey to undertake such work under present appropriations. The region is so remote that it is not likely to be developed by private capital under the limitations as to maximum area set by the present leasing law.

Many oil claims were staked and applications for prospecting permits filed in Alaska during the year. A total of 372 permits, aggregating 854,969 acres of land, have been granted. This large acreage includes a very considerable amount of land of which there is no geologic evidence that it is oil bearing—indeed, a part of it can not even be classed as legitimate wildcat territory.

Geographic distribution of lands in Alaska to which oil prospecting permits have been granted.

District.	Number of permits granted.	Total area (acres).	District.	Number of permits granted.	Total area (acres).
Cold Bay	221	517, 920	Kachemak Bay	1	2, 503
Iliamna	37	94, 720	Anchorage	17	35, 082
Katalla	41	71, 964	Southeastern Alaska	7	17, 600
Yakataga	44	110, 560			
Seward	4	4, 620		372	854, 969

Petroleum products shipped to Alaska from other parts of the United States, 1905–1921, in gallons.[a]

Year.	Heavy oils, including crude oil, gas oil, residuum, etc.	Gasoline, including all lighter products of distillation.	Illuminating oil.	Lubricating oil.
1905	2, 715, 974	713, 496	627, 391	83, 319
1906	2, 688, 940	580, 978	568, 033	83, 992
1907	9, 104, 300	636, 881	510, 145	100, 145
1908	11, 891, 375	939, 424	566, 598	94, 542
1909	14, 119, 102	746, 930	531, 727	85, 687
1910	19, 143, 091	788, 154	620, 972	104, 512
1911	20, 878, 843	1, 238, 865	423, 750	100, 141
1912	15, 523, 555	2, 736, 739	672, 176	154, 565
1913	15, 682, 412	1, 735, 658	661, 656	150, 918
1914	18, 601, 384	2, 878, 723	731, 146	191, 876
1915	16, 910, 012	2, 413, 962	513, 075	271, 981
1916	23, 555, 811	2, 844, 801	732, 369	373, 046
1917	23, 971, 114	3, 256, 870	750, 238	465, 693
1918	24, 379, 566	1, 086, 852	382, 186	362, 413
1919	18, 784, 013	1, 007, 073	3, 515, 746	977, 703
1920	21, 981, 569	1, 764, 302	887, 942	412, 107
1921	9, 209, 102	1, 403, 683	2, 021, 033	232, 784
	269, 140, 163	26, 773, 391	14, 716, 183	4, 245, 424

[a] Compiled from Monthly Summary of Foreign Commerce of the United States, 1905 to 1921, Bureau of Foreign and Domestic Commerce.

STRUCTURAL MATERIAL, ETC.

The quarrying of marble and mining of gypsum continued in 1921 on about the same scale as in 1920. The Alaska Sulphur Co. completed the building of its reduction plant on Akun Island, in the Aleutian chain, and expected to begin to produce sulphur in 1922.

REVIEW BY DISTRICTS.

The following review, in which the general arrangement is geographic from south to north, summarizes the principal mining developments in all the districts, so far as the facts about them are available. With the present reduced technical force of the Alaskan branch of the Geological Survey but few of the districts could be visited by a geologist during the year 1921. This fact and the failure of some of the mine operators to make reports leaves a dearth of information about some of the districts, especially those of the Kuskokwim region. The space here devoted to any district is therefore not necessarily a measure of its relative importance.

SOUTHEASTERN ALASKA.

The mineral output of southeastern Alaska in 1921 was derived from 10 gold and silver lode mines, 1 copper mine, a few small placer operations, a gypsum mine, and a group of large marble quarries. The total value of the mineral output decreased from $5,120,163 in 1920 to $3,865,150 in 1921. This decrease is due to the decline in output from the large gold mines at Juneau and the suspension of operations at the Salt Chuck palladium mine, in the Ketchikan district. In spite of the decline of output, there was a marked advance in the development of gold and silver bearing lodes, notably in the Portland Canal and Sitka districts.

KETCHIKAN DISTRICT.

The Rush & Brown copper mine was operated in 1921, as it has been for many years. Underground developments on the ore body are reported to have now reached a depth of 500 feet, and six levels have been opened. Operations at the Salt Chuck mine were suspended at the end of 1920. Productive mining was continued during 1921 at the Julia mine, owned by the Kasaan Gold Mining Co. The Chomley Mining Co. did some underground work at the Moonshine silver-lead prospect, on Prince of Wales Island. Except for assessment work, no other important mining development work was done in the district immediately tributary to Ketchikan.

More notable advances were made in lode mining in the region tributary to Hyder, at the head of Portland Canal.[6] The continued

[6] Westgate, L. G., Ore deposits of the Salmon River district, Portland Canal region, Alaska: U. S. Geol. Survey Bull. 722, pp. 117–140, 1921.

success of the Premier mine, lying on the Canadian side but close to the international boundary, has stimulated lode-mining development in the Alaska part of the district. In 1921 the Premier produced 4,356 tons of ore, "yielding 35,000 ounces of gold and 1,200,000 ounces of silver, valued at $1,400,000." [7]

The principal developments near Hyder were those made on the property of the Fish Creek Mining Co., from which some silver-lead ore carrying both gold and copper was shipped. This mine has been developed by adits and crosscuts, the work of some 10 to 15 men from June to the end of the year. Considerable underground work was also done in the same district on the New Alaska group, on the Hoveland property, and the Riverside and Lucky Bay groups, and a discovery was made on the Fitzgerald claim.[8]

Nothing but development work was done on the molybdenite deposits near Shakan, near the north end of Prince of Wales Island. Near by the quarries of the Vermont Marble Co. were as usual operated for about nine months in the year and employed from 40 to 50 men.

WRANGELL DISTRICT.

In 1920 the Northern Copper Co. purchased the copper claims of the Kupreanof Mining Co., on Kupreanof Island, in the Wrangell district. Development work, which began in 1920, was continued in 1921 and consisted of the opening of a 100-foot adit and a 500-foot open cut, besides considerable stripping and the digging of numerous pits. Assessment work only was done on other properties in the Wrangell district.

JUNEAU DISTRICT.

The Ready Bullion and Alaska Juneau mines were operated throughout the year. The Perseverance, owned by Alaska Gastineau Mining Co., was operated only until July 1, when the plant was dismantled and the mine abandoned, because, as the management reports, the "ore is entirely too low grade to mine at a profit." The value of the total metal contents of ore mined on this property in 1921 averaged 80 cents to the ton. Productive work was continued on a small scale at the Peterson mine, north of Juneau, and at the Daisy Bell, on Snettisham Inlet. Developments were continued at the Alaska Peerless mine, on Windham Bay, and the owners report that the mine will be on a productive basis in 1922. B. D. Stewart reports the discovery in 1921 of a silver-lead ore body carrying zinc on Howard Bay, on the west side of Lynn Canal, on which considerable development work was done.

[7] Robertson, W. F., Minister of Mines Ann. Rept. for 1921, p. G 71, Victoria, B. C., 1922.

[8] Idem, pp. G 71-72. Stewart, B. D., and Dyer, B. W., Territorial Mine Inspector Ann. Rept. for 1920, Juneau, 1922.

The Alaska Endicott Mining & Milling Co. continued work on its property near William Henry Bay. About 1,800 feet of underground work has been done, and the installation of a mill started.

A 25-foot shaft and 150-foot adit were excavated and considerable open-cut work was done at the Pekovich mine, on Funter Bay, Admiralty Island. Progress was also made in the installation of surface equipment. Some ore was mined and treated at the 10-stamp mill. The Alaska Dano Mines Co. (Nowell Otteson) continued development work on its claims on Funter Bay.

SITKA DISTRICT.

The Chichagof is still the only producing mine in the Sitka district and is one of the four largest gold mines in Alaska. In 1921 the main inclined shaft was sunk 142 feet, giving a total depth of 1,250 feet. The horizontal workings of the mine now aggregate 26,650 feet in length. Five stamps were added to the mill in 1921, making 25 in all. Mine and mill were operated throughout the year.

The Hirst Chichagof property, near by, has been developed by an 1,800-foot adit and a 200-foot raise. A 10-stamp mill is being erected on the property. A little work was also done at the Jumbo claim, owned by Louis A. Smith. Here a little ore was run through a half-ton test mill, which is on the property. The underground work consists of a 50-foot shaft, a 35-foot drift, and a 45-foot adit. The El Nido group of claims, near Lisianski Inlet,[9] has been developed by an adit 593 feet long and by crosscuts. A part of this work was done in 1921. Work was also continued on a parallel vein of gold quartz in the Apex group. B. D. Stewart reports that some developments were also made on the Brown Bear group of gold claims, near Deep and Diedrickson bays of Portlock Harbor, on the west side of Chichagof Island. According to Stewart, the quartz vein is 12 to 40 inches wide, averages about 2 feet in width on the outcrop, and has been opened for several hundred feet on the surface. Stewart also reports a pyrrhotite deposit, said to carry nickel, on Yakobi Island. Assessment work was done on a number of other gold quartz veins in the district.

The Pacific Coast Gypsum Co. operated its gypsum mine near Iyoukeen Cove, on Chichagof Island. The workings now reach a depth of 300 feet. About 25 men are employed.

MISCELLANEOUS LOCALITIES.

No gold placer mining was done in the Porcupine district during 1921. Some copper ore was shipped through the district from the Rainey Hollow region, an adjacent part of Canada. Assess-

[9] Brooks, A. H., The Alaskan mining industry in 1920: U. S. Geol. Survey Bull. 722, pp. 37-38, 1921.

ment work was done on placer claims in the Lituya Bay district, and four or five men did some beach mining at Lituya Bay and Yakutat.

COPPER RIVER BASIN.

The continuous operation of the three large copper mines of the Kennecott group and the summer placer mining in the Nizina and Chistochina districts constitute all the productive work done in the Copper River basin in 1921. The only other lode operations were assessment work on copper and gold claims.

The following statements on mining and milling at the Kennecott group of mines during 1921 are taken from the annual report of the company:[10]

Kennecott ores milled totaled 212,723 tons, assaying 5.62 per cent copper. From this tonnage there resulted 18,571.4 tons of concentrates, assaying 49.01 per cent copper. The recovery in the mill was 77.82 per cent, as compared to 82.29 per cent in 1920. This decrease in recovery was largely due to a more careful preliminary sorting of high grade from milling ores and to the generally lower grade of ore treated during the year. This applied particularly to the ores from the Glacier mine, it being thought advisable to treat a larger tonnage from this source while the copper market did not warrant the usual copper production. The cost of milling was 71.9 cents per ton, compared to 76 cents in 1920.

The leaching plant at Kennecott was operated but eleven months during the year, a shutdown being necessitated by a remodeling of the piping system. There were treated 192,551 tons of mill tailings, assaying 0.95 per cent carbonate copper, with recovery of 2,808,000 pounds copper in the form of precipitates assaying 74.63 per cent. The leaching recovery was 76.56 per cent, compared to 74.5 per cent in 1920.

The fact that the leaching plant did not operate continuously, added to the lower milling recovery above mentioned, reduced the total extraction on milling ores to 86.07 per cent, as against 90.10 per cent in 1920.

A total of 17,647 feet of development was done, 11,483 feet of this being at the Kennecott properties and 6,164 feet at Latouche. In addition, 8,343 feet of diamond drilling was done, all at Kennecott.

Even of more importance than the very favorable development of the Bonanza-Mother Lode vein in Bonanza ground was the discovery of a new ore body to the southeast of the main workings on the 700 level at the Jumbo mine.

Aside from the operations recorded above and those at the Mother Lode mine, there were no important developments of copper properties in the Chitina district. It is reported that a rich ore shoot was uncovered on the Green group of claims on McCarty Creek.

Hydraulic mining continued on a large scale in the Nizina placer district. Three hydraulic mines were operated for about 100 days during the summer, and some drift mining was done on bench placers. About 100 men were employed in this work. Practically the only placer mining in the Chistochina district was that of a hydraulic plant on Slate Creek, employing about 25 men. The value of the total placer gold output of the Copper River basin in 1921 was $220,000.

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[10] Kennecott Copper Corporation Seventh Ann. Rept., for 1921, p. 6, New York, 1922.

PRINCE WILLIAM SOUND.

In 1921 the only important mining on Prince William Sound was done at the Beatson copper mine, on Latouche Island. Here operations were continued throughout the year, but, on account of the low price of copper, on a reduced scale compared with previous years. A total of 6,164 feet of underground development work was done at Latouche. The following statement is taken from the report of the Kennecott Copper Corporation:[11]

The Latouche property was operated at 50 per cent capacity until April 1 and at approximately one-fourth capacity during the remainder of the year. A total of 168,108 tons of ore, assaying 1.83 per cent copper, were milled, with a resultant production of 17,207 tons concentrates assaying 15.33 per cent copper. The recovery was 85.92 per cent, as compared to 82.85 per cent for the previous year.

At Rua Cove, on Knight Island, W. A. Dickey continued driving a drift, now 60 feet in length, with several crosscuts at a depth of 800 feet below the highest outcrop of the ore body. No work was done at Girdwood, on Latouche Island; at the Fidalgo, on Fidalgo Bay; at the Midas mine, near Valdez; or at the Threeman mine, on Landlocked Bay.

A little gold ore was milled from three small mines in the Valdez district—that of the Valdez Gold Co., where 400 feet of underground work was done; the Tuscarora, where about 110 feet was done; and the Big Four, where about 450 feet was done. The many gold and copper claims of Prince William Sound on which a little assessment work was done during 1921 are too numerous to list here.

KENAI PENINSULA.

About eight placer mines were operated on Kenai Peninsula and in the adjacent region in 1921. These employed about 30 men and produced gold to a total value of about $25,000. The largest operations were on Crow Creek, north of Turnagain Arm, where a hydraulic plant was operated. Some advance was made on several other hydraulic installations on Kenai Peninsula.

At the Lucky Strike mine, in the Hope district, about 300 feet of adit was driven. On account of an accident, the mill was operated only for about six weeks. Work was continued at the Strong mine, at Mile 89, and some ore was shipped. These were the only two lode mines in the region that were productive in 1921. Work at the Jewel mine, in Crow Creek Pass, consisted of the installation of a 10-stamp mill, water power, and tram. Though no large lode developments were made in the Kenai Peninsula region during 1921, there was much prospecting of auriferous quartz veins. The only other mining on the peninsula was the operation of the McNally & Maitland lignitic coal mine, on Kachemak Bay (p. 17).

[11] Kennecott Copper Corporation Seventh Ann. Rept., for 1921, p. 6, New York, 1922.

SUSITNA-MATANUSKA REGION.

Productive mining in the Susitna-Matanuska region included gold placer mining in the Yentna district and at a few scattered localities, gold-lode mining in the Willow Creek district, bituminous-coal mining in the Matanuska field, and a little lignite mining at a number of scattered localities in the Susitna basin. (See p. 17.) The value of the total mineral production from this region was $324,810 in 1920 and $677,025 in 1921. The completion of the Alaska Railroad has made this region relatively accessible, and hence the search for mineral deposits has been greatly stimulated. The finding of a small oil seepage near Anchorage (p. 18) has raised the hope that petroleum may occur in the lower Matanuska and Susitna regions.

WILLOW CREEK DISTRICT.

Productive gold mining was done on seven lode mines in the Willow Creek district. The largest output came from the Gold Bullion and Lucky Shot mines, controlled by the Willow Creek Mining Co. Considerable development work was also done at the Kelly Gold Mint and Mabel mines, as well as on a number of prospects that have not yet been productive. The systematic underground exploration of the lodes in the Willow Creek district seems now assured, as certain small properties have been consolidated.

In the past the gold has come from small mines, many of which are equipped with mills more remarkable for their novelty than for their efficiency. The lodes of the district occur in well-defined fissures traversing dioritic rocks. Most of them are remarkably persistent, though some are faulted. Within these lodes are rich ore shoots, and mining has been limited to the search for and extraction of the ore from these shoots. In general the lodes have not been systematically developed to block out an ore tonnage, owing to lack of technical knowledge and of sufficient capital. As a consequence most of the mines are being worked on a hand-to-mouth basis. Plans have been formulated for larger-scale operations and above all for more systematic exploration of ore bodies. The surface indications more than warrant the careful underground exploration of the lodes already discovered.

Gold and silver produced at lode mines in the Willow Creek district, 1908–1921.

Year.	Mines operated.	Ore mined (short tons).	Gold.		Silver.	
			Ounces.	Value.	Ounces.	Value.
1908	1	12	87.08	$1,800	6.88	$3.64
1909	1	140	1,015.87	21,000	80.25	41.73
1910	1	144	1,320.15	21,290	104.29	56.31
1911	2	812	2,505.82	51,800	197.95	109.91
1912	3	3,000	4,673.02	96,600	369.07	226.97
1913	3	3,028	4,883.94	100,960	385.83	233.42
1914	3	10,110	14,376.28	297,184	1,330.00	735.00
1915	3	6,117	11,961.55	247,267	811.00	421.00
1916	3	12,182	14,473.46	299,193	1,468.00	967.00
1917	5	7,885	9,466.17	195,662	713.00	586.00
1918	5	13,043	13,043.05	269,624	724.00	724.00
1919	5	6,730	7,882.00	162,944	508.00	509.00
1920	3	2,850	3,067.00	63,400	148.00	158.00
1921	7	3,591	5,721.50	118,273	1,029.00	1,029.00
		69,644	94,476.89	1,946,997	7,875.27	5,800.98

YENTNA DISTRICT.

The most important event of the year in the Yentna district was the resumption of operations by the dredge on Cache Creek, which had been closed down pending the installation of a hydroelectric power plant. This plant was completed in 1920, and the dredge had a successful season in 1921. Twenty-four placer mines, employing 85 men, were operated in the Yentna district in 1921 and produced $120,000 worth of gold. There is a notable increase in the use of hydraulic methods in the district, 12 hydraulic plants being operated in 1921. As a consequence of the use of hydraulic and dredging methods, about 270,000 cubic yards of gravel was mined in the district during the year, with an average gold recovery of 44 cents to the cubic yard.

BROAD PASS AND TALKEETNA REGION.

Since the completion of the railroad through Broad Pass there has been renewed activity in the prospecting of copper and gold lode deposits in the tributary regions, but details are lacking. A little placer mining has also been done in this region. Considerable evidence has been found that there is a large lignite-bearing area in the upper Chulitna basin. Much of the coal is covered by bench gravels, but in many places this covering is not so thick as to preclude the economic exploitation of the underlying coal.

VALDEZ CREEK DISTRICT.

Valdez Creek is an eastern tributary of the upper Susitna River, about 60 miles by trail from the Alaska Railroad. Placer gold was discovered on this creek in 1903, and since then some mining has been done on it each year. The richest gravels occur as bench deposits, which are well located for hydraulic mining. A hydraulic plant has been installed and is engaged in exploiting these high gravels. So far as known, only one other placer mine was operated in this district in 1921.

SOUTHWESTERN ALASKA.

The most important event of the year in southwestern Alaska, including the Iliamna region, was the staking of oil claims, already noted (p. 18). In the Lake Iliamna region the prospecting of copper and gold bearing lodes was continued. At the Duryea copper claim some development work was done, and plans are under way to send out a test shipment of ore.

A few men were engaged in beach placer mining at the south end of Kodiak Island, and a little work was done on auriferous veins on the island. Progress at the sulphur mine on Akun Island has already been noted (p. 20).

YUKON BASIN.

The value of the total mineral output of the Alaska Yukon region was $2,093,088 in 1921, as compared with $2,329,286 in 1920. This brings the total value of the mineral products of the Alaska Yukon during 36 years of mining to $135,276,843.

Mineral production of the Yukon basin, Alaska, in 1921.

	Placer mines.		Lode mines.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold..............fine ounces..	89,977	$1,860,000	1,941	$40,130	91,918	$1,900,130
Silver....................do....	11,952	11,952	88,379	88,379	100,331	100,331
Coal....................tons..					14,584	65,932
Lead, copper, and tin...........						26,695
		1,871,952		128,509		2,093,088

Mineral production of the Yukon basin, Alaska, 1886–1921.

	Placer mines.		Lode mines.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold..............fine ounces..	6,395,835	$132,212,000	62,799	$1,297,675	6,458,634	$133,509,675
Silver....................do....	1,095,399	668,342	237,791	239,717	1,333,190	908,059
Coal....................tons..					57,435	319,553
Lead, copper, tin, antimony, tungsten, and platinum......						539,556
		132,880,342		1,537,392		135,276,843

In the summer of 1921 about 335 placer mines, employing 1,130 men, were operated in the Alaska Yukon, and during the previous winter about 80 mines, employing 335 men. The only other productive mining in this region in 1921 was done at eight lode mines, employing about 40 men, and two coal mines, employing about 25 men. None of these mines were operated throughout the year.

Estimated value of gold produced from principal placers of Yukon basin in 1921.

Fairbanks	$570,000	Circle	$60,000
Iditarod	350,000	Fortymile	50,000
Tolovana	285,000	Hot Springs	35,000
Ruby	170,000	All others	122,000
Innoko and Tolstoi	110,000		
Koyukuk	78,000		1,860,000

FAIRBANKS DISTRICT.

Placer and lode mining was continued at Fairbanks on about the same scale as in 1920. The value of the total mineral output of the district during 19 years of mining is $73,263,401. Some antimony, tungsten, and lead have been produced in the Fairbanks district, but, as shown in the following table, the mineral output has come chiefly from the placer mines.

Placer gold and silver produced in the Fairbanks district, 1903–1921.

Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
1903	1,935.00	$40,000	348	$188
1904	29,025.00	600,000	5,225	2,821
1905	290,250.00	6,000,000	52,245	28,212
1906	435,375.00	9,000,000	78,367	42,318
1907	387,000.00	8,000,000	69,660	37,616
1908	445,050.00	9,200,000	79,909	43,151
1909	466,818.75	9,650,000	84,027	45,375
1910	295,087.50	6,100,000	53,116	28,683
1911	217,687.50	4,500,000	52,245	27,690
1912	200,756.25	4,150,000	48,182	29,632
1913	159,637.50	3,300,000	20,274	12,245
1914	120,937.50	2,500,000	29,024	16,050
1915	118,518.75	2,450,000	28,444	14,421
1916	87,075.00	1,800,000	11,058	7,276
1917	63,371.25	1,310,000	8,379	6,904
1918	38,700.00	800,000	5,708	5,708
1919	35,313.75	730,000	5,197	5,820
1920	28,057.50	580,000	3,870	4,218
1921	27,573.75	570 000	3,941	3,941
	3,448,170.00	71,280,000	639,219	362,270

The placer output of 1921 came from 48 placer mines, employing 340 men, in the summer and 14 mines, employing 107 men, during the previous winter. During 1920 work was done at 45 summer mines, employing 345 men, and 9 winter mines, employing 54 men. About 425,000 cubic yards of gravel was sluiced in 1921, having an average gold content of about $1.34 to the cubic yard. The placer mines comprised 28 drift mines, of which 13 were operated in the winter as well as in the summer and 1 only in winter, 2 dredges, 9 open-cut mines using steam scrapers, 4 hydraulic mines, and 6 small open-cut mines without any special mechanical equipment. The drift mines sluiced about 52,000 cubic yards of gravel carrying $4.75 worth of gold to the cubic yard. Some 372,000 cubic yards of gravel were sluiced from the open-cut mines and the dredges. The gold recovery from this gravel was about 85 cents to the cubic yard. The sluicing season averaged about 130 days.

The largest single drift-mining operation was on Dome Creek, and the two dredges on Fairbanks Creek were the largest open-cut plants. On Cleary Creek, formerly the largest producer of placer gold, only half a dozen mines, most of them small, were in operation in 1921. Plans for dredging on Cleary Creek, long under consideration, appear to have not yet taken definite form. Seventeen placer mines, large and small, were operated in the Goldstream Creek basin in 1921. The extensive dredging ground on Cleary and Goldstream creeks is well worth careful examination. The only new placer discovery near Fairbanks in 1921 was made on Kokomo Creek, a southerly tributary of the Chatanika. This find seems in itself to be of no very great importance, but it indicates that the auriferous belt extends 10 miles farther east than had previously been known. The lowering of mining costs near Fairbanks which will be brought about by the Alaska Railroad and the making available of the lignitic coal from the Nenana field will undoubtedly soon lead to a renewal of placer mining in the Fairbanks district.

Approximate distribution of placer gold produced in Fairbanks district, 1903–1921.

Cleary Creek and tributaries	$23,142,000
Goldstream Creek and tributaries	14,836,000
Ester and adjacent creeks	11,394,000
Dome and Fairbanks creeks	16,236,000
Vault Creek and tributaries	2,673,000
Little Eldorado Creek	2,302,000
All other creeks	697,000
	71,280,000

The railroad and the availability of the Nenana coal will also greatly stimulate lode mining at Fairbanks. No large auriferous lodes have been developed in the district, but the fact that a number of small ones have been profitably exploited in spite of the high cost of supplies and fuel is an indication of the latent possibilities of the gold-quartz veins of the district. The average recovery from the gold ores mined during the last 12 years is $35 a ton, and at many of the mines little or no profit was made. Under present conditions ores of lesser value can no doubt be profitably mined. Nearly all the lode deposits of the Fairbanks district are readily accessible to good wagon roads, and some are only a few miles from the railroad.

During 1921 underground work was continued at a number of small quartz mines in the Fairbanks district. At the Billy Sunday the principal developments were drifting on the 120-foot level, stoping, and the sinking of a new shaft to a depth of 80 feet. The ore was treated at a mill on a property near by. At the Crites & Feldman Hi Yu mine the principal work was the continuation of an adit. The ore was treated in a mill on the property. On the Wyoming the main adit, 300 feet long, was extended, and a 60-foot winze was installed. The ore was treated at the near-by Rhoads & Hall mill. Some ore was mined by open-cut on the Discovery mine, on Bedrock Creek, and on its tributaries. This ore also was treated at the Rhoads & Hall mill. The above-named four were the only producing quartz mines in the district, but development was continued at some other lode properties.

Lode gold and silver produced in the Fairbanks district, 1910–1921.

Year.	Crude ore (short tons).	Gold.		Silver.	
		Fine ounces.	Value.	Fine ounces.	Value.
1910	148	841.19	$17,389	106	$57
1911	875	3,103.02	64,145	582	308
1912	4,708	9,416.54	394,657	1,578	971
1913	12,237	16,904.98	349,457	4,124	2,491
1914	6,526	10,904.75	225,421	2,209	1,222
1915	5,845	10,534.91	217,776	1,796	910
1916	1,111	1,904.81	39,376	140	92
1917	1,200	2,311.38	47,781	2,217	1,826
1918	1,035	1,294.04	26,750	616	656
1919	1,384	2,026.57	41,893	378	424
1920	504	967.48	20,000	164	178
1921	944	1,858.27	38,414	279	279
	36,517	62,067.94	1,283,059	14,189	9,374

HOT SPRINGS DISTRICT.

As seen by the subjoined table, gold placer mining has for several years been on the decline in the Hot Springs district. There are still large reserves of placer gold in the district, but the high cost of operation has of late not encouraged work. Eighteen placer mines, employing 40 men, were operated in the district during the summer of 1921, and five, employing eight men, during the previous winter. That the mining was done only on a small scale is shown both by the number of men employed and by the fact that only six of these mines produced more than $1,000 worth of gold each. Most of the gold produced in the district has come from drift mining, but this form of operation has very much declined. The shallower placers exploited by open cuts, with some hydraulicking, are now increasing.

Placer gold and silver produced in the Hot Springs district, 1902–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1902–3	12,717.79	$262,900	1,818	$964	1914	36,281.25	$750,000	6,125	$3,387
1904	7,038.56	145,500	1,007	584	1915	29,508.75	610,000	4,982	2,526
1905	5,805.00	120,000	831	507	1916	38,700.00	800,000	6,534	4,299
1906	8,707.50	180,000	1,245	843	1917	21,768.75	450,000	3,675	3,028
1907	8,465.63	175,000	1,210	798	1918	7,256.25	150,000	1,225	1,225
1908	7,256.25	150,000	1,038	550	1919	4,837.50	100,000	817	915
1909	15,721.88	325,000	2,248	1,169	1920	2,418.75	50,000	567	618
1910	15,721.88	325,000	2,248	1,169	1921	1,693.12	35,000	438	438
1911	37,974.37	785,000	5,430	2,932					
1912	19,350.00	400,000	3,267	2,009		300,573.23	6,213,400	47,972	29,934
1913	19,350.00	400,000	3,267	1,973					

TOLOVANA DISTRICT.

In the Tolovana district 32 summer mines, employing about 120 men, and 15 winter mines, employing 70 men, were operated in 1921. The output of gold, as shown in the subjoined table, was larger than in 1920, but this statement is somewhat misleading, for the gold was in part derived from the sluicing of gravels resulting from deep mining during the previous two years, when there had not been water enough to clean up the winter dumps. During the later half of the summer of 1921 there was a considerable rainfall, and as a consequence a number of hydraulic plants were operated on the small creeks of the district. The reports from six of the larger of these plants show gold recoveries exceeding $1 to the cubic yard. The drift mines, principally those on Livengood Creek, are by far the chief source of the Tolovana gold; their gold output in 1921, including that derived from the sluicing of gravels mined in previous years, had a value of about $235,000. The returns from seven of these drift mines were complete enough to determine that on the average they recovered about $6.50 worth of gold to the cubic yard of gravel sluiced.

Late in the summer of 1921 a discovery of placer gold was made on Wilbur Creek, a tributary to Tolovana River from the south, about 7 miles from the mouth of Livengood Creek. As yet this placer has proved of no great size, but it may be important by indicating a second zone of mineralization south of the Tolovana similar to the one north of the river from which the Livengood and associated placers derive their gold.

Placer gold and silver produced in the Tolovana district, 1915–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1915	3,870.00	$80,000	321	$163	1920	9,675.00	$200,000	819	$893
1916	33,862.50	700,000	2,813	1,851	1921	13,786.88	285,000	1,189	1,189
1917	55,631.25	1,150,000	8,430	6,946					
1918	42,328.12	875,000	4,060	4,060		184,550.63	3,815,000	19,773	17,556
1919	25,396.88	525,000	2,141	2,454					

RAMPART DISTRICT.

During 1921 mining was continued in a small way in the Rampart district. A total of nine summer placer mines, employing 20 men, and one winter mine, employing three men, were worked. The largest production came from Hunter and Little Minook creeks. According to the return made, the average gold recovery was about \$2.15 to the cubic yard. It is reported that a dredge is to be installed on Minook Creek.

Placer gold and silver produced in the Rampart district, 1896–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1896–1903	29,799.00	\$616,000	4,440	\$2,664	1914	1,451.25	\$30,000	257	\$142
1904	4,353.75	90,000	649	376	1915	1,693.13	35,000	300	152
1905	3,870.00	80,000	576	351	1916	1,935.00	40,000	343	226
1906	5,805.00	120,000	865	588	1917	1,596.37	33,000	280	231
1907	6,046.87	125,000	901	595	1918	1,161.00	24,000	206	206
1908	3,628.12	75,000	540	286	1919	1,451.25	30,000	90	101
1909	4,837.50	100,000	721	375	1920	967.50	20,000	69	75
1910	2,080.12	43,000	310	167	1921	967.50	20,000	68	68
1911	1,548.00	32,000	231	125					
1912	1,548.00	32,000	274	169		76,287.36	1,577,000	11,394	7,062
1913	1,548.00	32,000	274	165					

CIRCLE DISTRICT.

In the Circle district 21 summer mines, employing 41 men, and 7 winter mines, employing 12 men, were operated in 1921. The dredge on Mastodon Creek was the largest single plant in operation. It ran for 80 days. Most of the other operations were very small, except for a hydraulic plant on Eagle Creek. The average gold recovery from the open-cut mines of the district was about 45 cents to the cubic yard.

Placer gold and silver produced in the Circle district, 1894–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1894	483.75	\$10,000	123	\$77	1909	10,884.37	\$225,000	2,830	\$1,472
1895	7,256.25	150,000	1,886	1,226	1910	10,884.37	225,000	2,830	1,528
1896	33,862.50	700,000	8,794	6,080	1911	16,931.25	350,000	4,402	2,333
1897	24,187.50	500,000	6,289	3,773	1912	15,721.87	325,000	2,439	1,500
1898	19,350.00	400,000	5,031	2,968	1913	8,465.63	175,000	1,314	794
1899	12,093.75	250,000	3,144	1,886	1914	10,884.37	225,000	1,689	934
1900	12,093.75	250,000	3,144	1,886	1915	11,126.25	230,000	1,727	875
1901	9,675.00	200,000	2,512	1,507	1916	14,512.50	300,000	2,252	1,482
1902	9,675.00	200,000	2,512	1,331	1917	9,675.00	200,000	1,561	1,285
1903	9,675.00	200,000	3,144	1,698	1918	8,465.63	175,000	1,798	1,798
1904	9,675.00	200,000	3,144	1,823	1919	6,530.63	135,000	1,260	1,411
1905	9,675.00	200.000	3,144	1,918	1920	2,660.62	55,000	464	506
1906	14,512.50	300,000	3,773	2,565	1921	2,902.50	60,000	571	571
1907	9,675.00	200,000	3,144	2,075					
1908	8,465.63	175,000	2,212	1,166		320,000.62	6,615,000	77,133	48,468

RICHARDSON DISTRICT.

No extensive placer ground has yet been opened in the Richardson district, and most of the gold produced is obtained incidentally in prospecting. In 1921 reports of production were received from only four mines in this district, on Caribou, Democrat, and Tenderfoot creeks and Chena River, but there were probably other small producers. B. E. Shuff has done some open-cut work on the Democrat lode, on Democrat Creek, and reports it to be of high tenor in gold.

Placer gold and silver produced in the Richardson district, 1905–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1905	(a)	(a)	(a)	(a)	1915	4,595.62	$95,000	939	$476
1906	4,837.50	$100,000	989	$673	1916	3,870.00	80,000	790	520
1907	18,140.62	375,000	3,707	2,447	1917	1,289.37	25,000	245	202
1908	18,140.62	375,000	3,707	1,965	1918	290.25	6,000	59	59
1909	7,256.25	150,000	1,483	771	1919	483.75	10,000	99	111
1910	4,837.50	100,000	989	534	1920	338.62	7,000	69	75
1911	4,837.50	100,000	989	524	1921	145.13	3,000	26	26
1912	4,837.50	100,000	989	608					
1913	4,837.50	100,000	989	597		83,875.23	1,726,000	17,058	10,135
1914	4,837.50	100,000	989	547					

[a] Prospects.

EAGLE DISTRICT.

In the Eagle district 12 open-cut mines, employing 26 men, were operated in 1921. The largest operations were those of hydraulic plants on Alder and Crooked creeks.

Placer gold and silver produced in the Eagle and Seventymile districts, 1908–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1908	483.75	$10,000	76	$40	1916	822.37	$17,000	130	$86
1909	1,209.37	25,000	191	99	1917	628.88	13,000	96	75
1910	483.75	10,000	76	41	1918	1,209.37	25,000	191	191
1911	580.50	12,000	92	49	1919	969.50	20,000	152	170
1912	967.50	20,000	164	100	1920	725.62	15,000	99	108
1913	2,418.75	50,000	382	231	1921	774.00	16,000	93	93
1914	2,418.75	50,000	382	211					
1915	1,935.00	40,000	305	155		15,627.11	323,000	2,429	1,649

FORTYMILE DISTRICT.

In the Fortymile district 52 summer mines, large and small, employing 100 men, and 12 winter mines, employing 15 men, were worked during 1921. This large number of mines is misleading, for most of them were very small. Indeed, there were only 11 mines whose individual gold output exceeded $1,000. These 11 employed 40 men and produced $30,000. The average value of the gold content of the gravel sluiced by these mines was about $1.10. They were operated from 130 to 180 days during the summer. The most successful mining was done on Dome Creek, where a large hydraulic plant was operated. This plant is owned by the Dome Creek Gold Corporation, which reports that it is planning for still larger operations. This is the first attempt to mine bench placers on a large scale. As deposits of this type are common in the Fortymile district, the success of the Dome Creek plant will undoubtedly lead to further development of the bench gravels. It is worthy of note that this and several other smaller hydraulic plants were operated successfully in 1921, in spite of the fact that the rainfall appears to have been below normal.

Except for the plants noted above, the rest of the mining consisted chiefly of grubstake work. Indeed, about 20 of the "mines" represent nothing more than individuals working on the bars of Fortymile River, most of them for not over a month of the summer.

Placer gold and silver produced in the Fortymile district, 1886–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1886–1903	193,500.00	$4,000,000	30,553	$22,915	1914	2,418.75	$50,000	382	$211
1904	14,851.12	307,000	2,345	1,360	1915	2,418.75	50,000	382	194
1905	12,384.00	256,000	1,955	1,193	1916	2,418.75	50,000	382	251
1906	9,868.50	204,000	1,558	1,059	1917	3,870.00	80,000	624	513
1907	6,772.50	140,000	1,069	706	1918	3,628.12	75,000	573	573
1908	6,772.50	140,000	1,069	567	1919	1,983.37	41,000	313	350
1909	10,884.37	225,000	1,719	894	1920	1,935.00	40,000	348	380
1910	9,675.00	200,000	1,528	825	1921	2,418.75	50,000	448	448
1911	9,675.00	200,000	1,528	810					
1912	10,303.87	213,000	1,627	1,000		310,615.85	6,421,000	49,167	34,710
1913	4,837.50	100,000	764	461					

CHISANA DISTRICT.

In the Chisana district six mines, employing 16 men, were operated during the summer of 1921. The average gold recovery was about $1.45 to the cubic yard. The mining consists chiefly in removing the overburden by booming—that is, by the use of automatic dams. Later the gold-bearing gravels are shoveled into sluice boxes. Mining starts with the spring break-up in May and is generally uninterrupted until July, after which there are likely to be periodic shortages of water

Placer gold and silver produced in the Chisana district, 1913–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1913	1,935.00	$40,000	465	$280	1919	1,306.12	$27,000	314	$352
1914	12,093.75	250,000	2,910	1,609	1920	967.50	20,000	137	150
1915	7,740.00	160,000	1,862	944	1921	1,112.62	23,000	164	164
1916	1,935.00	40,000	465	306					
1917	1,935.00	40,000	420	346		29,750.62	615,000	6,897	4,311
1918	725.63	15,000	160	160					

BONNIFIELD DISTRICT.

The Bonnifield placer district is in general coextensive with the Nenana coal field. No rich placers have been found in this district, but placer mining in a small way has been going on for the last 19 years. Some auriferous lodes have also been found in the district. The coal-mining operations in the region have been described on page 17. There are in the district some very extensive sheets of gravel that carry gold prospects, but they have not been tested sufficiently to determine whether they form commercial gold placers. In general the physical conditions favor hydraulic mining, and now that the region is accessible by rail a careful examination of its low-grade placers is justified. In 1921 eight open-cut mines, employing 16 men, were operated in the Bonnifield district. The largest operations were on Grubstake, Moose, Eva, and Daniels creeks. The mining season is reported to be from 115 to 180 days in length, and the gravels sluiced carried less than $1 to the cubic yard.

Placer gold and silver produced in the Bonnifield district, 1903–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1903–1906	1,451.25	$30,000	227	$136	1915	967.50	$20,000	152	$77
1907	241.87	5,000	38	25	1916	483.75	10,000	76	50
1908	241.87	5,000	38	20	1917	580.50	12,000	98	81
1909	2,418.75	50,000	379	197	1918	580.50	12,000	91	91
1910	483.75	10,000	76	41	1919	483.75	10,000	75	84
1911	967.50	20,000	152	81	1920	241.87	5,000	38	41
1912	967.50	20,000	152	93	1921	774.00	16,000	114	114
1913	967.50	20,000	152	92					
1914	1,451.25	30,000	227	126		13,303.11	275,000	2,085	1,349

KANTISHNA DISTRICT.

The Kantishna district,[12] just north of Mount McKinley, has long been the scene of a little placer mining, as well as of small developments of gold and silver-bearing lodes. Two years ago a galena

[12] Capps, S. R., The Kantishna district, Alaska: U. S. Geol. Survey Bull. 687, 1919. Brooks, A. H., The Alaskan mining industry in 1920: U. S. Geol. Survey Bull. 722, pp. 52–53, 1921.

deposit was opened up, and since then about 1,100 tons of ore has been shipped. The district is about 50 to 70 miles west of the Alaska Railroad, but it has no road connection with that line and the ore had to be transported by horse sleds to Kantishna River and thence by small steamers to the Tanana. This method of transportation was so expensive that only the richest ore would stand shipment. Therefore the galena ore was hand picked, the grade of shipments being thus brought to an average of about 140 ounces of silver and $3.25 in gold to the ton, in addition to the lead and some copper.

The lodes from which this ore came and others at near-by localities are at or near Eureka Creek. The deposits lie in well-defined fissures traversing schistose rocks and are associated with granitic intrusive rocks. Some of the ore bodies are 8 to 15 feet wide, but the rich galena is in shoots from 6 inches to 2½ feet in width. Gold-bearing quartz veins of similar type are also found in this part of the district, as well as some deposits of antimony (stibnite). The few openings made indicate that the lodes are fairly persistent along the strike.

Work was continued at Quigley's Red Top claims in 1921. The development consists of a drift which follows the ore for over 200 feet and at its face is 60 feet below the outcrop. The entire lode is from 3 to 10 feet wide, and the valuable ore occurs in shoots from 6 inches to 3 feet wide. These shoots are somewhat irregularly distributed along the lode, and surface pits indicate that the lode may be traced for 1,000 feet or more. The ore shoots contain much silver and considerable gold. The ore is esentially an argentiferous galena but carries some copper and zinc.

The Alice mine is the only other property in the district where any considerable underground work was done. Unfortunately, when it was visited in August, 1921, this mine was entirely inaccessible on account of caving. The ore body has been described by Stewart.[13] Assessment work is being done on many other gold and galena deposits in the district.

In 1921 sulphide-bearing lodes were discovered in the foothills of the Alaska Range, 20 miles southeast of Eureka Creek, in what is sometimes called the Copper Mountain district. These deposits were found in July by O. M. Grant and F. B. Jiles, both experienced prospectors, who staked 22 claims. They lie some 14 miles from timber, but lignite beds are close at hand. They are readily accessible to pack horses. The construction of about 50 miles of wagon road would connect the locality with the Alaska Railroad at Riley Creek. Granodiorite is the prevailing country rock of the region and is found both in large areas and as dikes. Banded and massive quartzites with some limestones and slate, cut by granodiorite dikes,

[13] Stewart, B. D., Territorial Mine Inspector Ann. Rept. for 1920, pp. 12–14, Juneau, 1921.

constitute the formations in which the ores have been found. The sedimentary beds are much deformed and trend a little north of west.

The ore bodies are distributed through a zone that trends a little north of east and thus apparently cuts across the bedding of the sediments. This zone has been traced about 2 miles and is reported to be longer. As determined by present discoveries, its width is from one-fourth to 1 mile. This zone is characterized by an abundance of sulphide minerals, concentrated in more or less well-defined ore bodies. Some of these bodies have definite walls; in others the ore grades into the country rock. They occur chiefly in the quartzites, but some are in the granodiorite and others at the contact between the two. As no excavation has been done it is difficult to give exact statements as to width. At some places there is evidence of sulphide mineralization over a width of about 100 feet, but in these places the rich sulphides appear to be limited to certain shoots. Most of the lodes are much smaller and consist of shoots in zones 10 to 25 feet wide. The ore consists chiefly of galena, chalcopyrite, zinc blende, pyrite, and bornite. Among these minerals galena appears to predominate. A granular intergrowth of galena with chalcopyrite appears to form the typical ore, but larger masses of pure galena are also found. The gangue consists of quartz and of the country rock, chiefly quartzite. In the absence of sampling or even of cuts exposing the ore, a definite statement of metallic content is not justified. The grab samples taken by owners of claims have yielded from 0.20 to 270 ounces of silver and from a trace to $8 in gold to the ton. Three samples carried from 1 to 8.8 per cent of copper.

No work had been done on the Grant & Jiles claims when they were examined in August, 1921, nor on the other prospects reported in the same region. Their value can therefore not be predicted, but the surface exposures fully justify careful prospecting.

Fourteen small gold placer mines, employing about 24 men, were operated in the Kantishna district in 1921. The largest operations were on Little Moose Creek. This mining was all done by pick and shovel, and the recovery of gold was about $1 to the cubic yard.

The most important development of the year consisted of the plans of two companies to operate hydraulic plants on a large scale. The Kantishna Hydraulic Mining Co. has built a ditch and flume from Wonder Lake and will mine a group of claims on Moose Creek at the mouth of Eureka Creek. The Mount McKinley Gold Placer Co. (Inc.) is developing a project to hydraulic placer ground on Caribou and Glacier creeks. Caribou Creek and tributaries are to be the immediate source of water for this project, but it is reported that water is also to be taken from Wonder Lake.

Placer gold and silver produced in the Kantishna district, 1903–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1903–1906.	8,465.62	$175,000	1,325	$795	1915......	967.50	$20,000	152	$77
1907......	725.62	15,000	114	75	1916......	1,451.25	30,000	227	149
1908......	725.62	15,000	114	60	1917......	725.63	15,000	120	99
1909......	241.87	5,000	38	20	1918......	1,451.25	30,000	227	227
1910......	483.75	10,000	76	41	1919......	725.63	15,000	114	128
1911......	1,451.25	30,000	227	120	1920......	1,209.37	25,000	320	349
1912......	1,451.25	30,000	227	140	1921......	580.50	12,000	156	156
1913......	1,451.25	30,000	227	137					
1914......	967.50	20,000	152	84		23,074.86	477,000	3,816	2,657

RUBY DISTRICT.

The Ruby district has maintained its annual gold output for the last three years. Most of its gold has come from deep ground of rather high tenor. In 1921 the gravel sluiced averaged $4.50 in gold to the cubic yard. There were 21 mines operated in summer, employing 57 men, and 5 in the winter, employing 56 men. According to reports received all but four of these mines were operated in deep ground. The largest production came from Long, Flat, Poorman, and Solomon creeks.

Placer gold and silver produced in the Ruby district, 1907–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1907–8....	48.38	$1,000	7	$4	1918......	19,350.00	$400,000	3,000	$3,000
1912......	8,465.63	175,000	1,157	712	1919......	7,981.88	165,000	1,255	1,406
1913......	37,974.37	785,000	5,188	3,134	1920......	8,223.75	170,000	1,113	1,213
1914......	48,375.00	1,000,000	6,609	3,655	1921......	8,223.75	170,000	1,158	1,158
1915......	33,862.50	700,000	4,626	2,345					
1916......	41,118.75	850,000	5,618	3,697		256,435.89	5,301,000	35,804	25,370
1917......	42,811.88	885,000	6,073	5,046					

Galena veins cutting the schists of the Kaiyuh Mountains were discovered in September, 1918, at a locality near the headwaters of Bishop Creek, about 20 miles south of Yukon River at Louden and about 27 miles south of the new settlement of Galena, which is on the north bank of the Yukon opposite the lower end of Louden Slough, or about 15 miles below Louden. This locality was visited in July, 1921, by G. C. Martin, who has submitted the following description:

The galena prospects lie near the north end of the Kaiyuh Range, on the headwaters of Bishop Creek, which flows north-northeast for about 10 miles from the prospects, then takes an unknown meandering course across the flats, and enters the Yukon near Bishop Mountain. This region is also drained by Kalikaket Creek, which enters the upper end of Louden Slough. A summer trail leaving Louden

Slough 2 or 3 miles below its upper end and following the western slope of the ridge between Bishop and Kalikaket creeks leads to the prospects. The district is of moderate relief, most of the hills being 1,000 to 1,500 feet high and the higher peaks on the headwaters of Bishop and Kalikaket creeks reaching 2,000 or 2,500 feet. There is a thin scattered growth of spruce and birch throughout the region.

Near the prospects the country rocks are quartzose, micaceous, and chloritic schists and limestones. The exposures at the prospects are schists, the schistosity or bedding of which strikes northeast. A belt of limestone crosses Bishop Creek about half a mile above the prospects and is well exposed on the west side of the valley. It is a fine-grained limestone, not much recrystallized, resembling the limestone at Ruby. Its relations to the schists and its age are not known. The rocks of the Kaiyuh Mountains were described by Maddren [14] as quartzite and quartz-mica schists, with associated crystalline limestones, garnet schists, and fine-textured slaty schists or phyllites succeeded by ancient diabasic effusive rocks.

Ore is exposed only in the excavation, where it was discovered by stripping at a locality indicated by float. The workings, which had mostly caved in at the time of the visit, are said to show an irregular ore body up to 2 or 3 feet thick, broken up in places by bands and masses of rock that is barren or contains only scattered ore. The ore apparently contains no valuable minerals except silver-bearing galena. A blue stain on some of the ore is probably a mere tarnish not due to any foreign substances. Tests for copper and molybdenum gave negative results.

A small mine on the Perseverance claim was operated in the autumn and winter of 1920–21 under lease. At the same time the adjacent Valley claim was worked in a small way by the owners. The ore was sledded to the Yukon. In the summer of 1921 the Perseverance claim was being prospected by the owners, but no ore was being mined.

INNOKO AND TOLSTOI DISTRICTS.

In the Innoko district 23 summer mines, employing 85 men, and 5 winter mines, employing 10 men, were operated in 1921. The completion and operation for 50 days of a dredge on Yankee Creek was the most significant event of the year. Two other dredges were also on the way to the district—one to be installed on Yankee Creek and the other on Gaines Creek. Most of the mining in the district is done by open cuts, and four steam scrapers are reported to have been operated in 1921. An average of about $1.05 worth of gold to the cubic yard was recovered from the gravel sluiced. Some rich deep placer ground was discovered and developed in the summer on Victor Creek, near the wagon road about four miles south of Ophir. The largest gold production came from Little, Ophir, Yankee, and Gaines creeks.

The value of the gold output from the Tolstoi region was about $6,000. This was taken from five mines employing eight men.

[14] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, pp. 43–48, pl. 2, 1910.

Placer gold and silver produced in the Innoko and Tolstoi districts, 1907–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1907......	628.87	$13,000	67	$44	1916......	10,642.50	$220,000	1,130	$744
1908......	3,483.00	72,000	370	196	1917......	8,465.63	175,000	1,113	917
1909......	16,447.50	340,000	1,746	908	1918......	5,805.00	120,000	608	608
1910......	15,721.87	325,000	1,669	901	1919......	6,772.50	140,000	717	803
1911......	12,093.75	250,000	1,284	681	1920......	4,982.62	103,000	529	577
1912......	12,093.75	250,000	1,284	681	1921......	5,321.25	110,000	569	569
1913......	13,545.00	280,000	1,438	869					
1914......	9,675.00	200,000	1,027	568		134,869.49	2,788,000	14,527	9,561
1915......	9,191.25	190,000	976	495					

IDITAROD DISTRICT.

There were 22 productive placer mines, employing 120 men, in the Iditarod district during the summer of 1921. The two dredges on Otter Creek worked for 140 days and were the largest plants operating in the district. Most of the gold output came from Otter, Flat, Chicken, and Willow creeks. Five steam scrapers and six hydraulic plants are reported to have been operated. The average gold recovery for the entire district was about 70 cents to the cubic yard. The operation of a quicksilver mine in the headwater region of Iditarod River is described on page 13.

Placer gold and silver produced in the Iditarod district, 1910–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1910......	24,187.50	$500,000	4,254	$2,297	1917......	72,562.50	$1,500,000	11,050	$9,105
1911......	120,937.50	2,500,000	21,270	11,273	1918......	59,985.00	1,240,000	9,000	9,000
1912......	169,312.50	3,500,000	29,778	18,313	1919......	35,071.88	725,000	5,300	5,937
1913......	89,977.50	1,860,000	9,551	5,769	1920......	24,429.37	505,000	3,628	3,954
1914......	99,652.50	2,060,000	10,578	5,849	1921......	16,931.25	350,000	2,482	2,482
1915......	99,168.75	2,050,000	10,526	5,337					
1916......	94,331.25	1,950,000	10,013	6,589		906,547.50	18,740,000	127,430	85,905

MARSHALL DISTRICT.

About nine mines, employing 35 men, were operated in the Marshall district of the lower Yukon during 1921. In the past most of the gold mined in this district has come from Willow Creek, where, however, the richest deposits have now been mined out. In 1921 there were only three productive mines in the older part of the district immediately tributary to Marshall (Fortuna Ledge post office). There was, however, considerable mining activity in the Stuyahok region, about 40 miles northeast of Marshall but only about 10 miles from the Yukon at Tuckers Landing. In the summer of 1921 there were about 50 prospectors in this region. Information about the occurrence of the gold is lacking.

Placer gold and silver produced in the Marshall district, 1914–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1914	725.62	$15,000	94	$52	1919	4,837.50	$100,000	624	$699
1915	1,209.37	25,000	156	79	1920	4,353.75	90,000	552	602
1916	13,061.25	270,000	1,686	1,109	1921	1,451.25	30,000	192	192
1917	20,559.37	425,000	3,300	2,719					
1918	7,256.25	150,000	940	940		53,454.36	1,105,000	7,544	6,392

INDIAN RIVER AND GOLD HILL DISTRICTS.

Nothing new was developed in the Indian River and Gold Hill districts in 1921. So far as known only four or five small mines were operated in this region during the summer.

Placer gold and silver produced in the Indian River and Gold Hill districts, 1911–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1911	483.75	$10,000	69	$37	1918	193.50	$4,000	29	$29
1912	1,185.19	24,500	170	105	1919	338.62	7,000	52	58
1913	1,548.00	32,000	221	133	1920	96.75	2,000	13	14
1914	1,209.37	25,000	173	96	1921	96.75	2,000	27	27
1915	725.63	15,000	104	53					
1916	483.75	10,000	69	45		6,603.19	136,500	954	619
1917	241.88	5,000	27	22					

CHANDALAR DISTRICT.

According to reports received three deep mines and one open-cut mine were operated in the Chandalar district in 1921 and employed 14 men in summer and 12 in winter. A number of other deep mines were under development but did not reach a productive stage. The richest placers thus far found are on Squaw Creek, where two of the operating mines were located. The two other mines were on Big Creek. Three men were engaged in mining on Bear Creek, a tributary of Hogatza River. There were probably some other small placer mines in the Chandalar district, from which no reports have been received. The region is so difficult of access as to discourage the systematic prospecting which the discoveries made fully justify. The gravel sluiced in 1921 carried an average of $5.20 to the cubic yard.

Placer gold and silver produced in the Chandalar district, 1906–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1906–1912	2,902.50	$60,000	416	$241	1918	628.88	$13,000	96	$96
1913	266.06	5,500	38	23	1919	483.75	10,000	79	88
1914	241.87	5,000	35	19	1920	870,75	18,000	125	136
1915	241.87	5,000	35	18	1921	1,451.25	30,000	197	197
1916	435.37	9,000	62	41					
1917	725.63	15,000	104	86		8,247.93	170,500	1,187	945

KOYUKUK DISTRICT.

In the Koyukuk district 29 summer placer mines, employing 60 men, and 8 winter mines, employing 20 men, were productively operated in 1921. An average of $1.85 in gold to the cubic yard was recovered. The returns from 14 drift mines show an average gold recovery of $6.90 to the cubic yard, and those from 18 open-cut mines, including 3 hydraulic, show an average of $1.20 to the cubic yard. The largest output came from Nolan Creek. In the past most of the Koyukuk gold has been won from deep placers; the present tendency is to develop the more extensive shallow placers.

There are no productive lode mines in the Koyukuk district, but some galena ore has been found in the Wild River basin, 20 miles west of Coldfoot. Some development work has been done on a lode on Michigan Creek, a tributary of Wild River. These ores are said to occur in a limestone bedrock.

Placer gold and silver produced in the Koyukuk district, 1900–1921.

Y ar.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1900–1909	106,454.02	$2,200,600	15,242	$8,993	1917	12,093.75	$250,000	1,700	$1,401
1910	7,740.00	160,000	1,108	598	1918	7,256.25	150,000	860	860
1911	6,772.50	140,000	970	514	1919	5,321.25	110,000	760	851
1912	9,675.00	200,000	1,385	852	1920	4,353.75	90,000	146	159
1913	19,350.00	400,000	2,770	1,673	1921	3,773.25	78,000	119	119
1914	12,577.50	260,000	1,800	995					
1915	13,303.12	275,000	1,902	964		223,666.64	4,623,600	30,909	19,392
1916	14,996.25	310,000	2,147	1,413					

KUSKOKWIM REGION.

The returns from the Kuskokwim region placer operators are still very incomplete, so that a full statement of mining in 1921 is not possible. About 30 mines were operated, and they produced about $520,000 worth of gold. The largest single operation was that of the dredge on Candle Creek near McGrath. Plans are under way for the installation of other dredges in the Kuskokwim basin. About 100 men were employed in productive mining in the Kuskokwim in the summer, but there was almost no winter placer mining. The placer mining in the Georgetown and Tuluksak-Aniak districts was of about equal extent, and a lesser amount was done around Goodnews Bay. The search for gold placers on Holitna River has been continued, with reported encouraging results.

Developments were continued at the Alaska Treadwell claims, near Nixon Fork, in the McKinley district. The company reports 2,297 linear feet of underground work during the year. A maximum depth of 290 feet has been reached in one of the shafts. The erection of a 10-stamp amalgamating and concentrating mill was completed at about the end of 1921. Some ore was taken from an open cut and a 12-foot shaft on the Gold Butte lode claims, near Akiak. There are reports of other gold-lode developments in the Kuskokwim region, but nothing very definite. The work on quicksilver deposits of the lower Kuskokwim is noted elsewhere (p. 13).

SEWARD PENINSULA.

SALIENT FEATURES.

The value of the total mineral production of Seward Peninsula in 1921 was $1,465,297, of which $1,455,085, as shown in the subjoined table, was in gold, and the rest in silver, platinum, and a little coal and lead. There was no tin mining in Seward Peninsula in 1921. The platinum came chiefly from the Koyuk district. A small output of lignitic coal came from the Fairhaven district. The Independence mine, in the Fairhaven district, was developed, and some galena ore was shipped. The owners of the property report that the underground work includes a 136-foot shaft and 250 feet of drifts on two levels. This was the only producing lode mine on the peninsula. A small lot of rich auriferous quartz, taken from a hydraulic pit near Nome, was shipped. The only other lode development consisted primarily of assessment work.

PLACER MINING.

A total of 126 placer mines, employing about 622 men, were operating on Seward Peninsula in the summer of 1921, and 14 mines, employing 64 men, the previous winter. In 1920 there were about 112 summer mines, employing 540 men, and 8 winter mines, employing 60 men. The average output for each summer mine was about $10,000 in 1921 and about $11,000 in 1920. For each man employed in the summer mines the value of gold recovered was about $2,340 in 1921 and $2,220 in 1920.

In 1921 there were 45 mines, employing 76 men, each of which produced $1,200 or less in gold. The production per man employed was only about $400, and the gravel that was sluiced had an average gold content of only $1.30 to the cubic yard. Even if due allowance is made for the fact that many of these small mines were operated only for a short time, it is nevertheless clear that they are operated at a loss. The only exception is where the productive mining is only incidental to the development of deposits that are later to be exploited on a larger scale.

Placer gold produced in Seward Peninsula in 1921, by districts.

District.	Value of gold.	Summer.		Winter.	
		Mines.	Miners.	Mines.	Miners.
Nome	$585,000	42	230	6	23
Solomon and Casadepaga	120,000	12	63		
Koyuk	152,000	17	71	5	30
Council	420,000	8	101		
Kougarok	45,000	20	51	1	3
Fairhaven	120,000	20	84	2	8
Port Clarence	8,000	7	22		
	1,450,000	126	622	14	64

Placer gold produced in Seward Peninsula in 1921, by methods of mining.

Method.	Mines.	Men.	Value of gold.
Dredging	16	182	$690,000
Hydraulic mining (includes all operations where any water is used to move gravel to sluice box)	20	114	115,000
Open-cut mining (other than by hydraulicking)	74	241	451,000
Drifting	20	102	194,000

The 16 dredges operated on Seward Peninsula in 1921 dug about 1,690,000 cubic yards, as compared with 17 gold dredges and about 930,000 cubic yards in 1920. The gold recovery to the cubic yard was 41 cents in 1921 and 51 cents in 1920. The dredges were operated from 10 to 120 days. Those that were fully prepared at the beginning of the operating season worked from 90 to 120 days. The hydraulic mines handled about 162,000 cubic yards and made an average gold recovery of about 71 cents. About 40,000 cubic yards was mined by drifting and hoisting, with a gold recovery of about $5 to the cubic yard. Most of the deep mining was done in the Koyuk district.

Gold and silver produced on Seward Peninsula, 1897–1921.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1897	725.63	$15,000	87	$52	1911	149,962.50	$3,100,000	17,996	$9,718
1898	3,628.12	75,000	435	256	1912	145,125.00	3,000,000	17,415	10,710
1899	135,450.00	2,800,000	16,254	9,752	1913	120,937.50	2,500,000	12,094	7,305
1900	229,781.25	4,750,000	27,574	17,097	1914	130,612.50	2,700,000	15,673	8,667
1901	199,822.61	4,130,700	24,579	14,747	1915	140,287.50	2,900,000	17,510	8,878
1902	220,677.07	4,561,800	26,481	14,035	1916	142,706.25	2,950,000	14,271	9,391
1903	215,994.38	4,465,000	24,171	13,052	1917	125,775.00	2,600,000	13,770	11,346
1904	201,462.52	4,164,600	24,175	14,021	1918	53,599.50	1,108,000	6,022	6,022
1905	232,200.00	4,800,000	27,864	16,997	1919	65,790.00	1,360,000	6,940	7,773
1906	352,812.50	7,500,000	43,537	29,605	1920	62,887.49	1,300,000	6,813	7,426
1907	338,625.00	7,000,000	25,497	16,828	1921	70,389.75	1,455,085	6,411	6,411
1908	247,680.00	5,120,000	20,577	10,905					
1909	207,077.50	4,260,000	20,871	10,853		3,963,322.07	82,115,185	437,334	272,818
1910	169,312.50	3,500,000	20,317	10,971					

KOBUK REGION.

Placer mining continued during 1921 in a small way in the Squirrel River and Shungnak districts of the Kobuk River basin. About a dozen placer mines were operated during the year, most of them for only a part of the season. About 12 men were employed at mining during the summer and 10 during the previous winter. The largest production came from Klery Creek, but the value of the total output was only about $7,000. The gravels mined carried from $1 to $5 a cubic yard in gold, but the average was only about $1.50.

ADMINISTRATIVE REPORT.

By Alfred H. Brooks.

During 1921 nine parties were engaged in surveys and investigations in Alaska. These parties included 9 geologists, 3 topographers, 1 topographic assistant, and 20 packers, cooks, and other auxiliaries. Six parties were engaged in geologic work, two in topographic survey, and one was a combined geologic and topographic party.

The funds available for field and office work for the season of 1921 included an appropriation of $75,000, an unexpended balance of $13,800 from the appropriation of the previous year, and an allotment of $12,000 from the appropriation of 1921 for the classification of the public lands. The subjoined tables show the allotments of these funds geographically by types of work and by salaries and field expenses. A balance of $5,430 will be used for the field work of 1922. In these tables the money devoted purely to office work has not been allocated to the several projects.

Allotments for salaries and field expenses, field season, 1921.

	1920–21	1921–22
Scientific salaries	$500	$30,490
Field expenses	22,670	21,340
Miscellaneous expenses, including clerical salaries, etc.	2,630	9,240
Office of Director		8,500
To be allotted to field work, 1922		5,430
	25,800	75,000

The allotments shown in the subjoined tables as made to different kinds of work and to different regions are only approximations. To determine the true figures would require an elaborate cost-keeping system too expensive to justify the results to be achieved. Many parties and individuals divide their time between two or more projects. The following two tables will show in a general way, however, on what projects the funds have been spent. The geologic surveys include work that is used in the classification of public lands.

Approximate distribution of allotments for investigations in Alaska, field season of 1921.

	1920-21	1921-22
Administration, Alaska branch		$5,700
General investigation, mineral resources		4,520
Southeastern Alaska	$1,900	7,700
Cook Inlet	9,000	11,170
Alaska Railroad		2,350
Alaska Peninsula	8,930	9,210
Yukon basin	3,340	7,300
Map compilation		4,660
Collecting mineral statistics		1,800
Miscellaneous expenses, including clerical salaries, etc	2,630	6,660
Office of Director		8,500
To be allotted to field work, 1922		5,430
	25,800	75,000

Approximate allotments to different kinds of surveys and investigations, field season of 1921.

	1920-21	1921-22
Administration, Alaska branch		$5,700
Special investigation of geology and mineral resources	$500	11,900
Reconnaissance geologic surveys	8,820	13,950
Detailed geologic surveys	4,200	7,200
Reconnaissance topographic surveys	4,850	4,100
Detailed topographic surveys	4,800	5,100
Map compilation		4,660
Collecting mineral statistics		1,800
Miscellaneous expenses, including clerical salaries, etc	2,630	6,660
Office of Director		8,500
To be allotted to field work, 1922		5,430
	25,800	75,000

The following table shows the progress of investigations in Alaska and the annual grants of funds since systematic surveys were begun, in 1898.[1] It should be noted that a varying amount is spent each year on special investigations that yield results which can not be expressed in terms of area. In 1917, when the United States entered the World War, nearly all the Alaska funds were allotted to the investigation of minerals such as platinum, sulphur, and antimony, which were then of special importance, and few areal surveys were made. Since 1918 the reduction of the annual appropriation and the increased cost of all field work has not permitted extensive geologic and topographic surveys. Little progress has therefore been made in extending the topographic and geologic mapping which is essential to obtain an adequate knowledge of mineral resources of the Territory.

[1] The Geological Survey made some investigations of the gold and coal deposits of the Pacific seaboard region in 1895 and of the Yukon region in 1896.

Progress of surveys in Alaska, 1898–1921.

Year.	Appropriation.	Areas covered by geologic surveys.			Areas covered by topographic surveys.[a]					Investigations of water resources.	
		Exploratory (scale 1:625,000 or 1:1,000,000).	Reconnaissance (scale 1:250,000).	Detailed (scale 1:62,500).	Exploratory (scale 1:625,000 or 1:1,000,000).	Reconnaissance (scale 1:250,000; 200-foot contours).	Detailed (scale 1:62,500; 25, 50, or 100 foot contours).	Line of levels.	Bench marks set.	Gaging stations maintained part of year.	Stream-volume measurements.
		Sq. m.	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Miles.*			
1898	$46,189	9,500	......	......	12,840	2,070	......	......	......	......	......
1899	25,000	6,000	......	......	8,690	......	......	......	......	......	......
1900	60,000	3,300	6,700	......	630	11,150	......	......	......	......	......
1901	60,000	6,200	5,800	......	10,200	5,450	......	......	......	......	......
1902	60,000	6,950	10,050	......	8,330	11,970	96	......	......	......	......
1903	60,000	5,000	8,000	96	......	15,000	......	......	......	......	......
1904	60,000	4,050	3,500	......	800	6,480	480	86	19	......	......
1905	80,000	4,000	4,100	536	......	4,880	787	202	28	......	......
1906	80,000	5,000	4,000	421	......	13,500	40	......	......	14	286
1907	80,000	2,600	1,400	442	......	6,120	501	95	16	48	457
1908	80,000	2,000	2,850	604	......	3,980	427	76	9	53	556
1909	90,000	6,100	5,500	450	6,190	5,170	444	......	......	81	703
1910	90,000	......	8,635	321	......	13,815	36	......	......	69	429
1911	100,000	8,000	10,550	496	......	14,460	246	......	......	68	309
1912	90,000	......	2,000	525	......	......	298	......	......	69	381
1913	100,000	3,500	2,950	180	3,400	2,535	287	......	......	......	......
1914	100,000	1,000	7,700	325	600	10,300	10	......	......	......	......
1915	100,000	......	10,700	200	......	10,400	12	3	2	9	......
1916	100,000	......	5,100	636	......	9,700	67	......	......	20	......
1917	100,000	......	1,750	275	......	1,050	......	......	......	19	......
1918	77,000	......	3,500	......	......	1,200	......	......	......	......	......
1919	75,000	......	2,700	......	......	2,300	......	......	......	19	......
1920	75,000	......	1,480	......	......	770	......	......	......	19	......
1921	[b]87,000	......	2,130	150	......	300	205	......	......	......	......
	1,875,189	73,200	111,095	5,657	51,680	152,600	3,936	462	74	......	......
Percentage of total area of Alaska	......	12.48	18.95	0.96	8.81	26.02	0.67	......	......	......	......

[a] The Coast and Geodetic Survey, International Boundary Commission, and General Land Office have also made topographic surveys in Alaska. The areas covered by these surveys are of course not included in these totals.

[b] Includes $12,000 for classification of public lands.

By order of the Director, dated April 1, 1922, the division of Alaskan mineral resources was changed to the Alaskan mineral resources branch, and its executive chief made the chief Alaskan geologist.

The writer was engaged in office work until August 3 and was absent in Alaska until October 10. He visited Anchorage, Kantishna, and Juneau and, in company with B. W. Dyer, Federal mine inspector, the Willow Creek district. A statement of results in the Kantishna and Willow Creek districts and on the petroleum seepage at Anchorage is published elsewhere in this volume. In addition to the time devoted to field work, including that of June, 1922, the writer during the fiscal year divided his time about as follows: Geologic studies, 10 days; progress report, 20; annual press bulletin, 4; field plans, 7; the preparation and delivery of lectures, 14; proof reading, 7; statistics, 13; critical reading and revision of manuscripts of others, 7; attending scientific meetings, 8; and the preparation of an article on "The scientist in the Federal service," 32 days. The rest of his office time was devoted to administrative and routine matters.

R. H. Sargent was on furlough from March 18, 1920, to March 1, 1921. In September, 1921, he made a trip to southeastern Alaska to investigate areas and methods of topographic surveys. While in the office he was occupied chiefly in the administration of Alaska topographic surveys and map compilation.

A. F. Buddington spent from June 10 to September 16 in continuing the geologic mapping and investigation of mineral resources of the Wrangell district. A summary of his results is published elsewhere in this volume.

H. M. Eakin, geologist, was employed under contract to complete the report on the geology and mineral resources of Juneau and vicinity. He devoted one month to field work and about four months to office work.

A detailed geologic and topographic survey of the Iniskin oil field, on Cook Inlet was made, under the direction of F. H. Moffit. A. A. Baker assisted in the geologic work, and the topographic surveys were made by C. P. McKinley, assisted by Gerald Fitz Gerald. The topographic mapping was done from June 4 to August 30. On account of the marine strike, which delayed transportation, the main party did not begin field work until July 6. A preliminary edition of the topographic map of the Iniskin-Chinitna Peninsula has been issued. Mr. Moffit's results have been summarized in a press bulletin, issued in May, and are given at greater length elsewhere in this volume.

Richard K. Lynt was detailed to make topographic reconnaissance surveys in the Cold Bay district. On account of the very stormy weather of the summer, it was impossible to map more than 10 per cent of the most important part of the district. The field season extended from June 8 to September 4.

S. R. Capps, assisted by W. R. Smith, was employed in geologic reconnaissance surveys in the same district. The geologic surveys were greatly interfered with by the bad weather but covered about a third of the most important part of the district. Both parties were also greatly hampered by the seamen's strike, for as a consequence the steamer landing their horses did not arrive until July 2. A preliminary summary of Mr. Capps's results was published in May, and a more complete statement is contained in this volume. Mr. Capps devoted about one month to the continuation of his report on the geology and mineral resources of the region tributary to the Alaska Railroad. On April 16, 1922, he was furloughed for one year to engage in commercial oil work for an American company in a foreign country.

The geologic mapping and study of the mineral resources of the Fairbanks quadrangle was continued by J. B. Mertie, jr., who devoted from June 30 to September 10 to the field work. Mr. Mertie's office work was chiefly given to the study of geologic notes and specimens from the Yukon-Tanana region, but he also completed the long-delayed report on the Ruby-Kuskokwim region.

George C. Martin was engaged from July 5 to August 31 in studying the geology and mineral resources of the lower Yukon and Koyukuk region. Most of his office time has been devoted to geologic studies of the Alaska Mesozoic formations.

C. Arthur Hollick was employed from February 16 to June 30 in continuing his studies of the Alaska Tertiary fossil plants. His results will have an important bearing on the correlation of the Alaska coal-bearing formations.

James McCormick was employed for five months in the revision of the geographic dictionary of Alaska. John H. Renshawe devoted about a month to the completion of the relief map of Alaska, now nearly ready for publication. John B. Torbert has been engaged in Alaska cartographic work throughout the year. About half of R. K. Lynt's office time has also been devoted to map compilation.

The lack of funds has prevented the continuation of stream gaging in southeastern Alaska. This work is essential to the determination of water powers available for mining, pulp-wood, and other industries. In cooperation with the Forest Service, stream gaging was carried on from 1915 to 1920, and the results obtained each year have been published annually. A summary of these annual reports is now being prepared.

Miss Lucy M. Graves, chief clerk, has continued to carry much of the burden of the administration of the Alaska branch and has acted as chief during the absence of the chief Alaskan geologist and of the senior geologist, G. C. Martin. The details of collecting the statistics of the mineral production of Alaska have been in the hands of T. R. Burch.

During 1921 the Survey issued two complete bulletins relating to Alaska—Bulletin 714, "Mineral resources of Alaska, 1919," by Alfred H. Brooks and others, and Bulletin 719, "Preliminary report on petroleum in Alaska," by George C. Martin—also the separate chapters from Bulletin 722, "Mineral resources of Alaska, 1920," by Alfred H. Brooks and others. A report, including topographic maps, "The geology of the York tin deposits, Alaska," by Edward Steidtmann and S. H. Cathcart, is in press as Bulletin 733, and another, "The Kotsina-Kuskulana district, Alaska," by F. H. Moffit and J. B. Mertie, jr., is nearly ready for the printer. The manuscripts of two other reports—"The Ruby-Kuskokwim region, Alaska," by J. B. Mertie, jr., and G. L. Harrington, and "The Juneau district, Alaska," by H. M. Eakin—have been completed. The annual review of the mining industry of Alaska was issued as usual on December 31, 1921. In May, 1922, there was issued a press bulletin entitled "Petroleum in Alaska," which summarized the results of surveys made in 1921.

During the fiscal year 1922 the following Alaska maps were issued:

Kotsina-Kuskulana district, scale 1:62,500 (1 mile to the inch), by D. C. Witherspoon.

The Upper Tanana Valley region; scale 1:250,000 (4 miles to the inch), by D. C. Witherspoon and J. W. Bagley (preliminary edition).

Iniskin-Chinitna Peninsula; scale 1:62,500 (1 mile to the inch), by C. P. McKinley and Gerald Fitz Gerald (preliminary edition).

The compilation of the topographic map (scale 1:250,000) of the region tributary to the Alaska Railroad is approaching completion. This will be published in three sheets, of which the southern sheet (Seward-Matanuska) was sent to the engraver in June, 1922. A new map of Alaska (scale 1:2,500,000) has been compiled and is now in press. The drawing for a relief map on the same scale is almost completed.

MINERAL DEPOSITS OF THE WRANGELL DISTRICT.

By A. F. Buddington.

INTRODUCTION.

This report is based on a reconnaissance by the writer in the southern part of the Wrangell mining district during three months in 1921. F. E. and C. W. Wright[1] made a geologic reconnaissance of the Ketchikan and Wrangell districts in 1905, and the accompanying map (Pl. I) is in part based on their work. Further details of mining developments and economic resources of this district may be found in the annual summary reports on the mineral resources of Alaska for 1904 and later years.

GENERAL GEOLOGY.

Intrusive rocks.—The Coast Range batholith, which consists essentially of quartz diorite, is the predominant rock of the mainland except near the coast, where belts of schist are included. The batholith that forms the core of Etolin Island is made up of diorite cut by a mass of granite. Bosses and stocks of quartz diorite, diorite, and granite are found on the islands, and quartz diorite and granite dikes are common in their vicinity. Masses of gabbro and hornblendite, a dark rock consisting essentially of hornblende, occur on the west side of Zimovia Straits, on some of the adjacent islands, and in Circle Bay on Woronkofski Island (Pl. I).

Metamorphic complex.—The metamorphic complex comprises, in order of increasing metamorphism, phyllite and phyllitic quartzite and graywacke with thin dark hornblendic layers; kyanitic, staurolitic, and garnetiferous quartz-mica schists interbedded with micaceous quartz schist; local beds of marble; a little garnet-sillimanite schist; hornblende-plagioclase schist; and, where most intensively metamorphosed, aplitic injection gneiss. On the mainland the quartz diorite near the borders of the schist belts may show relics of disintegrated and shredded blocks of schist. The rocks of this complex are of sedimentary origin and may include beds of both Paleozoic

[1] The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, 1908.

and Mesozoic age which have been recrystallized under conditions of contact-regional metamorphism attendant upon the intrusion of the Coast Range batholith.

Undifferentiated rocks.—The group of undifferentiated rocks consists for the most part of relatively thick beds of gray to greenish-gray rocks which are distinctly grained but in which the boundaries of the individual grains are indistinguishable with the naked eye. Intercalated and associated with them are beds or thin layers of black slate. The predominant rock is a graywacke or quartzitic sandstone having a cleavage which ranges from that due essentially to original bedding to that due to intense shearing, mashing, and recrystallization. In the latter variety the rock splits readily into thin leaves, thus resembling phyllite, and weathers a characteristic light-gray color. The graywacke consists largely of quartz or of altered fragments of plagioclase feldspar in an argillaceous, chloritic, or sericitic groundmass. Quartz may be absent or it may constitute relatively pure quartzite or phyllitic quartzite. Fragments of slate and other rocks are common in the graywacke, and in places the fissile varieties weather with a pseudoporphyritic or tuffaceous aspect. Locally calcareous beds are intercalated. Ottrelitic slate, hornblendic quartzite, and phyllite are found in the areas of greater metamorphism, as in McHenry Inlet, on Etolin Island.

The age of these beds is doubtful, and it is probable that they include formations of two or more ages. At Wrangell, along Eastern Passage, and on the west side of Frederick Sound the slate layers show traces of organic remains which Edwin Kirk states resemble those associated with graptolites found by him at Wrangell. He assigns a Silurian or older age to this series. On the other hand, the belt on Etolin, Zarembo, and Kupreanof islands appears to underlie the greenstone breccia formation provisionally assigned to the Jurassic. This would indicate that these beds were possibly the equivalent of the Mesozoic rocks having similar relations and character that occur in the Ketchikan and Juneau districts. The data at hand do not permit a positive decision.

Devonian rocks.—The Devonian rocks comprise (1) dark argillaceous slate with thin layers of black or dark chert; (2) massive limestone interbedded with gray calcareous or dark slates, with which are intercalated thick beds of banded slaty black, green, and white chert and chloritic, siliceous dolomitic, and green hornblende schists; and (3) a series of volcanic rocks.

The chloritic and hornblende schists intercalated with the limestone are in part altered tuffs and in part sheared and altered andesitic lavas containing amygdules of calcite. On the Castle Islands, in Duncan Canal, the flows are more massive, show a well-developed

GEOLOGIC MAP OF PART OF WRANGELL DISTRICT, SOUTHEASTERN ALASKA

Scale $\frac{1}{500,000}$

5 0 5 10 MILES

1922

pillow structure, and are interbedded with limestone, slate, and a little siliceous dolomite and chert.

The volcanic series comprises schistose andesitic tuffs, breccias, and flows with intercalated beds of slate and rusty-weathering impure, siliceous, impalpably fine-grained dolomite. Calcareous tuffs are found in Kah Sheets Bay. The volcanic rocks are mostly dense, felsitic, and pale gray-green; in the porphyritic varieties plagioclose feldspars usually constitute the phenocrysts. Some schistose hornblende porphyry, however, is present.

Sills of much altered fine-grained diorite or greenstone are common throughout the sedimentary formations, and masses of medium-grained altered gabbro or diorite intrude the volcanic rocks on the west side of Woewodski Island.

Structurally, the slate and chert series appears to underlie the limestone and slate formation, and the volcanic rocks occupy the trough of a synclinorium in the limestone and slate. Fossils were obtained only from the limestone beds, which are best exposed along the two arms at the head of Duncan Canal, on Kupreanof Island, and in the arm northwest of Emily Island, in the same canal. Fossils obtained from several localities were identified by Edwin Kirk as of Middle Devonian age. Upper Devonian volcanic rocks are known at several localities in southeastern Alaska, and the volcanic series that overlies the limestone may be in part of this age. They present a contrast to the prevalent character of the greenstone formation mapped as Jurassic, in which the rocks are predominantly coarse porphyritic agglomerates with phenocrysts of altered augite.

Carboniferous and Triassic rocks.—Thick-bedded limestone and conglomerate, in a highly disturbed condition, form the Screen Islands, off the west coast of Etolin Island, in Clarence Straits. These beds are reported by G. C. Martin to comprise two limestone formations separated by a thick and massive conglomerate; the upper limestone is probably of Mesozoic age, and the lower limestone is probably Carboniferous. On the northernmost island there are exposed beds about 900 feet thick, comprising limestone with intercalated beds of coarse conglomerate and conglomeratic and sandy limestones about 200 feet thick. The conglomerate and overlying limestone are probably of Triassic age. The cobbles and pebbles in the conglomerate are predominantly chert and limestone with some rhyolite porphyry and greenstone. Fossils obtained by the writer from a limestone cobble in a conglomerate bed on the largest island were identified by T. W. Stanton as of Carboniferous age, which indicates that the conglomerate probably overlies the Carboniferous limestone unconformably.

Jurassic (?) rocks.—The rocks assigned tentatively to the Jurassic system consist predominantly of schistose and altered porphyritic basic volcanic breccias, with a minor amount of interbedded tuff, slate, and graywacke, and flows. The most conspicuous feature of the rocks consists of the abundant black hornblende crystals that occur as phenocrysts in the fragments of the breccias. In the more massive phases plagioclase feldspars, in all stages of alteration to epidote, chlorite, sericite, and other secondary products, form the groundmass. In the more altered phases actinolite is an abundant constituent and the feldspars may be entirely altered to secondary products. In other districts less altered phases of what is possibly the same formation have been determined as augite melaphyre and andesite porphyry. The rocks are similar to the greenstones of the Juneau gold belt and of Gravina Island, in the Ketchikan district. For those in the Gravina area a Jurassic age has been suggested by Chapin,[2] and the greenstone or schistose melaphyre agglomerate of this district may be of similar age, though no fossils were found to corroborate this conjecture, and the structural evidence is indeterminate.

Upper Jurassic or Lower Cretaceous rocks.—Neither the top nor bottom of the next series of rocks is shown. The lower portion of the series is essentially a black argillaceous slate formation, very thin bedded, with layers and partings of graywacke. Thin intercalated layers of rusty-weathering limestone are common, and many of the beds contain conspicuous nodules of blue-black chert and of limestone. Rarely a thin bed of fine conglomerate is present. The upper portion of the series comprises graywacke with intercalated beds of slate; the graywacke is in part thick bedded and in part thin bedded like the slate. Fossils collected from this formation were identified by T. W. Stanton as *Aucella crassicollis* Keyserling? and an imprint of *Belemnites* sp. He further stated that the *Aucella* occurs in the form of distorted specimens of the type *crassicollis*, which indicates Lower Cretaceous age if the specific identification is correct, and that the formation is not older than Upper Jurassic. The rocks of this series are the least metamorphosed of all the Mesozoic formations of this district. They are overlain unconformably by Tertiary volcanic rocks on the north.

Tertiary rocks.—The Tertiary formations consist predominantly of a series of tilted and slightly folded or faulted volcanic lava flows, with associated breccias, tuffs, and coarse lava conglomerates in the lower portion and some interbedded sandstones and normal quartz and slate conglomerates very near the base. The lavas comprise olivine basalt, feldspar basalt porphyry, basalt, and andesite, with intercalated rhyolite flows near the base. Dikes of feldspar basalt porphyry, augite-feldspar basalt porphyry, basalt, and andesite are

[2] Chapin, Theodore, The structure and stratigraphy of Gravina and Revillagigedo islands, Alaska: U. S. Geol. Survey Prof. Paper 120, pp. 95–97, 1918.

very abundant throughout the basal portions of the formation. Basaltic sills and dikes are abundant in the adjoining older country rocks, and dikes and sills of rhyolite porphyry are present but much less common. Amygdules with fillings of chalcedony, chlorite, calcite, and locally epidote are abundant in many of the basaltic and andesitic lavas. Felsite conglomerate in beds as much as 1,000 feet thick occurs in places, as northwest of Point Nesbitt, on Zarembo Island.

These rocks overlie the older formations unconformably. Plant impressions, fragments of silicified wood, and rare thin seamlets of coal are found in the shales intercalated in sandstone southeast of McNamara Point on Zarembo Island. The plant remains collected here were identified by F. H. Knowlton as *Sequoia langsdorfii* Heer, coniferous wood, fragments of dicotyledons, and stems, probably of grasses and sedges, indicating the probable age as Eocene.

ECONOMIC GEOLOGY.

Only two mineral deposits in the Wrangell district have passed beyond the prospecting or development stage. The Helen S. mine, on Woewodski Island, is reported to have produced about $35,000 worth of ore, mostly in gold, but this mine has been abandoned for several years. The garnet mine north of Wrangell, on the mainland, has been worked intermittently for many years and is a producer at the present time. Promising mineral deposits are found, however, both along a belt within the metamorphic complex on the mainland and along a belt of rocks in the vicinity of Duncan Canal on Kupreanof Island. (See Pl. I.)

RELATION OF MINERAL DEPOSITS TO ROCK FORMATIONS.

The great masses of igneous rocks, particularly the Coast Range batholith itself, are in general regarded by prospectors as unfavorable sites for the finding of ore deposits. This belief may possibly be relatively true for the main batholithic mass of the mainland, but the gold vein reported in a shear zone in the quartz diorite at the head of Thomas Bay, the gold veins in granitic rocks in the Ketchikan district, and the gold veins in the diorite of the Berners Bay area indicate that the outlying intrusive masses are not barren.

Within the metamorphic complex on the mainland there is a distinct belt of mineralization that includes the veins at Berg's Basin, Glacier Basin, and Groundhog Basin and at the Lake group, 10½ miles east of Wrangell. (See fig. 1.) The ores here are associated with intrusive sheets and dikes of acidic and basic porphyries and felsites. The veins include both high-temperature replacement deposits and fissure veins. Veins of zinc ores, of galena with a moderate content of silver, and of gold-silver ores are found. As indicated by float near the mouth of Andrews Creek the porphyries associated with the mineral veins of this belt are also found in the mountains on the east side of the south branch of Andrews Creek, and this extension of the belt has not, to the writer's knowledge, been thoroughly prospected. Gold veins have been found in the schist belts on Thomas and Le Conte bays.

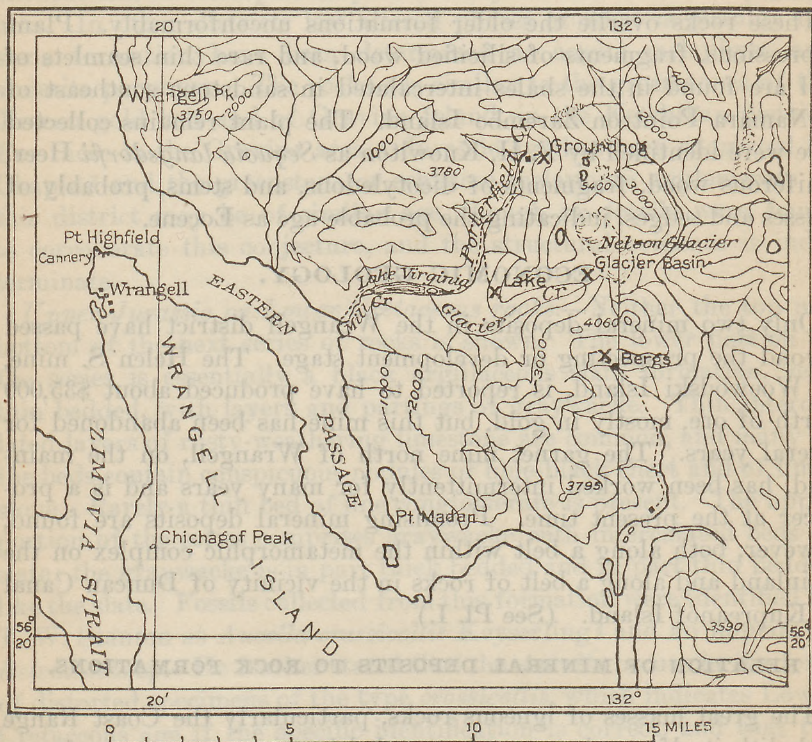

FIGURE 1.—Sketch map showing prospects east of Wrangell.

No prospects are known to the writer within the areas mapped as undifferentiated rocks, though in the Juneau and Ketchikan districts gold veins have been found in similar rocks.

In the Ketchikan district many prospects have been opened on veins in the Devonian rocks. Similarly, in the Wrangell district a belt of mineralization is found in the areas of Devonian rocks along and at the head of Duncan Canal and Portage Bay. This belt includes the copper deposits on Kupreanof Island at the head of Duncan Canal; copper veins with a little gold and silver on Portage Mountain; veins with galena, sphalerite, pyrite, and chalcopyrite in limestone on Taylor Creek; a pyrite body in Castle Islands Bay; the barite deposit of the Castle Islands; on Woewodski Island the gold lode worked by the Helen S. mine, the Maid of Mexico gold vein, and the gold prospects on the west side of Wrangell Straits; and a pyrite body near the head of St. Johns Harbor on Zarembo Island.

In the Ketchikan and Juneau districts gold-quartz veins and lodes have been found in the Jurassic (?) greenstone lavas and interbedded slates. No prospects were seen by the writer in the rocks of this formation so far mapped in the Wrangell district, though they may be expected to occur here also.

Ore veins are not known to occur in the rocks mapped as Lower Cretaceous or Upper Jurassic in the Ketchikan district. Many quartz veins are found in shear zones within these rocks in the Wrangell district, but here too none have yet been proved to be mineralized.

The main ore-bearing solutions that formed the veins of this district are believed to have been directly or indirectly due to the intrusion of the Coast Range batholith and its outlying masses. The Tertiary rocks were formed after the period of intrusion of this batholith, and therefore mineral veins connected in origin with the intrusion will not be found in Tertiary rocks. The fact that no ore veins are known in the Tertiary rocks in the Ketchikan and Wrangell districts is in line with this reasoning. Thin seams and beds of lignitic coal are locally intercalated with sandstone and shale of the Tertiary formations, but none of commercial value have been found in the Wrangell district. Fluorite occurs as a filling in brecciated zones in the volcanic rocks on the southwest side of Zarembo Island.

ZINC.

GENERAL OCCURRENCE.

A mineralized belt of metamorphic rock occurs on the mainland about 14 miles east of Wrangell. This belt is 1 to 1½ miles wide and lies between two masses of quartz diorite intruded parallel to the foliation planes of the metamorphic rocks. These rocks are predominantly fine-grained gneisses and crystalline schists, with sheets and dikes of quartz porphyry, rhyolite, and diabase porphyry. Narrow aplite veins, injected parallel to the foliation planes are locally abundant, especially toward the eastern mass of quartz diorite. The gneisses comprise interbedded dark hornblende-plagioclase gneiss and purplish-brown gneiss consisting of layers of plagioclase feldspar and quartz. Thin layers of green pyroxene granulite or of a diopsidic hornstone are found locally along some of the ore veins. In the mountain above Berg's Basin are hornblende-feldspar schist and thick beds of garnetiferous kyanitic quartz-mica schist intimately penetrated parallel to the schistosity by quartz veinlets. A few thin intercalated beds of crystalline limestone are also found here. The whole group of rocks represents a series of sedimentary strata such as calcareous shale and impure sandstone with some layers of slate and limestone which have been metamorphosed to gneiss and schist by the rise of temperature and pressure and the widely wandering highly heated solutions accompanying the intrusion of the quartz diorite, aplite veins, and porphyry sheets and dikes.

The portion of the belt of gneiss and schist in which ore veins have been reported is the only portion in which sheets of quartz porphyry, rhyolite, and diabase porphyry have so far been found. It may therefore be surmised that the ores and these intrusive rocks may have had a common origin.

Bands of rock with disseminated pyrite and pyrrhotite of the "fahlband" type are found throughout the gneisses and schists. They are conspicuous on weathering because of the rusty-brown or red belts to which they give rise. The ore veins are found in a mineralized zone at least 7½ miles long. The main bodies (Groundhog group) are tabular replacement veins of pyrrhotite and sphalerite in the gneiss, but at Glacier Basin there are replacement veins consisting of sphalerite and galena, and at Glacier Basin and Berg's Basin sphalerite, galena, and pyrite are found in veinlets and pockets in sheets of fractured rhyolite and in crosscutting quartz veins having a comb structure. The zinc replacement veins of Groundhog Basin and the zinc-lead-silver replacement veins in Glacier Basin appear to be older than the quartz porphyry and rhyolite dikes and sheets, but the mineralized quartz veins are younger. This indicates two periods of vein formation here, the deposits of the older period being high-temperature replacement deposits and those of the younger period comprising fissure fillings accompanied by some replacement deposits formed under intermediate conditions of temperature and pressure. The replacement deposits of Groundhog and Glacier basins are in their mineral associations allied to ore deposits of the contact-metamorphic type, but in structure they resemble high-temperature replacement veins.

GROUNDHOG BASIN.

The Groundhog Basin group of claims is on the mainland about 13 miles east by northeast of Wrangell. (See fig. 1.) The claims are reached by a trail that starts from the mouth of Mill Creek, on Eastern Passage, and follows the left bank of Mill Creek for three-quarters of a mile to the mouth of Lake Virginia, at an altitude of about 100 feet above high-tide mark; thence by boat across the lake for about 2¾ miles to the head; and thence by trail about 6 miles up Porterfield Creek to an altitude of about 800 feet. The main

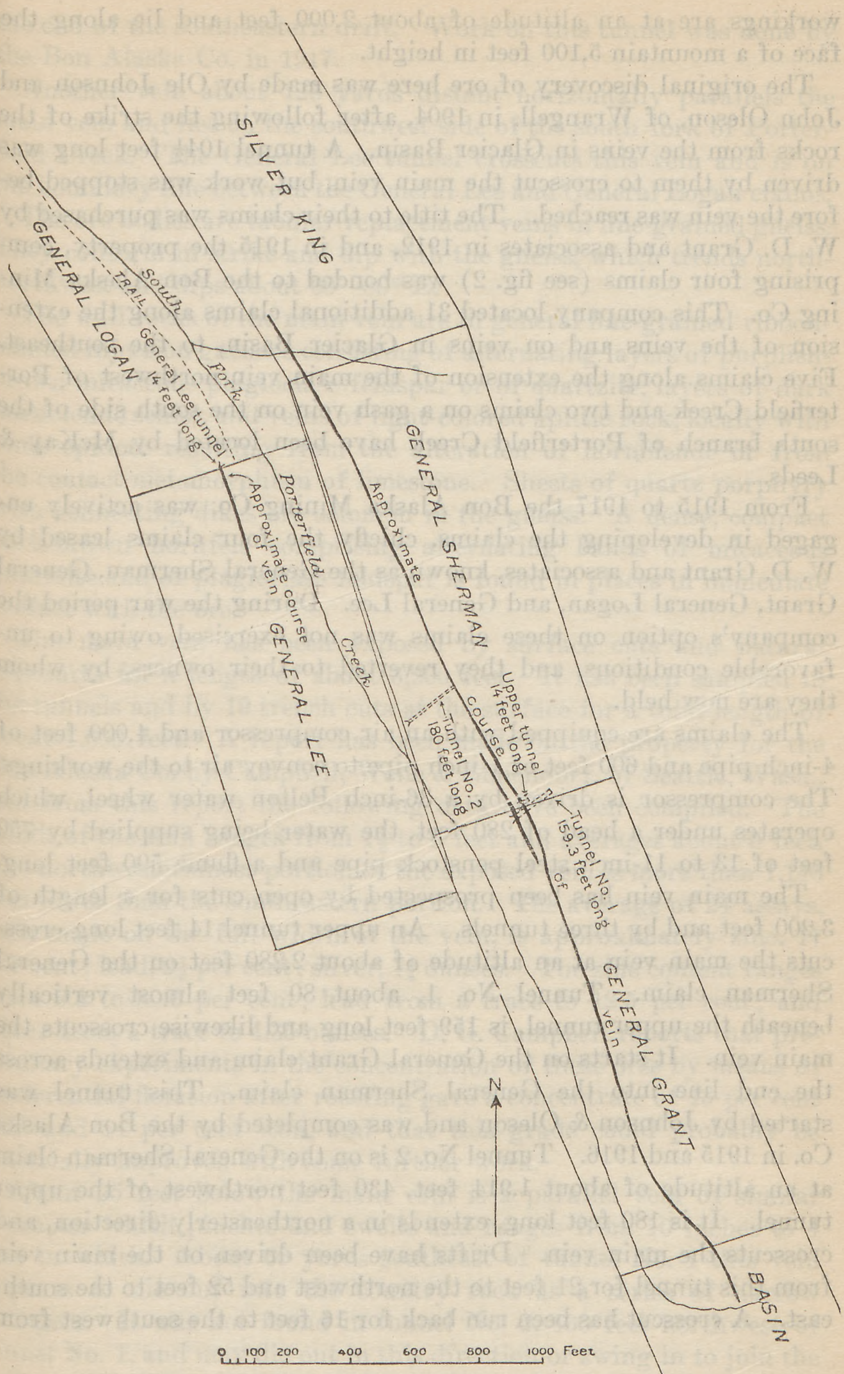

FIGURE 2.—Sketch map of Groundhog group of mineral claims.

workings are at an altitude of about 2,000 feet and lie along the face of a mountain 5,100 feet in height.

The original discovery of ore here was made by Ole Johnson and John Oleson, of Wrangell, in 1904, after following the strike of the rocks from the veins in Glacier Basin. A tunnel 104½ feet long was driven by them to crosscut the main vein, but work was stopped before the vein was reached. The title to their claims was purchased by W. D. Grant and associates in 1912, and in 1915 the property, comprising four claims (see fig. 2) was bonded to the Bon Alaska Mining Co. This company located 31 additional claims along the extension of the veins and on veins in Glacier Basin, to the southeast. Five claims along the extension of the main vein northwest of Porterfield Creek and two claims on a gash vein on the south side of the south branch of Porterfield Creek have been located by McKay & Leeds.

From 1915 to 1917 the Bon Alaska Mining Co. was actively engaged in developing the claims, chiefly the four claims leased by W. D. Grant and associates, known as the General Sherman, General Grant, General Logan, and General Lee. During the war period the company's option on these claims was not exercised owing to unfavorable conditions, and they reverted to their owners, by whom they are now held.

The claims are equipped with an air compressor and 4,000 feet of 4-inch pipe and 600 feet of 1-inch pipe to convey air to the workings. The compressor is driven by a 36-inch Pelton water wheel, which operates under a head of 280 feet, the water being supplied by 750 feet of 13 to 11-inch steel penstock pipe and a flume 500 feet long.

The main vein has been prospected by open cuts for a length of 3,200 feet and by three tunnels. An upper tunnel 14 feet long crosscuts the main vein at an altitude of about 2,280 feet on the General Sherman claim. Tunnel No. 1, about 80 feet almost vertically beneath the upper tunnel, is 159 feet long and likewise crosscuts the main vein. It starts on the General Grant claim and extends across the end line into the General Sherman claim. This tunnel was started by Johnson & Oleson and was completed by the Bon Alaska Co. in 1915 and 1916. Tunnel No. 2 is on the General Sherman claim at an altitude of about 1,914 feet, 430 feet northwest of the upper tunnel. It is 180 feet long, extends in a northeasterly direction, and crosscuts the main vein. Drifts have been driven on the main vein from this tunnel for 21 feet to the northwest and 52 feet to the southeast. A crosscut has been run back for 16 feet to the southwest from the end of the southeastern drift. Work on this tunnel was done by the Bon Alaska Co. in 1917.

Another vein about 125 yards distant horizontally parallels the main vein and lies on the southwest side of the south fork of Porterfield Creek. The General Lee tunnel crosscuts this vein and is on the boundary line between the General Lee and General Logan claims.

The ore bodies are tabular replacement veins in fine-grained gneiss. They conform in strike and dip with the gneiss, which trends north-northwest and dips about 60°–80° E.

The wall rocks of the main vein are in general fine-grained ribbon-banded injection gneisses consisting of alternating layers of purplish-brown micaceous plagioclase feldspar or of quartzite, layers of dark hornblende schist, and veins of light-colored aplitic rock, locally with some epidote resulting from the alteration of hornblende or from the contact metamorphism of limestone. Sheets of quartz porphyry with connecting dikes are common in the gneiss. A dense, compact dark-brown hornfels comprising alternating bands of micaceous quartzite and of plagioclase feldspar is found in places in immediate contact with the ore.

The main vein has been exposed by surface cuts and natural exposures for a length of about 3,200 feet. It has been sampled in the tunnels and by 19 trench cuts at the surface for a total length of about 1,600 feet. A report has been made on the property for the Bon Alaska Co. by Campbell, Wells & Elmendorf, of Seattle, Wash., and from this report the following data have been compiled. The width of the vein ranges from 1½ to 9 feet and averages about 3 feet. The northwesternmost portion of the exposed vein is more than 1,140 feet lower than the southeastern portion. The average of 24 assays, each made on the full width of the vein, is approximately zinc, 17 per cent; lead, 2½ per cent; silver, 1¼ ounces. The zinc content ranges from 9.4 to 30.6 per cent; lead from a trace to 12.5 per cent; and silver from a trace to 4.35 ounces. D. G. Campbell reports that preliminary experiments in the concentration of these ores by means of preferential flotation after roasting gave a concentrate of 45 per cent zinc and 14 per cent iron, and that this grade could probably be materially improved with some further work.

About 25 feet below the main vein is a parallel vein of similar character which pinches and swells and ranges from 10 inches to 4 feet in width. About 60 yards southeast of tunnel No. 1 this vein appears to die out into the country rock as a series of narrow stringers. It was not found in tunnel No. 2, 430 feet northwest of tunnel No. 1, and may die out in this direction or swing in to join the main vein. A layer of magnetite 6 inches thick, layers of pyroxene granulite, and a fine-grained to dense banded gneiss consisting of alternating layers of light-colored aplite, yellowish-green pyroxene granulite, and purplish-brown plagioclase feldspar are found at the southeast end of this vein.

About 350 feet beneath the main ore vein, measured at right angles to the dip, is another parallel vein. This has been crosscut by an adit where it is from 1 to 2 feet thick and of similar character to the others. An average sample of ore from both sides of this vein in the adit is reported by the Bon Alaska Co. to yield 8.60 ounces of silver to the ton, 4.85 per cent of lead, and 16.34 per cent of zinc. The immediate wall rock of this vein is a dense banded green and white hornstone consisting of alternating layers of light-green pyroxene, feldspar, and white quartzite with a trace of sphalerite and pyrrhotite. There is about 2 feet of such rock in the hanging wall, overlain by a compact ribbon-banded black and white quartzite. The black layers consist of very fine grained quartzite with a trace of feldspar and pyroxene and abundant disseminated particles of carbonaceous matter, from which they derive their color. The white layers are almost exclusively plagioclase and are locally adjoined by thin borders of pyroxene.

The ore in general consists essentially of pyrrhotite interstreaked and banded with gangue minerals (remnants of unreplaced country rock), dark-brown sphalerite, and a small and variable amount of galena and pyrite. A trace of chalcopyrite is present as dots and rods of microscopic size included in the sphalerite and locally as sparse grains in the ore. Minute veinlets of quartz and chalcopyrite cross the banding of the ore, and one 2-foot vein of this character is reported to have been found. The galena occurs as veinlets parallel to the banding of the other minerals, was brought in by solutions after the formation of the other minerals, and is irregularly distributed. The silver content varies roughly with the percentage of lead.

High-temperature replacement pyrrhotite-sphalerite deposits like this one are not common. The zinc deposits of Ammeberg, in Sweden, seem to bear the closest resemblance to it, and a summary description of their mode of occurrence will be of interest. The ore there is described[3] as occurring in fahlbands, layers, or zones in a banded gray "granulite" or fine-grained gneiss. Graphite, pyroxene, hornblende, and garnet are common accessory minerals. Small bands of grayish-green rocks composed essentially of diopsidic pyroxene are frequently seen in the banded "granulite." Some of the deposits contain essentially sphalerite; others are almost pure pyrrhotite formed by impregnation. Many of the smaller layers contain both

[3] Johansson, H. E., The Ammeberg zinc ore field: Cong. géol. internat., 11e sess., Guide des exc. No. 35, Stockholm, 1910.

sulphides in variable proportions. Pyrite is only locally present, and chalcopyrite is of exceptional occurrence. With the sphalerite traces of galena are usually present. Pyrrhotite does not occur in the zinc ore itself but is almost constantly seen in the footwall of the sphalerite deposits, where together with some galena and pyrite it impregnates a narrow band of silicate rock, usually associated with seams of siliceous limestone. The pyrrhotite does not everywhere form the definite footwall of the ore belt but may occur also within it, separating different branches or bands of the ore. The sphalerite deposits have a marked layer-like appearance and may be traced as a practically continuous band, generally not many meters in width, for almost $3\frac{3}{4}$ miles. Only the richer portions are worth mining. Some of the lenticular swellings are as much as 30 to 50 feet wide. The sphalerite is mostly of varieties poor in iron and hence of light-brown color. The low-grade milling ore averages about 21 per cent of zinc and forms the bulk of the product. The high-grade hand-picked ore averages 38 per cent of zinc. The total production from this field from 1857 to 1909 was 1,968,729 tons.

The country rock of the Swedish deposit, called "granulite," is similar to the banded gneiss described as occuring in association with the Groundhog ore. The mineral association, essentially pyrrhotite and sphalerite, is similar at both deposits. In the Swedish deposits, however, the sphalerite is an iron-poor variety and in the workable ore bodies is not intimately interstreaked with the pyrrhotite, like that of the Alaskan deposit. In their layer-like character and great extent in length the two deposits are similar. The veins of the Ammeberg deposit have been followed down the dip for 1,000 feet; and the great length and the present exposures of the Alaskan vein at greatly differing altitudes and its general character are favorable to its persistence in depth. The origin of the Swedish deposits is in doubt, but the mineral association indicates that they have been subjected to high temperatures.

SILVER-LEAD.

GENERAL OCCURRENCE.

Silver-lead veins have been prospected at the Lake group of claims (fig. 3), about $10\frac{1}{2}$ miles east of Wrangell, and silver-bearing galena is found along the mineralized zone 14 miles east of Wrangell, where it is associated with the zinc ores at the Groundhog group, is the principal ore mineral at the Glacier Basin prospects, and is associated with sphalerite and pyrite at the Berg's Basin prospects. A little silver-bearing galena is also associated with the gold ores in the prospects on Thomas Bay and in the Maid of Mexico vein, on Woewodski Island.

LAKE GROUP.

The Lake group of claims is a little more than 4 miles east of the mouth of Mill Creek on Eastern Passage. The claims are reached by a trail that turns off from the trail to the Groundhog Basin about 2 miles from the head of Lake Virginia. The vein lies below timber line, at an altitude of about 1,500 feet.

The country rock consists of quartzite, slate, and chloritic schist adjoined on the northeast by intrusive quartz diorite. The vein, in

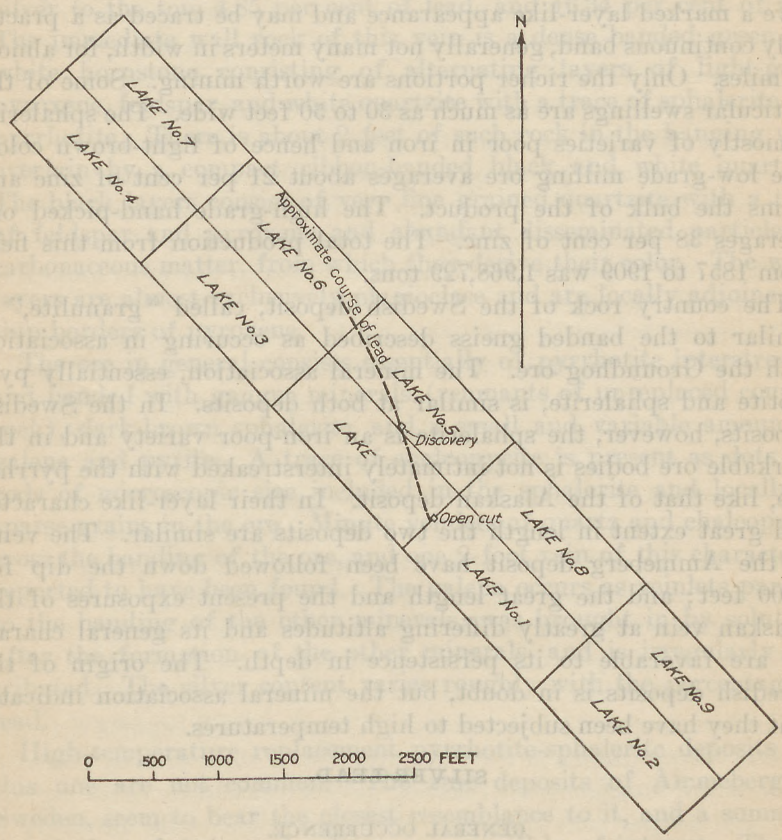

FIGURE 3.—Sketch map of Lake group of mineral claims.

general, conforms in attitude to the foliation of the country rocks, striking about N. 15° W. (magnetic) and having a vertical to steep easterly dip.

For the most part the vein consists of fissure fillings in or along a brecciated quartzite bed intercalated in chloritized schist. The ore minerals occur mainly in narrow veinlets along fractures in the quartzite but are found locally along the borders of the vein, where they may be several inches wide and several feet long and consist of almost solid galena. The maximum width seen of ore of this type was 6 inches.

The principal ore mineral is a coarse granular galena, with which occur here and there some sphalerite and a little chalcopyrite or pyrite. The gangue minerals are calcite and quartz.

An open cut 30 feet long has been made to crosscut the vein on Lake No. 5 claim, and a drift 25 feet long driven to the southeast. The vein here is from 4 to 5 inches wide and consists of nearly solid galena. An average of 4 tons of ore from the dump here is reported by Campbell, Wells & Elmendorf for the Bon Alaska Co. to yield 21 ounces of silver to the ton, 48 per cent of lead, and 9 per cent of zinc.

About 25 yards south of the open cut or tunnel the vein has been exposed by stripping of the overlying glacial débris and trenching of the vein along its strike for a length of a little over 100 feet. The vein lies along the face of the hill but strikes into it at a small angle, so that the upper portion of the stripping is about 60 feet above the lower end. In this stripping the vein has a width averaging about 13 inches and varying from 9 to 26 inches of well-mineralized rock. A basalt sill parallels the vein about 2 feet away on the east side. Another basalt sill parallels the vein at the south end on the west side for about 25 feet and then turns and cuts across the vein at the south end of the stripping. For about 20 feet it forms the footwall of the vein.

South of the long stripping several pits expose the brecciated quartzite, in which the fractures are filled with quartz veinlets but which shows only traces of ore minerals here and there. Drusy quartz is common, coating surfaces of the fractures. This relatively barren zone continues for about 150 feet. South of it the vein is again mineralized and is exposed for a length of 50 feet by two pits and a 15-foot stripping. The vein here is about 10 inches wide, and 6 inches of it is very heavily mineralized. At 100 feet farther south the mineralized vein is exposed by a pit in the glacial overburden.

The southernmost exposure of the vein is about 275 yards south of the tunnel, where a trench has been cut across the schists and exposes five stringers of galena aggregating perhaps 1 foot in a width of 10 feet.

About 200 feet south of the south end of the long stripping a tunnel has been driven on a stringer of galena and calcite several inches thick which strikes parallel to the foliation. This is a different vein from that described above. The entrance to the tunnel is now caved in.

These prospects are more favorably situated for development than other properties in this belt.

GLACIER BASIN.

Glacier Basin lies about 6½ miles in a straight line a little north of due east from the mouth of Mill Creek, on Eastern Passage. A trail formerly led up Glacier Creek to the prospects in the basin at its head, but this trail is now so overgrown that the best route is by the trail to the Groundhog claims and thence over the intervening mountain ridge by way of Nelson Glacier. One prospect is on the north wall of the basin at an altitude of about 2,400 feet, a little more than three-fifths of a mile downstream from the edge of the glacier in 1921. Nelson Glacier now extends much farther to the southeast than is indicated on the Coast Survey chart.

The prospects were located about 1899 by Nelson & Smith. The country rock consists of siliceous injection gneiss and hornblende schist and gneiss similar to the rocks of the Groundhog claims. Beds or "fahlbands" with disseminated pyrite and pyrrhotite are common and conspicuous because of their rusty brown or red color on weathering. Sheets of pale greenish-white rhyolite intrude the gneisses.

The vein, along which a tunnel about 40 feet long has been driven, is a tabular deposit formed by the replacement of what seems to be a bed of granulite consisting of epidote, diopsidic pyroxene, plagioclase feldspar ($Ab_{70}An_{30}$), and calcite, with a trace of garnet. The portion of the vein prospected by the tunnel, together with a border zone of gneiss, occurs as a long, narrow inclusion between two rhyolite sheets, which are seen to have resulted from the splitting of a single sheet farther up the mountain side. The western sheet appears to cut across the ore body, for a surface cut on the west side of the rhyolite, just west of the entrance of the tunnel, has exposed the continuation of the vein, and in the tunnel the ore is cut off on the northwest by the same sheet of rhyolite. At the entrance to the tunnel the granulite is 6 feet thick and very heavily mineralized for a width of 2½ feet. Narrow quartz veins with vugs lined with terminated quartz crystals or with a prevalent comb structure cross both the ore and the rhyolite. The rhyolite sills show slickensided or brecciated zones against the bordering gneiss, and the breccia zones are cemented with quartz. The hanging-wall rhyolite at the mouth of the tunnel is shattered and much reticulated by a network of quartz veinlets filling short fractures. Veinlets and sporadic pockets of galena, sphalerite, and pyrite are present throughout this shattered zone or stockwork, which is about 6 feet in width.

The ore consists of galena and sphalerite, with a little chalcopyrite and a trace of pyrite and pyrrhotite. For the most part the galena and sphalerite do not occur as a uniform mixed aggregate but as separate bands. Veins of almost solid galena or solid sphalerite several inches thick are found. The galena is reported to carry a moderate content of silver.

SILVER-GOLD.

The prospects in Bergs Basin are at the head of Bergs Creek and are reached by a trail 6 miles in length starting from tidewater at the head of Aarons Bay, at the north end of Blake Channel. The workings are at an altitude of about 1,600 feet.

The country rock is the same belt of gneiss and schist that contains the zinc veins of the Groundhog Basin and the silver-lead zinc veins of Glacier Basin, and the veins lie along the same general zone within this belt. The rocks comprise hornblende gneiss, kyanitic quartz schist, and light-colored gneiss injected by a few aplite veins. They are intruded by sills of creamy-white rhyolite and dark diabase porphyry. These intrusive sheets cut across the cleavage of the formations repeatedly at small angles. Here, as at Glacier Basin, one of these rhyolite sheets, about 12 feet thick, has been severely fractured and is intersected by a network of very narrow quartz veinlets carrying pyrite, galena, and sphalerite, thus constituting a stockwork. Sporadic pockets of sphalerite and galena are also found in this sheet. A quartz vein 1 foot wide, carrying moderate quantities of gold and silver, occurs within the same rhyolite sheet; and a tunnel, at present about 400 feet long, is being driven to intersect this vein in depth. Several open cuts have been made on narrow quartz veins along fault zones across the strike of the formation. One well-mineralized vein 2 feet wide, formed by the junction of two veins, is exposed at one place. Sulphides also occur in quartz vein fillings in breccia zones lying along the contacts of rhyolite and basalt sheets, but none over a foot thick were seen.

GOLD.

Several metalliferous veins carrying gold and some silver are found in the Wrangell district, but none are being actively worked. Most of the veins consist of milky-white quartz carrying a minor amount of sulphides and a trace of free gold and are localized as fissure fillings along shear or fracture zones. At the Helen S. mine, on Woewodski Island, however, a lode of pyritized greenstone and diorite (or altered gabbro), having a width of about 40 feet and exposed for a length of 1,000 feet, was worked as a low-grade gold mine. It is reported that the ore ran $3.66 a ton at the mill heads. This property was dismantled and abandoned several years ago.

MAID OF MEXICO VEIN.

The Maid of Mexico vein is about 1¼ miles east of the Helen S. mine on Woewodski Island. It lies along the contact between black slates and a rusty-weathering, impalpably fine-grained impure siliceous dolomite, the slate or the dolomite forming the hanging wall and the dolomite the footwall; the vein thus lies within the dolomite, or between the dolomite and the slate. The vein strikes about east and dips 60°–90° S. It has been traced at the surface for a length of 2,000 feet and ranges from 2 to 6 feet in width, averaging 4½ feet in the underground workings. The vein material consists predominantly of milky-white quartz with a little calcite and included lenses and films of the country rock, which is impregnated with a varying amount of disseminated sulphides. A rich pay streak, from 5 to 18 inches in width, is found in some places along the footwall, in others along the hanging wall, and in still others along both walls. The average value for the full width of the vein is reported to be about $20 to the ton. The ore minerals are predominantly sphalerite, pyrite, and galena, with a little chalcopyrite and free gold.

THOMAS BAY.

Just north of Elephant Head on the north arm of Thomas Bay is a gold lode held by Colp & Lee, of Petersburg. This lode is reported to consist of a mineralized shear zone 140 feet wide with associated sulphide-bearing quartz stringers in quartz diorite. The minerals in the quartz veins are predominantly pyrite and galena, with a little sphalerite and chalcopyrite. The tenor for the full width of the lode is low, averaging about $3 to the ton, but the richest part of the zone, 5½ feet in width, is reported to carry about $16 to the ton.

Another gold vein occurs in the southeast arm of Thomas Bay, on the conspicuous point of the mainland shown on the charts just south of Spray Island. The country rock here comprises a series of hornblende and quartz-mica schists. Some of the beds of quartz-mica schist, with thicknesses up to 100 feet, are so full of quartz veinlets that they literally consist of glassy quartz lenticels with mica schist partings. Locally there is little feldspar in these quartz veins. The ore vein at the shore is parallel to the foliation of the quartz-mica schist and appears to be only slightly mineralized. The vein can be traced about 250 feet from the shore to the mouth of a tunnel and is found to cross the foliation at a slight angle and enter a bed of hornblende schist. The ore zone exposed by the tunnel is a sheeted zone about 12 feet thick composed of milky-white quartz veins with a variable sulphide content and schist layers in about equal quantities. The included schist stringers are silicified and slightly pyritized, and slickensides along the walls of the quartz veins are abundant. The full width of the sheeted zone is not exposed in the tunnel and is possibly as much as 25 to 30 feet, although the zone is not equally mineralized throughout. The predominant sulphides are pyrite and arsenopyrite, with which occur a little chalcopyrite, pyrrhotite, and galena. Specimens of almost solid arsenopyrite several inches wide are common on the dumps.

EAST ARM, DUNCAN CANAL.

On a small creek that enters East Arm at about the middle of the east side a small gold prospect has been opened on the Silver Star claim (see fig. 4), about 2 miles from the coast, at an altitude of about 400 feet. Cuttings on the northwest side of the creek expose a pyritic black schist lying between walls of gneissoid diorite. This schist is composed essentially of hornblende with conspicuous crystals of biotite and is probably a basic segregation phase of the diorite, as the diorite becomes much more hornblendic at the immediate contact and grades into the schist. The schist is exposed along the creek for a length of about 20 yards. About 10 yards of the central zone is more highly pyritic than the border zones, the pyrite occurring as disseminated deposits and irregular veinlets. The border zones contain lenses of diorite similar to the wall rock, and adjacent to the walls veinlets of the black schist may be seen reticulating through the diorite. The whole mass of schist, as exposed, is in an advanced stage of disintegration and crumbles in the hand to a granular aggregate. About 10 feet of gneissoid diorite intervenes between the mineralized zone and another narrow zone of the hornblende schist on the northwest side, but the latter is nonpyritic.

Assays made for J. T. Towers by I. F. Laucks (Inc.), of Seattle, upon a sample of the mineralized phase of the schist yielded about 0.4 ounce of gold, 2 ounces of silver, and 0.3 ounce of copper to the ton and a trace of platinum. Samples of the pyritic schist collected by the writer were submitted to Ledoux & Co. for assay for metals of the platinum group, with the following results: Palladium, none; platinum, 0.0006 ounce to the ton; iridium, possible trace. The results show that the sample undoubtedly contains metals of the platinum group, but the amount is altogether too small to be of commercial value.

PYRITE.

A body of pyrite lies near the head of St. Johns Harbor on Zarembo Island. It is reached by a trail that leaves the beach about 200 yards south of the mineral spring on the west side near the head of the harbor. The trail runs about a mile southeast to the prospect, on the bank of a creek that enters the harbor on the west side near the head.

The vein consists of a tabular layer of very fine grained pyrite almost completely replacing a bed of chert and conformable with the bedding, which strikes east (magnetic) and dips 20° S. The footwall of the sulphide body is a crumpled siliceous schist, probably sheared chert, and the hanging wall is composed of thinly cleavable white chert beds. Underlying the chert is gray very fine grained sandstone with black slate laminae which give the whole rock a dark appearance.

The vein has been developed by a tunnel about 50 feet long driven down the dip of the sulphide layer and by a shaft about 100 yards due north of the tunnel and about 40 feet above it. The pyrite body is 7½ feet thick at the entrance to the tunnel, with a 7-inch barren layer of chert in the central portion. It is exposed along the brook for a length of 130 feet. About 100 feet west of the tunnel the vein is cut off by a fault striking N. 65° E. and dipping 60° N. A pyrite layer about a foot thick appears in the chert to the west of the fault. The shaft was partly full of water at the time of the writer's visit, and no examination was made.

Most of the pyrite retains a banded character resulting from the incomplete replacement of the chert layers. The amount of gangue, predominantly cherty quartz, is variable. Although some of the vein is solid pyrite, most of it contains some gangue.

Another layer of pyrite partly replacing siliceous schist is found on Kupreanof Island, on the beach above high-tide mark in the northwest corner of the bay about 3 miles due west of the Castle Islands in Duncan Canal. The siliceous schist is probably the result of shearing and metamorphism of chert beds. The pyrite layer here is about 4 feet wide and is exposed for 50 feet.

COPPER.

Traces of copper are found at most of the prospects in this district, but the only developed copper ore bodies are those of the Northern Copper Co. near the head of Duncan Canal, on Kupreanof Island (fig. 4). This property was formerly held by the Kupreanof Mining Co. The mine is 5¾ miles inland, at an altitude of 1,275 feet. Development work and the construction of a plank motor-truck road with connecting tram to the mine was started in November, 1918, and was in process of completion in 1921.

The ore bodies occur within a series of black slate and phyllite interbedded with chert and associated greenstones. In part the greenstones are altered dikes and sheets of diorite, in part they may be intercalated andesite flows, and in part they are probably contact-metamorphosed limestone beds. The ore is reported to occur predominantly along the contact of the greenstone and the slate, usually as replacement bodies in the greenstone but also replacing the slate. The property has been developed by many prospect pits, several open cuts, two main tunnels, and a shaft. At the time of the writer's

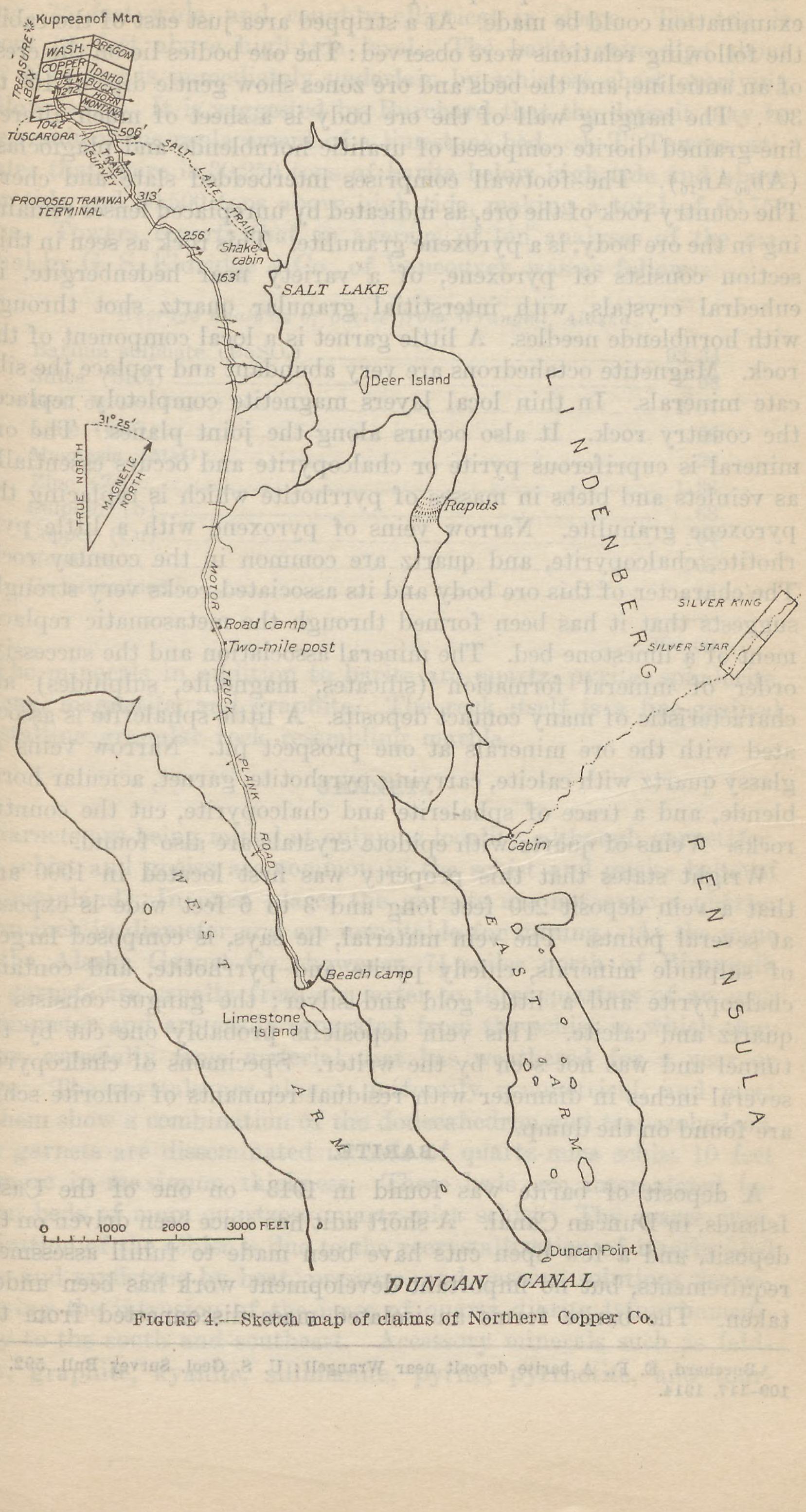

FIGURE 4.—Sketch map of claims of Northern Copper Co.

visit the trenches and prospect pits were caved in, and no detailed examination could be made. At a stripped area just east of the cabin the following relations were observed: The ore bodies lie on the crest of an anticline, and the beds and ore zones show gentle dips of 10° to 30°. The hanging wall of the ore body is a sheet of much altered fine-grained diorite composed of uralitic hornblende and plagioclase ($Ab_{90}An_{10}$). The footwall comprises interbedded slate and chert. The country rock of the ore, as indicated by unreplaced lenses remaining in the ore body, is a pyroxene granulite. This rock as seen in thin section consists of pyroxene, of a variety near hedenbergite, in euhedral crystals, with interstitial granular quartz shot through with hornblende needles. A little garnet is a local component of the rock. Magnetite octahedrons are very abundant and replace the silicate minerals. In thin local layers magnetite completely replaces the country rock. It also occurs along the joint planes. The ore mineral is cupriferous pyrite or chalcopyrite and occurs essentially as veinlets and blebs in masses of pyrrhotite which is replacing the pyroxene granulite. Narrow veins of pyroxene with a little pyrrhotite, chalcopyrite, and quartz are common in the country rock. The character of this ore body and its associated rocks very strongly suggests that it has been formed through the metasomatic replacement of a limestone bed. The mineral association and the successive order of mineral formation (silicates, magnetite, sulphides) are characteristic of many contact deposits. A little sphalerite is associated with the ore minerals at one prospect pit. Narrow veins of glassy quartz with calcite, carrying pyrrhotite, garnet, acicular hornblende, and a trace of sphalerite and chalcopyrite, cut the country rocks. Veins of quartz with epidote crystals are also found.

Wright states that this property was first located in 1900 and that a vein deposit 200 feet long and 3 to 6 feet wide is exposed at several points. The vein material, he says, is composed largely of sulphide minerals, chiefly pyrite and pyrrhotite, and contains chalcopyrite and a little gold and silver; the gangue consists of quartz and calcite. This vein deposit is probably one cut by the tunnel and was not seen by the writer. Specimens of chalcopyrite several inches in diameter with residual remnants of chlorite schist are found on the dump.

BARITE.

A deposit of barite was found in 1913[4] on one of the Castle Islands, in Duncan Canal. A short adit has since been driven on the deposit, and a few open cuts have been made to fulfill assessment requirements, but no important development work has been undertaken. The barite forms an isolated mass disconnected from the

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[4] Burchard, E. F., A barite deposit near Wrangell: U. S. Geol. Survey Bull. 592, pp. 109–117, 1914.

main island at high tide. At low-tide level it is about 200 feet long, 75 feet wide, and roughly elliptical in shape. The top is about 35 feet above high-tide level. The barite vein dips about 50° NE. and is immediately underlain by schistose chert overlying pillow lavas. It is suggested by Burchard that the deposit may be the result of the replacement of a limestone bed. J. T. Towers estimates that there is 30,250 tons of barite below high tide and above low tide and 30,500 tons above high tide, making a total of 60,750 tons. Towers reports that an average of ten analyses of the material by G. S. Eldridge & Co., of Vancouver, was as follows:

Average analysis of barite from Wrangell, Alaska.

Barium sulphate ($BaSO_4$)	93.34
Silica (SiO_2)	2.68
Iron oxide (Fe_2O_3)	1.07
Lime (CaO)	.06
Magnesia (MgO)	.24
Zinc (Zn)	1.38
Sulphur (S)	.68
Copper (Cu)	.04
Moisture	.08
Undetermined	.43
	100.00

The minerals in addition to barite are quartz, pyrite, sphalerite, galena, magnetite, and graphite. The rock itself is a fine-grained crystalline granular rock resembling marble.

GARNET.

Garnets are being mined at only one locality, although garnetiferous schist and gneiss are common in the schist and gneiss belts of the mainland. In most places the garnets are not over a quarter of an inch in diameter and are unsuitable for mining. At the mine of the Alaska Garnet Co., however, 7½ miles north of Wrangell, the garnets are usually from a quarter to three-quarters of an inch in diameter and are easily separated from the schist in which they occur, especially from material that has weathered for a year or more. The crystals are almost uniformly symmetrical, and most of them show a combination of the dodecahedron and trapezohedron. The garnets are disseminated in beds of quartz-mica schist 10 feet or more in maximum thickness. These beds are intercalated between beds of more quartzose quartz-mica schist. The coarse crystallization of the schist is due to the recrystallization of interbedded slate and sandstone by heat, pressure, and gaseous solutions accompanying the intrusion of the mass of quartz diorite lying immediately to the south and southeast. Accessory minerals such as feldspar, graphite, kyanite, sillimanite, pyrite, pyrrhotite, and tourmaline are present in the groundmass of the garnetiferous schist. Tourmaline is usually considered to be of pneumatolytic origin, and sills of granite are found in the schist. The evidence indicates that the schist in which the economically valuable garnet ledges are found is of direct contact-metamorphic origin, and that the ordinary garnetiferous schist is due to regional metamorphism not so close to the contact with large masses of quartz diorite.

MARBLE AND LIMESTONE.

Beds of crystalline limestone, in many places true marble, are found in the belt of schist and gneiss along both sides of Bradfield Canal, on Ham Island in Black Channel, in the belt of schist and phyllite paralleling Eastern Passage and extending from the northwest end of Blake Channel to Lake Virginia, and on the east side of Mosman Inlet. They consist of limestone that has been recrystallized and metamorphosed to marble through the heat, pressure, and solutions attendant upon the intrusion of the closely associated large masses of quartz diorite. They are not necessarily at the immediate contact with such masses and may therefore be interpreted as of regional-metamorphic origin in contrast to contact-metamorphic origin.

These deposits have been described in detail by Burchard,[5] and those interested are referred to his report.

Beds of limestone of considerable thickness are found in Duncan Canal along the north shore and at the head of the arm running northwest from Emily Island, along and at the heads of the center and western arms, and on the islands at the head of the canal.

GRAPHITE.

The slates of the Wrangell district are prevailingly black from their carbonaceous content. With increasing intensity of metamorphism and recrystallization of these rocks the carbonaceous material became crystalline flake graphite. In the incipient stages of this process the carbonaceous material appeared first as disseminated dust; at a more advanced stage as a collection of this dust into microscopic spherules or into clotlike aggregates of spherules; and finally as individualized flakes. The graphite schist with crystalline flakes occurs only in the areas of more thoroughly recrystallized schist and gneiss, such as the belts on the mainland. Beds of schist with crystalline flake graphite are intercalated in the hornblende-feldspar schist north of Wind Point on Thomas Bay, particularly at the east edge of the schist belt, which here lies near the quartz diorite. The graphitic schist is more siliceous in character and usually

[5] Burchard, E. F., Marble resources of southeastern Alaska: U. S. Geol. Survey Bull. 682, 1920.

weathers a rusty brown, owing to the oxidation of its contained pyrrhotite and pyrite. A specimen examined from a bed near the east edge of the schist belt is a graphitic feldspathic quartz schist. It contains 6 per cent of graphite as disseminated flakes, with a diameter ranging from 0.2 to 0.7 millimeter and averaging 0.4 millimeter and an average thickness of 0.08 millimeter. The other minerals are quartz 54 per cent, plagioclase and orthoclase feldspar 26 per cent, biotite mica 9 per cent, and pyrrhotite 5 per cent. This schist is very similar in percentage of graphite and mineral character to some of the graphitic schists mined in New York. The percentage of biotite in the specimen examined is higher than desirable for the separation process used in New York; but this mineral varies from bed to bed, and other specimens with a very low mica content were seen. Specimens of graphitic schist obtained near Duck Island Cove, on Bradfield Canal, are reported by J. Ulmer, of Ketchikan, to have shown on analysis 8 to 10 per cent of graphite. Beds of graphite-bearing schist were also noted near the head of Knygs Lake on Stikine River and in the schist belt crossed by Andrews Creek.

FLUORITE.

The rocks along the southwest coast of Zarembo Island are Tertiary volcanic rocks with some sedimentary beds near the base. From McNamara Point to Point Nesbitt many narrow breccia zones and seams are present in the volcanic rocks, which include amygdaloid, rhyolite lava, and rhyolite porphyry. The spaces in the breccia zones and the small openings along seams in the rocks have been as a rule partly or completely filled with a fine-grained quartz showing mammillary surfaces or a drusy coating of small terminated quartz crystals. Less commonly these breccia zones and cavities have a filling of fluorite. One such zone, N. 50° E. (magnetic) of the buoy opposite Bushy Island, ranges from an inch to several feet in thickness. The fragments of the breccia were here first incrusted with a thin layer of chalcedonic quartz, on which fluorite was deposited. Coatings of clear pale-green crystalline fluorite a quarter of an inch thick and as much as an inch in width commonly incrust the fragments in such breccia zones or occur as fillings in narrow fractures. Fragments of basalt as large as a foot in diameter are completely incrusted with chalcedony and fluorite from a quarter to half an inch thick.

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THE COLD BAY DISTRICT.

By Stephen R. Capps.

INTRODUCTION.

LOCATION AND AREA.

The Cold Bay district, as here defined, occupies a part of the southeast half of Alaska Peninsula west of Kodiak Island and extending from the east side of Cold Bay southwestward to and including Kialagvik Bay. The local use of the term " Cold Bay district " to include an indefinite area in the vicinity of Cold Bay is inherited from the days of the oil excitement in 1903–4, when passengers, supplies, and drilling outfits were landed at Cold Bay, and several miles of wagon road was constructed to drilling sites in the " east field." At that time Cold Bay was the center of activity and supply point for the whole district. In 1920–21 prospecting and staking were extended over a larger area, particularly to the southwest, and Portage Bay was more generally used as a port, many persons even landing at Kialagvik Bay, yet the whole district is still generally referred to as the Cold Bay district. The present report is the result of a reconnaissance examination of the area reaching along the Pacific coast from Cape Kekurnoi, at the northeast entrance of Cold Bay, to the west end of Kialagvik Bay (or Wide Bay, as it is known locally) and extending inland to Becharof and Ugashik lakes. The area lies between latitude 57° 15′ and 57° 45′ north and longitude 155° 17′ and 156° 30′ west. (See Pl. II.) It includes about 740 square miles and comprises a part of the mountain range that lies along the Shelikof Strait shore line and a part of the inland lowland in which lie Becharof and Ugashik lakes.

HISTORY AND PREVIOUS SURVEYS.

The historical record of this district, though incomplete, dates back well toward the beginning of white settlement in Alaska. By 1762 the Russians had sent trading expeditions as far east as Kodiak Island, and in 1783 a permanent trading post was established at Three Saints Bay, on Kodiak Island. The rugged islets in the mouth of Cold Bay and elsewhere along the mountainous coast of the Alaska Peninsula furnished rich hunting grounds for the eagerly sought sea otter, and the Russian influence was soon felt among the native hunters and has continued ever since through the conversion of the natives to the Russian church. Even since the transfer of the territory to the United States the missionaries of the Russian church have still ministered to the spiritual needs of the natives.

A bibliography of the early publications in which reference is made to the presence of petroleum in Alaska was published in 1905,[1] and the publications that concern the Cold Bay district are cited here. The presence of petroleum in this part of Alaska was first recorded in print in 1869, by Davidson and Dall.[2] Dall[3] in 1896 also referred to the occurrences of petroleum on the portage from Katmai. An anonymous article[4] published in 1903 described briefly the occurrence of petroleum at Cold Bay and contained some notes on the geology of the area. In 1904 Martin gave an abstract[5] of the fuller report issued later,[6] in which he not only included the results of his own field studies but summarized the existing information concerning the Cold Bay district, as well as other petroleum fields. Other publications by Martin[7] and Stanton[8] were issued in 1905. In 1911 Atwood[9] in describing the geology of parts of the Alaskan Peninsula, summarized the previous reports of Martin and Stanton on the Cold Bay district. In 1921 Martin[10] made a general report on petroleum in Alaska, in which he reviewed the results of his earlier work in the Cold Bay district and advanced some new interpretations concerning the geology of the district. In 1921 Moffit[11] mapped the oil field of the Iniskin-Chinitna Peninsula on Cook Inlet, in detail.

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[1] Martin, G. C., Petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 10–11, 1905.

[2] Coast Pilot of Alaska, 1st ed., pt. 1, pp. 36, 199, 1869.

[3] Dall, W. H., Coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, p. 799, 1896.

[4] The Cold Bay oil field: Eng. and Min. Jour., vol. 76, pp. 618–619, 1903.

[5] Martin, G. C., Petroleum fields of Alaska and the Bering River coal fields: U. S. Geol. Survey Bull. 225, pp. 365–382, 1904.

[6] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, 64 pp., 1905.

[7] Martin, G. C., Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, pp. 134–139, 1905.

[8] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 393–397, 401–402, 1905.

[9] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, 137 pp., 1911.

[10] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, 83 pp., 1921.

[11] Moffit, F. H., The Iniskin-Chinitna Peninsula, Alaska: U. S. Geol. Survey Bull. — (in preparation).

It is quite likely that the occurrence of petroleum on the Alaska Peninsula was known to the Russians nearly 100 years ago, but it was not until the closing years of the last century that any general interest was attracted to the Alaska oil fields. The first well was drilled at Katalla in 1901, and another was drilled in the Cook Inlet district, at Oil Bay, at about the same time. In 1902 to 1904 oil exploration was active throughout the Territory, and at that time the Cold Bay oil boom was at its height, and a large number of claims were staked in what were then known as the Cold Bay field, extending from the head of Trail Creek to Portage Bay; the Lake field, which lay between Bellim Bay of Lake Becharof and the northeast end of Cold Bay field; and the Becharof field, lying west of Becharof Lake and including what is now known as the West field. Four wells, of varying depth, were then drilled in the Cold Bay or East field, and although some paraffin-saturated beds were penetrated and a little oil was found, no commercially productive wells were brought in, and the excitement gradually died down. No important developments took place from 1904 to 1910, and in the fall of 1910, when all Alaska oil lands were withdrawn from entry, title had not been granted to any of the claims in the Cold Bay district. Then followed a long period of stagnation in oil prospecting and development in Alaska. A few prospectors of unusual perseverance had retained their faith in the ultimate development of the Cold Bay field and had kept their claims there. In 1918 a geologist made a private examination of the field for a group of claimants, and although his report was confidential, its contents became generally known in the district. The more intelligent prospectors were keenly alive to the relation of geologic structure to productive oil pools, and the most eagerly sought claims were those which lay along the crests of the anticlines or domes of the region.

In 1920 Congress passed an oil leasing bill permitting the staking and development of oil lands under certain restrictions. That act stimulated oil prospecting throughout the Territory, and those areas in which there were known indications of petroleum received particular attention, among them the Cold Bay field.

Soon after word was received that the oil leasing bill had become law, a considerable number of prospectors hastened to the Cold Bay district, and before the snow had disappeared in the spring of 1920 a large part of the most promising oil land had been staked. No drilling was done in the summer of 1921, but prospecting was continued energetically, the boundary lines of a large number of claims were surveyed, and a number of petroleum geologists representing strong producing companies in the western United States visited the field. The United States General Land Office also sent a party to this district to continue the work already begun of carrying out land surveys and to establish reference lines to which the claim surveys could be accurately tied.

PRESENT INVESTIGATION.

Realizing the importance to Alaska and to the country at large of a possible new oil field, the United States Geological Survey considered it wise to extend geologic and topographic mapping into this promising district and to make a study of the geologic structure and its relation to possible oil pools. Two parties were organized to carry out this work, one in charge of R. K. Lynt, consisting of five men and eight pack horses, to conduct the topographic mapping, and one in charge of the writer, including also W. R. Smith as geologic assistant, three camp hands, and eight pack horses, to map the geology and to study the structure and its relation to the possible accumulation of commercial petroleum pools.

The plans for these two parties were completed and preparations made to sail from Seattle on May 18, but at the last moment the officials of the steamship company decided that, owing to the reduced number of sailings to Alaska on account of the seamen's strike, only passengers and foodstuffs could be loaded, and that the pack horses, the only means of field transportation for the parties, must be left behind. Accordingly, Mr. Lynt sailed on May 18 with all the supplies for both parties and seven men. The writer and two packers remained in Seattle with all the horses and sailed on June 18. The horses were landed at Portage Bay on July 2, and were taken overland to Cold Bay on July 3. Field work for both parties commenced immediately and was continued until September 4; the men then returned to Kodiak by small power boat and thence to Seattle by steamship. Unfortunately, the weather during July and August was generally foggy and rainy, with only a few clear days, so that conditions were highly unfavorable for phototopographic mapping. With only four working days Mr. Lynt completed a topographic map of about 150 square miles on a scale of 1:180,000, and the geologic mapping was carried over an area of about 740 square miles. Considerable time was also spent in a study of the stratigraphic section and in a reconnaissance trip to Kialagvik Bay, but the results of this work can not be expressed in terms of area. At the time the field work on which this report is based was planned it was thought that the topographic party would be able to map an area of at least 1,000 square miles on a scale of 1:180,000 and thus furnish a base map upon which the areal geology could be accurately plotted. As a result of the unfavorable weather only a small part of the area was covered, and in consequence the geologists had no accurate topographic map for field use. It has therefore not been possible to present in this report a geologic map that shows the degree of refinement in mapping that could have been attained if an adequate base map had been available.

While the field work on which this report is based was being done independent explorations and examinations in the district were made by geologists representing at least three western oil companies. All these geologists showed the greatest cordiality and generosity in placing at the disposal of the Geological Survey the information they obtained. Especial acknowledgment is due to Mr. Ernest Marquardt, of the New York Oil Co., of Casper, Wyo., who furnished copies of his traverses, notes, and maps and supplied a number of valuable fossil collections and who alone is responsible for the topographic map of the Pearl Creek dome, published herewith; and to Mr. L. C. Decius, of the Associated Oil Co., and Mr. E. D. Nolan, of the General Petroleum Co., who furnished several geologic sections for comparison, as well as other useful information.

GEOGRAPHY.

DRAINAGE.

In the latitude of Cold Bay the Alaska Peninsula has a width of about 90 miles. Toward the north it widens, and toward the southwest it becomes narrower. Between Port Moller and the base of the peninsula the position of the divide is notably asymmetrical, for it lies much closer to the Pacific shore than to Bristol Bay. In the Cold Bay district the southeast coast is bordered by a mountain range which reaches elevations of about 2,000 feet near Cold Bay but which becomes increasingly higher to the southwest and at the west end of Kialagvik Bay culminates in a group of peaks that rise over 4,000 feet above the sea and contain vigorous glaciers. This mountain range forms the divide between the streams that flow in a southeasterly direction to Shelikof Strait and the Pacific and those that flow west or northwest to Bristol Bay. The area draining to the Pacific, however, is small, and the streams are in general short, swift, and of only moderate size. Most of them can be waded easily on foot during the summer, except at times of flood. The one notable exception is the glacier-fed stream that empties into the west end of Kialagvik Bay. This is a turbulent river during the season of glacial discharge and can be waded with difficulty even at favorable places.

The Bristol Bay drainage, by contrast, is characterized by large lakes and sluggish rivers. On the northwest flanks of the coastal mountain range many of the small streams are swift, but these descend quickly to the great lowland that occupies much of the peninsula. A remarkable feature of this lowland is the series of lakes that occur along the center line of the peninsula from its base to the constriction at Port Moller and Stepovak Bay, a distance of over 300 miles. Much of this area has not been accurately surveyed, but its general features are well known. These lakes lie against the northwest or inland front of the coastal mountains but are bordered on the northwest by a broad lowland that extends to Bristol Bay. Their elevation above sea level is generally less than 50 feet, and with one or two minor exceptions they drain to Bristol Bay through broad, sluggish rivers in which the effects of the Bering Sea tides are felt for long distances inland. These lakes and their tributary streams are favored spawning grounds for salmon, and an extensive salmon-canning industry has been established on Bristol Bay to utilize the fish that migrate from salt water to these great fresh-water lakes. Becharof Lake, the largest of the Alaska Peninsula lakes, is over 40 miles long and probably has an area of more than 450 square miles. Naknek Lake is about 45 miles long, though of smaller area, and the two Ugashik Lakes together are about 30 miles long. Naknek River, which drains Naknek Lake, Egegik River, the outlet of Becharof Lake, and Ugashik River, between the Ugashik Lakes and the sea, are all fairly large, rather sluggish streams that are easily navigable by small boats, and they with the lakes furnish convenient routes of travel through the lowland and from one coast to the other.

RELIEF.

As has been stated, the Pacific coast of the Alaska Peninsula in general is bordered by mountains that rise steeply from the water's edge, and the coast line is irregular and deeply indented with embayments. The visitor approaching from the southeast receives the impression that the entire peninsula is mountainous and rugged, but this is by no means the case. The mountain range along the coast, at least in the Cold Bay district, is narrow. Nearly all the southeastward-flowing streams head in low passes or in easily traversed divides, and after crossing the coastal range the traveler soon descends into a broad lowland area of slight relief, broken by isolated mountains and by large fresh-water lakes. In the immediate vicinity of Cold Bay the mountain ridges have rather smooth outlines and reach only moderate elevations, the highest peaks standing from 1,500 to 2,400 feet above sea level. Near Portage Bay the mountains are higher and more rugged, and at the southwest end of Kialagvik Bay there is a group of mountains whose peaks attain heights of 4,000 to 5,000 feet.

Northwest of the coastal mountains there are a few isolated mountains and at least one notable mountain chain that rises from the surrounding lowlands. The field work on which the present report is based covered only the coastal mountain strip between Cold and Kialagvik bays and a part of the interior lowland, and these interior prominences were not examined or their position accurately determined. One conspicuous ridge, however, the Kejulik (Garkulik) Mountains, forms a prominent topographic feature north of Cold Bay. This mountain ridge lies about 15 miles inland from the head of Cold Bay and extends from a point near Becharof Lake northeastward to merge with the coastal mountains in the Katmai region. Its crest line is conspicuously rugged, and its general character and topography suggest that the ridge has a core of granitic rocks, flanked by sedimentary beds. The highest peaks are probably little less than 5,000 feet above sea level.

The axial line of the Alaska Peninsula is marked at irregular intervals by volcanic peaks, of which some are still active and many others are of so recent origin that their topography still shows the conical shape characteristic of volcanic mountains. The high peaks of the Katmai region, with their smoke plumes, are visible on clear days from the Cold Bay district. Mount Peulik, an extinct volcano, forms a conspicuous topographic feature between Ugashik and Becharof lakes. Although sculptured somewhat by gulches, it still preserves its conical shape, and, rising to a height of about 5,000 feet above the lake, it dominates the lowlands to the northwest.

A feature less impressive but no less notable than the mountain ranges is the great lowland plain that occupies more than half of the Alaska Peninsula, on its northwest side. This plain stands, for the most part, less than 100 feet above sea level and consists of grassy meadows, marshes, and lakes. In summer travel in this lowland is confined to the rivers, which are sluggish and easily navigated by small boats. The lowland has little attraction for man, however, and is almost entirely uninhabited except for the fishing communities along the coast. In winter it is occasionally visited by trappers.

CLIMATE.

No systematic weather records have been kept in the Cold Bay district, and as the climate there is completely influenced by local conditions the weather records for Kodiak, the nearest important town, on Kodiak Island, more than 100 miles southeast of Cold Bay, are of little value for comparison. The following observations are therefore based on experience during the summer of 1921 and on information obtained from persons who have lived for considerable periods of time in the district. An understanding of the geographic position of the Cold Bay district, which lies in a range of mountains that extends along the axis of a peninsula separating two oceans, goes far to explain a somewhat unusual climate. This part of the Alaska Peninsula is especially notable for its prevalent high winds and for the frequency of cloudy and foggy weather. Any differences in barometric pressure that may exist between the Pacific Ocean and Bering Sea result in winds that blow across the peninsula either from the northwest or from the southeast, and a complete reversal in the direction of the wind often takes place suddenly. Furthermore, any wind that blows is a sea wind, and the air, having a high moisture content, is chilled on passing over the mountain barrier and forms fog or clouds. Thus windy days are generally cloudy or foggy, and as windy weather is the rule, the mountain tops are generally in clouds. The few clear days that occurred in the summer of 1921 were relatively calm.

Although the actual precipitation as rain or snow is probably moderate in amount, there are many days of drizzling rain or of driving wet fog in which travel is disagreeable. The temperature is cool in summer and cold in winter. The winter snowfall is said to be light on the average, though in the winter of 1920–21 it was unusually heavy, and in September, 1921, many gulches still contained heavy snow banks, even at low altitudes. It is said that there is often insufficient snow for good sledding until after Christmas. The winters are reported to be unusually severe, not so much on account of very low temperature as from the combination of cold and heavy wind. It is said that there are frequent intervals of several days each during the winter when the heavy cold winds make travel impossible and when even the wild animals lie in shelter and refuse to brave the weather.

VEGETATION.

The Cold Bay district is completely lacking in timber, and the problem of obtaining lumber for buildings and other structural purposes is a serious one, as is that of obtaining fuel. Willow and alder brush sufficient for the moderate needs of the camper can be found in most of the creek valleys at low altitudes, but camp sites must generally be chosen rather with a view to the availability of brush for fuel than for convenience in other ways. Most of the brush is small and crooked, and poles long and straight enough to serve as tent poles are to be had at only a few places and in a very meager supply. In most places along the shore there is abundant driftwood, especially at the heads of the bays, and this material is generally used as fuel and has furnished logs and timbers for building cabins. The Cold Bay field and the West field each contains a large patch of paraffin residue, the accumulation of the less volatile portions of petroleum that has seeped from the ground and saturated the peat and soil near by. This residue is somewhat plastic and may be cut and burned in stoves or under boilers. For camping or domestic use it is dirty and forms much soot, but it has been found to be a satisfactory fuel when used under boilers for power and will be a valuable asset as fuel for oil-drilling rigs in this country, where other fuel is lacking.

Grass for summer pasture for live stock is very abundant in most of the stream valleys, and thousands of acres of luxuriant grass are available during the summer months. The prevailing variety is the so-called redtop, which grows in thick stands to a height of 3 or 4 feet and furnishes excellent grazing from about the middle of May or the first of June until it is killed by frost some time in September. After it is frosted, however, it has little nourishment. It makes a fair grade of hay if properly cut and cured.

With the exception of the grassy valleys and their small areas of willow and alder brush, the surface of the ground is covered with a mantle of moss and heather everywhere except on the highest ridges and the steepest cliffs and talus slopes.

WILD LIFE.

This part of the Alaska Peninsula is not a particularly good game country. A few caribou formerly ranged through this district, but they have completely disappeared. There are no moose or mountain sheep or goats. The great brown bear is the largest wild animal and is abundant in those places where there are few people, but in the district here described the bears have been frightened away and are only occasionally seen. The ptarmigan vary in abundance from year to year; in 1921 they were numerous after a period of years during which they had almost disappeared. A few Arctic hare were seen during the summer. Ducks and geese breed in great numbers on the lakes and in the low marshy areas.

This region is notable for the abundance of its food fish. The lakes and streams are stocked with trout and grayling the year round, and in the summer they teem with salmon. The red salmon, the most desirable variety, come into Bristol Bay in the early summer and follow the rivers up to their spawning grounds in the lakes and smaller streams, and an extensive canning industry has been established on Bristol Bay. The Pacific streams have only a meager run of red salmon, though other varieties are present in abundance. There are prolific fishing grounds for halibut, cod, and herring, almost completely unexploited, and many other varieties of edible fish are obtainable.

The trapping of fur-bearing animals for their pelts is carried on each year by natives and by a few white trappers. Many red fox and a lesser number of silver-gray fox are taken, as well as mink, marten, ermine, and land otter. This coast was formerly a rich hunting ground for the highly prized sea otter, but they are now almost exterminated, and their capture is forbidden by law.

POPULATION.

The only permanent native settlement is the Aleut village of Kanatak, at the head of Portage Bay, with a population in the winter of 30 to 40 people. These natives scatter in the summer, many going to Bristol Bay to work in the salmon canneries, and others spending the summer at a temporary village near the head of Becharof Lake in catching and drying salmon. In August, 1921, there was only one family resident at Kanatak. These natives belong to the Russian church and indeed have a considerable admixture of Russian blood. They eke out a precarious living by fishing, hunting, and trapping and on occasion will perform services for wages, especially as guides and packers. Most of them are improvident and fail to cure enough fish during the summer, when salmon are easily caught and dried, to last through the cold months, and by late winter they are usually on the verge of starvation. On this coast, however, it is always possible to catch fish when the weather permits.

The white population of this district is extremely variable and depends in large measure upon the activity in the oil fields. In the period from 1902 to 1904, when active developments were under way near Cold Bay, a considerable number of white men were engaged in road building, drilling, and prospecting. A base camp was established on the west shore of Cold Bay, near its entrance, and several substantial frame buildings were constructed. These buildings are still intact and are now used as a trading station. A small stock of goods is kept at the store, and this has long been the supply point for the district.

From 1904 to 1920 the permanent white population was limited to one or two persons at the trading post, a very few holders of oil claims who retained their faith in the district, and a few trappers. In the spring of 1920, after the passage of the oil-land leasing law, there was a new influx to the district, and there has since been a variable population, depending upon the season and upon the activity of governmental and private surveys and examinations. In 1921 several new buildings were erected at the head of Portage Bay, near the native village of Kanatak, a small stock of goods for sale was landed there, and that point was generally considered the port of access to the oil fields of the district. Probably a dozen white men spent the winter of 1921–22 in the region. Plans were said to be under way for active drilling in 1922, and the future of the district will depend upon the degree of success in the oil-field developments.

ROUTES OF TRAVEL.

The Cold Bay district is invariably approached by sea from the east. A regular steamship service is maintained from Seattle by way of Alaska ports to the town of Kodiak, on Kodiak Island, with sailings scheduled about once a month, the trip requiring 10 or 12 days. From Kodiak the usual means of travel to the peninsula is by means of small motor boats that make occasional trips or that may be especially chartered. Most of these boats take about 24 hours for the run from Kodiak to Cold Bay or Portage Bay. A monthly mail boat leaves Seward and after stopping at a number of Cook Inlet ports calls at Cold Bay. This boat (1921) has accommodations for a few passengers, but its route to Cold Bay from Seward is indirect. In 1921 the steamship from Seattle made one call at Portage Bay to discharge passengers and cargo, and if active development work is begun in the district and there is sufficient traffic to justify it, some port in the Cold Bay district will no doubt receive regular calls from the through ships from Seattle. Plans were also under way to establish a better mail service.

In 1921 there were no wharves or other landing facilities anywhere in the district, the waters were largely uncharted, and so far as is known there was no anchorage for large vessels protected from south and east winds. Passengers and freight could be landed only by small boat or by lighter, and the only lighter available was a privately owned one that was at Portage Bay for part of the summer. If the oil fields are developed and prove productive some better landing facilities will have to be provided. At present Cold Bay seems to be the best harbor, for it is said to have plenty of deep water and offers fair protection from north and west winds, but in south and east gales ships can not safely enter or lie at anchor there, and the bay is inconveniently far from the promising West field. Portage Bay and Kialagvik Bay are about equally distant from the West field, but Portage Bay is better located with respect to the Cold Bay field. Portage Bay at present seems to have been generally selected as the port of the district, and in 1921 most of the passengers and supplies were landed there. Vessels drawing 4 or 5 fathoms can enter the bay, and a lagoon affords good protection for small craft. Most of the bay, however, is shallow. Large ships can not approach close to the village site at the head of the bay, and they have no protection from south winds. Besides the native village of Kanatak there were half a dozen small buildings at the head of Portage Bay, and trails radiate from the village to both the West and the Cold Bay oil fields.

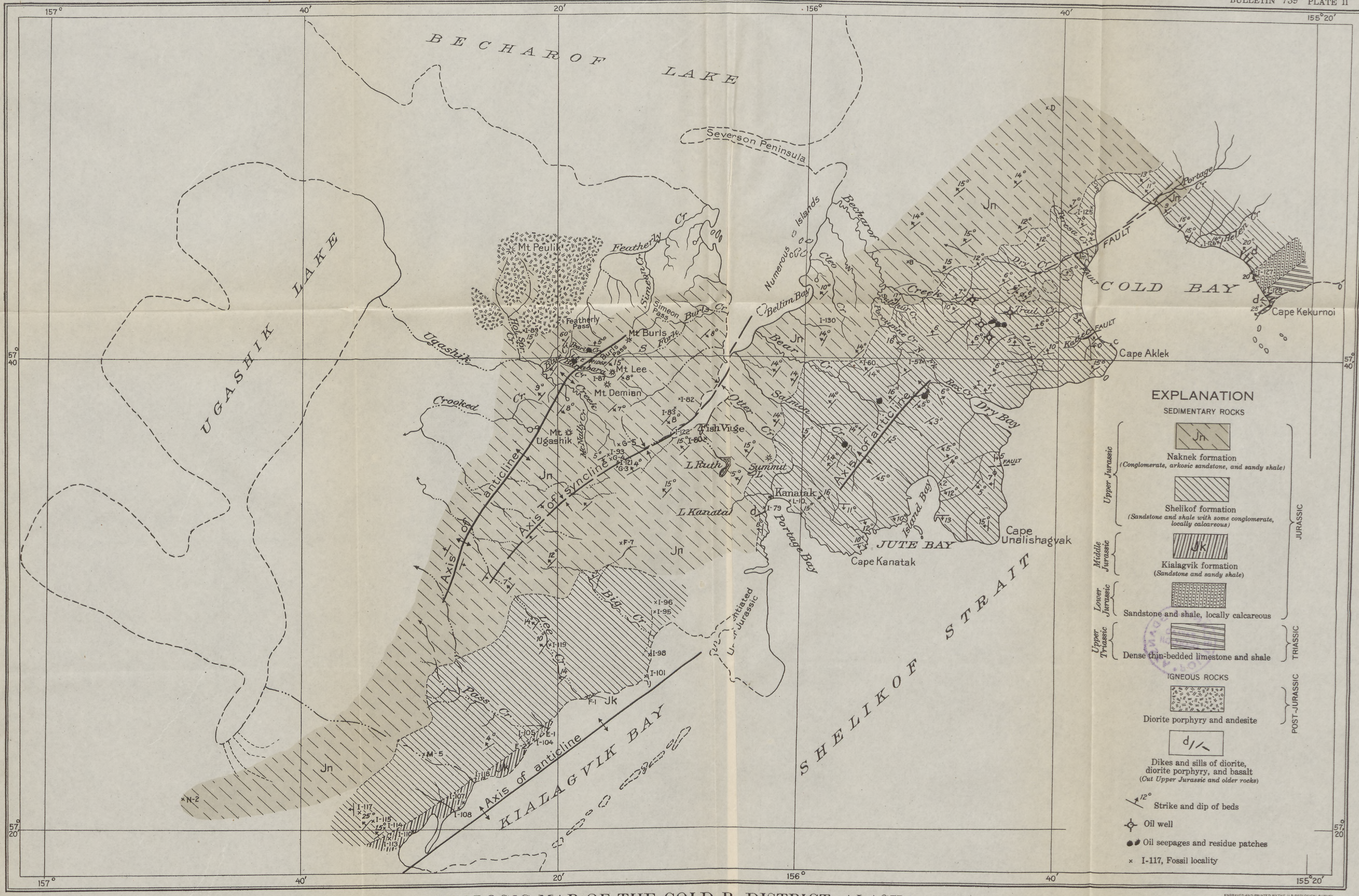
There is a lack of agreement among those interested as to whether Kialagvik Bay does not offer a better harbor and port for the West field than Portage Bay. The distance by trail is about the same, but the Kialagvik Bay route demands less climbing and offers better grades. It is said that Kialagvik Bay has an entrance channel containing deep water, has sufficient water inside the inclosing islands for anchorage, and gives protection in gales from any direction. The question as to which bay is more suitable for development into a port can be determined only when the waters have been adequately charted.

Within the district travel from place to place is fairly easy. There are many easy passes from the Pacific slope through the coastal mountains to the interior, and these passes and the large lakes and their outlets through sluggish rivers to Bristol Bay have long been used by the natives in their journeys from the Pacific coast to Bering Sea. From Cold Bay there are easy passes to the Kejulik (Garkulik) Valley, and a wagon road was built by way of Trail Creek to the well sites near the divide between Cold Bay and Becharof Lake, a distance of 7 or 8 miles. This road is now badly out of repair but can still be used for pack horses. From the end of the road an easy route is available to Becharof Lake. With the exception of the wagon road and a trail from Kanatak to a native fishing village on Becharof Lake, there were scarcely any discernible trails in the district in the spring of 1921. By fall, however, the pack trains and foot travelers had beaten out plain trails in many places. One trail could be followed continuously from Cold Bay to Portage Bay by way of Trail and Becharof creeks, across Bear and Salmon Creek valleys, and down Kanatak Creek to Kanatak. Another trail was broken from Kanatak around the head of Becharof Lake and thence across the hill to the head of Ugashik Creek and to the West field. Passable routes are available from Oil Bay up Oil Creek to the head of Becharof Creek; from Dry Bay up Rex Creek to Arvesta or Porcupine Creek; from Jute Bay into the valleys of both Bear and Salmon creeks; from Portage Bay by two routes to Becharof Lake; and from Kialagvik Bay by half a dozen passes through the mountains to the Ugashik Lake drainage basin. Pack horses may be taken to almost any place desired, and grass is sufficiently abundant everywhere during the summer to afford plentiful forage. There are few places in Alaska where land travel for horses and men is so easy.

GEOLOGY.

PRINCIPAL FEATURES.

In the lack of an accurate topographic base map in the field, it has been possible to delineate only a few of the larger geologic features on the geologic map (Pl. II). The present investigation



GEOLOGIC MAP OF THE COLD B[illegible] DISTRICT, ALASKA

Scale, $\frac{1}{250,000}$

0 1 2 3 4 5 6 7 8 9 10 11 12 MILES

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

was a reconnaissance only, with especial attention to study of the rock structure and of the possibilities of the district as a potential oil field. Little time was available for the tracing out of the contacts between lithologic units. It may be said, however, that this district is in many ways ideal for detailed geologic mapping, for exposures are generally abundant and good, the rocks are divided into rather distinct lithologic units, and from most of them fossils can be obtained. Furthermore, the attitude of the beds is such that although a thick series of rocks is exposed, the structural features are large and persistent and can be easily recognized, even from a distance. Even in a reconnaissance examination much more detailed information was obtained in places than can be shown on a map of the scale of Plate II.

In a study of the stratigraphy and structure of an area such as the Cold Bay district it is often difficult or impossible to trace the boundaries of a particular bed continuously, or to correlate the beds of one locality with those of another on the evidence of their similarity alone, for rock beds may vary greatly in thickness and character within short distances. In such places the fossil remains of animals and plants may prove invaluable in correlating the beds in one part of the area with those in another and with beds of the same age in distant areas. In the Cold Bay district the fossils collected were of the greatest aid in making such correlations. About 40 collections from as many localities were made by the writer and his assistant, W. R. Smith, and 10 collections made by Ernest Marquardt were generously turned over by him to the Geological Survey for identification and use. The localities from which all these collections were made are indicated on Plate II, and lists of the fossil forms as determined by T. W. Stanton are given in the descriptions of the rock formations.

The geology of the Mesozoic rocks of the Alaska Peninsula has already been discussed in some detail, and for a correlation of the rocks of the Cold Bay district with those of other parts of the peninsula the reader is referred to the original descriptions.[12]

A generalized section of the sedimentary rocks of the Cold Bay district is given on page 91. (See also fig. 5.)

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[12] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 50–49, 1905; Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, pp. 134–139, 1905.

Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 393–397, 401–402, 1905.

Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, 1911.

Moffit, F. H., The Iniskin-Chinitna peninsula, Alaska; U. S. Geol. Survey Bull. — (in preparation).

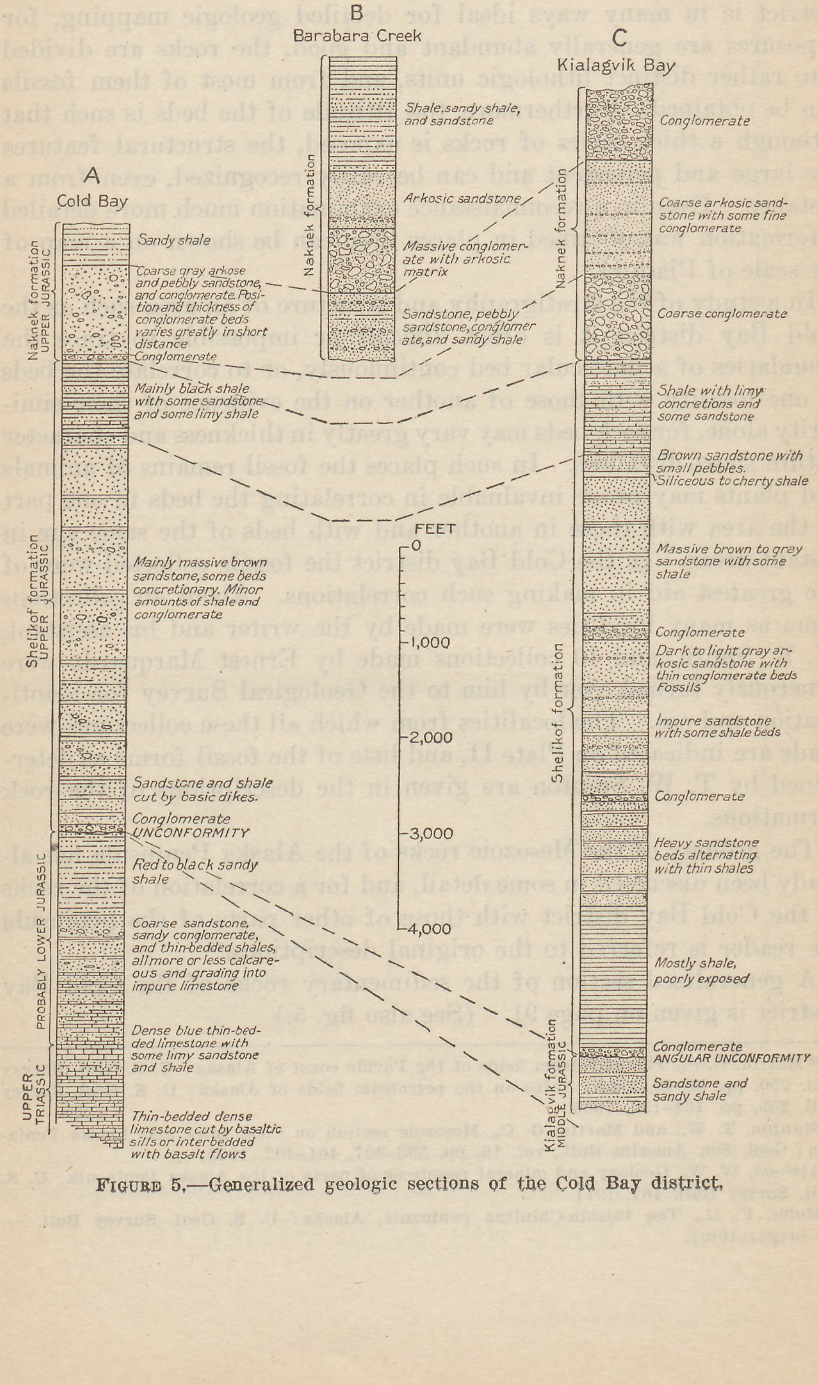

FIGURE 5.—Generalized geologic sections of the Cold Bay district.

Generalized section of the sedimentary rocks of the Cold Bay district.

	Feet.
Upper Jurassic:	
Naknek formation (conglomerate and arkosic sandstone from 1,000 to 3,000 feet thick, overlain by sandy shale)	5,000+
Shelikof formation (700 to 1,000 feet of black shale, with some limestone lenses at top, overlying a thick series of sandstone, with minor amounts of conglomerate and sandy to calcareous shale; carries the Chinitna fauna)	5,000–7,000
Unconformity.	
Middle Jurassic: Kialagvik formation (sandstone and sandy shale at Kialagvik Bay)	500+
Lower Jurassic (calcareous sandstone and sandy shale, with limestone at Cold and Alinchak bays)	2,300±
Upper Triassic (thin-bedded limestone and calcareous shale with basaltic dikes and sills at Cape Kekurnoi)	1,000+

The oldest rocks in the district include Upper Triassic sandstone, calcareous and sandy shales, and limestone, with basalt dikes and sills, that occupy the end of the peninsula back of Cape Kekurnoi, at the northeast entrance to Cold Bay. These rocks are in places highly contorted but in general dip 15°–25° NW. Apparently they either form the northwest limb of an anticline whose crest lies out in Shelikof Strait or are terminated in that direction by a fault. No older rocks are known on the Alaska Peninsula, and in fact these are the only Triassic rocks that have been recognized. Their total area on land is only a few square miles.

Next younger than the rocks of known Triassic age is a series that crops out along the north shore of Cold Bay and consists mainly of sandstone and shale that are in part highly calcareous and in places include beds of impure limestone. These beds are somewhat contorted and faulted, but apparently they lie conformably above the Upper Triassic sandstone. They have yielded fossils that are apparently of Lower Jurassic age. Their area is small, and they have not been recognized except on the peninsula back of Cape Kekurnoi.

Except in the small area of Triassic rocks near Cape Kekurnoi, all the sedimentary rocks of the Cold Bay district are of Jurassic age. Middle Jurassic beds are represented by a narrow belt of sandstone and sandy shale that occur along a part of the northwest shore of Kialagvik Bay, where they appear to lie unconformably beneath the Upper Jurassic beds. Only a part of the Middle Jurassic series that occurs farther north in Cook Inlet, at Tuxedni Bay, is present here, and on Cold Bay Middle Jurassic beds have not been recognized and are probably not present.

In by far the greater part of the Cold Bay district the prevailing rocks are of Upper Jurassic age. The entire thickness of Upper Jurassic beds is at least 10,000 feet and may be considerably more. These rocks have especial economic importance, for it is from them that the oil seepages of the district emerge, and they offer the most promising beds for oil exploration. On the accompanying map they have for convenience been divided into two portions. The lower portion consists predominantly of sandstone and shale and is overlain by a heavy conglomerate that forms the basal member of the upper portion, which also includes conglomerate, arkosic and tuffaceous sandstones, and sandy shale. No sedimentary rocks younger than the Upper Jurassic occur within the area shown on Plate II.

Igneous rocks are rather sparingly represented in this district. Some basaltic dikes and sills or interbedded lava flows occur in the Upper Triassic limestone of Cape Kekurnoi, and basic dikes cut beds of Upper Jurassic age on Cold Bay. On Portage Bay a few dikes also cut Upper Jurassic beds. An area of granitic rocks is reported on the west shore of Becharof Lake, but it was not visited, and its area and outline are unknown. These rocks, however, doubtless cut beds of Upper Jurassic age.

The most recent hard rocks in the district are the lavas and intrusive masses associated with the old volcano Mount Peulik. Nothing definite is known of the age of this volcano except that its lavas broke through Upper Jurassic rocks and were poured out over them. The present form of the mountain, however, and the relation of its lava flows to the topography indicate that the volcanic activity occurred in comparatively recent geologic time and that this volcano is to be correlated with the other volcanic peaks of the Alaska Peninsula, including Mounts Katmai, Douglas, Chernabura, Iliamna, and Redoubt, most of which are still smoking.

SEDIMENTARY ROCKS.

TRIASSIC SYSTEM.

The only known locality in the Alaska Peninsula in which Triassic rocks occur is at Cape Kekurnoi, where a small area extending from Cold Bay northeastward to Alinchak Bay is occupied by beds of this age. This formation includes a thickness estimated as well over 1,000 feet of hard, dense thin-bedded limestone and limy shale, cut by dikes and sills of basalt. There is evidence that some of the bodies of basalt are lava flows interbedded with the sediments, but this was not proved conclusively. Near Cape Kekurnoi the beds are locally much distorted and folded in several directions, and the included basaltic intrusives are metamorphosed and reticulated with a network of calcite veinlets. Farther northwest, along the shores of Cold Bay, the structure is less intricate, and the beds have a general northeasterly strike and dip 10°–20° NW. Calcite veinlets are abundant in the limestone.

Many layers of the limestone abound in fossil shells which consist almost exclusively of the single form *Pseudomonotis.* A collection from this locality was reported on by T. W. Stanton as follows:

10821. No. 1–128. North shore of Cold Bay half a mile northwest of mouth of bay:

Stoliczkaria sp. related to S. granulata (Stoliczka).
Pseudomonotis subcircularis (Gabb).
Upper Triassic.

In proceeding northwestward along the shore of Cold Bay, and so getting higher in the stratigraphic section and above the *Pseudomonotis*-bearing beds, the observer notes that the zone of limestone and calcareous shale gradually gives place to less calcareous and more sandy beds, and some distance farther northwest the sandy beds contain fossils of Jurassic age (fig. 5, A). The Upper Triassic beds are therefore considered to end at the point where the sandy phase begins to appear, but there is apparently perfect conformity between the Triassic and Jurassic beds, the transition having been marked by continuous deposition but a gradual change in the character of the material deposited.

At Alinchak Bay, the next indentation northeast of Cold Bay, the succession as reported by Martin[13] consists of basic igneous rocks at the bottom, succeeded by contorted cherts that have yielded no fossils, and these in turn overlain by shale and limestone yielding *Pseudomonotis.*

JURASSIC SYSTEM.

LOWER JURASSIC SERIES.

The only known Lower Jurassic rocks of this district, and in fact of the Alaska Peninsula, occur near Cape Kekurnoi in a narrow belt that extends from Cold Bay across the narrow pėninsula to Alinchak Bay. The Triassic rocks at the cape, described above, become more sandy and less calcareous northwestward from the highest *Pseudomonotis* zone, although without any observed structural break. The transition from the Triassic limestone and limy shale to impure limestone, calcareous sandstone, and shale is gradual, and it is believed that deposition was here continuous. About 1⅓ miles from the cape a collection of fossils was made

[13] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, p. 58, 1921.

that has been determined by T. W. Stanton as probably of Lower Jurassic age. His determinations are as follows:

10820. No. 1-127. North shore of Cold Bay, 1½ miles northwest of mouth of bay:

Terebratula sp.
Rhynchonella sp.
Leda? sp.
Nucula? sp.
Pleurotomaria? sp.
Several genera of ammonites which in form and sculpture resemble Arietites, Aegoceras, Amaltheus, etc., but which do not show details of sutures and can not be positively identified.

This lot is probably from the Lower Jurassic and older than the oldest fauna from Kialagvik Bay.

The sandstone from which this collection was made and some similar conglomerates for some distance above and below the fossiliferous zone are characteristic in that they contain abundant grains of bright-red jasper and brightly colored greenstone particles, with larger fragments of carbonaceous shale.

Of the total thickness of about 2,300 feet of beds here included in the Lower Jurassic, the lower 1,500 feet is prevailing limestone and limy sandstone and shale at the bottom and prevailingly sandstone at the top. It was in the upper portion that the only fossils were found. Above the portion in which sandstone is dominant there is about 800 feet of beds that consist mainly of black to rusty weathered sandy shales with some thin beds of limestone. It is not certain that these shaly beds belong in the Lower Jurassic, but as they seem to lie conformably on the sandstone, they are here tentatively included with the Lower Jurassic. The shales are overlain by a conglomerate 75 feet thick which is believed to mark an unconformity between the Lower Jurassic and the overlying Upper Jurassic beds. It is possible, however, that these shales are to be correlated with the shales in the lower part of the Shelikof formation, as exposed in the Kialagvik Bay section (fig. 5, C); if so, they are of Upper Jurassic age.

The general structure of the beds above described is monoclinal, with a general northeasterly strike and dips of 10°-25° NW.

MIDDLE JURASSIC SERIES.

KIALAGVIK FORMATION.

The rocks here named the Kialagvik formation occupy a narrow belt along the northwest shore of Kialagvik Bay from a point near the mouth of Pass Creek to the southwest end of the bay. Their extent southwest of the bay is not known. They consist of a few hundred feet of sandstone, sandy shale, and conglomerate that form the bluffs along the beach and extend a short distance inland.

Little is known of the character or thickness of this formation, for the outcrops are scanty and are largely limited to rather widely separated exposures in the shore cliffs, in which massive sandstone, sandy shale, and conglomerate were seen. The exposures are so far from one another that it is not yet possible to construct the stratigraphic section. The contact with the overlying Shelikof formation is in most places concealed on the vegetation-covered benches between the shore and the mountains, but on the shore a short distance east of the mouth of Lee Creek a conglomerate was seen overlying with angular unconformity a series of sandy shales, and this unconformity is believed to mark the contact between the Shelikof formation and the Kialagvik beds. The Kialagvik formation is abundantly fossiliferous, and its fauna is somewhat different from any other known Alaska fauna. It is considered by Stanton to be either the correlative of the basal part of the Tuxedni sandstone of Tuxedni Bay or to be slightly older and is therefore of Middle Jurassic age and represents only the lower portion of the Middle Jurassic. At the type locality of the Tuxedni sandstone there is a thickness of several thousand feet of Middle Jurassic sediments that are not represented in the Cold Bay district. These missing beds may, in part at least, have never been laid down in the Cold Bay district. The presence of an angular unconformity at Kialagvik Bay, however, and the absence of most of the beds of Tuxedni age there and at Cold Bay indicate that there was an erosion interval of considerable duration in the Cold Bay district during Middle Jurassic time, and that some Middle Jurassic beds were then removed by erosion.

The following fossil collections from the Kialagvik formation were identified by T. W. Stanton:

10804. No. 1–104. Kialagvik Bay, about 9 miles northeast of southwest end of bay and 1 mile southwest of mouth of Pass Creek:

- Ostrea sp.
- Anomia? sp.
- Pecten sp., smooth form.
- Pecten sp., ribbed form.
- Pecten sp., large, very coarse ribbed form.
- Lima sp. related to L. gigantea Sowerby.
- Cucullaea increbescens White.
- Grammatodon sp.
- Protocardia sp.
- Venerids?
- Pleuromya dalli (White).
- Thracia? sp.
- Turbo? sp.
- Hammatoceras howelli (White).
- Hammatoceras? kialagvikense (White).
- Harpoceras whiteavesi (White).
- Phylloceras sp.
- Belemnites sp.

The named species in this list were all originally described by White as found in a collection from Kialagvik Bay, probably from the same locality as the present lot. Pompeckj has referred the fauna to the upper Lias, and Hyatt said that the nearest relatives to the fauna are found in the "lowest parts of the Inferior Oolite, in formations placed by many German and French authors in the upper Lias." It is either basal Tuxedni or slightly lower.

10806. No. 1–107. Kialagvik Bay, 3 miles from southwest end:

Pecten sp., ribbed form, same as in lot 1–104.
Inoceramus lucifer Eichwald?
Hammatoceras sp., related to H. howelli (White).
Hammatoceras sp., related to H. variabile (D'Orbigny).

These belong in the same general fauna with lot 1–104.

10807. No. 1–108. Same as 1–107, but 100 yards farther southwest along the shore:

Pecten sp., smooth form.
Lima sp., small costate species.
Pteria sp.
Grammatodon sp.
Trigonia sp., costatae group.
Trigonia sp., glabrae group.
Trigonia sp., clavellatae group.
Cypricardia? sp.
Pleuromya dalli (White).
Pleuromya? sp.
Tancredia? sp.
Cerithium sp.
Hammatoceras sp. related to H. howelli.
Hammatoceras ? sp. related to H.? kialagvikense.

Either basal Tuxedni or slightly lower.

10808. No. 1–110. Shore cliffs on point 2 miles from southwest end of Kialagvik Bay:

Pecten sp., smooth form.
Eumicrotis? sp.
Cucullaea sp.
Trigonia, three species.
Protocardia sp.
Hammatoceras? kialagvikense (White).

Same fauna as 10804.

10809. No. 1–113. On creek that enters Kialagvik Bay from the northwest at southwest end of bay. Lowest collection:

Ostrea sp.
Inoceramus lucifer Eichwald?
Pleuromya sp.
Sonninia? sp.
Belemnites sp.

This little collection permits pretty definite correlation with the lower part of the Tuxedni sandstone. The ammonite *Sonninia* and the *Inoceramus* are both identical with forms in No. 33 of Martin's Tuxedni Bay section (U. S. Geol. Survey Bull. 485, p. 61), which is 250 feet above the base.

11064, 11065. Nos. E–1, E–2. These collections contain only forms found in 10804.

In discussing the above collections as a whole, Stanton makes the following statement:

Lot No. 1–104 from Kialagvik Bay contains the fauna, rich in ammonites, described by C. A. White many years ago from the same locality. Lots 1–107, 108, and 110 also have the same or a closely related fauna. The ammonites of this fauna are all different from those of the Tuxedni sandstone, which also has a varied ammonite fauna, but some of the other mollusks of the Kialagvik Bay fauna are identical with species found in the lower part of the Tuxedni sandstone. A faunal zone in No. 33 of the type section of the Tuxedni sandstone, 250 feet above the lowest bed of the formation there exposed, seems to be pretty definitely represented in lot 1–113, which I am assuming to be higher than 1–104. I judge therefore that lot 1–104 is not much older than the lowest fossiliferous bed of the Tuxedni Bay section and that its horizon may well be included in the Tuxedni formation. I would refer it to the lower part of the Middle Jurassic rather than to the Lias or Lower Jurassic.

UPPER JURASSIC SERIES.

SHELIKOF FORMATION.

Rocks of Upper Jurassic age predominate in the Alaska Peninsula from Cape Douglas to Chignik, and in the Cold Bay district they occupy by far the greatest part of the land surface. Lithologically and on the basis of the fossil fauna these Upper Jurassic beds may be divided into two main divisions, of which the lower is here called the Shelikof formation and the upper the Naknek formation. The Shelikof formation is so named because it is the prevailing rock formation on the northwest shore of Shelikof Strait from Katmai Bay at least as far southwest as Kialagvik Bay, and in the Cold Bay district it forms nearly all the bold headlands and coastal mountains that are visible from the strait. A general idea of the lithology of the Shelikof formation may be obtained from the columnar sections shown in figure 5, A and C. Although the thickness and the relations of its different members vary considerably from place to place, some features are rather constant. Nearly every normal section shows that the uppermost member, lying immediately beneath the basal conglomerate of the Naknek formation, consists of a massive black shale from 700 to 1,000 feet thick which contains some limestone lenses and nodules. This shale is in places sandy and calcareous and is poorly fossiliferous. It has great economic significance in certain areas, for under proper structural conditions it should serve admirably as a cap rock to retain oil or gas.

A number of fossil collections were obtained from this shale and are described by T. W. Stanton as follows:

10791. No. 1–60. About 300 feet below the base of the Naknek on the Bear Creek-Porcupine Creek divide, 5 miles east-southeast of the mouth of Bear Creek:

Terebratula? sp.
Thracia sp.
Jurassic; formation not determined.

10792. No. 1–65. About 200 feet below base of Naknek on Bear Creek-Salmon Creek divide 4¼ miles east-southeast of mouth of Salmon Creek:

Nucula sp. a.
Nucula sp. b.
Pteria sp.
Grammatodon sp.
Thracia? sp.
Dentalium sp.
Amberleya sp.
Jurassic; formation not determined.

10793. No. 1–79. About 300 feet below base of Naknek on shore of Portage Bay half a mile southwest of Kanatak village:

Serpula sp.
Grammatodon, two species.
Nucula sp.
Pteria sp.
Astarte? sp.
Undetermined gastropod.
Belemnites sp., fragment.
Jurassic; formation not determined.

Although the above faunas were not characteristic enough to warrant a close age determination from the fossil evidence alone, the field relations of the shale from which they came admit of no doubt that this heavy shale lies immediately beneath the persistent conglomerate that is believed to mark the base of the Naknek formation, and the shale is therefore included with little uncertainty in the Shelikof formation, which, at least in large part, is to be correlated with the Chinitna shale of Chinitna Bay.

Beneath the heavy shale member just described the Shelikof formation comprises 4,000 to 4,700 feet of beds that consist dominantly of massive brown to gray sandstones, with minor amounts of shale and of conglomerate. In many places the sandstone is concretionary, the concretions ranging from small hard well-rounded spherical bodies a few inches to a foot or more in diameter to large irregular, poorly defined masses with indefinite boundaries. The sandstone and included shale are locally calcareous and are in places so impure that they might well be called sandy shales. The only localities visited where the base of the Shelikof formation was seen are at Cold Bay and on the creeks tributary to Kialagvik Bay from the northwest. On Kialagvik Bay the lower 1,500 feet of the formation is mostly shale, with some limy lenses and concretions. At Cold Bay the lower limit of the formation is placed at a conglomerate below which is 800 feet of shale that has been tentatively placed in the Lower Jurassic, though it may correspond to the basal shale of the Kialagvik Bay section and therefore properly belong in the Shelikof formation.

The characteristic fossil of the Shelikof formation below the upper shale member is the ammonite *Cadoceras*, which correlates the lower part of this formation with the Chinitna shale of Chinitna Bay, of Upper Jurassic age. The following collections of fossils from this formation have been identified by T. W. Stanton:

10787. No. 1. Dry Bay, three-fourths of a mile north of the mouth of Rex Creek, at an elevation of 1,150 feet:

Cadoceras sp., fragment.
Phragmacone of belemnite.
Chinitna shale.

10788. No. 2. East shore of Jute Bay, half a mile south of head of bay:

Terebratula? sp.
Inoceramus sp., young shells.
Jurassic; formation not determined.

10790. No. 1–57. About 3½ miles above mouth of Rex Creek:

Terebratula? sp.
Pleuromya sp.
Cadoceras grewingki Pompeckj?
Chinitna shale.

10800. No. 1–95. About 1½ miles northeast of mouth of Big Creek, a tributary of Kialagvik Bay at its northeast end:

Terebratula sp.
Cadoceras? sp.
Belemnites sp.
Probably Chinitna shale.

10801. No. 1–96. Same as 1–95, but about 1,200 feet higher in section:

Cadoceras sp. related to C. schmidti Pompeckj.
Chinitna shale.

10802. No. 1–98. Shore of Kialagvik Bay 1 mile south of mouth of Big Creek:

Inoceramus sp. related to I. eximius Eichwald.
Belemnites sp., fragments.
Jurassic; formation not determined.

10803. No. 1–101. Kialagvik Bay near Barabara on point 1½ miles south of mouth of Big Creek:

Cadoceras doroschini (Eichwald)?
Belemnites sp., fragment.
Chinitna shale.

10805. No. 1–105. Kialagvik Bay stratigraphically 1,000 feet more or less above 1–104:

Inoceramus sp.
Cadoceras grewingki Pompeckj?
Belemnites sp.
Chinitna shale.

10810. No. 1–114. On creek that enters Kialagvik Bay from the northwest at extreme southwest end of bay. Higher in the section than 1–113:

Cadoceras? sp., a single crushed specimen.
If the genus is correctly identified, it indicates a horizon within the Chinitna shale.

10811. No. 1–115. Same as 1–113, but higher in section:

Grammatodon sp.
Phylloceras sp.

Cadoceras sp., numerous young shells.
Fragment of keeled smooth ammonite.
Belemnites sp.
Chinitna shale.

10812. No. 1–116. Same as 1–115, but higher in section:
Pecten sp., smooth form.
Astarte sp.
Pleuromya sp.
Thracia sp.
Amberleya sp.
Cadoceras wosnessenski Grewingk.
Belemnites sp.
Chinitna shale.

10813. No. 1–117. Same as 1–116 but higher in section:
Pteria sp.
Grammatodon sp.
Cadoceras stenoloboide Pompeckj.
Chinitna shale.

10814. No. 1–118. Shore of Kialagvik Bay, 4 miles from its southwest end; from a loose boulder:
Pecten sp., smooth form.
Inoceramus sp.
Pteria sp.
Pinna sp.
Astarte.
Pleuromya sp.
Amberleya sp.
Cadoceras? sp. with narrow umbilicus.
Belemnites sp.
Probably Chinitna shale.

10815. No. 1–119. Lee Creek, a tributary of Kialagvik Bay, collected 3 miles above mouth of creek:
Pteria sp., single imprint.
Cadoceras sp., imprint of fragment.
The *Cadoceras* indicates that the bed from which it came is in the Chinitna shale.

10818. No. 1–126. North shore of Cold Bay, 4 miles northwest of mouth of bay:
Cadoceras doroschini Eichwald.
Chinitna shale.

10819. No. 1–125. Head of Cold Bay, on west shore three-fourths mile southwest of mouth of lagoon:
Pteria sp.
Pleuromya sp.
Belemnites sp.
Probably Chinitna shale.

10822. No. 3. Head of creek above store, Cold Bay:
Pecten sp., smooth form.
Goniomya sp.
Tornatellaea? sp.
Phylloceras sp.

Cadoceras doroschini (Eichwald)?, probably immature shells.
Cadoceras grewingki Pompeckj?
Chinitna shale.

10824. No. C. Southwest shore of Cold Bay:
Turbo? sp.
Cadoceras doroschini (Eichwald)?
Cadoceras catostoma Pompeckj.
Belemnites sp.
Chinitna shale.

10826. No. E. Creek that enters Cold Bay at store:
Pteria sp.
Not sufficient for determining horizon.

11072. No. M–5. About 3 miles northwest of shore of Kialagvik Bay on creek that empties into bay 4 miles southeast of mouth of Lee Creek:
Pteria sp.
Burrow of a mollusk?
Cadoceras sp., fragmentary imprint.
Chinitna shale.

It will be seen from the above determinations that the portion of the Shelikof formation lying below the upper shale member is definitely correlated with the Chinitna shale of Chinitna Bay, of Upper Jurassic age, and it is believed to be probable that these *Cadoceras*-bearing beds and the overlying 700 to 1,000 feet of shale that together form the Shelikof formation are in a general way to be considered the correlative of the Chinitna shale of the type locality.

NAKNEK FORMATION.

The Naknek formation is extensively developed in the part of the Alaska Peninsula here discussed, though most of its area lies on the Bristol Bay side of the divide. The formation as originally described by Spurr[14] from observations in the vicinity of Naknek Lake and Katmai Bay consists of a series of granitic arkose and conglomerate that he estimated to be about 1,500 feet thick, and these beds are probably exposed continuously from Naknek Lake and Katmai Bay to and beyond the Cold Bay district. As here used, the term Naknek formation includes all the beds in the area mapped (Pl. II) that lie stratigraphically above the Shelikof formation.

The basal member of the Naknek in this district is generally a coarse conglomerate that lies with structural conformity upon the top of the upper shale member of the Shelikof formation. The conglomerate shows great variations in thickness from place to place. At the head of Cold Bay there is a basal conglomerate 70 feet thick overlying the black-shale member of the Shelikof formation and succeeded by gray arkosic sandstone containing scattered pebbles and

[14] Spurr, J. E., A reconnaissance of southwestern Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 169–171, 1900.

some thin beds of fine conglomerate (fig. 5, A). At the head of Dry Creek the conglomerate has thickened to 200 feet, at Bear Creek to about 300 feet, at the head of Portage Bay to 500 or 600 feet, and at the head of Lee Creek to about 900 feet. In most places a massive coarse conglomerate lies directly upon the top of the Shelikof shale. Elsewhere coarse arkosic sandstone or alternating sandstone and thin conglomerate constitute the base of the formation, with the thick conglomerate higher in the section. At the head of Lee Creek (fig. 5, C) a hastily studied section seems to show a lower conglomerate 900 feet thick overlain by about 1,200 feet of arkosic sandstone and conglomerate, which are in turn succeeded by a second conglomerate 800 feet or more in thickness. The Pearl Creek dome shows 1,500 feet of beds that include massive conglomerate, thin-bedded conglomerate, pebbly sandstone, and some shale, with the bottom of the formation not exposed.

The basal conglomerate of the Naknek consists of well-rounded pebbles and boulders of igneous rocks, the most conspicuous of which are gray granite and greenstone, in a matrix of coarse arkosic sand. In some places the boulders are of fairly uniform size. In others large and small boulders are mixed together. Granite boulders several feet in diameter are common, and well-rounded boulders 5, 6, and even 9 feet in diameter were seen. At one place on the trail near the main forks of Becharof Creek, on a débris-covered slope, a body of granite 10 feet wide and 30 feet long projects through conglomerate débris. It looks remarkably like an exposure of granite in place, but no other areas of granite are known for many miles from this locality, and granitic rocks intrusive into the Naknek formation are not known to exist in this district. The granite is of the same composition and texture as that composing the granite boulders that are so abundant in the conglomerate.

The relations of this granite mass to the structure of the surrounding sediments require that it must be either the sharp pinnacle of a granite mass buried by the conglomerate or the broken remnants of a remarkably large boulder. Well-rounded boulders of similar granite as much as 8 feet in diameter lie on the surface not far away, and in view of all the conditions it seems likely that this is an unusually large boulder weathered out from the underlying conglomerate.

The basal conglomeratic phase of the Naknek, which in this district locally includes also some sandstone and sandy shale, appears to correspond closely in position and character with the Chisik conglomerate on Chisik Island and Iniskin Bay, as described by Martin and Katz.[15] Its separation there was based solely on its lithologic

[15] Martin, G. C., and Katz, F. J., Geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 68–69, 1912.

character, for at the type locality, as in the Cold Bay district, these beds are almost devoid of fossils. It is characterized wherever it has been studied by its coarseness and by its great variability in thickness from place to place. It is desirable that this coarse basal phase of the Naknek should be separately mapped in the Cold Bay district, but time for this work was not available in the short field season on which this report is based. On the accompanying map (Pl. II) the basal conglomerate and the associated thinner beds of conglomerate and sandstone are included in the Naknek formation, in accordance with the earlier usage of that formation name.

Above the basal conglomeratic phase of the Naknek there is a variable thickness of light-gray to brownish-gray arkosic sandstone. Observed sections of this portion of the Naknek range in thickness from 500 or 600 feet to 1,600 feet, with an average of perhaps 800 feet. The sandstones generally contain pebbly beds and thin conglomerates, but very little shale. As described by Martin[16] the Naknek on the west shore of Cook Inlet contains arkosic sandstone, conglomerate, shale, and a considerable admixture of tuffs and andesite flows. In the Cold Bay district no igneous flows or tuffs were noted, and arkosic sandstone, derived from the disintegration of a granite mass, predominates in the part of the formation above the basal conglomeratic phase and below the upper sandy phase, described below. The arkosic sandstone is not generally very fossiliferous, but it has yielded enough collections to show that it should undoubtedly be included in the Naknek.

The highest part of the Naknek formation that has been recognized in the Cold Bay district consists of a heavy series of sandy shales that lie above the arkosic sandstone. These shales are well developed between the extreme head of Becharof Lake and Mount Lee, where they have an estimated thickness of 1,200 feet, although their upper part has been removed by erosion. They are believed to have a wide development in the basin of upper Becharof Lake and to extend northeastward into the Kejulik (Garkulik) Valley, as well as in the basin of the Ugashik Lakes. The shales are locally fossiliferous and have yielded many forms of shells, the most common and most characteristic of which are several species of *Aucella*. The collections from the Naknek have been studied by T. W. Stanton, who reports as follows:

10794. No. 1–80. Shore of creek between Lake Ruth and Becharof Lake at upper Indian village:

Pecten sp.
Aucella sp. related to A. bronni Lahusen.
Belemnites sp., fragments.
Phylloceras sp., fragments.
Naknek formation.

[16] Martin, G. C., and Katz, F. J., op. cit., pp. 69–74.

10795. No. 1–82. About 1,000 feet above the base of the Naknek shale 3 miles southeast of Mount Lee and 1 mile west of shore of Becharof Lake:

Aucella sp. related to A. erringtoni (Gabb).
Phylloceras sp.
Crustacean, genus undetermined.
Naknek formation.

10796. No. 1–83. About 1,000 feet above the base of the Naknek shale three-fourths of a mile southeast of 1–82:

Ostrea sp.
Aucella sp. related to A. bronni Lahusen.
Astarte sp.
Amberleya sp.
Phylloceras sp., same as in 1–82.
Perisphinctes sp.
Naknek formation.

10798. No. 1–89. Naknek, 5 miles southeast of Mount Peulik:

Pecten sp.
Astarte sp., same as in 1–83.
Aucella sp. related to A. bronni Lahusen.
Aucella sp. related to A. erringtoni (Gabb).
Turbo? sp.
Phylloceras sp., fragments.
Cardioceras sp. related to C. canadense Whiteaves.
Naknek formation.

10799. No. 1–93. 5 miles south-southwest of Mount Lee:

Aucella sp. related to A. bronni Lahusen.
Pteria sp.
Pleuromya sp.
Belemnites sp.
Naknek formation.

10817. No. 1–122. Southeast shore of Becharof Lake between extreme south end of lake and the fish village:

Pteria sp.
Aucella sp. related to A. erringtoni (Gabb).
Arca? sp.
Phylloceras sp.
Naknek formation.

10823. No. B. Oilwell Creek, Cold Bay:

Aucella sp. related to A. bronni Lahusen.
Naknek formation.

10825. No. D. Five miles northwest of head of Cold Bay:

Aucella pallasi Lahusen?
Naknek formation.

10827. No. 1–130. Two miles southeast of Bellim Bay, Becharof Lake:

Aucella pallasi Lahusen?
Eumicrotis? sp.
Tancredia sp.
Pleuromya sp.
Naknek formation.

11069. No. G–4. On summit of Crooked Creek-Becharof Lake divide:

Aucella sp. related to A. bronni Lahusen.
Naknek formation.

11070. No. G–5. On ridge three-fourths mile north of G–4.

Aucella sp. related to A. bronni Lahusen.
Pleuromya sp.

11073. No. N–2. About 3 miles south-southwest of south end of Ugashik Lakes:

Aucella sp. related to A. bronni Lahusen.

Naknek formation.

QUATERNARY SYSTEM.

The youngest consolidated sedimentary rocks of this district are of Upper Jurassic age, and the only geologic record now remaining here of the long time interval that elapsed between the Upper Jurassic and the Quaternary is to be found in the volcanic rocks of Mount Peulik. It should not be understood, however, that during this long period the Cold Bay district remained a land area and received no sediments. Farther to the southwest, at Herendeen and Chignik bays, there is a considerable thickness of Cretaceous sediments, and both southwest and northeast of the Cold Bay district there are beds of Tertiary age, and it is altogether likely that some of these sediments were once present in the Cold Bay district but have since been removed by erosion.

During Pleistocene time parts of this district were subjected to rather severe mountain glaciation. The limits of the glaciated area have not been determined, and morainal deposits are not conspicuous, but all the larger valleys in the higher mountains show evidence of vigorous glacial scour, and glacial ice once pushed down to the sea in all the bays of this district. Some idea of the development of these ancient glaciers is given by the fact that at one time ice accumulated on the inland slope of the mountains north and west of Portage Bay to so great a depth that although the main glacial movement was northward, into the basin of Becharof Lake, yet one lobe spilled southeastward across Kanatak Pass, at an elevation of about 850 feet. As Lake Ruth, on the inland slope, has an elevation of less than 50 feet above sea level, the glacier that moved into Becharof Lake must have been over 800 feet thick at Lake Ruth. The numerous islands in upper Becharof Lake are reported to consist chiefly of morainal material, and it is probable that glacial ice filled the Becharof Lake basin at least as far north as Severson Peninsula.

There are no glaciers now remaining in the area shown on Plate II, but in the high mountains southeast of the head of Kialagvik Bay there are many vigorous ice tongues, some of which are several miles long.

In addition to the morainal deposits, the materials of Quaternary age include the present stream gravels and beach deposits of sand and gravel. The rugged shore of the district is for the most part now subject to wave erosion, and erosion is more prominent than deposition. The shore line is a succession of wave-cut cliffs below which there is in most places a sand and gravel beach visible at low tide. At many places, however, sheer cliffs descend into the water with no beach visible, even at low tide. The only beach deposits of considerable area are at the heads of the bays, where the shores are somewhat protected from the violence of the waves, and where the beach sand and gravel merge with the delta deposits of the streams.

IGNEOUS ROCKS.

The only igneous rocks seen in the district, besides the few small dikes and sills that cut the beds of Upper Triassic, Lower Jurassic, and early Upper Jurassic age, are the volcanic rocks at and near Mount Peulik.

The vicinity of Mount Peulik has been a center of volcanic activity from at least the Pleistocene epoch up to comparatively recent geologic time. The mountain itself still retains a striking conical form, only slightly dissected by erosion. This peak, which no longer shows any signs of activity, is on the north edge of a much older crater which is outlined by the two forks of Hot Springs Creek. This older crater is deeply dissected and shows the upturned edges of the Naknek rocks, through which the volcano broke its way, forming a nearly circular rim around a central core of diorite porphyry. Over this rim lava flows extend to the east and to the southwest. Mount Peulik itself was not visited but is believed to consist of closely related rocks. It is reported that lavas from Mount Peulik extend north and northeast of the peak, covering a considerable area between the mountain and Becharof Lake. Other volcanoes along the axis of the Alaska Peninsula are reported to consist of rocks ranging in character from diorite to basalt.

It is reported that a considerable area on the west side of Becharof Lake, near the mouth of Featherly Creek, is occupied by granitic rocks, but this locality was not visited, and neither the outlines of the granite area nor the relations of the intrusive mass to the surrounding sedimentary rocks are known.

A specimen of an intrusive rock from Aniakchak Bay, some 50 miles southwest of Kialagvik Bay, proved to consist of quartz diorite porphyry containing abundant laths of hornblende. It is apparently intrusive into Jurassic sediments.

Near the head of Portage Bay a dike that cuts the Shelikof and Naknek formations is composed of diorite, in places heavily impregnated with small cubes of pyrite. The oxidation of the pyrite has locally stained both the dike and the inclosing sediments to a rusty red.

The igneous rocks near Cape Kekurnoi consist of dikes and sills of basalt that cut the Triassic, Lower Jurassic, and Shelikof (Upper

Jurassic) beds. The field relations suggest that some of the basalts may be lava flows interbedded with the Triassic limestones.

INDICATIONS OF OIL.

For many years it has been known that the Cold Bay district contains indications of the presence of petroleum, and it was these surface evidences that led to the staking of many claims and to the drilling of several wells near Cold Bay in 1903 and 1904. Plate II shows the location of these oil seepages that were visited or that were reported on reliable information. It will be noted that all these seepages occur along two structural uplifts—the anticline that extends from Salmon Creek northeastward to Rex Creek and flattens out at the northeast end, to be continued by the Dry Creek fault, and the Ugashik Creek anticline, in the vicinity of Pearl Creek, often called the Pearl Creek dome.

The most frequently visited seepages are those on the head of Oil Creek, about 5 miles west of Cold Bay. Here the largest seepage emerges from a smooth vegetation-covered slope in which no rock outcrops can be seen. The oil, accompanied by an abundant flow of water and considerable gas, bubbles forth as a strong spring, the surface of which is coated with a thick layer of brown oil. A rough estimate placed the volume of the oil flow at about half a barrel a day. The gas flows by heads and is of sufficient volume to support a strong flame for several seconds at a time. From this seepage the escaping water and oil flow down a long grassy slope in which most of the oil is entrapped. Similar conditions have existed for a long time, with the result of building up a large area of the less volatile paraffin residue of the oil, which has now hardened to a stiff, putty-like consistency. This residue, intimately intermixed with vegetation, covers an irregular but roughly triangular area, the base of which is 450 feet across and the long sides about 600 feet, in which the residue is from 1 to 6 feet thick. The material is stiff enough to bear a man's weight but soft enough to yield considerably under foot. This residue was utilized in 1903–4 as boiler fuel for the well rigs, and it is reported that the results were satisfactory. It will thus prove a valuable source of fuel for future drilling operations, at least until sufficient gas has been developed to supply fuel for the boilers.

A short distance below the Oil Creek residue patch a number of oil seepages emerge from Shelikof sandstone along the banks of Oil Creek. The quantities of oil emerging are small, and the disturbed condition of the outcrops makes it difficult to decipher the larger features of rock structure. It is apparent, however, that the locality in the vicinity of the seepages lies at about the point where the persistent northwest dip of the upper part of the Shelikof and the

Naknek formation gives way to a flattening or even slight southeast dip, and erosion has been deep enough to expose certain beds of the Shelikof formation in which there has been some concentration of oil. Oil-impregnated sands of the same formation crop out abundantly on upper Trail Creek.

A small oil seepage is reported in the valley of South Fork of Rex Creek, and another in a gulch tributary to Bear Creek from the northeast. On upper Salmon Creek a small quantity of heavy brownish-black oil appears in the stream gravels a short distance from the sandstone bluffs that border the stream flat. The location of these seepages is shown on Plate II. Although they all lie on the Bear Creek-Salmon Creek anticline, they are not on the crest of the fold but some distance down on the flanks. This indicates that the concentration of oil from which these seepages come is not in beds that lie below the lowest rocks exposed on the crest of the fold but is in sandstone beds some distance stratigraphically above the rocks exposed on the crest of the anticline in the valleys of Bear and Salmon creeks. A discussion of the possibility of commercial oil pools existing in this anticline is given in another section of this report.

The only other area in this district in which oil seepages are known to occur is in the so-called West field, in the headwater drainage area of Ugashik Creek, generally called the Pearl Creek dome. There, on the north side of Barabara Creek, near its mouth, is a large patch of residue similar in size and character to that on the head of Oil Creek. The point of emergence of the oil, of which the residue constitutes the less volatile remainder, was in a small tributary gulch, and from that point the residue extends down the gulch and out into the main valley a distance of about 1,200 feet, covering an area of about 1 acre. Its thickness was not determined but is doubtless irregular, being influenced by the irregularities of the surface on which it has accumulated. A small drainage line that runs through the residue contains depressions in which the water is covered with thick dark-brown oil, but no point could be located from which the oil could be seen emerging. This residue is somewhat softer than that on Oil Creek and like it contains a large percentage of vegetable matter as an impurity. The exposures of the bedrock near the residue are poor, but it is certain that the oil emerges from sandy or conglomeratic beds of the Naknek formation.

Another small patch of residue on the Pearl Creek dome occurs in the valley of Pearl Creek about 1 mile northeast of the large patch just described. It has an area of about 3,000 square feet and probably has a maximum thickness of not more than a few feet. The material closely resembles that on Barabara Creek. No oil was seen emerging from the rock, but a thick brown oil in considerable quantities oozes from the residue and flows down the creek. Several other small seepages are reported to occur in the valley of Pearl Creek near the residue but were not seen. The bedrock near the seepages consists of pebbly sandstone overlain by massive conglomerate, all belonging to the Naknek formation.

GEOLOGIC STRUCTURE.

PRINCIPAL FEATURES.

It is now generally recognized that there is a close relation between geologic structure and the accumulation of commercial petroleum pools, and that intelligent prospecting for oil, especially in unproved fields, can be done only after a close scrutiny of the character and structure of the rocks. In the present investigation, which was made primarily for the purpose of studying the possibility of valuable oil pools in the district, special attention was given to the structural features. It is outside the province of this paper to discuss in detail the types of geologic structure that have elsewhere been found to favor oil accumulation, but it may be stated that in this area the features most likely to contain oil pools of importance are domes, anticlinal folds, monoclines containing lenticular sands, terraces on monoclines, and important faults. The domes and anticlines should be first tested, and if they prove productive, drilling may be justified on structural features of other types. No sharp definition has been drawn to differentiate a dome from an anticline, for an anticline may have domes upon it, and a dome may merge into an anticline. Both, however, are the result of compression of the underlying rocks, which have yielded by bulging upward. If the fold so produced is long and a line drawn along its crest is a nearly straight line it is called an anticline. The term "dome" is self-explanatory, the bulge being oval or circular in general outline, with the beds dipping away from the center in all directions.

One of the most prominent structural features in this district is the anticline that crosses the headward basins of Salmon and Bear creeks into the valley of Rex Creek and is continued to the southwestward by the Kialagvik Bay anticline and to the northeastward by the Dry Creek fault. This fold is well exposed along the valleys of Bear and Salmon creeks, both of which cut across the anticline at right angles. On the northwest limb the beds dip uniformly to the northwest at angles of 12° to 15° as far as the head of Becharof Lake, which lies along the axis of a syncline, a distance of 8 miles. The southeast limb has much gentler dips and extends only 2 or 3 miles from the crest of the anticline before it is interrupted by a flattening or reversal of the dips.

South of the Salmon Creek basin this anticline plunges sharply to the southwest, beneath Portage Bay, but it rises again at Kialagvik Bay, which lies along the axis of the fold. To the northeast the fold flattens out in the basin of Rex Creek and is inconspicuous between Rex Creek and the head of Becharof Creek. At the low pass in which Becharof, Trail, and Dry creeks head compression similar to that which caused the formation of the Bear Creek-Salmon Creek fold started the formation of an anticline, but to the northeast this compression resulted in a fault. The Dry Creek fault probably had its greatest displacement at its intersection with the west shore of Cold Bay, where the base of the Naknek formation is displaced at least 2,500 feet, the northwest side of the fault having moved relatively upward. The fault plane appears to be almost vertical. This fault apparently dies out near the head of Dry Creek, and to the northeast it probably splits somewhere in Cold Bay, as two faults are apparent on the northeast shore of the bay.

BEAR CREEK-SALMON CREEK ANTICLINE.

The rocks exposed along the crest of the Bear Creek-Salmon Creek anticline comprise the sandstones and sandy shales of the Shelikof formation, with beds of the Naknek formation lying on the north limb. Near Cold Bay a few outliers of the basal part of the Naknek occur on the southeast side of the Dry Creek fault. The columnar section of the rocks at Cold Bay (fig. 5, A) shows the general stratigraphic sequence as exposed on the northwest shore of Cold Bay. The oil-saturated sands of upper Trail Creek lie in the Shelikof formation, a few hundred feet below the base of the heavy shale member that forms the top of the formation. The oil seepages at the head of Oil Creek emerge from the same sandstones, though at a somewhat lower stratigraphic horizon. The seepages on Rex, Bear, and Salmon creeks also all emerge from the sandstones of the Shelikof formation, though from a much lower part of it. On Bear and Salmon creeks the lowest beds exposed are approximately 5,000 feet stratigraphically below the base of the Naknek formation, and the oil seepages are about 4,000 feet stratigraphically below the base of the Naknek and 1,000 feet, more or less, above the lowest exposed beds. It is therefore apparent that if the oil-saturated sandstones of upper Trail Creek represent the horizon at which an accumulation of oil occurred, then the source of the oil seepages on Bear and Salmon creeks is much lower in the stratigraphic section. On Bear and Salmon creeks the beds at the horizon of the oil-bearing beds of both Trail and Oil creeks are so thoroughly exposed that any commercial oil accumulations that may once have existed there must have long ago escaped. The only chance of obtaining oil at this locality is therefore to find a lower oil sand than any yet known. Although the stratigraphic section shows great variability in the thickness of the formations from place to place, yet a study of the sections as exposed at Cold and Kialagvik bays (fig. 5, A, C) indicates that erosion on Bear and Salmon creeks has exposed the beds of the Shelikof formation well down toward its base. Furthermore, the lower 1,000 feet or more of the Shelikof formation at Cold and Kialagvik bays is composed predominantly of shale and would therefore not be expected to contain large accumulations of oil. In this district no evidences of oil have been found below the Shelikof formation. It is not intended to intimate here, however, that oil may not be found in lower formations On the west side of Cook Inlet, near Oil Bay, petroleum seepages emerge from the Tuxedni sandstone. The only place in the Cold Bay district where beds of Tuxedni age appear is at Kialagvik Bay, where only the lowest part of the Tuxedni formation appears to be represented in the Kialagvik formation. On Cold Bay the entire Tuxedni formation is missing. Whether or not the Tuxedni formation is represented below the Bear Creek-Salmon Creek anticline is not known, but probably most of it is missing there. Next lower than the Tuxedni is the Lower Jurassic, of which about 2,300 feet is exposed on Cold Bay. The upper 800 feet of this formation is composed of sandy calcareous shale with a few thin beds of limestone. The lower 1,500 feet is prevailingly limy sandstone at the top and limestone and limy sandstone beneath. At Cold Bay these beds show no evidence of being oil bearing. Below them lie the Triassic limestone and shale, which at Cold Bay are too dense and too lacking in pore space to offer a reservoir for the accumulation of petroleum in quantity.

The immediate vicinity of the patch of residue and the oil seepages of upper Oil Creek does not appear to have particularly favorable prospects of containing large oil pools, though there is a chance that such pools exist there. The monoclinal beds that dip very uniformly 12°–15° NW. from the head of Becharof Creek to Becharof Lake give way at the heads of Trail and Oil creeks and as far to the southwest as Rex Creek to nearly flat-lying beds. At the head of Dry Creek there is a slight anticlinal fold, with the southwesternmost outlier of the Naknek formation lying in the trough of a small syncline. This anticline is short and is narrow on its southeast limb, though the northwest limb extends far out toward Becharof Lake. The anticline apparently does not extend southwestward across the trail, and to the northeast it is continued by the Dry Creek fault. The beds at the horizon of the oil-saturated beds in the Shelikof sandstone on Trail Creek are exposed on Dry

Creek, so that any oil concentrations there must occur at a lower stratigraphic horizon than the oil showings on Trail and Oil creeks. No seepages were seen or reported on Dry Creek.

If it is shown that considerable concentrations of oil occur far down in the Shelikof formation, there is a possibility that oil pools may be found on the northwest side of the Dry Creek fault. The maximum observed displacement of that fault, at the west shore of Cold Bay, is about 2,500 feet, and the upper 2,500 feet of the Shelikof formation is there exposed. No oil indications were seen there, and any oil that may have existed in the upper 2,500 feet of the Shelikof beds at that place has had ample opportunity to escape. It is possible, however, that some lower oil-bearing bed, beneath an impervious shale, has been sealed off at the fault against the thick shale at the top of the Shelikof formation.

KIALAGVIG BAY ANTICLINE.

The Kialagvik Bay anticline is a continuation of the same general structure as that which makes up the Bear Creek-Salmon Creek anticline and the Dry Creek fault, but it is separated from the Bear Creek-Salmon Creek fold by an interruption at Portage Bay. The ends of the Kialagvik Bay anticline were not examined in detail, and little is known concerning their structure. No folding is conspicuous along the west shore of Portage Bay, in line with the anticlinal axis. Farther southwest it could be seen that the anticlinal structure extends several miles beyond Kialagvik Bay, but no examination was made beyond the borders of the area mapped (Pl. II).

As seen from the shore of Kialagvik Bay it is apparent that the axis of the Kialagvik Bay anticline lies between the shore and the line of islands that nearly incloses the bay. The islands, which were not visited, can be plainly seen to consist of sediments that dip to the southeast. The prevailing dips on the mainland are to the northwest. It is highly probable that the islands are composed of the rocks of the Shelikof formation. All the rocks exposed along the shore from the vicinity of Lee Creek to the southwest end of the bay belong to the Kialagvik formation, of Middle Jurassic age, and are therefore older than any other rocks of the district except the Lower Jurassic and Triassic beds that occur only in a small area at Cape Kekurnoi. The Kialagvik formation, as has been shown, is probably the equivalent of the lowest part of the Tuxedni formation of Cook Inlet and is of Middle Jurassic age. Its base is not exposed. It is overlain to the northwest by more than 6,000 feet of beds of the Shelikof formation, which is in turn overlain by the Naknek formation.

Little information is at hand upon which to base an opinion concerning the oil possibilities of the Kialagvik Bay anticline. The

Tuxedni formation contains oil seepages at Oil Bay, but they emerge from beds at a higher stratigraphic horizon than is represented by any part of the Kialagvik formation. It is not known how thick the Kialagvik formation is below the lowest exposures on Kialagvik Bay, nor what beds would be reached by the drill below the Kialagvik formation. It can only be stated that if strata sufficiently porous to form a reservoir for oil exist below the exposed portion of the Kialagvik formation and have an impervious cover, the structural conditions at Kialagvik Bay are favorable for the accumulation of oil.

UGASHIK CREEK ANTICLINE.

A strongly developed anticline roughly paralleling the Kialagvik Bay and Salmon Creek-Bear Creek folds but 8 to 14 miles inland from them occurs in the drainage basin of the Ugashik Lakes. It extends from Mount Burls, between upper Becharof Lake and Mount Peulik, southwestward for at least 15 miles, crossing the basins of Ugashik, Crooked, and a number of smaller unnamed creeks. Near its northeast end this anticline, which as a whole is here called the Ugashik Creek anticline, is sharply domed, and that part is commonly referred to as the Pearl Creek dome. On this dome there are two patches of oil residue and several seepages. The Ugashik Creek anticline apparently flattens out to the northeast, beyond Mount Burls, and although it has been traced continuously for 15 miles to the southwest, its amplitude diminishes in that direction, and it apparently fades out somewhere between the west end of Kialagvik Bay and the head of the Ugashik Lakes. The entire area of this anticline is covered by rocks of the Naknek formation, except in the vicinity of Mount Peulik, an old volcano that has broken through the Jurassic sediments and has a core of dioritic material, with some andesite lava flows that were poured out over the Naknek formation. Mount Peulik is on the northwest flank of the anticline and is a comparatively young cone standing on the rim of an older crater that is roughly outlined by the forks of Hot Springs Creek. The eruptions that formed this old crater, breaking through the northwestward-dipping Jurassic beds, bowed them up around its margin and so interrupted at that place the prevailing northwesterly monoclinal dips.

The Ugashik Creek anticline as a whole is a symmetrical fold, the beds on the northwest flank dipping 12°–14° NW., toward the Ugashik Lakes, and those on the southeast flank dipping about 12° SE., toward Becharof Lake. At the Pearl Creek dome the southeast limb extends for about 5 miles to the synclinal axis in upper Becharof Lake. Farther southwest, as the size of the fold diminishes, the anticline and the syncline converge. The northwest flank has not been completely outlined but probably extends to a syncline in the Ugashik Lakes.

The Ugashik Creek anticline, on which no wells have yet been drilled, gives promise of containing oil in commercial quantities. The accompanying topographic map of a part of the Pearl Creek dome (fig. 6) was made and generously furnished by Mr. Ernest Marquardt and shows accurately the topography of the central por-

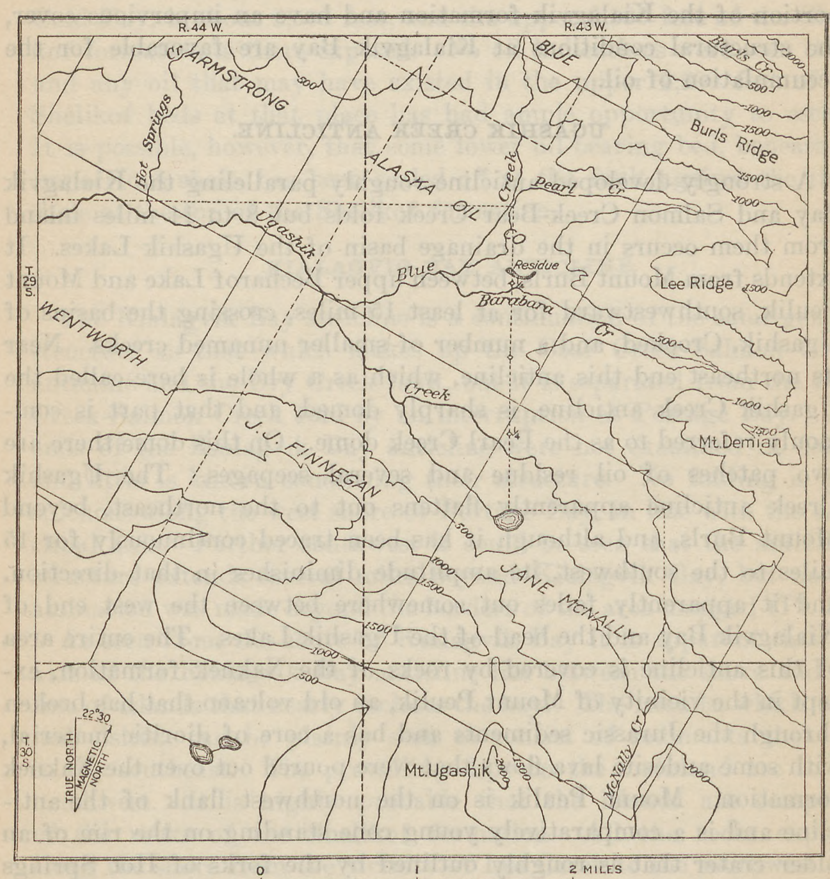

FIGURE 6.—Topographic map of Pearl Creek dome. By Ernest Marquardt.

tion of the dome. Here, where the lowest beds along the axis of the fold are exposed, seepages emerge from the conglomeratic sandstone that forms the lowest part of the Naknek formation exposed, but the base of the Naknek does not appear at the surface. It is of course important to determine the thickness of the Naknek beds that remain to be penetrated by the drill on the top of the Pearl Creek dome, but the problem involves certain unknown factors which can not be accurately determined in advance of drilling. From the hasty study of this area that was made in the field, it appears that the point within the dome at which the underlying Shelikof formation approaches nearest to the surface is on Barabara Creek about 2 miles above its mouth, or about 1 mile above the lower end of the residue patch. The stratigraphic horizon at that place is about 1,500 feet below the top of the massive conglomerate of the Naknek. This conglomerate, which probably corresponds to the Chisik conglomerate of the Cook Inlet section, normally occurs at the base of the Naknek formation. In the Cook Inlet field it has a maximum thickness of 400 feet or more and thins out to nothing laterally. In the Cold Bay district its variability in thickness and character is even more striking. At Cold Bay this basal conglomerate is about 70 feet thick and is underlain by the Shelikof formation, of which the upper 800 feet is shale. From Cold Bay to Portage Bay the basal conglomerate increases to about 600 feet in thickness, and in the Kialagvik Bay section, at the head of Lee Creek, it is about 900 feet thick and is apparently overlain by about 1,200 feet of coarse, pebbly sandstone, which is in turn overlain by another massive conglomerate about 1,000 feet thick.

If this hastily studied section is correctly interpreted, there seem to be two very heavy conglomerates separated by about 1,200 feet of pebbly sandstone, and this whole assemblage corresponds to the 70-foot conglomerate at Cold Bay. It is apparent, therefore, that, with a variation in thickness of more than 3,000 feet in 36 miles, any estimate of the total thickness of the coarse basal beds of the Naknek formation on the Pearl Creek dome, at a distance of 10 miles from the nearest outcrop of the underlying Shelikof formation, can be little better than a guess. At a well location 1,500 feet stratigraphically below the top of the basal conglomerate of the Naknek the depth to the upper Shelikof shale may not be great, or it may be as much as 1,500 feet if the section corresponds to that on Lee Creek and if the Lee Creek section has been properly interpreted. Once in the Shelikof formation the drill should penetrate 800 to 1,000 feet of shale, below which the Shelikof sandstones should be reached. It seems likely that there are oil-bearing beds in these sandstones. Oil-saturated sands of this formation occur on Trail Creek not far below the base of the shale, and the oil seepages of Oil Creek emerge from them. It would be wise, therefore, for anyone preparing to drill on the Pearl Creek dome to be equipped to drill to a depth of at least 3,000 feet, although there is a good chance that oil-bearing beds may be encountered at considerably shallower depths.

If commercial oil pools exist on the Ugashik Creek anticline, wells drilled on the Pearl Creek dome should demonstrate that fact, for conditions there are most favorable for the concentration of oil. When it has been shown that this dome contains commercial oil pools, other parts of the anticline may be worth drilling. The log of a well on the dome should give highly valuable information as to the thickness of the basal conglomerate of the Naknek formation in that vicinity and the depth within the Shelikof formation of the oil-bearing beds. With that information in hand, a geologic study of any particular well site should furnish a fairly accurate estimate of the depth of the oil sands at that place.

CONCLUSIONS.

Geologic surveys have been made of only a relatively small area in the Cold Bay district, and these are only of a reconnaissance type. Some of the dominating structural features in the district are described above, but few structural details have been determined. There is almost no information at hand in regard to the structure in the unsurveyed part of the district. The oil seepages in the Cold Bay district have been described; others are reported in adjacent parts of the Alaska Peninsula. There appears to be definite evidence of an oil seepage on Aniakchak River, 60 miles south of Cold Bay. The reports of oil seepages near Chignik Bay have not been officially verified.

The outlook for the finding of petroleum in commercial quantities in this general region is good, because certain structural features in this district and probably in other parts of the Alaska Peninsula are favorable for the accumulation of oil and are of dimensions indicating the possibility that they may contain large oil pools.

THE INISKIN BAY DISTRICT.[1]

By Fred H. Moffit.

INTRODUCTION.

The district described in this paper is on the west side of Cook Inlet between Iniskin and Chinitna bays. It is a peninsula with an area of about 150 square miles separated from the mainland mountains on the west by a narrow valley extending from the right arm of Iniskin Bay northeastward to the head of Chinitna Bay. For convenience it may be called the Iniskin-Chinitna Peninsula. Seldovia, on the southwest end of Kenai Peninsula, is directly across Cook Inlet from Chinitna Bay and is the nearest white settlement and post office except Iliamna, a native village on Iliamna Lake.

Oil Bay, on the south side of the Iniskin-Chinitna Peninsula, at one time received considerable attention because of its petroleum seeps and was the scene of drilling for a number of years. Shortly before the Alaskan oil lands were withdrawn from entry in 1910 the oil properties were abandoned, and no further attention was paid to them till the new leasing law was passed in 1920. This law renewed interest in the district, so that much ground was restaked, and it became necessary, in order to carry out the provisions of the law, to collect information regarding the areal geology and structure of the area likely to be prospected for oil.

Oil Bay was visited by Martin in 1903 and by Martin and Stanton in 1904, and the results of their work, published in different papers from time to time, have been summarized by Martin[2] in a recent bulletin.

The investigations of the summer of 1921 on the Iniskin-Chinitna Peninsula include surveys by C. P. McKinley for a topographic map to be published on the scale of about 1 inch to the mile and a study of the areal and structural geology of the same area by Arthur A. Baker and the writer.

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[1] This paper is a preliminary report on surveys made in the Iniskin Bay district in 1921. A more detailed report containing the topographic and geologic maps resulting from these surveys is in preparation.

[2] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, 1921.

The Cook Inlet side of the peninsula (Pl. III) is bordered by a curving belt of rugged mountains extending from Chinitna Bay to Iniskin Bay and decreasing from a maximum height of 3,130 feet on the north to 2,410 feet on the south. The west side is bordered by a lower, less rugged belt extending about north-northeast. The central area is occupied by rounded hills. Three principal streams heading near the center of the area take care of most of the drainage. Bowser and Brown creeks cut through the coast mountains at Oil and Dry bays, and Fitz Creek flows northward into Chinitna Bay.

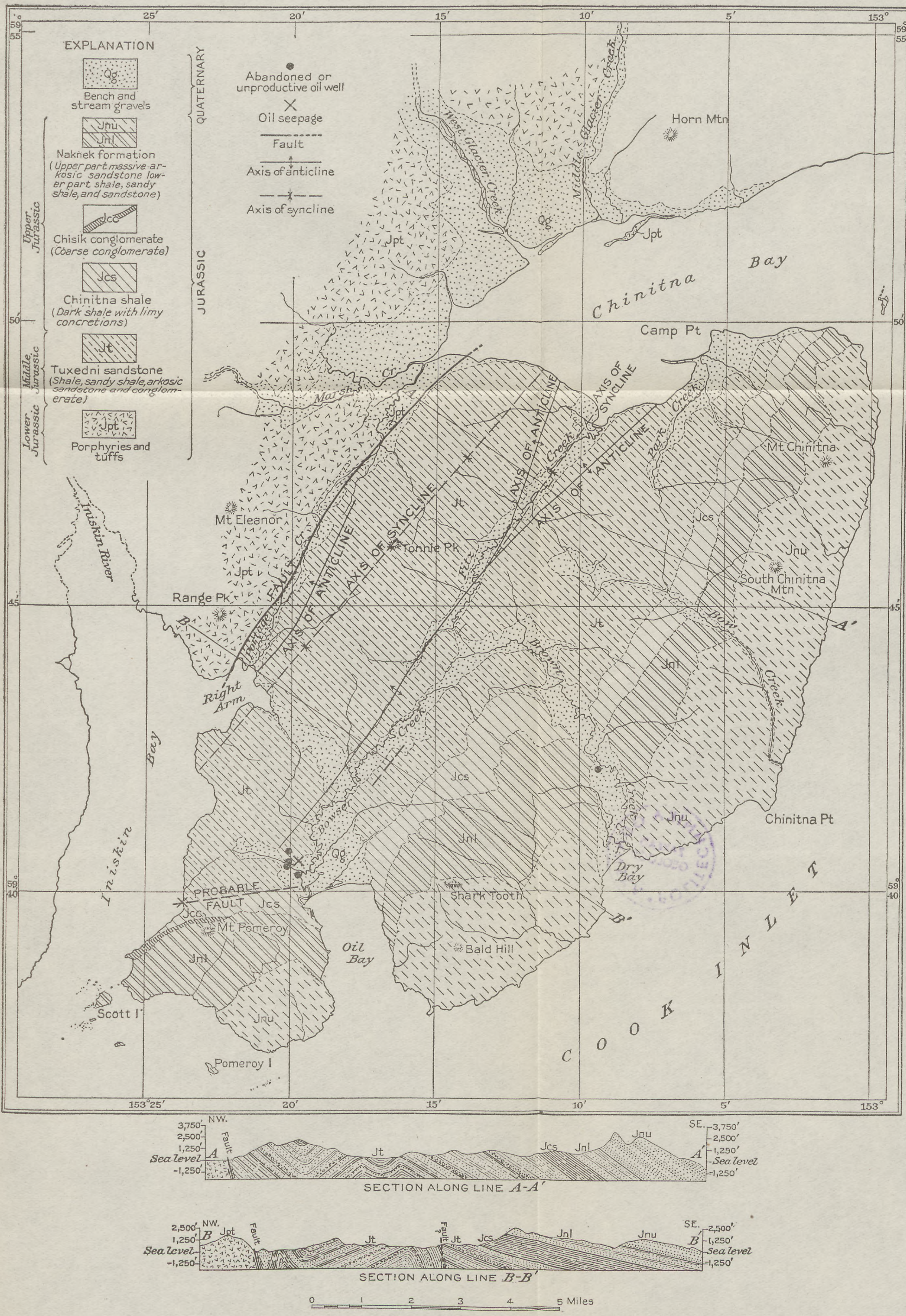
At present the peninsula is without roads or trails, for those established during the time of the earlier oil excitement are now grown up to alders and willows or are washed out by the streams. Some of the old trails, however, could be reestablished without great labor or expense. The peninsula not only is without trails but is inconvenient to reach because it lacks direct steamship communication. Iniskin Bay has deep water with protection for vessels on its lower west side and is the only place where vessels can enter and discharge freight, for Oil Bay and Chinitna Bay are both shallow and Dry Bay is a mere indentation in the shore line.

Spruce timber sufficient for local demands is present in the interior valleys and in places is of excellent quality. Many fine trees were seen in the vicinity of Oil Bay. Piling for fish traps and the wharf at the cannery on Chisik Island have been cut on Chinitna Bay for a number of years. Cottonwood also grows in the district but is not likely to have much value for building or similar uses. All of the peninsula is abundantly supplied with grass suitable for pasture and for hay, so that during the days when drilling was in progress at Oil Bay native grass was cut and cured as winter feed for horses.

GEOLOGY.

OUTLINE.

The rocks of the peninsula between Iniskin and Chinitna bays are almost exclusively marine sedimentary deposits but are composed of clastic material derived in large part from older igneous rocks, among which granite and related granitic rocks were abundant. The sedimentary rocks are cut by a few dark-colored dikes or are intruded by light-colored sills and are separated by a great fault from the volcanic rocks of the mountains between the heads of the two bays. Named in the order of their age from the oldest to the youngest, they are the Tuxedni sandstone, which is Middle Jurassic, and the Chinitna shale, Chisik conglomerate, and Naknek formation, which are Upper Jurassic.



GEOLOGIC MAP OF INISKIN-CHINITNA PENINSULA.

By F. H. Moffit.

The Tuxedni sandstone is composed of sandstone, arkose, conglomerate, and sandy shale and reaches a thickness of probably 8,000 feet. In the lower part of the formation the sandstone and other coarser-grained beds predominate over shale, but in the upper part shale predominates greatly over sandstone. The shale is commonly more or less sandy except at the top of the formation, where it is argillaceous instead of arenaceous and grades into the overlying Chinitna shale.

The Chinitna shale is a fairly homogeneous formation of gray, black, and reddish shales with subordinate sandstone and calcareous beds and is approximately 2,300 feet thick.

The Chisik conglomerate overlies the Chinitna shale. This formation in its largest and most typical exposure is 290 feet thick and includes boulders and cobbles of igneous rock, especially granitic rocks. It is of variable thickness and character, however, and throughout most of the district either is represented by beds of grit and arkose or is absent altogether.

The Naknek formation, which overlies the Chisik conglomerate, includes possibly 4,500 feet of shale and sandstone and is the youngest formation in the district. At its base is about 1,500 feet of shale with subordinate sandstone. This is overlain by beds of white or light-colored sandstone which are the conspicuous cliff-forming rocks of the mountains bordering Cook Inlet in this peninsula.

These four formations succeed one another without structural unconformity so far as is known. They are in places abundantly fossiliferous, so that their age is well determined.

The beds are folded rather closely on the west side of the peninsula near the volcanic rocks of the main mountain chain of the mainland but are less compressed toward the east and dip in a great monocline beneath the waters of Cook Inlet. The strike in general is about N. 30° E. in the central part and west side of the peninsula but is parallel with the coast line on the east side and changes from N. 30° E. near Chinitna Bay to nearly due east on Iniskin Bay.

Deposits of gravel are present along the streams and on the coast, but bench gravels and glacial deposits are uncommon. Erratic boulders of rock not present in the bedrock of the peninsula, however, bear evidence that the glaciers brought in and left morainal material, but apparently the glacial deposits were reworked by streams or the sea, so that typical glacial deposits were not seen.

The character and relations of these rocks are summarized in the following table:

Rocks of the west side of Cook Inlet.

Age.	Formation.	Lithologic character.	Thickness (feet).
Quaternary.		Stream and coastal gravel and sand. Glacial deposits: Sand, gravel, and erratic boulders.	
Upper Jurassic.	Naknek formation.	Massive light-colored sandstone, arkose, and tuff.	3,000
		Gray shale with sandstone beds.	1,500
	Chisik conglomerate.	Massive conglomerate with boulders, possibly represented in many places by grit and arkose.	290
	Chinitna shale.	Fairly homogeneous argillaceous gray, black, and reddish shales with subordinate calcareous and arenaceous beds.	2,300
Middle Jurassic.	Tuxedni sandstone.	Arenaceous gray shale with subordinate sandstone beds. Sandstone, shale, arkosic sandstone, and conglomerate.	8,000
Lower Jurassic.		Volcanic rocks; porphyry and tuff (basaltic and andesitic lavas and tuffs).	1,000?

MIDDLE JURASSIC ROCKS.

TUXEDNI SANDSTONE.

Character and distribution.—The Tuxedni sandstone is not a homogeneous sandstone formation. It consists principally of sandstone and sandy shale but includes also conglomerate, grit, arkose, and, in the type locality, limestone. In general the lower part of the formation shows all the rocks mentioned, but the upper part is made up of sandy shale with which thin beds of sandstone in subordinate amount and rare conglomerate beds are interstratified. A generalized section based on observations of the formation in different parts of the district follows.

Generalized section of the Tuxedni sandstone in the Iniskin-Chinitna Peninsula.

	Feet.
Shale	1,075
Coarse gray sandstone	75
Shale	1,000
Coarse conglomerate.	
Shale	300
Gray sandstone.	
Shale	1,000
Coarse conglomerate	20
Thin shale.	
Heavy sandstone.	
Dark shale	1,200
Fine-grained gray sandstone with small beds of shale and sandy shale	1,500
Conglomerate	30
Sandy beds, including sandstone, sandy shale, and conglomerate. Dark shale, sandy shale, and thin sandstones	1,800
	8,000+

Thickness and structure.—Study of the Tuxedni sandstone during the summer of 1921 shows that the formation is much thicker than earlier work in Cook Inlet seemed to indicate. No single section is known where the thickness of all the beds can be measured consecutively. The evidence of the thickness is therefore obtained from a number of incomplete sections in different localities and is subject to errors arising from incorrect correlation of beds in these sections and also from possible duplication of beds through faulting or folding. Furthermore, the base of the Tuxedni sandstone has never been unmistakably recognized in this district, although the top, determined solely on paleontologic evidence, was seen in a few places. The combined sections from all the localities indicate a maximum thickness of 8,000+ feet for the formation. These figures are large and represent a thickness much greater than the formation attains elsewhere on Cook Inlet, so that some doubt is felt as to their correctness, although they are comparable with the thickness of the overlying Upper Jurassic rocks in that region.

The structure of the Tuxedni sandstone is shown on the map (Pl. III) and is of particular importance to those interested in the problem of finding petroleum in the district, for the known seepages and the holes that were drilled and produced oil or gas are within the area of this formation.

The valley of Portage Creek, extending northeastward from the Right Arm of Iniskin Bay to Chinitna Bay, marks the course of a great fault and the axis of a closely compressed anticlinal fold which meet each other at a slight angle. All the rocks on the west side of the valley, except a small area on the Right Arm, belong in the belt of volcanic rocks bordering the main mountain range. The great fault that brought the Tuxedni sandstone into contact with the volcanic rocks appears to lie on the west side of the anticlinal axis at Right Arm but possibly crosses to the east side in the valley farther north, for it cuts off the west limb of the anticline. The valleys of Bowser and Fitz creeks mark the position of a second anticlinal fold, parallel to and somewhat less compressed than the fold previously described, which extends from a point near the head of Oil Bay to Chinitna Bay. This fold is compound and divides into two minor anticlines in the Fitz Creek valley. East of Bowser and Fitz creeks the Tuxedni sandstone dips toward the coast and passes beneath the Chinitna shale in a monocline that is interrupted in places by small local folds.

The western anticline is hidden on the south by the waters of Right Arm and Iniskin Bay, so that its character there is not known, but the anticline of Bowser and Fitz creeks and the synclinal trough between it and the Right Arm anticline flatten out toward the south and pitch or dip beneath the younger rocks of the mountains between Iniskin and Oil bays. The relation of the Tuxedni sandstone to the Chinitna shale between Iniskin and Oil bays is not simple, however, for faulting disturbs the normal relation and is known from the exposures on Iniskin Bay and the absence of the higher beds of the Tuxedni sandstone. Unfortunately, the low shale hills between Oil and Iniskin bays are so thickly covered with timber and particularly with alders that only scanty information about the faulting was obtained, in spite of the realization that such information may have an important bearing on the accumulation of oil.

Age.—The Tuxedni sandstone is the most highly fossiliferous formation in the district and contains abundant fossils at many horizons. Good collections were accordingly made to supplement those of earlier workers in this and in other localities. On the evidence of all these collections the Tuxedni sandstone is assigned to the Middle Jurassic.

Intrusive rocks.—The intrusive rocks in the Tuxedni sandstone are rare and, so far as they were observed, are confined to the vicinity of Iniskin Bay. They include sills of quartz diorite and basaltic dikes.

Two sills of quartz diorite, one of them 10 feet thick and the other 50 feet thick, were seen on the shores of the Right Arm of Iniskin Bay. The rock is soft, is of a dark greenish-gray color, and is speckled or mottled with small blotches of altered feldspar, but it is so dense and fine-grained that the other minerals can not be identified with the unaided eye. In the surface exposures the rock is weathered and much altered, so that it is soft and breaks easily. The sills crop out on both shores of the Right Arm and are structurally conformable with the beds of sandstone and conglomerate with which they are associated. Under the microscope it is seen that the rock owes its green color to chlorite.

Several dikes cutting Tuxedni beds are exposed on the east shore of Iniskin Bay. They are not conspicuous, for the color of the dikes is much like that of the including shale. The dikes consist of dense fine-grained black basalt and reach a maximum thickness of 10 feet. One small dike, 10 inches thick, is vesicular, and the vesicles are filled with a white secondary mineral resembling heulandite. The microscope shows phenocrysts of feldspar, augite, and olivine in a groundmass of feldspar and augite.

Neither the sills nor the dikes are indicated by topographic features. No direct evidence of their age was found aside from the fact that they are manifestly younger than the Middle Jurassic rocks which they intrude.

UPPER JURASSIC ROCKS.

The Upper Jurassic rocks include the Chinitna shale, the Chisik conglomerate, and the Naknek formation. These formations succeed one another and the Tuxedni sandstone without structural unconformity and form a belt of high mountains, averaging less than 4 miles in width, along the coast of Cook Inlet from Chinitna Bay to Iniskin Bay. About 50 per cent of the area mapped is occupied by Upper Jurassic rocks.

CHINITNA SHALE.

Character and distribution.—The Chinitna shale consists of gray, black, and reddish argillaceous shale, in which are interstratified some sandy and calcareous beds and rare beds of grit. This formation is of fairly homogeneous character and differs from the prevailing shales of the upper part of the Tuxedni sandstone in that it is argillaceous rather than arenaceous, yet the shales of both formations at their contact are similar in appearance and composition and are distinguished from each other on paleontologic and not on lithologic evidence. Lines of fossiliferous concretions indicating the bedding planes are numerous in the lower part of the formation, and in most places where exposures are good they make it possible to determine within narrow limits the boundary line between this and the underlying formation. The upper part of the Chinitna shale, on the other hand, yields few fossils, yet it is characterized by discontinuous thin calcareous beds which are shaped like much elongated lenses and have a conspicuous yellowish color where weathered. These yellowish bands, although present throughout the upper 500 feet of the shale, give much assistance in determining the position of the formation boundary.

The Chinitna shale occupies the intermediate slopes of the landward side of the coast mountains, overlying the Tuxedni sandstone of the foothills and lower slopes and underlying the Chisik conglomerate and Naknek formation, which form the brow and crest of the ridge. It thus appears on the map as a narrow band nowhere more than a mile wide.

Thickness and structure.—The thickness of the Chinitna shale in its type locality, as measured by Stanton, is 2,315 feet, and that of the partial sections on Iniskin and Oil bays is 1,308 feet and 1,294 feet, respectively. The base of the shale is not included in either of these partial sections, yet the thickness represented by them is nearer the thickness of some other sections between Iniskin and Chinitna bays than that of the type section. A section at the head of Bowser Creek gives 1,425 feet as the thickness of the Chinitna shale at this locality.

So far as is known, this figure is not made questionable by folding and faulting, although faulting might be difficult to detect. Such a thickness would contrast strongly not only with that of the type section, but especially with that of the formation on the Alaska Peninsula, where it reaches a maximum of 7,000 feet.

The Chinitna shale nearly everywhere shows a seaward dip, although at one locality a small fold with reverse dips was seen. In general, then, the formation has a monoclinal structure with dips that range from 15° to 35° and strikes that approximate the trend of the coast line.

Age.—The Chinitna shale was at first included by Martin in the "Enochkin formation," together with the Tuxedni sandstone, and regarded as of Middle Jurassic age. Later studies, however, led to the separation of the "Enochkin formation" into two formations and the assignment of the Chinitna, or upper part, to the Upper Jurassic.

This formation is less fossiliferous than the Tuxedni sandstone but yields numerous fossils at some horizons in its lower part, especially certain ammonites, among which several species of *Cadoceras* are predominant. These forms were regarded as diagnostic in mapping the formation boundary.

CHISIK CONGLOMERATE.

Character and distribution.—The Chisik conglomerate is typically a coarse, massive conglomerate made up of cobbles and boulders of granite or diorite and other igneous rocks in a tuffaceous andesitic matrix. The only locality within the area mapped where it is found with the character described is on the east shore of Iniskin Bay and the adjacent mountain, where, as measured by Martin, it reaches a thickness of 290 feet. It lies with structural conformity on the Chinitna shale and is overlain conformably by the coarse sandy beds of the lower part of the Naknek formation.

On the geologic map the Chisik conglomerate is represented as a narrow band extending only part way between Iniskin and Oil bays, for the beds resting on the Chinitna shale on both sides of Oil Bay are grits or fine conglomerate and arkosic sandstone and bear no resemblance to the beds occupying this position on Iniskin Bay. In all other places from Oil Bay to Chinitna Bay where the base of the Naknek formation was examined the beds consist of coarse arkose and fine grit. It therefore appears that the Chisik conglomerate of Iniskin Bay is probably a local phase of the basal Naknek. It is separated from the Naknek on the map because of its lithologic character and its conspicuous outcrops, although a somewhat similar conglomerate of less thickness within the Tuxedni sandstone was not separately mapped. Blocks of the conglomerate have fallen from the cliffs on the east shore of Iniskin Bay and have been worn by the sea waves into the peculiar shapes that gave them the name Mushroom Rocks, a name also applied to certain small islands near the entrance to the bay.

Age.—The Chisik conglomerate has furnished no fossils, but its age is known from the fact that it lies between the Chinitna shale and the Naknek formation, both of which are Upper Jurassic.

NAKNEK FORMATION.

Character and distribution.—The Naknek formation, like the Tuxedni sandstone, includes a heterogeneous mixture of shale, sandstone, arkose, andesitic tuff, and conglomerate and may be separated into a lower and an upper part with distinctive lithology and conspicuous differences as expressed in topography and the landscape. In the area between Chinitna and Iniskin bays the lower part of the formation, ranging from about 1,500 to 1,645 feet in thickness, consists of gray shale with dark arkosic beds and fine conglomerate or grit at the base and thin sandy beds scattered through it. The overlying sediments are white or light-colored sandstones containing an abundance of igneous material, in part tuff, in part clastic material derived from granite or granite-like rocks, and in part intrusive sills. This upper part includes the remainder of the formation as exposed in the district. These rocks are confined to a curving belt from 2 to 4 miles in width and extend along the whole seaward side of the peninsula from Iniskin Bay to Chinitna Bay.

The basal arkosic beds are also made up of material from a land mass where granite or granitic rocks supplied an abundance of waste for the formation of new sediments and are believed to be the time equivalent of the Chisik conglomerate of Iniskin Bay, for no conglomerate comparable to the Chisik conglomerate of Iniskin Bay was seen elsewhere in the district. The thickness of the coarse-grained basal beds is 147 feet on the east shore of Oil Bay and is approximately the same in other places where the beds were examined. Sandy shales with beds of sandstone succeed the basal beds and together with them make up the lower part of the Naknek formation below the light-colored cliff-forming beds. This part of the Naknek reaches a thickness of 1,645 feet in the section measured by Martin at Oil Bay.

The upper part of the Naknek formation is conspicuous wherever it crops out because of its light color and because it resists erosion better than the underlying beds. It forms the dip slope on the seaward face of the mountains along the coast. Its scarp makes the white cliffs along most of the crest of the mountains as seen from the landward side. This part of the Naknek formation reaches a thickness of at least 3,000 feet. The beds are prevailingly hard and massive but in large exposures show distinctly the bedding lines. They include hard arkosic sandstone, andesitic tuff, coarse and fine sandstone, shale, and conglomerate. Thin sills of quartz diorite are intruded into the sedimentary beds and are distinguished from them only on close examination. The strike of beds of the Naknek formation ranges from about N. 30° E. on Chinitna Bay to nearly due east on Iniskin Bay. The dips are everywhere toward the sea and decrease from an average of about 35° on Chinitna Bay to about 15° between Oil and Iniskin bays and on the Iniskin shore. Local variations of dip are found, as at Mount Chinitna, where the beds are tilted to an angle of nearly 45°, but no such high dips were seen in the Naknek formation farther south.

Age.—Fossils are less numerous in the sedimentary beds of the Naknek formation than in the underlying Chinitna shale and Tuxedni sandstone. They are abundant at certain horizons, however, and yield conclusive evidence that the formation is of Upper Jurassic age.

QUATERNARY SYSTEM.

The unconsolidated deposits of the Iniskin-Chinitna Peninsula include coastal-plain deposits, stream and bench deposits, and glacial deposits. The coastal and stream deposits are much more extensively developed than those resulting from glaciation.

Coastal gravel and sand form a narrow band limited by high tide along the outer shores of the peninsula but are somewhat better developed within the bays, where they are protected from the strong currents of the inlet. The marshy flats on the south side and around the head of Chinitna Bay are in part built up of marine shore gravel intermingled with gravel and sand contributed directly by streams and with accumulations of vegetable matter. The flats around Camp Point are of this nature, as are probably also the lowlands at the heads of Oil and Dry bays. Without doubt the sea at no distant geologic time extended much farther into valleys like that of Bowser Creek, probably cutting off the mountains between Oil and Iniskin bays from the rest of the peninsula and leaving marine deposits on the valley floors on its retreat. Deposits of this kind, however, would be subject to more or less redistribution by streams and possibly by glaciers and may no longer remain. No gravel of marine origin was recognized except along the shore line.

Stream and bench gravels are here considered together because the only deposits of bench gravel seen are but a few feet above the level of the near-by streams and were evidently laid down by the streams. Deposits of gravel and sand are less common in this area than in much of interior Alaska and are restricted to the flood plains of the streams and to the adjacent valley floors. The deposits are mostly of local origin but contain erratic boulders, which were doubtless brought to their present resting places by ice moving from the high mountains west of this area. Owing to the rapid weathering of the shale that occupies a large part of the peninsula within the bounding zone of the sandstone at the top of the Naknek formation, the stream and bench gravels contain much argillaceous material and pack down so as to give firm footing for horses, except where they are poorly drained, as in the grass-covered flats at the head of Chinitna Bay. Quicksands were not found in any of the streams traversed during the summer. So far as is known, the stream gravels contain no gold or other valuable minerals. The readiness with which the shale and sandstone disintegrate and the ease with which the resulting loose material is carried away by the streams are probably the principal reasons for the lack of conspicuous gravel deposits in the district.

In spite of the fact that ice must have once covered most of the peninsula, glacial deposits are conspicuously uncommon and were recognized only where foreign material was seen in the local stream gravel. The common topographic expressions of glacial deposits were not observed, although they are evident in neighboring areas and may once have been here.

PETROLEUM.

As far as is now known petroleum is the only mineral resource of the Iniskin-Chinitna Peninsula that offers a possibility of profitable commercial development. In earlier years a few prospectors panned the stream gravel in the search for placer gold and examined the hills in the hope of finding gold lodes, copper, or other metals, but without success. Petroleum seepages, however, were known in the vicinity of Oil Bay many years before the great rush of gold seekers who came to Alaska after the early discoveries in the Klondike, and attempts were made to prove or disprove the presence of an oil pool. The work met with inconclusive results, although a number of wells were drilled, and was finally abandoned, probably from lack of means to continue it.

SEEPAGES.

The indications of petroleum that first directed attention to the possibility of producing oil in this part of the Cook Inlet region are springs or seepages of oil and gas. Many such springs have been reported and have led to the staking of numerous claims in the earlier days, before the oil lands were withdrawn from entry, and again in recent years, after the leasing law of 1920 was passed. An attempt was made to examine all the seepages that have been reported, but in the absence of anyone familiar with their exact location this was not fully accomplished.

Martin reports a strong seepage between high and low tides on the east shore of Iniskin Bay about 1,000 feet below the lower cabin, which produced an intermittent flow of oil, at one place coming from a crevice in the shale of the upper part of the Tuxedni sandstone. No sign of this seepage was seen by the writer, and it is suggested that the seepage either has been diverted or is exhausted.

One of the oil seepages at Oil Bay is at the foot of the hill about 100 feet east of the place where the old road from the cabin starts up the hill to the fourth well. The oil rises in a water spring and collects on the surface of the water in a small pool. At the time it was visited in 1921 not more than an ounce or two of oil could be taken from this pool in a day.

A strong flow of gas bubbling up through water about 2 miles west of Dry Bay was the inducement that led to drilling at that locality.

Oil claims have been staked recently on the shores of Chinitna Bay, where oil seepages are also reported. Although the south shore of Chinitna Bay was examined rather carefully, no seepages were found there by the surveying parties in 1921. Oil springs might easily be missed, however, unless their locations were fairly well known, for the vegetation by midsummer is so rank as to hide them.

The seepages, with the probable exception of the gas spring at Dry Bay, are within the area of the Tuxedni sandstone. Some of them appear to be near or at places where the dip of the sedimentary beds increases toward the coast. Such places would be favorable for the accumulation of oil, but probably the presence of the seepages is more dependent on the fact that they are near places where the rocks are faulted or conspicuously jointed, thus giving an opportunity for oil and gas to escape to the surface.

EXPLORATION FOR PETROLEUM.

Oil Bay and its vicinity were visited by Martin[3] in 1903 and again in 1904 during the time when drilling operations were in progress. Martin's reports on the investigations he then made are the best available source of information on the development of the district and the character of the oil seeps.

Martin states that indications of petroleum were discovered in the Iniskin Bay region in 1853 and that the first samples of petroleum

[3] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 37–49, 1905. Martin, G. C., and Katz, F. J., Reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 126–130, 1912. Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 51–55, 1921.

were taken by a Russian named Paveloff in 1882. A Mr. Edelman staked claims near the heads of Bowser and Brown creeks in 1892, but these claims were not drilled, and apparently no work of any kind was done on them. Pomeroy and Griffen staked claims near the head of Oil Bay in 1896, organized the Alaska Petroleum Co. in 1897, and began preliminary work on the ground in 1898.

Drilling is reported to have been in progress in 1900, although Oliphant[4] says that the well at Oil Bay was started in 1902 after unsuccessful attempts had been made in 1899 to land machinery and in 1901 to begin drilling. Work on the first well was ended in 1903.

Martin was unable to get authentic information about this well but states that it was said to be more than 1,000 feet deep, that gas was encountered all the way below 190 feet, and that considerable oil was found at a depth of either 500 or 700 feet. It seems improbable that the reported flow of 50 barrels a day was obtained, although oil was undoubtedly present. When the well was drilled deeper a strong flow of salt water was met and shut off the flow of oil. Efforts to recover the oil or to drill deeper were not successful. At present water flows from the pipe and gas bubbles continually through it, but practically no oil accompanies the water.

A second hole was drilled in 1904 near the base of a hill three-tenths of a mile northwest of the first well and nearly 400 feet north of the road to Iniskin Bay. When this well had reached a depth of 450 feet it was abandoned because of caving shale. The log of the well, as furnished by Mr. August Bowser, who had charge of the drilling, is as follows:

Record of well No. 2 at Oil Bay.

	Feet.
Sandstone	200
Shale	120
Oil and some gas	1
Shale (caving)	129
	450

A third well was started in the same year almost directly south of the second well and about 150 feet from the road. It was sunk to a depth of 900 feet but was cased for only 630 feet. Caving ground was encountered at 830 feet. At 770 feet three oil sands 6 to 8 inches thick and 4 or 5 feet apart were passed through. It is said that the well produced about 10 barrels of oil a day and had a gas pressure sufficient to blow water into the derrick to a height of 20 feet.[5] Water now flows from the pipe in this well but in less amount than from the first well. A little gas and oil also come up the pipe with the

[4] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1903, p. 691, 1904.
[5] Information furnished by Mr. August Bowser.

water, but the quantity is less than that in the natural seepage at the foot of the hill a short distance to the east.

A fourth hole was started on the low hill half a mile north of the cabin at the first hole. The derrick is still standing, but no information concerning this hole is at hand. The pipe was plugged, and no evidence of oil, gas, or water was seen when the place was visited in 1921. No drilling was done at Oil Bay after 1906, and in 1908 the claims were abandoned.

Drilling operations at Dry Bay began at about the same time as at Oil Bay. They were undertaken by the Alaska Oil Co., which was organized in 1901 and began drilling in 1902. The first well was put down that year, but the tools were lost at a depth of 320 feet without having encountered oil and the hole was abandoned. The well had a diameter of 8 inches to a depth of 212 feet and of 6 inches below that. A second well near the first was started in 1903 but was soon given up because of an accident to the machinery. No other drilling was undertaken at Dry Bay after 1903.

CHARACTER AND OCCURRENCE OF THE PETROLEUM.

Samples of the seepage petroleum from Oil Bay were collected by Martin for analysis. The oil when it first rises to the surface of the water is dark green, but it turns dark brown after it has been exposed to the air for a time and has lost part of its volatile constituents. It has a paraffin base and would doubtless be a refining oil.

It was pointed out that the oil seepages and drill holes showing oil are within the area of the Tuxedni sandstone. So far as is known none of the seepages, except possibly the gas spring at Dry Bay, are within areas of the Chinitna shale or the Naknek formation. It is therefore believed that the source of the oil is within the Tuxedni sandstone or at some lower horizon. Two of the drill holes at Oil Bay are reported to have penetrated oil-bearing sands at depths ranging from 500 to 770 feet and to have shown a considerable quantity of oil. No other direct evidence for the depth at which the oil originated was observed.

The relation of the oil seepages and wells to the geologic structure of the formation in which they are situated is of importance in predicting the location of a possible oil pool. The seepage on Iniskin Bay is near a fault, and the principal seepage at Oil Bay is in a zone of jointing and faulting. The east and west shores of Oil Bay were determined by a system of vertical faults and closely spaced joints, which in general strike N. 20° W. A glance at the geologic map shows clearly that the seepage and drill holes at Oil Bay are in line with the west shore of the bay and that unless the fracturing does not extend that far northward the position of the seepage may readily have been controlled by the same structure that controlled the form and location of Oil Bay.

The accumulation of oil, however, would be determined by other structural features than these and may be related to either one or both of two types of folds. The rocks of a narrow curving belt along the Cook Inlet coast dip eastward in a monocline that carries them from view beneath the water. This structure is so pronounced that it suggested for the mountains of this belt the name Tilted Hills. The landward margin of the belt is marked approximately by the boundary line between the Tuxedni sandstone and the Chinitna shale. This boundary line in turn marks the locality of a slight change in dip between the rocks of the Tilted Hills and those of the interior of the peninsula. This change is not everywhere noted, but in places the dip of the rocks along the coast is greater than that of the interior beds and thus produces one of the types of structure well known in some oil fields as favorable for the accumulation of oil.

The Tuxedni sandstone of the interior of the peninsula has been thrown into a succession of folds with axes running about N. 30° E. The position of these folds is indicated on the geologic map, where it is shown that one of the two principal anticlines follows the valleys of Bowser and Fitz creeks. This anticline divides into two minor anticlines in the lower part of the Fitz Creek valley and flattens out on the south near Oil Bay, losing its identity and pitching beneath the southward-dipping beds of Mount Pomeroy.

These two structural features—the line of changing dip along the inner slopes of the coast mountains and the anticline marked by the valleys of Fitz and Bowser creeks—are believed to be more favorable for the accumulation of oil than others in this district. One possible unfavorable condition in the Bowser-Fitz Creek anticline should be pointed out. Fitz Creek has cut its valley deep into the Tuxedni sandstone near Chinitna Bay, so that the rocks exposed there are probably lower in the formation than the beds at Oil Bay. It is thus possible that the lowest beds exposed on Fitz Creek are below the horizon of the oil-producing bed and therefore that no oil will be found in them. Whether or not this is true can not be determined till more is known about the source of the oil.

The valley of Portage Creek would seem to offer a less favorable locality to test for oil because the rocks are so closely compressed that the limbs of the narrow fold are almost parallel in places and because the fold is affected by a profound fault which cuts off its north end completely.

Oil may be found in other structural features than the two types of folds already mentioned. One such feature is a porous sandstone bed capable of holding oil inclosed in a shale bed tight enough to prevent the escape of the oil. Beds of this nature are doubtless present in the upper shaly part of the Tuxedni sandstone, but their presence at a particular locality could not ordinarily be predicted from surface indications and could be determined only by the drill.

A tilted sandstone bed cut off by a tight fault might also provide a reservoir capable of holding oil, but here again the difficulty of finding it would usually be great in an undeveloped field.

It seems evident to the writer that if other drill holes are put down in the search for oil in this district they should be located with reference to one or the other of the two principal structural features just described. The anticline in Fitz and Bowser Creek valleys is in reality the crest of an unsymmetrical fold, of which the monocline along the Cook Inlet shore is the eastern limb. In at least one place there is a small minor fold between the crest and the monocline, but in other places no such minor fold was found. If oil in considerable quantity were moving up along the beds of the monocline it would probably in places find its way past the line of decreasing dip into the crest of the anticline. The tilted sedimentary beds bordering Cook Inlet would seem to provide a good gathering ground for oil and conditions favorable for its accumulation, but the presence of oil can not be predicted and can hardly be determined by any other means than the drill.

In summarizing it may be said that the Iniskin Bay region includes a number of long, narrow anticlines, which are adjoined on the seaward side by a great monocline. This monocline should have afforded a considerable underground drainage area for oil and may contain valuable pools.

A PETROLEUM SEEPAGE NEAR ANCHORAGE.

By Alfred H. Brooks.

Prior to 1921 no evidence of petroleum near Anchorage had been found. Some shallow drilling had been done, but it did not reach the hard rock, and the character of the nearest exposed formations gave no encouragement to the hope of finding oil at greater depths. In July, 1921, however, a small petroleum seepage was found in sec. 24, T. 23, R. 3, about a mile southwest of the town of Anchorage. This locality was visited in August, and oil seeping from a gravel bank on top of a clay layer at about sea level was found. The seepage was estimated to yield about 2 fluid ounces a day. Its location precluded the possibility of its being due to an accidental leakage from an oil tank. Other reported seepages in the district were not seen. A sample of the petroleum was collected and submitted for examination to the Bureau of Mines, which reported as follows:

The sample consisted of a mixture of oil, water, and sediment. By simple filtration and separation it was possible to obtain about 30 cubic centimeters of the oil. This quantity, of course, is not sufficient to permit a complete analysis, but the following results were obtained:

Bureau of Mines No. 0088:
- Specific gravity, 0.880.
- Degrees Baumé, 29.1.
- Sulphur, 0.50 per cent.
- Viscosity (Saybolt Universal at 100° F.), 45 seconds.

The gravity and viscosity indicate that this is a genuine crude oil of fairly high grade. The sample was distilled with the following results, which, however, are only approximate:

- First drop, 196° C.
- Boiling below 225° C., 30 per cent.
- Boiling between 225° and 250° C., 22 per cent.
- Boiling between 250° and 275° C., 12 per cent.

In all 64 per cent was recovered by boiling between 196° and 275° C., which would indicate that the distillate consisted almost entirely of kerosene. No gasoline was present. An approximate analysis of the oil could be given as:

- Gasoline, none.
- Kerosene, 64 per cent.
- Gas oil, lubricating oil, and residuum, 36 per cent.

The fact that the petroleum has without doubt traveled a long distance from its bedrock source may account for the absence of gasoline.

There is no positive evidence of the source of the petroleum of this seepage. The surface of the region for several miles is mantled with a cover of gravel and sand, probably at least 300 feet thick. Soft sandstones containing a little lignitic coal occur on the shores of Knik Arm, not far from the seepages. So far as known these beds are only gently tilted. Even if oil might be distilled from the vegetable remains in these beds, the fact that the formation is nearly unaltered except for slight cementation of sandstone seems to preclude the idea that the physical conditions have been favorable to distillation. Moreover, the same Tertiary lignite-bearing beds occur in large areas both north and south of this locality. These beds have been examined in considerable detail, but nowhere have they revealed any evidence that they contain petroleum, and they can with confidence be excluded as a possible source of this oil. This seepage occurs near the eastern margin of the great Susitna lowland, which covers over 1,500 square miles and is filled with silts, sands, and gravels to an unknown but probably great depth. These delta deposits undoubtedly contain some vegetable remains and possibly some animal remains. It is not impossible that such deposits might afford favorable conditions for the formation of petroleum, but such an explanation of the facts in hand is a mere speculation. Moreover, the unconsolidated silts, sands, and gravels certainly do not afford favorable conditions for the formation of oil pools.

With regard to a possible hard-rock source for this oil the available facts obtainable from outcrops are all negative. The gravel bench from which the oil emerges stretches eastward for 7 miles to the base of the mountains, mantling all rock exposures. In the mountains the formations consist of closely folded and faulted altered sediments and igneous rocks,[1] possibly of Mesozoic age, but entirely unfavorable to the presence of petroleum and so much altered and disturbed as to preclude the possibility that they contain oil pools.

The outcropping bedrock in the vicinity of Anchorage therefore affords no clue to the source of the seepage oil. The great lowland described is occupied almost entirely by alluvial deposits, the only bedrock being a few outcrops of the Tertiary lignite-bearing beds. Neither of these formations is a promising source of petroleum. The formations in the highland bounding this alluvium-covered

[1] Capps, S. R., The Turnagain-Knik region: U. S. Geol. Survey Bull. 642, pp. 152–165, pl. 8, 1916.

lowland are not believed to be oil bearing, yet this lowland tract may itself contain oil-bearing rocks. The nearest known oil-bearing rocks are those of Iniskin Bay, 150 miles to the south, which are of Jurassic age. The extension of the strike of these distant formations would carry them into the lowland region near the eastern margin of which the Anchorage seepage is situated. If the Anchorage seepage is derived from such buried oil-bearing rocks, a careful search in the lowland region should lead to the discovery of other seepages, if they have not already been found.

Evidently, therefore, the presence of oil in this region, except for the small seepage described or others that may be found, can be proved only by drilling. In the absence of bedrock exposures, geologic examinations are of little or no value. The fact that the region is readily accessible by steamer, railroad, and wagon road will make it far less expensive to drill than other parts of Alaska. It should be added, however, that in the absence of any clue to the structure and any knowledge of the depth of the oil-bearing formations, even if they are present, all drilling in this region must be classed as wildcatting.

A SUPPOSED PETROLEUM SEEPAGE IN THE NENANA COAL FIELD.

By George C. Martin.

INTRODUCTION.

During the last two years the discovery of several supposedly genuine petroleum seepages have been reported from the Nenana coal field, Alaska, and several prospecting claims have been staked. The reports of seepages were sufficiently definite to justify a field examination, and therefore the writer visited one of the localities in August, 1921. The evidence obtained in the field and from laboratory investigations of material collected appears to indicate that the supposed petroleum residue is not derived from petroleum but is a tar distilled from burning coal beds.

It is the duty of official geologists not only to indicate the areas that are favorable for the finding of oil pools or other mineral deposits but also those that are unfavorable. Much of the most valuable results of geologic work, including the work of both official geologists and of those in private employment, consists in reducing the expense and hazard of mining investment by pointing out the localities or regions where mining operations are not justified. The supposed Nenana oil seepages have attracted enough public attention to make it imperative to give in full the reasons why they have proved not to be true petroleum seepages. This presentation will, it is hoped, discourage any further expenditures in this region in search for petroleum.

Petroleum seepages and residues are generally and rightly regarded as among the most useful and reliable indications of oil pools. Although those who are not familiar with oil seepages sometimes mistake iron stains, mineral salts, and living organic slimes for them, it is generally considered that a true oil seepage is unmistakable. It is important, therefore, to describe a material which has some of the generally accepted characteristics of a petroleum residue but which is believed to be something else. The purpose of the present paper is not merely to report a supposed oil discovery that is believed to be based on misleading indications but to call attention to the broader question of the possible general inadequacy of a commonly accepted class of evidence.

It was reported in the summer of 1920 that a petroleum seepage had been discovered [1] in the vicinity of Healy Creek, near the southern margin of the Nenana coal field. There are also reports, which apparently have not been referred to in print, of indications of petroleum in other parts of the Nenana coal field, notably on Totatlanika Creek in the northeastern part of T. 11 S., R. 5 W. A sample of sand impregnated with bituminous material that was supposed to be petroleum or petroleum residue was taken from the Healy Creek locality in 1920 and is said to have been subjected to tests in which oils bearing some resemblance to petroleum were extracted by solution. Considerable interest in the possible occurrence of petroleum was aroused thereby, and application has been made for several oil leases in this vicinity. A brief visit to the supposed seepage was made in August, 1921, by the writer, who, although he had never seen the precise locality before, was thoroughly familiar with much of the neighboring territory. While in the field the writer suspected that the supposed petroleum residue was really a natural coal tar produced by the distillation of burning coal beds. Chemical tests made in the laboratory of the United States Geological Survey by E. Theodore Erickson tend to confirm this suspicion.

The reasons for believing that this material is not a petroleum residue are as follows:

No adequate original source of petroleum is known in the strata that crop out at and near the supposed seepage or in the rocks that underlie them.

The structure is not favorable for the accumulation of bodies of oil in the vicinity nor for its escape at this point.

If petroleum were escaping at this locality it would almost certainly escape at many other places in the Nenana coal field where it would probably not have been overlooked by the writer and his associates in the detailed investigation which they made in 1916 or by the several other geologists and many engineers and prospectors who are familiar with the district.

The material differs in odor and chemical composition from most petroleums and contains substances that are generally regarded as characteristic of coal tars.

An adequate source for natural coal tar is found in distillation from coal beds that are known to have burned at many places throughout the field and that are believed to have burned at this very spot.

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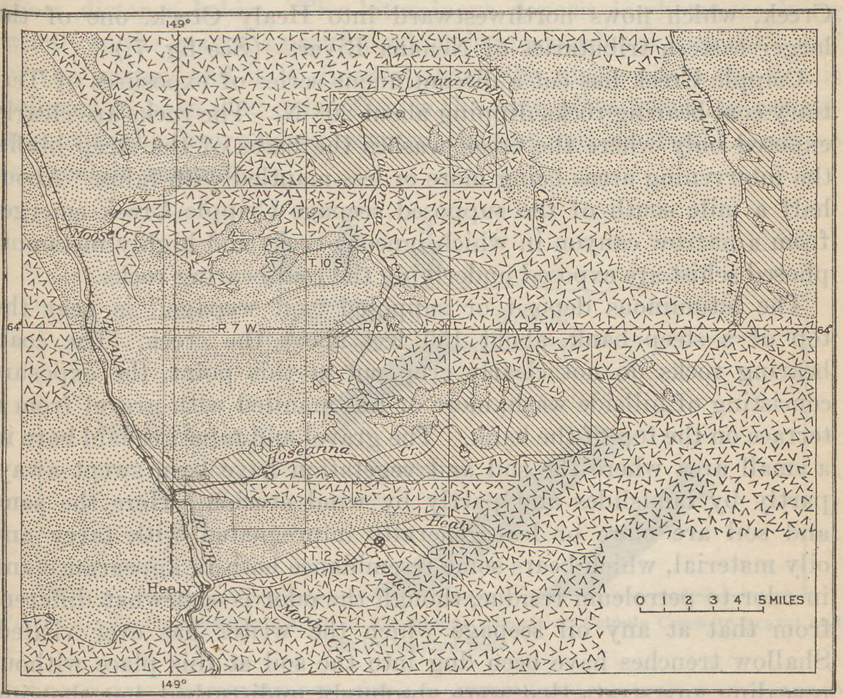
[1] Martin, G. C., Preliminary report on petroleum in Alaska; U. S. Geol. Survey Bull. 719, p. 73, 1921.

THE BITUMINOUS DEPOSIT.

The locality of the supposed seepage is just inside the southern border of the Nenana coal field, which lies in the northern foothills of the Alaska Range, in the central part of Alaska. (See fig. 7.)

The Nenana coal field, which has been described by Prindle,[2] Brooks and Prindle,[3] Capps,[4] and Martin,[5] contains a thick section of Tertiary (probably Eocene) coal-bearing rocks resting unconform-



EXPLANATION

Gravels (Bench and glacial gravels, sands, and silts. Small areas of bench and stream gravels omitted)

Coal-bearing rocks (Slightly indurated sands, clays, and gravels, with many thick beds of lignite)

Schists and igneous rocks (Micaceous and quartzitic schists, gneisses, and phyllites; and rhyolites, andesites, and dacites)

Bituminous deposit

FIGURE 7.—Geologic map of the Nenana coal field.

ably on igneous and highly metamorphic rocks and overlain by Quaternary gravel. The coal-bearing strata are at least 1,200 feet and possibly 1,500 or 2,000 feet thick and consist of slightly consoli-

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[2] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, pp. 205–226, 1907.

[3] Brooks, A. H., and Prindle, L. M., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 188–192, 1911.

[4] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, 64 pp., 1912.

[5] Martin, G. C., The Nenana coal field, Alaska: U. S. Geol. Survey Bull. 664, 54 pp., 1919.

dated sand, clay, and gravel with numerous beds of lignite, there being at least 12 coal beds of workable thickness, six or more of which measure 20 feet each and several of them 30 to 35 feet. No organic matter, other than the coal and the disseminated vegetable detritus which it is customary to find in the sandstones adjacent to coal beds, has been seen.

The supposed seepage is in sec. 15, T. 12 S., R. 6 W. Fairbanks meridian, on the east bank about a mile above the mouth of Cripple Creek, which flows northwestward into Healy Creek, one of the larger eastern tributaries of Nenana River. (See fig. 7.)

Cripple Creek has cut a discontinuous series of exposures of Tertiary coal-bearing rocks dipping about 20° N. The rocks are clearly exposed only where the creek washes the bases of the steep bluffs, the intervening areas being more or less mantled with talus. About half a mile south of the supposed seepage Cripple Creek emerges from a narrow canyon in which igneous rocks and highly metamorphosed schist are exposed underlying the coal-bearing rocks.

The bituminous deposit or supposed "oil seepage" is near the top of a steep bank, about 150 feet above the creek. The coal-bearing rocks do not clearly crop out at this point, the exposure consisting of hillside wash, more or less mantled with gravel from a terrace on the top of the bank. The gravel and talus are laid bare in a small area where the soil and vegetation have been swept away, partly by landslides and partly by wind erosion. Here the sand and soil are more or less generally impregnated with tarry and oily material, which bears some resemblance both in appearance and in odor to petroleum residue, though the odor is somewhat different from that at any oil seepage which the writer has ever visited. Shallow trenches have been dug into the soil at this place without revealing any strata that were absolutely undisturbed, but showing considerably more of the bituminous material than was apparent on the natural surface. The oil or tar is possibly disseminated throughout the exposed material, but it is not uniformly distributed. Small irregular masses of sand seem to be completely saturated with black tarry and oily material, so that they have about the appearance and consistency of the tarry sands that were formerly used in laying sidewalks. The odor of the material was noticeable to one walking over the area and is said to have led to the discovery. The accompanying sketch (fig. 8) shows the relation of the bituminous deposit to the gravel and to the underlying lignite-bearing beds. This sketch is a copy of a rough diagram furnished by Mr. W. E. Dunkle, who is thoroughly familiar with the locality, although he did not have his detailed notes at hand when he prepared the diagram. The sketch indicates conditions substantially in accord with the observations of the writer and supplies evidence in confirmation of the theory here set forth, although it was prepared by one who did not have that theory in mind. It should be noted that the 5-foot bed of lignite has its position merely indicated in the lower left corner of the sketch. This is where the writer saw no exposure of the lignite but only fragments of clinker indicating that a bed had been burned. Only the upper part of this lignite bed is drawn solid in the sketch. This would seem to indicate that the fire did not extend to the base of the gravel but was probably drowned out a short distance below. The bituminous deposit is shown as lying wholly in the gravel, a position which is in accordance with the belief of the writer, and it is directly above the place where the fire is believed to have died out. This is the very place where, in accordance with the theory here presented, the tars and oils would condense in greatest amount.

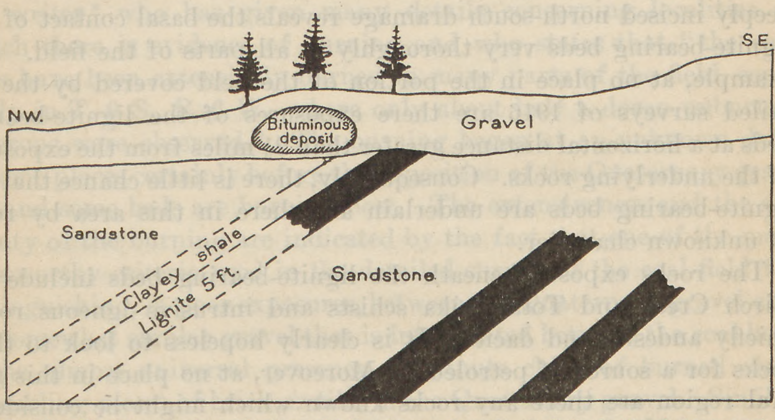

FIGURE 8.—Sketch showing relation of bituminous deposit on Cripple Creek to gravel and lignite-bearing beds.

GEOLOGIC EVIDENCE THAT THE MATERIAL IS NOT PETROLEUM RESIDUE.

The only sedimentary strata known near this locality, or anywhere else in the Nenana coal field, which might be considered as a possible source of petroleum are the Tertiary lignite-bearing beds. These beds are composed of slightly consolidated sand, gravel, and clay, with numerous beds of lignite. Their organic constituents include only the beds of lignite and the vegetable detritus which is common in sandstone associated with coal beds. The intervening strata are dominantly sand and gravel, with no observable organic constituents. The argillaceous members (clay) are relatively few and thin, probably being subordinate to the lignite in amount, and they consist of light-colored clay which is notably lacking in organic matter. Carbonaceous or bituminous clay or shale is relatively scarce if not wholly lacking. No beds of limestone or of diatomaceous or infusorial earth or any marine or brackish-water beds are known. The strata, in brief, contain little or no organic matter from which petroleum might be derived unless it may be the remains of the higher forms of vegetable life in and associated with the lignites, and these remains are not generally regarded as a possible source of petroleum. It may therefore be considered certain that the lignite-bearing strata of the Nenana field are not a probable source of petroleum.

In discussing the question as to whether petroleum could have been derived from strata beneath the lignite-bearing beds, brief consideration must first be given to the general structure and distribution of the beds. The Nenana coal field (see fig. 7) consists of a group of narrow and gently warped basins. The combination of shallow basins having a dominant east-west structural trend with deeply incised north-south drainage reveals the basal contact of the lignite-bearing beds very thoroughly in all parts of the field. For example, at no place in the portion of the field covered by the detailed surveys of 1916 are there exposures of the lignite-bearing beds at a horizontal distance greater than 2½ miles from the exposures of the underlying rocks. Consequently, there is little chance that the lignite-bearing beds are underlain anywhere in this area by rocks of unknown character.

The rocks exposed beneath the lignite-bearing beds include the Birch Creek and Totatlanika schists and intrusive igneous rocks, chiefly andesite and dacite. It is clearly hopeless to look to these rocks for a source of petroleum. Moreover, at no place in this general region are there any rocks known which might be considered as possibly oil-bearing. The northern foothills of the Alaska Range are known geologically for 100 miles or more both east and west of this locality, and throughout this belt the rocks beneath the Tertiary lignite-bearing beds are almost wholly crystalline. It should be noted that relatively unaltered Devonian limestones and Ordovician shales occur on the north flank of the Alaska Range, but they have not been seen within a great many miles of this locality and are known only in the mountains and not in the extension of the foothill belt. The marine Jurassic and Tertiary strata that contain the known petroleum of Alaska have not been found north of the Alaska Range, except in the Arctic coastal province, and are believed never to have been deposited there.

GEOLOGIC EVIDENCE THAT THE MATERIAL IS TAR.

The belief of the writer that this material is a natural coal tar produced by distillation from burning coal beds finds geologic support in the fact that coal beds have burned at many places throughout the field and have probably burned at this very spot. This is, moreover, one of the places where the geologic conditions are especially favorable for a trapping and condensation of the liquids and gases that must inevitably be given off whenever a coal bed is burned.

The lignite beds throughout the Nenana field have been extensively burned from unknown natural causes. There is hardly a single large exposure anywhere in the western part of the field in which one or more of the coal beds have not been burned in greater or less degree. The burning of the lignite in the Nenana field was first described by Prindle,[6] who states that on Healy Creek " some beds in almost every section have been destroyed by fire." The burned coal beds are also described by Capps,[7] who says that on Healy Creek " some beds of coal have burned out in almost all sections examined."

Reference to the burning of the coal beds has also been made by the writer,[8] who has given many details concerning localities at which there is evidence of burning and who states that " the coal beds have been extensively burned in many parts of the field, especially in T. 9 S., R. 6 W., where only about half a dozen unburned outcrops were observed." The burning began at an unknown date, in some places certainly before the deposition of the Quaternary gravels, and some beds are burning now. The extensiveness and the antiquity of the burning are indicated by the fact that one of the most trustworthy criteria used in the detailed survey of the coal field for distinguishing, in poor exposures, between the Quaternary gravel and the somewhat similar gravel that is intercalated between the coal beds is the almost universal presence of minute chips of burned clay, resembling pieces of brick or tile, in the Quaternary gravel. Similar pieces of burned clay, which doubtless came from the Nenana coal field, have been found by the writer in the gravel of the low terraces along Tanana River. It may be noted that the burning of lignite in past geologic time, as shown by the presence of pebbles of clinker in terrace gravel, has also been observed in Montana.[9]

Although no burned coal beds have been seen at the bituminous deposit, the coal beds and accompanying strata not being actually exposed at the place, abundant fragments of burned clay and also masses of scoriaceous material resulting from the complete fusion of the rocks were seen by the writer in the soil immediately below

[6] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, pp. 222–244, 1907.

[7] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 55, 58, 60, 61, 1912.

[8] Martin, G. C., The Nenana coal field, Alaska: U. S. Geol. Survey Bull. 664, 54 pp., 1919.

[9] Allen, J. A., Metamorphism produced by the burning of lignite beds in Dakota and Montana Territories: Boston Soc. Nat. Hist. Proc., vol. 16, pp. 258–259, 1874. Collier, A. J., and Smith, C. D., The Miles City coal field, Mont.: U. S. Geol. Survey Bull. 341, p. 45, 1909.

the deposit. It may therefore be confidently assumed that the coal beds have been burned at this very place. There is no conclusive evidence as to when the burning took place here. This fire is not burning now, but the fact that volatile material still remains in the bituminous deposit is perhaps an indication that the burning was of comparatively recent date.

It is evident that whenever a coal bed is burned in the ground there will be distillation of liquid and gaseous hydrocarbons in advance of the actual combustion. When the coal is heated to a sufficient temperature, liquids and gases will be driven off in the same way as they are in the manufacture of coke or in the artificial distillation of tars and oils from coal and lignite.[10] These liquids and gases will, for the most part, burn or escape into the air, but part of them will migrate through the rocks, and if they reach cool or damp places they will undoubtedly condense there. The gases given off near the margins of the burned areas are the more likely to escape combustion. If the margin of the burned area approaches the surface of the ground without actually reaching it, the gases are likely neither to be burned nor to escape into the air but will be in part condensed in the damp, cool soil.

The special conditions favorable for the trapping and condensation of distillation products at this locality are the presence of a nearly horizontal bench of Quaternary gravel lying unconformably across the beveled edges of the Tertiary lignite beds. (See fig. 8.) The surface of this bench, if it is like the similar neighboring benches, is dotted with marshy areas and pools of water. The materials composing the bench are doubtless either wet or frozen. The burning of the coal beds would probably approach without reaching the base of the bench gravel. The gases and liquids given off from the combustion and distillation of the coal would be trapped beneath the wet or frozen gravel and would in part condense there.

The natural burning of coal beds is a well-known phenomenon which has been described by many observers. Only a few of the more comprehensive descriptions need be cited here.[11] The published descriptions deal with the destructive effects on the coal beds and with the effect of heat on the overlying rocks, with special reference to the fusion of the rocks and the development of glass,

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[10] Scheithauer, W., Shale oils and tars and their products (English translation by Charles Salter), 183 pp., 1913.

[11] Allen, J. A., Metamorphism produced by the burning of lignite beds in Dakota and Montana Territories: Boston Soc. Nat. Hist. Proc., vol. 16, pp. 246–262, 1874.

Collier, A. J., and Smith, C. D., The Miles City coal field, Mont.: U. S. Geol. Survey Bull. 341, pp. 45–46, 1909.

Bowie, Alexander, The burning of coal beds in place: Am. Inst. Min. Eng. Trans., vol. 48, pp. 180–193, 1915.

Rogers, G. S., Baked shale and slag formed by the burning of coal beds: U. S. Geol. Survey Prof. Paper 108, pp. 1–10, 1918.

slag, and silicate minerals. No reference has been made in print, as far as the writer knows, to condensation products from the distillation of the coal. The reason for this omission is believed to be that in most regions the coal has burned vigorously to the very outcrop and that consequently the distillation products have either burned or escaped into the air at the places where they might otherwise be most easily observed. The gases given off at great depth will as a rule be diffused through buried rocks, where their condensation products will not be observable till these buried rocks are laid open by natural or artificial excavation. The fact that natural tars have not been commonly noted in connection with the natural combustion of coal beds may also be due to the lack of a wet or frozen cover. Generally either the rocks are wet to great depths, so that the coal beds do not burn, or else they are dry to the very surface, so that they heat to the surface and the gases escape.

CHEMICAL TESTS.

In order to obtain more positive evidence as to whether the organic matter of this place was actually derived from the distillation of coal beds, samples have been studied by E. Theodore Erickson in the chemical laboratory of the United States Geological Survey. The following report has been submitted on three samples collected by the writer, all from the same locality. Sample A was a selected sample made up of numerous small samples of the more bituminous black sand. Samples B and C were representative selections of the less bituminous (average) finer and coarser material.

Sample A: A chloroform extract indicated a small part of bitumen together with considerable soluble sulphur. The bitumen when heated with alkali solution and likewise the sample when so directly treated yielded strong odors of the pyridine series of compounds. Red litmus paper in the emitted odors readily turned blue. The intensity of these results is sufficient to indicate that considerable quantities of these substances are present in the comparatively small amount of bitumen in the sample.

Phenol-like compounds were detected by the following procedures: The sample was treated directly with strong boiling alkali solution. The alkali extract after filtration from insoluble matter was acidified with HCl, boiled gently, and again filtered. The final filtrate was colored reddish with organic matter, an ether extract was made, and upon evaporation of the ether a small amount of reddish organic matter remained. It possessed a phenol-like odor, and when dissolved with a small amount of water the aqueous solution gave with dilute ferric chloride solution a positive reddish-violet color. Pure phenol under the same conditions gave a bluish-violet color. The phenol-like residue when heated in the usual way with a small quantity of a mixture of two parts of H_2SO_4 and one part of HNO_3 gave the yellow color of the picric acid test. The characteristic phenolic results of a moderately colored yellow solution in water, which deepened much upon the addition of ammonia, were obtained. Phenolic compounds were detected in the phenol-like residue by dissolving in

20 centimeters of normal NaOH solution and adding a small amount of diazobenzene chloride solution. A reddish color and precipitate were obtained, identically as for small amounts of pure phenol. Under the same conditions negative results were obtained in a blank test and in a second blank test containing a small amount of pyridine.

There is also present some pyrobitumen or chloroform-insoluble bitumen in the sample. A trace of arsenic and considerable free sulphur were detected.

An approximate determination of the amount of soluble material in sample A showed 3.6 per cent of bitumen and 7 per cent of soluble sulphur. In this test carbon disulphide was used as the solvent, instead of chloroform, because it was found to yield a sharper separation of sulphur and bitumen upon evaporation.

Sample A was heated for 10 days at 105° C., when it showed a total loss of 10.42 per cent, which is believed to be chiefly moisture, as considerable water and no observable oils condensed. The sample gave an odor of volatile substance both before and after the heating.

Sample B: A chloroform extract indicated a small amount of brittle bitumen. It gave pyridine and phenolic indications, but not as intense as in sample A. Free sulphur did not separate out from the chloroform-evaporated extract, as in sample A. It contains practically no arsenic and a slight amount of pyrobitumen.

Sample C: The amount of bitumen obtained from sample C was intermediate in amount between that from samples A and B. The free sulphur obtained was less than in sample A. The pyridine and phenolic indications are also intermediate between those of samples A and B. The sample contains not over a trace of pyrobitumen and practically no arsenic.

The detecting of the pyridine series of compounds together with appreciable amounts of phenol-like compounds in the organic matter in sample A may be considered as evidence of the presence of coal-tar products that have resulted from the destructive distillation of coal. To differentiate the bitumen from a natural petroleum bitumen and asphalt on this ground becomes tenable when it is considered that petroleum in general contains small amounts of these substances, especially the phenol-like bodies. The diazobenzene chloride test is considered by Marcusson[12] to give for natural asphalt and petroleum pitch a yellow or orange color and not the reddish-colored results above noted, which are obtained from lignite-tar pitch that contains phenol.

Loebell[12] uses the diazobenzene chloride test to differentiate coal-tar pitch from natural or petroleum asphalt, the latter giving negative results with this test.

Of the nitrogen constituents in petroleum it appears likely that allowance must be made for the presence of hydrochinolines other than the pyridine series of compounds, as is evident in Mabery's work on the California petroleums.

It is understood that the samples here tested are directly connected with the natural combustion of coal, with which the results here reported accord.

Mr. Erickson has shown above that the customary tests for distinguishing coal-tar pitch from petroleum pitch or natural asphalt indicate that all three samples contain coal-tar pitch. These tests are based on the presence in coal tars of certain compounds, notably compounds related to phenol and pyridine, which are rare or lacking

[12] Holde, D., The examination of hydrocarbon oils and of saponifiable fats and waxes (English translation by Edward Mueller), p. 222, 1915.

in most petroleums. The tests show that substances related to phenol and pyridine are present in comparatively large amounts in the material under consideration and indicate very strongly that the material is a coal tar rather than a petroleum residue. These chemical tests are possibly not absolutely conclusive, as phenol and pyridine have been recognized in small amounts in a few petroleums, notably in some from California. Moreover, the writer would suggest that perhaps these substances may occur in larger quantities in natural petroleum residues than they do in live oils. The large quantity of sulphur is perhaps a further indication that the material was derived from burning coal beds, because although sulphur is a common constituent of petroleum, it usually occurs in only small quantities. Sulphur occurs also in all coals and lignites, from which it would be easily volatilized and condensed, and it is a common and troublesome constituent[13] of the tars that are artificially distilled from lignites. As Mr. Erickson's studies tend to confirm the conclusions drawn from the geologic field relations it is believed that this material is with little doubt a natural coal tar and not a petroleum residue.

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[13] Scheithauer, W., Shale oils and tars and their products (English translation), pp. 142–143, 1913.

THE OCCURRENCE OF METALLIFEROUS DEPOSITS IN THE YUKON AND KUSKOKWIM REGIONS.

By J. B. Mertie, Jr.

INTRODUCTION.

Topographic and geologic surveys, together with studies of mineral resources, have been carried on by the United States Geological Survey in Alaska for 25 years, with the primary object of fostering a mining industry in the Territory. The economic geologic investigations have been planned with a twofold purpose—to gain a better understanding of the known mineral deposits and to aid in the discovery of new deposits. The first of these objectives is attained by geologic studies in various mining districts to determine the origin, character, and extent of known deposits. The second is accomplished by regional geologic investigations in unknown areas and by the application to such areas of data from developed districts. The work of the first type aids the mining operator of the present day; that of the second benefits the prospector and the mining operator of the future.

Nearly all the developed mining districts in Alaska have been examined by members of the Geological Survey, and contiguous areas have been visited and described. Such work has resulted in important conclusions, which, however, are not as available to the public as might be desired, being scattered through many reports. It is the purpose of this paper to present in a condensed form some generalizations and deductions regarding the distribution and occurrence of mineral deposits in interior Alaska. The paper is intended primarily as a guide to the prospector.

The data here presented are based largely on investigations in the regions lying between Yukon and Tanana rivers and between the Yukon and the Kuskokwim. Relatively little is known of the region north of Yukon River, but so far as known the geologic conditions affecting the formation of ore deposits there are similar to those south of the river. Between Tanana River and the Alaska Range the same conditions exist, but the presence of glacial gravels has complicated the distribution of the placer deposits. Seward Peninsula is really a province in itself but has nevertheless many points in common with interior Alaska.

A list of publications by the United States Geological Survey containing the latest geologic and metallogenetic data on the districts of interior Alaska is given below.

Bulletin 375. The Fortymile quadrangle, Alaska, by L. M. Prindle, 1909.

Bulletin 520 (pp. 201–210). Gold placers between Woodchopper and Fourth-of-July creeks, by L. M. Prindle and J. B. Mertie, jr., 1912.

Bulletin 525. A geologic reconnaissance of the Fairbanks quadrangle, Alaska, by L. M. Prindle, 1913.

Bulletin 532. The Koyukuk-Chandalar region, Alaska, by A. G. Maddren, 1913.

Bulletin 535. A geologic reconnaissance of a part of the Rampart quadrangle, Alaska, by H. M. Eakin, 1913.

Bulletin 538. A geologic reconnaissance of the Circle quadrangle, Alaska, by L. M. Prindle, 1913.

Bulletin 622 (pp. 292–360). Gold placers of the lower Kuskokwim, by A. G. Maddren, 1915.

Bulletin 630. The Chisana-White River district, Alaska, by S. R. Capps, 1915.

Bulletin 631. The Yukon-Koyukuk region, Alaska, by H. M. Eakin, 1916.

Bulletin 649. Antimony deposits of Alaska, by A. H. Brooks, 1916.

Bulletin 655. The Lake Clark-Central Kuskokwim region, Alaska, by P. S. Smith, 1917.

Bulletin 662. (pp. 221–277). The gold placers of the Tolovana district, by J. B. Mertie, jr., 1917.

Bulletin 667. The Cosna-Nowitna region, Alaska, by H. M. Eakin, 1918.

Bulletin 683. The Anvik-Andreafski region, Alaska, by G. L. Harrington, 1918.

Bulletin 687. The Kantishna region, Alaska, by S. R. Capps, 1919.

Bulletin 692 (p. 329). A molybdenite lode on Healy River, by Theodore Chapin, 1919.

Bulletin 692 (pp. 351–362). Lode deposits near the Nenana coal field, by R. M. Overbeck, 1919.

Bulletin 714 (pp. 207–228). Mineral resources of the Goodnews Bay region, by G. L. Harrington, 1921.

Bulletin ——. The Ruby-Kuskokwim region, Alaska, by J. B. Mertie, jr., and G. L. Harrington (in preparation).

CLASSES OF DEPOSITS.

Only the metalliferous deposits are considered in this paper. If Seward Peninsula is included, it may be said that all the common metalliferous ores are present in interior Alaska. Gold, silver, lead, copper, tin, tungsten, antimony, quicksilver, and platinum metals have been produced on a commercial scale, and zinc, molybdenum, chromium, iron, manganese, bismuth, nickel, and arsenic are found. Gold has been and probably will continue to be the main mineral product of the region. At present silver, lead, copper, and tin are also being recovered on a small scale.

The mineral deposits of interior Alaska may be divided into two general classes, lodes and placers. A complete genetic classification is not needed for the purpose of this paper, but certain subdivisions of these types, based on differences in the manner of origin, will be mentioned if such differences may influence the method of prospecting.

LODE DEPOSITS.

OUTLINE.

A lode of some kind must exist before a placer can be formed; therefore it is natural to consider first the lode deposits. Emphasis will be laid upon the ores which are now or which may be in the near future economically important. The origin and distribution of such metals as chromium, which are not likely ever to be of importance in interior Alaska, are of more scientific than economic interest and merit only the barest allusion.

Most metallic deposits have been derived directly or indirectly from igneous rocks, though in some deposits the connection is indirect and remote. In interior Alaska the connection between the metallic lodes and igneous activity is everywhere apparent, and many of the lodes are so closely associated with igneous rocks that this relation is of great assistance to the prospector in his search for minerals.

Many kinds of igneous rocks exist in interior Alaska. Silicic, basic, and intermediate types are present, both as intrusive bodies and as surface flows. Moreover, igneous rocks of the same general character have been intruded and extruded at different epochs, so that two rock bodies of the same character may be of widely different age and may have produced differing types of mineralization. At first sight this complex history of volcanism in the region may seem a stumbling block to the practical miner, who is endeavoring to utilize geology in his search for minerals. But fortunately only certain special types of igneous rocks, which are also those that are most easily recognized, have any important bearing on the metallic lodes that are likely to be of commercial value.

With the exception of the platinum metals and certain of the ores of copper, all the minerals of interior Alaska that have been or are likely to be developed on a commercial scale are connected genetically with silicic igneous rocks of the type usually designated granodioritic rocks. This group includes granite, syenite, monzonite, quartz monzonite, granodiorite, quartz diorite, and diorite, together with specialized varieties of these rocks, such as aplite, pegmatite, and certain sodic varieties. All these rocks, however, resemble one another to a greater or less degree, and the true petrographic character of many specimens can be recognized only after close examination under the microscope. The ability to determine the exact petrographic name is therefore not so important as the ability to recognize this general group of rocks in the field.

In general the granitic rocks are composed essentially of the minerals quartz and feldspar, together with mica, hornblende, or pyroxene, or mixtures of these. The quartz and feldspar are light colored; the other minerals are dark. The resulting color of the rock is usually light gray but ranges from white or creamy to dark gray, depending on the proportions of the constituent minerals. The grain is usually so coarse that the individual minerals of the rock can be easily discerned with the naked eye. Few prospectors or mining men will have any difficulty in recognizing the granitic rocks.

METALLIZATION CONNECTED WITH GRANITIC INTRUSIVE ROCKS.

GENERAL CONDITIONS.

Deposits of gold, silver, lead, tin, tungsten, antimony, quicksilver, molybdenum, and copper in interior Alaska are connected with granitic intrusive rocks. Such rocks, however, have been intruded in this region at a number of different periods during its geologic history, and it is probable that several or all of these granitic invasions have been attended by the formation of metalliferous deposits. At present definite proof of two such periods of metallization has been obtained in interior Alaska, and a third is inferred with a considerable degree of assurance. The earliest of these periods occurred during the Mesozoic era, probably in late Jurassic or early Cretaceous time. The latest occurred in late Eocene or more probably in post-Eocene time. Between these two, in early Tertiary time, a third period of metallization is believed to have occurred. It may later become necessary, as more evidence accumulates, to expand this hypothesis still further, for metallization before the Mesozoic is already suspected in some areas and may later be definitely proved.

The igneous rocks that accompanied and produced the metallization of the earliest and latest of the recognized periods differed from one another in some important respects, although they all fall under the general designation granitic rocks. These differences are of little significance in the field, but when recognized in microscopic study they aid in distinguishing the two types. A more important matter is the marked difference that exists in the character and distribution of the metalliferous lodes accompanying these two groups of rocks. This difference is easily recognized in the field and is of interest to the prospector and geologist alike.

For convenience in discussion, the three periods of metallization above postulated are designated the early, intermediate, and late periods. These designations, however, are relative, not absolute, for they are not intended to imply that this enumeration represents the totality of metallization associated with granitic rocks in this region. The age and character of the intermediate period of granitic intrusion and metallization in interior Alaska are somewhat obscure and must be inferred in part from the geology of the Alaska Range. So far as known, the metallization of this intermediate period is more nearly related in character to the early than to the late metallization; in fact, evidence of it has not yet been surely recognized except in areas affected by the early metallization. The early and intermediate periods of metallization are therefore discussed together. The late period is entirely distinct.

Metallization occurred in connection with intrusions and extrusions of basic igneous rocks at other periods also, but it was of relatively slight extent and will be discussed briefly in a separate paragraph.

EARLY AND INTERMEDIATE PERIODS OF METALLIZATION.

The most widespread metallization in interior Alaska is believed to have occurred during Mesozoic time and is therefore representative of what is here designated the early period. Metallization of this type appears to be dominant in the Fortymile, Seventymile, Circle, Fairbanks, and Rampart districts of the Yukon-Tanana region, in the Ruby-Poorman district, and in the valleys of Koyukuk and Chandalar rivers. South of the Tanana also metallization of the early type occurred, though perhaps to a less extent than farther north. The lodes of Seward Peninsula were probably formed in part during this period. The chief metallic constitutent of all these early lodes was gold.

The intermediate metallization occurred in the Fairbanks and Kantishna districts and may also be represented in the Rampart and Tolovana districts. The lodes of this period carry gold but contain in addition sulphide ores such as stibnite and galena, locally in commercial quantities.

The common intrusive rocks connected with the early period of metallization are granite, quartz diorite, diorite, pegmatite, and aplite. The intrusive rocks connected with the intermediate period of metallization are not so well known, because ore deposits of intermediate age that are entirely distinct from the early ore deposits have not been recognized with assurance. The intrusive granitic rocks in the vicinity of Broad Pass, which are believed to be in part of early Tertiary age, are described as essentially granite, quartz monzonite, and quartz diorite.[1] The granitic intrusives of the Rampart district are described as quartz monzonite and related rocks of late Mesozoic or early Tertiary age, but as no fossils have been found in

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[1] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, p. 59, 1915.

the invaded sedimentary rocks near by, this determination of age can not be regarded as conclusive.[2] It is believed, however, that monzonitic rocks were important in this intermediate metallization.

Mineral associations constitute another valuable criterion in separating deposits belonging to the early and intermediate periods of metallization. Gold and silver are common to both groups of deposits. It has been shown by Brooks[3] that the stibnite ores were formed later than the Mesozoic metallization of Alaska and are probably of Tertiary age. Cassiterite, the common ore of tin, is believed by the writer[4] to have been formed only during the Mesozoic or early period of metallization, although the tin deposits near Hot Springs, in the Rampart district, may present a possible exception to this general statement. Tungsten occurs in the early group of deposits as wolframite and scheelite. Molybdenite, so far as known, occurs only with the granitic intrusives of Mesozoic age. Silver-lead ores, accompanied in places by other ore minerals, such as stibnite, chalcopyrite, bornite, sphalerite, pyrite, arsenopyrite, jamesonite, and bismuthinite, occur in associations which suggest that they originated mainly in the intermediate period. The sulphide ores of the Fairbanks and Kantishna districts are believed also to fall within the intermediate group.

The lodes of the early and intermediate periods of metallization were produced as a result of igneous intrusions, but the connection is indirect—that is, the lodes do not occur in the granitic rocks but in fissure veins and other types of deposits either near by or at some distance from the intrusive rocks. The ores commonly occur in quartz veins, but ores containing little or no quartz are found. Disseminated deposits are present at some localities, the metal-bearing solutions having followed lines of cleavage or other structural partings. Shear-zone lodes are found at some localities. Probably when more is learned of the metallization of these two periods it will be found that the intrusions gave rise also to contact-metamorphic deposits, as in southeastern Alaska, as well as deposits of other types. The type of deposit is influenced mainly by local conditions, such as the thickness and character of the superincumbent rocks.

It also appears that only the granitic bodies of smaller size were the source of economically important lodes in all three periods of mineralization. Immense bodies of granitic rocks, such as that which extends for 75 miles across the Circle quadrangle, do not appear to

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[2] Eakin, H. M., A geologic reconnaissance of a part of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, pp. 23–24, 1913.

[3] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, pp. 14–17, 1916.

[4] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. — (in preparation).

have produced any valuable mineral deposits. The explanation lies in the probable concentration of metallization, except possibly that due to contact metamorphism, at the higher points or apexes of the invading igneous masses. By this hypothesis an immense body of granitic rock, such as the one just mentioned, may be conceived to have produced mineral deposits in the locality of its apex, when the mass was deeply buried. Such deposits and the rocks that contained them have been removed by the long-continued erosion that has bared the lower part of the intrusive body. The sedimentary rocks formed later from the products of this erosion may contain a large part of the gold content of the original deposits. The gold contained in the conglomerate that stretches from Eagle westward to Woodchopper Creek, in the Yukon-Tanana region, may have originated in this way.

The lodes of the Fairbanks district may be cited as the best-known examples of the early and intermediate periods of metallization. The group of lodes that extend from Pedro Dome northeastward show metallization of two kinds. The oldest known lodes in this group are gold-quartz veins that occupy ancient fissures in the country rock. Igneous rocks similar to those exposed at Pedro Dome doubtless lie at no great distance beneath the surface, and their intrusion doubtless caused the fractures and fissures. Solutions of ores and vein minerals, originating from these rocks at a late stage in their cooling, subsequently moved upward and were deposited in such openings, forming the gold lodes of this area. The veins appear to have been formed at moderate depth, yet under sufficient cover to insure a fair degree of regularity.

Later, probably in early Tertiary time, there was another period of metallization, here termed the intermediate, probably likewise resulting from the intrusion of granitic rocks. In the Fairbanks district the granitic intrusives of this period, if exposed at the surface, have not been separated with certainty from the Mesozoic intrusives. The deposits formed by the metallization of the intermediate period, however, are distinct. Sulphide ores, accompanied by gold, appear to form the dominant type of lodes. Stibnite is the most common sulphide, but pyrite, galena (in part silver-bearing), arsenopyrite, sphalerite, bismuthinite, jamesonite, chalcocite, and tetrahedrite are also known. Some of these lodes contain quartz and some do not, but where vein quartz of this period is present it is different in character from that in the gold-quartz veins. Some of the old gold-quartz veins were reopened in this intermediate period and enriched, so that ores of the two periods are found at some localities in juxtaposition. This same intermingling of the ores of two different periods also occurs in the lodes of the Kantishna district.

The physical conditions under which the ores of the early and intermediate periods of metallization were formed do not appear to have been materially different.

Tungsten ores, consisting essentially of scheelite, are also found in the Fairbanks district, where they occur as disseminated deposits and also in veins, almost invariably accompanied by quartz. The valuable deposits are close to a body of porphyritic granite, with which they are believed to be connected genetically. These scheelite lodes seem to be more closely related to the gold-quartz veins than to the sulphide ores, and therefore they probably belong to the early period of metallization.

LATE PERIOD OF METALLIZATION.

In late Eocene or perhaps post-Eocene time there was another period of intrusion of granitic rocks, accompanied by the formation of ore deposits.[5] These late deposits are found in the Innoko, Iditarod, and McGrath districts and thence at intervals southwestward into the lower Kuskokwim and Yukon valleys. It is possible that ore deposits formed during this period may be present almost anywhere in Alaska, for the metal-bearing solutions in their upward passage from the underlying intrusive masses must have penetrated the older as well as the younger rocks. It is a remarkable fact, however, that these later ores appear to be very scarce in the regions of dominantly older rocks. Thus, in the Yukon-Tanana region ore deposits of this late period have been recognized only at Livengood, in the Tolovana district. It appears, therefore, that the late metallic ores are restricted areally as well as geologically.

It is likely that this restricted distribution is in some way related to the orogenic history of Alaska, but the exact connection is not yet understood. If the character of the earth movements of the region has had an important influence, then the movements that accompanied the formation of these ore deposits must have been of a different type and in some degree independent of the Tertiary disturbances that resulted in the uplift of the Alaska Range, for lodes of the late type, as here defined, have not been found close to the Alaska Range on the north side, nor in the range, nor south of it.

The intrusive granitic rocks associated with these ores are quartz monzonite, monzonite, granodiorite, quartz diorite, and diorite, together with varieties of these rocks containing relatively high percentages of soda, such as soda granite and soda diorite. Although these rocks belong in the general family of granitic rocks, they show certain peculiarities that are readily recognized under the microscope.

[5] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. — (in preparation).

One is the prevalence of rocks of the monzonitic type over the true granite; a second is the common occurrence of the sodic feldspars albite and soda microcline instead of the potassic feldspars orthoclase and microcline. A third difference is seen in the character of the dark minerals of the rock. Hornblende is as plentiful as in the older granitic rocks, but pyroxene is much more plentiful, and mica is probably less plentiful and is more likely to be biotite than muscovite. The late granitic rocks, therefore, commonly have a little darker color.

The metallic content of the late lodes includes chiefly gold, cinnabar (the sulphide of mercury), and stibnite (the sulphide of antimony). Locally scheelite is found with cinnabar and stibnite in the gold placers, as on Otter Creek, in the Iditarod district, and on Lillian Creek, in the Tolovana district. These associations suggest a common origin of the gold, cinnabar, stibnite, and scheelite. It is probable, however, that these minerals may have been deposited in different stages within the one general period of metallization. Cinnabar is not known to occur in the lodes of the early and intermediate periods.

The great difference between the deposits of the late period of metallization and those of the two earlier periods is seen in their relations to the granitic intrusive rocks and in their mode of occurrence. The genetic connection between the monzonitic rocks and the lodes of the late period is direct and very intimate. At almost every locality where the late deposits have been recognized they occur either directly in or closely adjacent to bodies of quartz monzonite or related rocks. This feature is particularly apparent in the Iditarod district; on Candle Creek and the upper part of Nixon Fork of the Kuskokwim, in the McGrath district; and in the Tuluksak-Aniak district, in the lower part of the Kuskokwim Valley. The mode of occurrence of the late deposits is also different. The gold occurs usually in small veins and veinlets of bluish quartz, in places chalcedonic, which cut the quartz monzonite and the sediments near by. In some deposits quartz is absent. The gold and accompanying vein materials do not occupy strong fissures with some degree of uniformity in direction, as in the Fairbanks lodes, but form irregular stockworks and brecciated zones. The cinnabar-stibnite ores, however, which occur both with and without quartz, are more commonly at some distance from the intrusive rocks, and many of the deposits occupy somewhat stronger fissures.

In general, these lodes have originated much closer to the surface than the lodes of the early and intermediate periods, as is indicated by the character of the vein quartz and by the character and position of the fissures and other openings that contain the ores. The quartz monzonite does not reflect this difference in a finer-grained fabric, as might be expected, but recent work has shown that under favorable conditions granitic rocks may solidify with coarse grain relatively close to the surface. The differences mentioned, however, together with the restriction in areal distribution, indicate strongly that this type of metallization must be considered quite distinct from the two earlier types.

METALLIZATION CONNECTED WITH BASIC INTRUSIVE AND EXTRUSIVE ROCKS.

The metallic lodes connected genetically with basic igneous rocks in interior Alaska are of little value. The platinum metals, some of the ores of copper, and ores of chromium and nickel belong in this category, but of these only the platinum metals and copper promise to be of economic interest.

Platinum metals in small quantities are widely distributed in Alaska, but the production has been small and restricted largely to one mine. Practically nothing is known of the bedrock association of the platinum metals in interior Alaska, for these metals have been found only in placers. Platinum has been found in the placers on Boob Creek, in the Tolstoi district; in the Marshall district, on Aloric River, in southwestern Alaska; and on Dime, Bear, and Sweepstakes creeks, in Seward Peninsula. In southeastern Alaska, where a palladium-copper lode has been successfully operated, the platinum metals occur in a body of pyroxenite. More commonly, however, the platinum metals are in peridotite or in serpentine derived from peridotite. It is therefore safe to state that most deposits of the platinum metals are derived from basic rocks.

Copper ores associated in part with basic lavas and in part with diorite are found in the upper valleys of Chisana, Nabesna, and White rivers. These deposits have been described in United States Geological Survey Bulletins 417 and 630. The difficulty and expense of mining and transporting such ores is at present prohibitive in interior Alaska.

LODE PROSPECTING.

Most lode prospectors will search mainly for deposits of native gold and for high-grade sulphide ores that contain also gold and silver. From what has already been said, it is apparent that such prospecting should be done in and around the bodies of granitic rocks, more particularly near the smaller bodies. Valuable ore deposits have seldom been found in interior Alaska in association with granitic masses larger than 3 or 4 miles in diameter, and most of those known are associated with much smaller intrusive masses or with dikes and sills.

Granitic masses are relatively resistant to erosion and are therefore likely to stand out conspicuously among the other rocks of the region. Exceptions to this rule are known, however, as for instance on Candle Creek, in the McGrath district, where a body of quartz monzonite lies in the valley of Candle Creek and the surrounding ridges and spurs are composed mainly of basaltic rocks. In the Kuskokwim basin, however, the granitic intrusives are commonly surrounded or adjoined by bodies of basic igneous rocks, some intrusive and some extrusive. The presence of basic rocks in this part of Alaska is therefore an indication that granitic rocks may also be present.

Dikes and sills are also important to locate, for they have been the source of some valuable ores. The Innoko district is one example of the importance of dikes and small intrusive bodies as metallizing agents, and the Parks quicksilver lode, on Kuskokwim River, is another. Such smaller intrusive bodies are difficult to find, because of their inconspicuousness and lack of topographic expression. They may occur close to larger bodies of granitic rocks, and their presence may sometimes be inferred from this fact. Some dikes, however, are offshoots from underlying larger bodies of igneous rock that do not crop out. Only diligent prospecting will reveal the location of such dikes.

On geologic maps made by the Geological Survey the positions of the larger masses of granitic rocks are shown. Sometimes, however, especially in reconnaissance geologic mapping, smaller granitic masses are overlooked, and it is probable that a large proportion of the existing dikes and sills are not seen on a linear traverse. As it is these smaller intrusive masses and dikes that are likely to have originated ore deposits, reconnaissance geologic maps should be taken as general guides rather than infallible indicators of metallization or the lack of it.

After a small intrusive body of granitic rock is found it still remains to be determined whether the intrusion has given rise to any metalliferous deposits. Not all intrusive bodies nor even all small intrusive bodies of granitic rocks have effected metallization, but, on the other hand, no valuable ore deposits have been found in interior Alaska that were not connected in some way with such rocks. They are therefore the most favorable places for prospecting, but they are by no means certain to yield commercial ores. Two general methods of prospecting can be recommended. In the Kuskokwim region, where ore deposits are closely associated with the granitic rocks, the prospector should confine his work to these rocks and their immediate margins. If no signs of metallization are found in a narrow zone close to the main granitic mass, further search might be made for dikes and other inconspicuous intrusive bodies in the near vicinity before turning to a new area. In the upper Yukon, Tanana, Koyukuk, and Chandalar valleys, however, where ores of the early and intermediate periods are more abundant, the prospector should search for a considerable distance from a granitic body, looking particularly for quartz veins, before he decides that this particular granitic intrusive has not produced any ore deposits. The search in these regions is really a search for quartz veins as such, the position of granitic masses serving only as a general indicator of areas that may be favorable prospecting ground.

The above paragraphs have been written for the lode prospector who is going into a new country. It happens more often in Alaska that lode prospecting follows the development of some gold-placer district. Commercial placers have not usually been transported any great distance from their bedrock source; and if the lodes that have produced the placers are also of commercial value they are usually located sooner or later by considering the position and direction of the pay streaks and by laborious prospecting. Knowledge of the character of the metallization in a region, however, will often be of great value in deducing and locating the bedrock source of the placer deposit. Short cuts that result from an understanding of conditions are certainly worth while.

PLACER DEPOSITS.

Most of the metals and metallic ores known in the lodes are found likewise in the placers, but only a few of them occur in placers of commercial value. Gold, of course, is the chief commercial placer metal of Alaska. Tin-placer mining is carried on in a small way on Seward Peninsula, and cassiterite has been recovered on a small scale at other places in connection with gold-placer mining, notably near Hot Springs, in the Rampart district. Tungsten has also been recovered from the placers. A residual scheelite placer on Seward Peninsula was worked during the war, and some wolframite was saved from the placers in the Circle district. The platinum so far recovered in interior Alaska has come entirely from placers that were mined primarily for their content of gold.

TYPES OF PLACERS.[6]

Placer deposits may be divided into several classes, as follows:

I. Residual placers.
II. Eluvial placers.

[6] Alfred H. Brooks has discussed the classification of Alaska gold placers in U. S. Geol. Survey Bull. 328, pp. 111–139, 1908, and Bull. 592, pp. 27–32, 1914.

III. Fluviatile placers:
- A. Simple stream placers:
  1. Present stream placers.
  2. Ancient stream placers:
     - a. Bench placers.
     - b. Deeply buried placers.
- B. Coalescing stream placers:
  1. Present coalescing stream placers.
  2. Ancient stream placers:
     - a. Coalescing bench placers.
     - b. Coalescing deeply buried placers.

IV. Glacio-fluviatile placers.

V. Beach placers:
- A. Present beach placers.
- B. Ancient beach placers:
  1. Elevated beach placers.
  2. Buried beach placers.

All these types are found in Alaska, but not all are economically important in interior Alaska.

Residual placers are formed by rock weathering and decay in place, transportation by water playing no part in the process. Such deposits may be considered the disintegrated surficial parts of metalliferous lodes. Deposits of this type are rare in Alaska. The scheelite deposit on Sophie Gulch, in the Nome district, is a typical example.

Eluvial placers are residual placers that have been transported to some extent by means of soil creep, frost heaving, and the action of tiny rivulets within the decayed rock débris. Such deposits are common in interior Alaska and are more likely to be of economic value than true residual placers, because the movement of the soil and rubble results in concentration of the gold near bedrock. Hillside placers and the uppermost placers of gulches belong to this type. The "upgrade" placers at the head of Flat Creek, in the Iditarod district, have been described as residual placers, but in a strict sense they belong to the eluvial type.

Fluviatile or stream placers of present streams are too common and too well understood by mining men in Alaska to require any description. Corresponding placers that have formed in ancient streams, however, are not so well understood. All bench placers, when first laid down, were stream placers similar to those of the present stream valleys. In the course of time the stream gravels, if not reworked by later erosion, may be left as terraces or benches on the sides of the valley, if the local base-level is lowered and the stream continues to cut down its channel. Such deposits constitute the so-called bench gravels. On the other hand, if the regional or local base-level is raised, the original placer may be deeply buried and a second or later placer deposit may be laid down above it. This has occurred on Olive Creek, a tributary of Tolovana River, in the Tolovana district, where a shallow and a deep channel have been formed at different times. The deep channel is probably synchronous with the elevated or bench channel on Livengood Creek, in the same district. If the local base-level remains practically stationary for a very long period, a condition seldom realized, ancient and recent placers may form a perfectly continuous deposit in a long valley, for the deposition of a gold placer is known to occur at that point in a valley where the stream action changes from erosion to alluviation, and such deposits are therefore formed progressively upstream.

Where several parallel and contiguous streams that are forming placers emerge from their valleys upon an open plain, perhaps into some wide valley floor, a continuous or coalescing placer may be formed along the front of the hills. If the streams empty into some lake or estuary, a delta placer, genetically the same but perhaps different in some minor respects, may be formed. Manifestly such compound placers may be formed by either present or ancient streams and may be elevated or buried in the same way as simple stream placers. Some of the gravel-plain placers of Seward Peninsula are coalescing placers of this general character, and there is evidence that some of the placers near Hot Springs, in the Rampart district, may also be in part compound.

Glacio-fluviatile placers are small and very irregular pay streaks in outwash glacial gravels, some of which are valuable enough to render profitable the mining of great banks of glacio-fluviatile gravel and glacial débris. Such placers are found only in regions that have been extensively glaciated, such as the slopes of the Alaska Range. Placers of this type are worked in the Yentna district, south of the range, but are unimportant in interior Alaska.

Beach placers are formed through the sorting and distribution of the heavy constituents of gravel by shore currents and waves. They are not known in interior Alaska, but those in the present and ancient beaches of the Nome district are of high value.

PROSPECTING FOR PLACERS.

The prospector of interior Alaska will continue to search for stream and bench placers of gold, for these are the only types of placer deposits, both as to metal content and as to origin, that warrant exploitation at present.

All that has been said of lode prospecting applies equally well to placer prospecting, for the lode antedates the placer. It is a great waste of time and effort to prospect blindly from year to year, as many prospectors do, without having any good reason for believing beforehand that a gold placer may exist where they undertake to prospect. Some rich placers have been found in this way, but it is equally true that an understanding of geologic conditions has often resulted in discoveries that otherwise might not have been made for a long time. The discovery of the high-bench ancient beach placers at Nome is a case in point, for it was predicted by Federal geologists,[7] and other examples might also be cited in interior Alaska, where men who have been guided by geologic knowledge, either their own or that gained from others, have been able to precede the uninitiated in making important discoveries.

In searching for placers the prospector should hunt first for areas of granitic rocks that give evidence of having been metallized, just as in lode prospecting, and then after the occurrence of metallization has been established he should prospect the streams leading from such areas. One difference, however, must be cited. It is not necessary to find a high degree of metallization nor to discover a rich lode before beginning placer prospecting, for a lode deposit of very low grade may by long-continued erosion and stream concentration develop into a high-grade placer. The placers of the Klondike region are an example of this condition. In fact, if the prospector finds a small area of granitic rocks or an area cut by many quartz veins or granitic dikes, he would do well to prospect the streams draining such an area, even if evidence of metallization had not been discovered in the bedrock. If a commercial gold placer is present in the vicinity, some inkling of the fact is rather likely to be obtained by panning on the bars and riffles of some of the streams near by.

Another point that deserves stress is the desirability of searching in particular for bench deposits. The conditions that make for the development of continuous commercial pay streaks are long-continued and deep residual weathering, moderate stream gradients, and a nice adjustment between the factors that regulate the erosion and transportation of rock débris. It is believed that favorable conditions of this sort prevailed more generally in interior Alaska during the physiographic cycle just preceding the present one than they do now. For this reason where bench and stream placers both occur the former are likely to be the richer. The placers of the Fairbanks and Tolovana districts prove the correctness of this hypothesis. Bench placers, of course, are harder and more costly to prospect, because the gold in them is usually buried beneath a great thickness of muck and gravel. The discovery of a pay streak in the present

[7] Schrader, F. C., and Brooks, A. H., Preliminary report on the Cape Nome gold region (U. S. Geol. Survey special publication), pp. 22–23, 1900. Brooks, A. H., A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900 (U. S. Geol. Survey special publication), pp. 80–91, 1901.

creek channel may perhaps be a logical preliminary step, but when this is accomplished, a thorough search for bench gravels should be made. The original discoverers of placer gold on Livengood Creek did not profit in fullest measure by their discovery, because they overlooked the possibility of a higher channel, and the rich bench placers fell into the hands of later arrivals in the camp.

Last of all some consideration should be given to the physiographic type of country in which workable placers are most likely to be developed. One of the conditions that is regarded as favorable for the accumulation of commercial placers is a moderate stream gradient; and such gradients are prevalent in the lower parts of the country. To be sure, moderate gradients may be found in the lower courses of larger streams, even in a district of high relief, but the chances for the formation of a workable placer are less in a wide valley drained by a large stream than in the smaller tributary valleys. It does not necessarily follow from these considerations that workable placers will not be found in the higher country, for a sufficiently rich lode may give rise to rich placers under conditions that in general are considered very adverse. The chances of discovering workable placers, however, are much better in the regions of low relief if the conditions for bedrock metallization appear to be equally favorable. With few exceptions the rich placer camps of interior Alaska have been found at an elevation of less than 1,000 feet. The Koyukuk camp is an important exception to this rule, but even in this rugged country the principle has its application, for the richest placers occur on the lower parts of the tributaries close to the middle, south, and north forks of Koyukuk River and to Bettles, Wild, and John rivers—all large streams. The gradients of the parts of the streams that contain the placers are therefore the lowest that the country affords.

Although the gold and the valuable sulphide ores in interior Alaska are all derived originally from the granitic rocks, yet some gold placers have a proximate source of different character. Although the gold contained in the belt of conglomerate that stretches westward from Eagle to Woodchopper Creek, in the Yukon-Tanana region, came originally from granitic rocks, yet for the prospector of to-day this conglomerate may be considered a bedrock source of the gold. Not all the placer gold in this belt, however, comes from this conglomerate, for without doubt some is derived directly from the older rocks, but the importance of the conglomerate as a contributing source of gold should not be overlooked. This example is given to illustrate a principle rather than to indicate that this particular area is of any great importance as a placer field.

Another example of a proximate source of placer gold other than the original bedrock source is afforded by the glacial gravels and débris. Mention has already been made of the possibility at some localities of working such deposits. More commonly, however, the original glacial deposits have been reworked by the present streams, which have concentrated the gold and developed workable stream placers. Practically nothing can be said that will aid the prospector either in finding the original pay streaks in the glacial gravels or in finding the stream placers derived from them. Fortunately placers of this type are rare in interior Alaska, being confined largely to the slopes of the Alaska Range.

INDEX.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

The maps whose price is stated are sold by the Geological Survey and not by the Superintendent of Documents. On an order amounting to $5 or more at the retail price a discount of 40 per cent is allowed.

GENERAL.

REPORTS.

*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp. No copies available. May be consulted at many public libraries.

*Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin 259, 1905, pp. 18–31. 15 cents.

*The mining industry in 1905, by A. H. Brooks. In Bulletin 284, 1906, pp. 4–9. 25 cents.

*The mining industry in 1906, by A. H. Brooks. In Bulletin 314, 1907, pp. 19–39. 30 cents.

*The mining industry in 1907, by A. H. Brooks. In Bulletin 345, 1908, pp. 30–53. 45 cents.

*The mining industry in 1908, by A. H. Brooks. In Bulletin 379, 1909, pp. 21–62. 50 cents.

*The mining industry in 1909, by A. H. Brooks. In Bulletin 442, 1910, pp. 20–46. 40 cents.

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*The possible use of peat fuel in Alaska, by C. A. Davis. In Bulletin 379, 1909, pp. 63–66. 50 cents.

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*Prospecting and mining gold placers in Alaska, by J. P. Hutchins. In Bulletin 345, 1908, pp. 54–77. 45 cents.

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*Map of Alaska (B); scale 1 : 1,500,000; 1915, by A. H. Brooks and R. H. Sargent. No copies available.

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Map of Alaska showing distribution of mineral deposits; scale 1 : 5,000,000; by A. H. Brooks. 20 cents retail or 12 cents wholesale. New editions included in Bulletins 642, 662, and 714.

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Map of Alaska (E), scale, 1 : 2,500,000.

SOUTHEASTERN ALASKA.

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*Economic developments in southeastern Alaska, by F. E. and C. W. Wright. In Bulletin 259, 1905, pp. 47–68. 15 cents.

*The Juneau gold belt, Alaska, by A. C. Spencer, pp. 1–137, and A reconnaissance of Admiralty Island, Alaska, by C. W. Wright, pp. 138–154. Bulletin 287, 1906, 161 pp. 75 cents.

*Lode mining in southeastern Alaska, by F. E. and C. W. Wright. In Bulletin 284, 1906, pp. 30–53. 25 cents.

*Nonmetallic deposits of southeastern Alaska, by C. W. Wright. In Bulletin 284, 1906, pp. 54–60. 25 cents.

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*The Ketchikan and Wrangell mining districts, Alaska, by F. E. and C. W. Wright. Bulletin 347, 1908, 210 pp. 60 cents.

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*Report of water-power reconnaissance in southeastern Alaska, by J. C. Hoyt. In Bulletin 442, 1910, pp. 147–157. 40 cents.

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*Juneau gold belt, Alaska; scale, 1:250,000; compiled. In *Bulletin 287. 75 cents. Not issued separately.

Juneau special (No. 581A); scale, 1:62,500; by W. J. Peters. 10 cents retail or 6 cents wholesale.

Berners Bay special (No. 571B); scale, 1:62,500; by R. B. Oliver. 10 cents retail or 6 cents wholesale. Also contained in Bulletin 446.

Kasaan Peninsula, Prince of Wales Island (No. 540A); scale, 1:62,500; by D. C. Witherspoon, R. H. Sargent, and J. W. Bagley. 10 cents retail or 6 cents wholesale. Also contained in Professional Paper 87.

Copper Mountain and vicinity, Prince of Wales Island (No. 540B); scale, 1:62,500; by R. H. Sargent. 10 cents retail or 6 cents wholesale. Also contained in Professional Paper 87.

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*The McKinley Lake district, by Theodore Chapin. In Bulletin 542, 1913, pp. 78–80. 25 cents.

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*Mineral deposits of the Ellamar district, by S. R. Capps and B. L. Johnson. In Bulletin 542, 1913, pp. 86–124. 25 cents.

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*Mining in central and northern Kenai Peninsula in 1917, by B. L. Johnson. In Bulletin 692, 1919, pp. 175–176. 50 cents.

*Nickel deposits in the lower Copper River valley, by R. M. Overbeck. In Bulletin 712, 1919, pp. 91–98. 20 cents.

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Headwater regions of Copper, Nabesna, and Chisana rivers, reconnaissance map; scale, 1:250,000; by D. C. Witherspoon, T. G. Gerdine, and W. J. Peters. In *Professional Paper 41. 50 cents. Not issued separately.

Controller Bay region (No. 601A); scale, 1:62,500; by E. G. Hamilton and W. R. Hill. 35 cents retail or 21 cents wholesale. Also published in *Bulletin 335. 70 cents.

Chitina quadrangle (No. 601), reconnaissance map; scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, and others. 50 cents retail or 30 cents wholesale. Also published in Bulletin 576.

Nizina district (No. 601B); scale, 1:62,500; by D. C. Witherspoon and R. M. La Follette. In Bulletin 448. Not issued separately.

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Prince William Sound; scale, 1:500,000; compiled. In *Bulletin 526. 30 cents. Not issued separately.

Port Valdez district (No. 602B); scale, 1:62,500; by J. W. Bagley. 20 cents retail or 12 cents wholesale.

The Bering River coal fields; scale, 1:62,500; by G. C. Martin. 25 cents retail or 15 cents wholesale.

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