DEPARTMENT OF THE INTERIOR
Hubert Work, Secretary

U. S. GEOLOGICAL SURVEY
George Otis Smith, Director

Bulletin 773

MINERAL RESOURCES OF ALASKA

REPORT ON PROGRESS OF INVESTIGATIONS IN

1923

BY

A. H. BROOKS AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

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PREFACE

By Alfred H. Brooks

This volume is the twentieth 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 mineral deposits and of the statistics of mineral production of the Territory.

The previous volumes of this series have been made to cover, so far as practicable, the entire mining industry of the Territory, because for many years the Geological Survey was the only organization that had for its mission the investigation of the Alaska mining industry, and therefore it perforce attempted to cover the entire field. The available funds did not permit the investigation of the technique of mining,[2] but for many years efforts were made to collect information about mining in addition to that on mineral resources and production, with the collection of which the Survey is charged by law. Data on the methods and the progress of mining are now given in the reports [3] of the Territorial mine inspector, who is also resident supervising engineer of the Bureau of Mines. To avoid duplication of his report, the references to the technology of mining will be limited to those that are incidental to a consideration of the mineral deposits and to an understanding of the statistics of mineral production. As a Federal official, the mine inspector does not collect mineral statistics except those relating to the production of mineral fuels on leased public lands. Therefore this report, unlike those previously issued, relates only to mineral production, statements on mining being left to the mine inspector.

This volume, like those previously issued, deals primarily with the mineral resources of Alaska, and its chief purpose is to give prompt publication of the more important economic results of the year. The articles included are mainly statements of preliminary results and may be modified when the field material is more fully studied. Those who are interested in any particular problem or district are therefore urged to procure a copy of the complete report on it as soon as it is available.

[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, 722, 739, and 755.

[2] The only exception to this was a study of placer-mining methods of Alaska, made in 1904 by the late C. W. Purington (The methods and costs of gravel and placer mining: U. S. Geol. Survey Bull. 263, 1905).

[3] Annual report of the Territorial mine inspector to the Governor of Alaska for the year 1920, Juneau, 1921; for 1921, Juneau, 1922; for 1922, Juneau, 1923.

The reports included in this volume could not be prepared without the information furnished by many residents of the Territory. Some of these have rendered assistance for many years.

Special acknowledgment should be made to the late George W. Ledger, who died in 1923. From 1914 until his death Mr. Ledger every year made a careful summary of the mineral discoveries and mining development in the Rampart district, of which he was a resident. As it is impossible with the small force of technical men available, limited by the appropriation, to reexamine more than a small percentage of the mining districts in Alaska, the free service rendered by Mr. Ledger and many like him is of inestimable value in furthering the achievement of knowledge of the mineral wealth of Alaska. It is impossible to record here the names of all who have rendered aid to the Geological Survey, but the list would include a large majority of the mine operators, as well as many others, and would number in all over a thousand residents. Special acknowledgment should be made to B. D. Stewart, Territorial mine inspector and resident engineer of the Bureau of Mines, who furnished the data on coal production, as well as much other valuable information; to N. L. Wimmler, also of the Bureau of Mines, for information about gold placers; to George Parks and H. K. Carlisle, of the General Land Office; to the Directors and other officers of the Bureau of Mines and Bureau of the Mint; to the collector and other officers of the Alaska customs service; to the officers of the Alaska Railroad; to Charles H. Flory, forest supervisor for Alaska; to E. H. Bartholf, of Hyder; John C. McBride and the Alaska-Juneau Gold Mining Co., of Juneau; Thomas Vogel, of Haines; J. H. Cann, of Chichagof; Thomas G. White, of Katalla; the Kennecott Copper Corporation, of Kennicott; G. Howard Birch, of Nizina; Thomas Larson, of Chitina; J. M. Elmer, of Dempsey; Alex Liska, Sumner Smith, and Felix Brown, of Anchorage; Arthur Moose Johnson of, Chulitna; Charles Zielke, of Nenana; W. E. James, of Chisana; William Yanert, of Beaver; J. J. Hillard and E. A. Robertson, of Eagle; Alfred Johnson, of Deadwood; the First National Bank, George Hutchinson, and Henry Cook, of Fairbanks; Charles E. M. Cole, of Jack Wade; Edward Schneirla and Frank Speljack, of Ophir; Alexander Mitchell and Mason C. Farrar, of Kantishna; H. S. Wanamaker, of Wiseman; Tom Plunkett, of Marshall; J. W. Wick, of Russian Mission; George Jesse and John Flanagan, of Long; Omar J. Quinn, W. E. Leska, and H. Jensen, of Poorman; Lynn Smith and Ernest Werner, of Ruby; A. J. Griffin, of Richardson; A. M. Bainbridge, of Tolovana; L. F. Bullard and Thomas P. Aitken, of McGrath; A. Stecker and John Haroldson, of Kwinak; the Miners and Merchants Bank, A. W. Kah, and Jack Gale, of Nome; E. M. Marx, of Teller; S. M. Gaylord, of Solomon; Louis Lloyd, Frank R. Ferguson, and James C. Cross, of Shungnak; and J. J. Elliot, of Haycock.

ALASKA'S MINERAL RESOURCES AND PRODUCTION, 1923

By Alfred H. Brooks

GENERAL FEATURES

In 1923, in spite of the continuation of the high cost of all forms of mining and the low value of copper and other metals, more men than in 1922 engaged in the search for mineral wealth and a greater number of projects were under way in preparation for productive mining. In other words, the work of the prospector and that of the capitalist, guided by the mining engineer, showed advances during the year. There is good evidence that the widespread pessimism in regard to the Alaska mining industry that has persisted during the postwar period of financial depression is gradually disappearing. It has come to be realized that although the facts in hand about Alaska's mineral wealth show that the days of quick returns from the exploitation of bonanza placer mining, which are so favorable to local communities, are passed, yet there are in the Territory abundant mineral resources that can be profitably exploited by the use of improved mining methods. However, in practice these methods require the services of mining engineers and ample capital.

It is therefore evident that the Alaska mining industry has passed through its period of lowest depression and is now being gradually built up on a stable basis. This gain is, to a large extent, due to the improvement of the general business situation, but it has been greatly accelerated by a gradual lowering of mining costs through the betterment of transportation facilities. The mining public has come to realize that the Federal Government, by completing the trunk-line railroad from tidewater to the heart of Alaska, by affording better steamboat service on the Yukon, and by making more liberal grants for wagon roads and trails, has definitely embarked on a policy of fostering the mining industry, which has greatly stimulated mining advances. With the rapid exhaustion of the bonanzas, successful alluvial mining necessitates a greater use of power-driven machinery to recover the gold from Alaska's very large reserves of low-grade auriferous gravels, but such work is possible only in easily accessible districts. Lode gold, copper, and coal can, of course, be profitably mined only at localities served by steamers, railroads, or highways. The expansion of mining is possible only in districts served by reasonable freight rates. Twenty years ago 60 per cent of Alaska's mineral output came from remote districts not reached by well-organized transportation; in 1923 only 5 per cent came from similar isolated districts.

Though completed only a year ago, the Alaska Railroad has already stimulated mining development in the immediately tributary regions, but the contributions from these regions have not yet greatly increased the mineral output. In 1922 [1] the value of the mineral output from the railroad region was $1,840,000; in 1923 it was $2,080,000. The output in 1923 came from 170 small mines employing 1,000 men, not including the prospectors and others employed in nonproductive development, who will probably aggregate 500 more. The industrial population represented by these 1,500 employees is of course too small a number to support 500 miles of railroad. It should be regarded, however, as only the forerunner of a larger mining industry, which will be developed. This advance may be much accelerated by the building of wagon roads and trails as feeders to the railroad. The increase in a mining population will afford a greater market for the product of the farming lands tributary to the railroad. The increase in Alaska coal mining—though the output is still small—since the completion of the Government railroad has been all-important to Alaska industries. In 1914, when Alaska coal was first thrown open to utilization by the enactment of the leasing law, all but 1 per cent of the coal consumed in the Territory was imported, at heavy expense. In 1922 64 per cent and in 1923 70 per cent of the coal consumed in the Territory was obtained from the Alaska fields, at a cost per ton to the consumer much less than that of the imported coal.

Alaska is still dependent on imported petroleum, though she contains valuable oil fields now under development under the leasing law of 1920. It is to be expected that Alaska will soon supply her own mineral fuels. This means that with the utilization of her own abundant water power the Territory will in time become entirely self-supporting in the matter of sources of energy, a condition which will benefit all her industries.

Much has been said of the vast mineral reserves of Alaska, but nearly all of it has been based on information gleaned from geologic surveys that have covered less than a third of the Territory. Though the areas surveyed include most of the regions that have the greatest promise of mineral wealth, yet it is also true that the unsurveyed areas of Alaska are more than two and a half times as large as the surveyed areas, and there is reason to believe that they also contain districts of mineral importance. There is, for example, an unsurveyed area of 20,000 square miles lying between Cook Inlet on the east and Kuskokwim River on the west, in which copper, gold, and coal are reported and petroleum may occur along its eastern margin. In another unsurveyed area of about 3,000 square miles that extends eastward along the southern margin of the Tanana Valley from the

[1] The statistics in this report have been compiled by Miss E. C. Nichols.

Richardson Highway metal deposits are also reported. These two fairly accessible regions in central Alaska include areas equal to three times that of Massachusetts which are entirely unsurveyed and whose resources are wholly unknown and must therefore be ignored in an estimate of mineral wealth. Moreover, until this vast region is geologically surveyed it may not be regarded as a potential source of wealth to the Territory and hence of tonnage to the railroad. There are of course much larger unsurveyed areas in the more remote parts of Alaska, the investigation of which might disclose sources of mineral wealth, but the utilization of such sources is a matter of the future and does not affect the immediate situation, for the mining advances will first take place in the regions already made accessible. These facts are set forth to show that the prospector still has a large field outside of the areas that have already been productive of minerals.

The geologic survey of that part of Alaska that has been mapped has revealed a large array of facts on the potential mineral resources of the Territory. More concrete evidence of this is given by the statistics of mineral production. Mining began with the development of gold placers in 1880 in the Juneau district, where lode mining began two years later. The silver and lead output of Alaska has nearly all been won incidentally to the exploitation of gold and copper deposits. Silver and lead have been recovered in recent years from Alaska galena deposits.[2] A little coal has long been annually mined in Alaska, but a noteworthy production began in 1917. Gypsum mining began in 1906, and marble quarrying in 1901. The production of Alaska tin began in 1902, and platinum in 1916. Antimony, tungsten, and chromite were mined in Alaska during the period of urgent demands caused by the war. A little petroleum has been produced annually in the Katalla field since 1907. At various times quicksilver, graphite, abrasives, and limestone have also been produced in Alaska.

As shown in the following table, Alaska mines have since 1880 produced $517,627,000 worth of minerals, all raw material except that between 1905 and 1909 some copper ores were smelted in the Ketchikan district. During 43 years of mining in Alaska the Territory has made an output of $517,627,000 worth of minerals, of which over 50 per cent has been produced during the last decade.

The total mineral production, both by years and by substances, is given in the subjoined table, which differs somewhat from those previously published. The figures here presented are probably for the most part as accurate as can ever be determined, for the statistics of the first 25 years of mining were not systematically collected. There are, however, some data on the silver and lead output of the earlier years that may slightly modify the figures here presented.

[2] A little galena was produced at the Omalik mine, Seward Peninsula, as early as 1881.

Value of total mineral production of Alaska, 1880–1923

By years				By substances	
1880–1890	$4, 193, 919	1908	$20, 092, 501	Gold	$340, 955, 074
1891	1, 014, 211	1909	21, 140, 810	Copper	158, 109, 158
1892	1, 019, 493	1910	16, 875, 226	Silver	9, 501, 934
1893	1, 104, 962	1911	20, 720, 480	Coal	3, 580, 500
1894	1, 339, 332	1912	22, 581, 943	Tin	939, 199
1895	2, 588, 832	1913	19, 547, 292	Lead	829, 414
1896	2, 885, 029	1914	19, 109, 731	Platinum	285, 084
1897	2, 539, 294	1915	32, 790, 344	Antimony	237, 500
1898	2, 329, 016	1916	48, 386, 508	Marble, etc	3, 189, 080
1899	5, 425, 262	1917	40, 694, 804		517, 626, 943
1900	7, 995, 209	1918	28, 218, 935		
1901	7, 306, 381	1919	19, 626, 824		
1902	8, 475, 813	1920	23, 330, 586		
1903	9, 088, 564	1921	16, 994, 302		
1904	9, 627, 495	1922	19, 420, 121		
1905	16, 490, 720	1923	20, 330, 643		
1906	23, 501, 770				
1907	20, 840, 571		517, 626, 943		

In 1906 the value of the annual mineral production first exceeded $10,000,000, and from that time to the beginning of the World War it ranged from over $16,000,000 to nearly $23,000,000. This was the period of maximum output from the bonanza placers; then came the war period (1915–1918), when the value of the annual output, chiefly copper, was from $28,000,000 to $48,000,000. During the postwar epoch the value of the annual mineral output has been about $20,000,000, which is greater than that of the pre-war decade. Measured by the value of the annual output, the industry has reached its pre-war prosperity, though this is only because the increased output of copper has more than made up for the falling off in gold mining. The value of the total mineral output in 1923 was greater than that of the previous year, as shown in the following table:

Mineral output of Alaska, 1922 and 1923

	1922		1923		Decrease or increase in 1923	
	Quantity	Value	Quantity	Value	Quantity	Value
Gold ... fine ounces	359, 057	$7, 422, 367	289, 539	$5, 985, 314	−69, 518	−$1, 437, 053
Copper ... pounds	77, 967, 819	10, 525, 655	85, 920, 645	12, 630, 335	+7, 952, 826	+2, 104, 680
Silver ... fine ounces	729, 945	729, 945	814, 649	668, 012	+84, 704	−61, 933
Coal ... short tons	79, 275	430, 639	119, 826	755, 469	+40, 551	+324, 830
Tin, metallic ... do	1. 40	912	1. 90	1, 623	+. 50	+711
Lead ... do	377	41, 477	410	57, 400	+33	+15, 923
Platinum metals . fine ounces	28. 30	2, 830	25. 90	3, 004	−2. 40	+174
Miscellaneous nonmetallic products, including petroleum, marble, and gypsum	----------	266, 296	----------	229, 486	----------	−36, 810
	----------	19, 420, 121	----------	20, 330, 643	----------	+910, 522

Compared with 1922 and measured by production, gold mining decreased about 20 per cent, copper mining increased 10 per cent, and coal mining increased 50 per cent in 1923. Though the value of the total mineral output of 1923 is greater than that of 1922, it should be noted that this increase is due almost entirely to the output of three large copper mines. On the other hand, the systematic drilling for oil and the increased lode-mining development are very encouraging features of the industry.

In 1880 mining was begun at Juneau by a score or two of prospectors. During the next decade the mining population gradually increased, but it did not aggregate more than 6,000 men employed in profitable mining until 1900, during the Nome gold rush. From that time until the present there have always been a greater number of men employed in placer work than in any other form of mining. Such employment, however, is limited to 100 to 150 days in the year. The gradual stabilization of the mining industry is shown by the fact that each year there is a greater percentage of the mine labor employed in other than placer mining.

Estimates of number of men employed at productive mines of Alaska in 1890, 1900, and 1910–1923 [a]

Year	Placer mines		Lode mines and reduction plants	All other mining and quarrying	Total, not including winter placer mines
	Summer	Winter (omitted from total)			
1890 [b]	175		200		375
1900 [b]	5,000		1,200	20	6,220
1910 [b]	5,500		2,000	120	7,620
1911	4,900	670	2,360	150	7,410
1912	4,500	900	2,500	150	7,150
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	4,200	340	8,590
1917	3,550	950	3,220	270	7,040
1918	3,000	610	1,897	400	5,297
1919	2,180	320	1,757	310	4,247
1920	1,990	340	1,880	360	4,230
1921	2,150	460	1,681	400	4,231
1922	2,198	402	1,623	280	4,101
1923	2,081	287	1,500	270	3,851

[a] Placer miners by the Geological Survey. Other figures chiefly from reports of Federal and Territorial mine inspectors.
[b] Figures only approximate.

GOLD AND SILVER

GENERAL STATISTICS

The Alaska gold miner shares with his colleagues in the rest of the world the disability produced by present economic conditions, which cause very high costs of operation, while the value of his product remains fixed. It can not be foreseen what the future holds forth for gold mining, but two conclusions appear to be justified. The period of maximum costs has passed; but, on the other hand, the general economic conditions reveal no evidence that there will be any marked reduction of costs in the immediate future. The Alaska gold miner must therefore plan for a future under the present operating costs, except in so far as these are reduced by a cheapening of transportation, brought about by improvement of rail and highway service.

Alaska gold-mining methods as developed at the Juneau lodes and in dredging are examples of what can be accomplished in reducing mining costs and compare favorably with the methods used in similar operations in more accessible parts of the world. How far these methods can be applied elsewhere in the Territory is the problem of the engineer.

The gold output of 1923 makes a remarkable showing considering the lesser number of large lode mines and the unusual lack of water because of the dry summer in many of the placer districts. In spite of the adverse conditions that now confront gold mining, the outlook for an increased gold output in the immediate future is good, because of the increase of dredging and the marked advances that are being made in the development of the higher grade of auriferous lodes in many widely separated localities. Under present economic conditions there seems to be no likelihood that large projects will be launched involving the exploitation of the large bodies of quartz lodes having only a low gold tenor.

The subjoined table shows the total gold and silver output of Alaska from lode and placer mines by years. It includes the gold recovered from copper ores, which is given in detail in a later table (p. 9). The figures given in this table differ somewhat from those previously published, owing to the revision of the estimates of output of the first 25 years of mining, for which there are no accurate statistics.

Gold and silver produced in Alaska, 1880–1923

Year	Gold		Silver		Value of gold by sources	
	Fine ounces	Value	Fine ounces	Commercial value	Placer mines	Lodè mines
1880	290	$6,000			$6,000	
1881	726	15,000			15,000	
1882	1,113	23,000			20,000	$3,000
1883	2,709	56,000	10,320	$11,146	51,000	5,000
1884	3,483	72,000			51,000	21,000
1885	20,559	425,000			125,000	300,000
1886	26,123	540,000			150,000	390,000
1887	31,782	657,000			130,000	527,000
1888	32,169	665,000	2,320	2,181	135,000	530,000
1889	40,635	840,000	8,000	7,490	140,000	700,000
1890	40,151	830,000	7,500	6,071	150,000	680,000
1891	48,375	1,000,000	8,000	7,920	220,000	780,000
1892	48,617	1,005,000	8,000	7,000	240,000	765,000
1893	52,729	1,090,000	8,400	6,570	250,000	840,000
1894	63,855	1,320,000	22,261	14,257	450,000	870,000
1895	122,582	2,534,000	67,200	44,222	809,000	1,725,000
1896	134,483	2,780,000	145,300	99,087	960,000	1,820,000
1897	117,793	2,435,000	116,400	70,741	665,000	1,770,000
1898	108,602	2,245,000	92,400	54,575	645,000	1,600,000
1899	257,113	5,315,000	140,100	84,276	3,480,000	1,835,000
1900	381,921	7,895,000	73,300	45,494	5,623,000	2,272,000
1901	348,300	7,200,000	47,900	28,598	4,980,000	2,220,000
1902	403,206	8,335,000	92,000	48,590	5,887,000	2,448,000
1903	423,185	8,748,000	143,600	77,843	6,010,000	2,738,000
1904	440,938	9,115,000	198,700	114,934	6,025,000	3,090,000
1905	766,550	15,846,000	132,174	80,165	12,340,000	3,506,000
1906	1,066,030	22,036,794	203,500	136,345	18,607,000	3,429,794
1907	936,043	19,349,743	149,784	98,857	16,491,000	2,858,743
1908	933,290	19,292,818	135,672	71,906	15,888,000	3,404,818
1909	987,417	20,411,716	147,950	76,934	16,252,638	4,159,078
1910	780,131	16,126,749	157,850	85,239	11,984,806	4,141,943
1911	815,276	16,853,256	460,231	243,923	12,540,000	4,313,256
1912	829,436	17,145,951	515,186	316,839	11,990,000	5,155,951
1913	755,947	15,626,813	362,563	218,988	10,680,000	4,946,813
1914	762,596	15,764,259	394,805	218,327	10,730,000	5,034,259
1915	807,966	16,702,144	1,071,782	543,393	10,480,000	6,222,144
1916	834,068	17,241,713	1,379,171	907,495	11,140,000	6,101,713
1917	709,049	14,657,353	1,239,150	1,021,060	9,810,000	4,847,353
1918	458,641	9,480,952	847,789	847,789	5,900,000	3,580,952
1919	455,984	9,426,032	629,708	705,273	4,970,000	4,456,032
1920	404,683	8,365,560	953,546	1,039,364	3,873,000	4,492,560
1921	390,558	8,073,540	761,085	761,085	4,226,000	3,847,540
1922	359,057	7,422,367	729,945	729,945	4,395,000	3,027,367
1923	289,539	5,985,314	814,649	668,012	3,608,500	2,376,814
	16,493,700	340,955,074	12,278,241	9,501,934	233,122,944	107,832,130

Gold and silver produced in Alaska, 1923, by sources

Source	Gold		Silver	
	Fine ounces	Value	Fine ounces	Value
Siliceous ores (2,502,901 short tons)	113,274.71	$2,341,596	57,763	$47,365
Copper ores (731,168 short tons)	1,627.00	33,633	715,040	586,333
Lead ores (123 short tons)	76.67	1,585	19,474	15,969
Placers (6,015,595 cubic yards of gravel)	174,561.18	3,608,500	22,372	18,345
	289,539.56	5,985,314	814,649	668,012

GOLD LODES

Southeastern Alaska continues to be the scene of the most important gold lode discoveries and development in the Territory, both because the physical conditions favor economical development and because the geologic history of the region has brought about a wide distribution of the auriferous deposits. Everywhere in southeastern Alaska the gold deposits are closely associated with the granitic intrusive rocks.[3] The largest belt of intrusives is that which forms the country rock of the Coast Range. Along its western margin is an auriferous zone where gold was first mined over 40 years ago. Here the alluvial gold deposits were the first to excite interest, for they were rich enough to mine in spite of the fact that the geologic conditions were not especially favorable to the formation of rich placers. During glacial time the huge ice masses advanced through the valleys and swept away and scattered any concentrations of gold that had been formed during the preceding epochs of bedrock erosion and deposition of gravel, and the present gold-bearing gravels were deposited after the glaciation of the region.

The results of auriferous mineralization along the western margin of the Coast Range belt of granite are best known in the Juneau gold belt, along which profitable mining has been done at scattered localities, stretching from Windham Bay on the south to Berners Bay on the north, a distance of 100 miles. Some evidence of the extension of this auriferous belt throughout southeastern Alaska is afforded by the discovery of gold placers and some small gold quartz veins at its north end, in the Porcupine placer district, and to the south, in the Ketchikan district. The Porcupine district produced some $700,000 worth of gold between 1898 and 1906, after which mining there practically ceased, not because the deposits were worked out but because there were then more attractive fields in Alaska. Now systematic development is under way to mine these deposits by hydraulic means, for which they are favorably located as regards water supply and stream gradients. The gold lodes of the Ketchikan district have received attention at various times for many years, and in 1923 work was more systematically undertaken at Helm Bay, on Cleveland Peninsula. The evidence thus indicates the presence of a gold belt extending along the the western margin of the Coast Range belt of granite from the Porcupine district to the Ketchikan district, a distance of some 350 miles. The width of this gold belt has not yet been accurately determined, except at Juneau, where the auriferous deposits occur in a zone about 3 miles in width. This, of course, does not mean that the entire zone is auriferous, for the metallization was confined to certain bands of country rock lying within the zone.

[3] These intrusives, which can be conveniently grouped together as "granitic," range in composition from granite to diorite.

To the south and north of the Juneau gold belt the auriferous zone is narrow and is far less well defined. Broadly speaking, the entire Coast Range zone may be regarded as a site of future mineral discoveries.

The enormous output from large lode deposits carrying a low percentage of gold at Juneau should not obscure the fact that the zone includes many richer ore shoots that have been profitably mined on a small scale. It is the latter type of deposit which at present is likely to attract the miner, for in spite of the continued success of the mining at the Alaska Juneau mine, capitalists are not likely to enter into similar new ventures in gold mining under present economic conditions.

It has long been known that some metallization has occurred along the eastern margin of the Coast Range belt of granite, which is for the most part on the Canadian side of the international boundary. This gold and silver bearing zone, though long prospected, had attracted no great attention until the development of the great Premier mine in 1918. This mine is on the Canadian side but close to the boundary, and when its development showed it to include a large ore body carrying a high silver content with some gold, many miners were attracted to the adjacent Hyder district in Alaska. The work of 1923 showed an extension of the metallized belt of the district beyond that previously known.[4] Though thus far only test shipments have been made from the Hyder district, an early and regular production from this camp is to be expected.

There is good reason to believe that a metallized zone extends along the entire eastern margin of the Coast Range belt of granite. Evidence of such a zone has been found along Unuk, Stikine, and Taku rivers, as well as near the White Pass Railroad, but it probably lies chiefly on the Canadian side of the boundary. Alaska will, however, receive at least an indirect benefit from any mining in this belt.

A. F. Buddington has found evidence that there are within the Coast Range granite belt some bodies of schist which in places are metallized. These schists are for the most part in rather inaccessible localities within the higher part of the range. The commercial value of the deposits, which carry silver and gold, is yet to be determined, but they serve to indicate that the area mapped as granite may include zones of commercial ore bodies, provided they are rendered accessible.

A belt of granite intrusives stretches through the central part of Chichagof Island and extends southward into Baranof Island. A metallized zone has been found along the western margin of this granite belt, in which lie the Chichagof and Hirst-Chichagof mines. Farther away from the granite but in the same general zones are the auriferous veins south of Sitka, which were the first to be discovered

[4] The ores of the Hyder district are described by A. F. Buddington in another part of this volume.

in Alaska. Evidence of auriferous mineralization has also been found near the eastern margin of the Chichagof belt of granite, notably on Lisianski Inlet, where work is being markedly advanced at the Apex mine.

In addition to these main granite belts, there are in southeastern Alaska many scattered smaller granite areas, along the margins of which gold and silver deposits have been found. An example of such an area is found near Funter Bay, near the north end of Admiralty Island, where the Pekovich, Alaska Dano, and Williams gold properties are being developed.

The geologic association of the auriferous lodes with the granite intrusives in southeastern Alaska, an association which, indeed, is common to most of the Alaska gold deposits, has long been known.[5] It is here again noted as evidence that there are large areas in the Panhandle in which there are strong hopes of new discoveries, and therefore the future of gold mining is not to be measured by the present discoveries. Gold-bearing quartz was mined in a small way at Sitka in 1879, and yet it was not until 1905 that the northern extension of this belt was recognized by the discovery of the deposit worked by the famous Chichagof mine. In spite of the accessibility of southeastern Alaska, prospecting in this region is difficult because a heavy mat of vegetation mantles the bedrock.

The genetic relation between gold lodes and igneous stocks and dikes is illustrated by the deposits on Prince William Sound and Kenai Peninsula. Here gold mining has been continued in a small way for many years, but no large or very rich ore bodies have been found. In 1923 a new gold-bearing lode was found on Nuka Bay, in the southwestern part of Kenai Peninsula. This region has long been known to be gold bearing,[6] but the new discovery is reported to be promising enough to attract considerable interest.

The Willow Creek district has been a producer of lode gold since 1908. The geology of the district is well known, and the surface croppings show that the lodes are persistent along the strike. Most of the mining has been done at shallow depths, and many rich shoots of ore have been found. No considerable quantity of ore has been developed, and until this is done no large production of gold is to be expected. If these gold veins are proved to be persistent at greater depth, the prospector will no doubt extend his search into adjacent regions. The margin of the granite zone stretches parallel to the Matanuska Valley for 20 to 30 miles, northeast of the Willow Creek district and about 10 to 15 miles from the railroad. Some of the streams cutting along this margin are known to carry a little

[5] Spencer, A. C., The Juneau gold belt: U. S. Geol. Survey Bull. 287, pp. 21-22, 1906.

[6] Grant, U. S., Geology and mineral resources of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 229-230, 1915.

alluvial gold. This zone seems well worth prospecting for auriferous lodes, though none have yet been discovered, so far as known. The granite margin extends from Kaskawulsh River, north of the Willow Creek district, northeastward for 20 miles to Sheep Creek, and this zone also is worth prospecting.

In 1923 a deposit of ruby silver, the first found in Alaska, was discovered on Portage Creek, 12 miles from Chulitna station on the Alaska Railroad. The geologic occurrence of this ore is unknown, but it may prove to be an indication of a new source of valuable mineral.

For reasons unknown the development of gold lodes in the Fairbanks district was unexpectedly small, considering that the region is now readily accessible by rail and wagon roads. No new discoveries of gold lodes were reported, and mining was practically restricted to small operations at three mines, which made only small outputs. As the district has been proved by underground work to contain some small but fairly rich veins though no large ore bodies, productive mining is to be expected at an early date. The auriferous mineralization here, as elsewhere in Alaska, occurred near the margins of granitic intrusives.

The ores of the Kantishna district occur both in schist, like those at Fairbanks, and in slate and limestone, but both types appear to be genetically related to igneous intrusives. They are essentially galena ores, some of which carry much silver and some gold. Copper, zinc, and antimony ores have also been found in the district. Under the present high transportation charges it has been found that even the richest galena ores, on which there were two operations in 1923, can not be mined at a profit. This condition will be changed when the district is reached by a wagon road, now being built from the railroad.

A belt of slate and limestone has been traced for 100 miles to the southwest of the Kantishna district, along the inland front of the Alaska Range, and granitic intrusives are also present. Deposits of gold, silver, and copper have been found at several places in this region, and some ore bodies have been reported. The geology of the region appears favorable for the occurrence of valuable metals, but of this there is as yet no definite evidence.

A rather ill-defined auriferous belt stretches from the Ruby district, on the Yukon, to the southwest, including the Innoko and Iditarod districts. Its southwest limit is marked by the placers of the Kuskokwim region. The gold deposits of this belt occur along the margins of granitic intrusives, and their linear arrangement is probably due to the fact that the granites were intruded along one general axis of deformation. In this general belt the gold mineralization was intimately associated with the granite. There has long been some quartz prospecting in this region, but on account of high transportation costs lode mining has been slow of development. Some prominsing lodes are said to have been prospected in the Iditarod district during 1923.

The distribution of placer gold in the Iditarod district suggests that its occurrence in bedrock is probably more concentrated here than in most other Yukon districts. Most of the placer gold of the Iditarod district has been recovered from the gravel of streams like Flat, Happy, and Chicken creeks, which have their sources in a single granite dome. Some auriferous zones occur in this granite, a fact which suggests that there may be a considerable body of granite that contains gold enough to constitute a low-grade ore. Under existing conditions this material could not be profitably mined, and the auriferous lodes which have received consideration are richer veins that penetrate the limestone and slate adjacent to the intrusive granite.

Gold and silver produced from gold-lode mines in Alaska in 1923, by districts

District	Number of mines	Ore mined (short tons)	Gold		Silver		Average value per ton of ore in gold and silver
			Fine ounces	Value	Fine ounces	Value	
Southeastern Alaska	5	[a] 2,489,280	95,341.85	$1,970,891	53,825	$44,137	[b] $0.81
Willow Creek	6	9,132	8,622.29	178,238	912	748	19.60
Fairbanks district	3	1,270	1,190.77	24,616	300	246	19.58
Other districts	5	[a] 3,342	8,196.47	169,436	22,200	18,203	56.15
	19	2,503,024	113,351.38	2,343,181	77,237	63,334	[b] .96

[a] Including small amounts of galena ore.
[b] Average value of ore milled, southeastern Alaska $1.77, total Alaska, $2.07.

As shown in the above table, 19 gold and silver lode mines were operated in Alaska during 1923; in 1922 there were 25. Some gold and silver was also produced from half a dozen other lode properties incidentally to development. The low average recovery of gold and silver per ton of ore from southeastern Alaska, as well as from the total quantity mined in the Territory, is due to the overwhelming output of ore from the Alaska Juneau mine. The figures given in the table include all the ore mined by the Alaska Juneau, of which over half is rejected after coarse crushing and hand sorting. If this were not included, the value of the average gold and silver content of the southeastern Alaska ores would be $1.77, and of all Alaska ores $2.07. Though the auriferous lode discoveries and developments during the year were very encouraging, yet so far as producing mines are concerned the status is even less favorable than the above table would indicate. Of the 19 mines classed as productive, only nine made an output of $10,000 worth of gold or more, and only three exceeded

$100,000. The present outlook in regard to Alaska lode mines indicates small rather than large operations.

The Alaska Juneau, the only productive mine in the Juneau district and the largest in the Territory, was operated throughout the year. The Chichagof, in the Sitka district, was operated until July, when the property was taken over by a new management, which expects to resume operations in 1924. Close to it is the Hirst-Chichagof, which was operated on a small scale. In the Ketchikan district the Julia (Kasaan Gold), on Prince of Wales Island, and the Helm Bay King, on Cleveland Peninsula, were operated on a small scale. Productive mining was also done on the North Midas, in Chitina Valley; the Tuscarora, near Valdez; and the Lucky Strike, on Kenai Peninsula, all gold properties. In the Willow Creek district gold was produced at the Gold Bullion, Lucky Shot, and War Baby, of the Willow Creek Mines, and at the Mabel and Fern Gold mines. There was also a small gold output from prospects under development. The gold from the Fairbanks district came chiefly from the Mohawk, Smith Bros., and Crites & Feldman mines. The Nixon mine was the only productive lode property in the Kuskokwim basin.

GOLD PLACERS

THE DEPOSITS

Distribution and yield.—Auriferous gravel is very widely distributed in Alaska, for it has been found in the streams of southeastern Alaska and of the Copper, Susitna, Kuskokwim, Yukon, Kobuk, and Noatak basins, as well as those of Seward Peninsula. It also occurs in a few streams of Alaska Peninsula and in the beach gravel at a number of places along the Pacific shore line. In almost all these regions fine particles of alluvial gold are present in the stream gravel, but only in certain ones have workable gold placers been developed. A placer can be defined as a deposit of sand, gravel, and other loose material containing a sufficient percentage of gold or other valuable minerals to permit its profitable recovery. It is evident that profitable mining of auriferous gravel will depend on its accessibility, as well as on the ease of its excavation and on the gold content. Under the expensive mining methods used by the Alaska pioneer, gravel carrying less than $5 worth of gold to the cubic yard could seldom be profitably exploited. In contrast to this, the gradual increase in profitable operation of lower-grade placers in Alaska is shown in the subjoined table. This table is based in part on estimates, and therefore the figures are by no means exact, but they are near enough to the truth to indicate the marked decline in the average gold recovery to the cubic yard.

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

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 cubi yard
1908	4,275,000	$3.74	1916	7,100,000	$1.75
1909	4,418,000	3.66	1917	7,000,000	1.40
1910	4,036,000	2.97	1918	4,931,000	1.20
1911	5,790,000	2.17	1919	4,548,000	1.10
1912	7,050,000	1.70	1920	3,439,900	1.13
1913	6,800,000	1.57	1921	4,812,700	.88
1904	8,500,000	1.26	1922	5,226,000	.84
1915	8,100,000	1.29	1923	6,015,595	.60

The average gold recovery to the cubic yard for all forms of placer mining in 1923 was only 60 cents and for dredging only 40 cents. An estimate of the gold placer reserves of Alaska must take account of the cost of mining, for, on the one hand, deposits of auriferous gravel whose gold content and cost of mining has not been determined must not be included, and, on the other hand, a given deposit of placer gold must not be ignored becaues of its present inaccessibility or because the cheapest form of mining has not been contemplated.

The above table covers all placer-mining operations. The figures are somewhat misleading owing to the fact that, especially in the later years, a few unprofitable mining ventures are included. Eventually such errors in judgment are abandoned, but while they are continued they affect the significance of the total averages. It seems probable that under present economic conditions the average value of the gold recovery per cubic yard will not admit of any reduction.

Types.—The gold of placer deposits has its original source in bedrock. Therefore, the first requisite to the formation of placers is the separation of the gold from the hard rock by weathering and abrasion. The gold of the bedrock may occur in rich lodes, from which little concentration is necessary to form a workable placer. This concentration may be almost nothing except the process of weathering, or it may be increased by the action of gravity which carries the auriferous débris. More commonly the gold is disseminated in the bedrock and forms placers only after water sorting and transportation.

The most valuable Alaska placers are those which have been formed by water transportation, either as stream deposits or beach deposits. The stream placers are the most extensive, for the beach placers, though some are of extraordinary richness, are usually too small to permit large-scale mining operations. Some placers have been formed by gravel of glacial origin, though in general deposits of this type are not of any great richness. Geologically the Alaska placers are chiefly of Recent formation. Among the deeply buried and elevated placers there are deposits believed to be of Pleistocene age. In the Yentna district Mr. Capps has found gold placers in early Tertiary sediments, resting on weathered pre-Tertiary rocks, and there are probably other occurrences of this age in Alaska.

It has been shown that alluvial gold is derived by weathering from bedrock deposits, and placers are formed by subsequent concentration through gravity and water sorting and transportation. The process of water sorting may be repeated in later erosion cycles that reconcentrate the alluvial gold and therefore form richer placers, which are called "re-sorted placers." The following classification of Alaska placers [7] is essentially genetic:

I. Residual: Rest directly on bedrock source of gold, from which the gold has been separated by weathering.
II. Eluvial: Concentrated by gravity, which has led to soil creep down a slope, but without sorting by running water.
III. Fluviatile: Sorted and transported by running water:
  1. Present streams.
  2. Ancient streams: Deposited in former watercourses:
    a. Bench deposits.
    b. Buried channel deposits.
IV. Beach: Formed by marine erosion and deposition:
  1. Present shore line.
  2. Ancient shore line:
    a. Elevated beaches.
    b. Depressed beaches.
V. Glacio-fluviatile: Fluviatile deposits of débris formed by glacial erosion.
VI. Re-sorted: Deposits formed by the erosion of old placers and the reconcentration of their gold content:
  1. Fluviatile.
  2. Marine (beach).

Most placer gold was originally derived from residual deposits, though in some placers the process of weathering has had little influence, for the metal was separated from bedrock chiefly by water abrasion. As there is a constant tendency for all weathered material to move down the slopes, most residual gold soon becomes eluvial, in which there is a tendency toward the concentration of the heavy material. When sorting and transportation by running water take place the third and last stage in the formation of a placer formed in one erosion cycle has been reached, and the deposit is a fluviatile placer. The fluviatile placers may occur in the gravel in the present streams or may have been formed in the streams of an older erosion cycle, evidence of which may be preserved in benches above the present valley bottoms or in buried channels lying far below them.

Beach placers represent a special type of formation along present or ancient shore lines. Many of these are of the re-sorted type, for the gold, accumulated by wave action, may be derived from older fluviatile placers of the coastal plain. Gradual elevation may give a series of beach placers, which by merging into one another may

[7] This subject has been discussed by the writer in U. S. Geol. Survey Bull. 328, pp. 111-139, and Bull. 592, pp. 27-32, and by J. B. Mertie, jr., in Bull. 739, pp. 160-162.

constitute an almost continuous placer. More commonly, however, the individual beaches stretching parallel to the coast are very sharply bounded.

The glaciation of a region is usually unfavorable to the formation of placers. Ice erosion sweeps away the decomposed bedrock and stream gravel and dissipates their gold content. There are, however, some glacio-fluviatile deposits that contain gold placers. These have resulted from the water sorting and transportation of material derived, often in very large bulk, from glacial scouring. The gold derived from glacial débris may be concentrated by stream or wave action. Glacio-fluviatile placers are likely to occur in gravel containing large boulders, the presence of which may increase the cost of mining. Some of the rich placers found in glaciated regions are concentrations that have been formed before glacial time and are remnants of ancient fluviatile deposits, which occur as buried channels.

Stream erosion and deposition constantly tend to a greater concentration of the heavy material, such as gold, and therefore the enrichment of any placers that are formed. This process goes on more or less through every physiographic cycle, and there is a continuous re-sorting of the alluvium. If, however, elevation renews active erosion, this process of re-sorting will be much accelerated. If placers already formed are then dissected and their gold content reconcentrated in a new placer, the deposit becomes a "re-sorted placer," which is usually far richer than one resulting from only a single epoch of erosion. Re-sorted placers may be formed by the dissection of old bench placers by streams or by wave action on old fluviatile placers on a coastal plain.

In considering the classification of the above table, it should be realized that many of the types merge into one another. Thus a residual placer may pass by insensible stages into an eluvial placer, which in turn will merge into a fluviatile placer. A region, as will be shown, may contain both fluviatile and glacio-fluviatile placers. It may also be difficult in any given locality to distinguish the placers due to one cycle of erosion from those which are re-sorted and therefore have resulted from two cycles.

Residual placers.—Though originally the formation of residual placers was probably very general, most of them have been swept away by subsequent erosion. Only a few small residual placers have been found in Alaska, and these have yielded but little gold.

Eluvial placers.—It has not been uncommon to find in Alaska deposits of loose rock containing a large amount of gold. This rock occurs in angular and subangular fragments derived by weathering of bedrock and accumulated by soil creep not far from its source. Running water has played no part in its sorting or deposition. An eluvial placer of extraordinary richness was mined in 1900 on the Caribou claim of Nekula Gulch, in the Nome district.[8] Another was discovered in 1906 on Coffee Creek, in the Kougarok district.[9] Such deposits are in the form of pockets and are of small linear extent. The "hill-slope placers," also eluvial, which occur on the bedrock underneath the talus of the valley walls, are due to talus creep resulting in local accumulations in irregularities of the bedrock surface. The concentration may have taken place in small irregular benches, as on Ophir Creek, on Seward Peninsula.[10] Examples of residual and eluvial placers are found in the Iditarod district, on the dome at the heads of Flat, Chicken, and Happy creeks.[11] Here the gold occurs in deeply weathered metallized granite and shows no evidence of sorting and transportation by running water. The richness of the placer appears to be due to heavy bedrock metallization. A similar deposit has been found on Hill Creek, in the Fairbanks district, where the placer gold rests directly on and within weathered granite, from the metallization of which it has been derived. The metallization, unlike that in the Iditarod district, was not strong enough to furnish rich placers, but the occurrence affords an example of eluvial placers in the Fairbanks district. In another section of this report Mr. Capps describes what is essentially an eluvial placer in the Yentna district.

Examples of rich eluvial placers formed since the region was glaciated have been found in southeastern Alaska. The first gold mined in the Juneau district, over 40 years ago, was found in deposits lying directly on or near the slope below the auriferous lodes that were later developed in the Alaska-Juneau, Perseverance, and Treadwell mines. In general, however, the time since the ice scouring has not been long enough to permit the weathering necessary to the formation of rich eluvial placers. As most of the Yukon basin and Seward Peninsula veins were never glaciated, one condition favoring the formation of eluvial placers is present. The placers of this type in Alaska that can be profitably mined by ordinary methods are but small. As they are located in valley slopes, the dredge can not be used for their exploitation. Such placers are believed to occur in many of the Yukon districts, such as Fairbanks, but the gold in them is so widely disseminated that it can not be mined except by methods permitting the economic handling of large quantities of talus material. It is believed that if water were available to hydraulic off the valley slopes of the gold-bearing areas of, say, the Fairbanks district, a large amount of gold could be recovered and a new epoch of placer mining would begin. Moreover, the clearing off of the

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8 Collier, A. J., The gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, p. 200, 1908.

9 Brooks, A. H., idem., p. 313.

10 Collier, A. J., op. cit., fig. 14, p. 247.

11 Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region: U. S. Geol. Survey Bull. 754, pp. 114-115, 1924.

valley slopes would undoubtedly reveal gold lodes that are now hidden by the heavy talus. Without definite evidence that water for hydraulicking can be made available, however, it is visionary to speculate on such a project. Fairbanks lies in a semiarid region, in which stream gradients are low, and thus far no large hydraulic mining project has been undertaken there.

Fluviatile placers.—The descriptions of residual and eluvial placers show that they are formed by processes which are usually the first stages in the making of the placers that finally result from the sorting and transportation by running water. It should be noted, however, that the residual and eluvial stages may be almost entirely lacking, the gold being separated from the bedrock chiefly by abrasion, while weathering plays only a minor part. In such a deposit the concentration of gold may be effected entirely by the action of running water. Be that as it may, concentration and transportation by flowing water are the most potent factors in the formation of placers. Running water moves both coarse and fine material derived from erosion. The heavy particles, such as gold, are invariably concentrated at or near the bottom of the alluvial deposit, which is moving downstream. The effectiveness of stream transportation depends on the volume and grade of the stream, but in general it will not carry coarse gold more than 1 or 2 miles from its source, though the fine particles may be transported many miles. Experience has shown that the rich placers are confined to the surface of bedrock or at most to the lower 10 feet of the gravel resting on bedrock. Fine gold may occur throughout the gravel of the alluvium, though there is always a concentration in its lower part. "Bar placers" form a special type of fluviatile deposits which are concentrated on stream bottoms, many of them far above the bedrock. These placers are the result of eddies of the stream bottom interrupting the current and affording favorable sites for the deposition of fine gold. Bar placers are usually of small volume but are found in most placer districts.

The gold on Buck Bar, on the lower Stikine River, discovered in 1861, was the first to be profitably mined in Alaska. "Bar diggings" were also the first placers found in the upper Yukon basin, and some of these were rich enough to give profitable return to miners using rockers. Cassiar Bar, on Lewes River, was the most famous of these places, but others were mined on Hootalinqua, Salmon, Stewart, and other rivers. Bar placers had no economic significance except in giving support to the pioneer prospector. At present they serve to give a scanty living to the "sniper" and also to deceive the inexperienced gold seeker into the belief that bar placers are not simply a surface concentration but a sure evidence that richer placers will be found at depth. Many a dredging project has failed because the purely surface character of bar placers has not been recognized.

The fluviatile placers of the present streams are the commonest type and occur in every Alaska gold camp. They are usually shallow deposits and as such are cheaply exploited, but they do not include the richest of the Alaska placer deposits.

The placers formed by the ancient streams afford several types. These may occur in the valleys of the present streams, having been formed during a previous erosion cycle. The most easily recognized are those that occur on rock benches of the valley slope, which mark an older cycle of stream cutting and are of common occurrence in Alaska districts. The true bench placer is a different form of deposit, occurring in a rock-cut bench. By long usage placer-mining claims are called either "creek claims" or "bench claims." The creek claims are those located at and across the streams, and all parallel claims are called bench claims, irrespective of the type of placer they include. If the alluvial floor of the valley is wide one or more tiers of bench claims may be located in its bottom; if it is narrow claims may be staked on the valley slope where there is no bench, and the placer if present is properly a hillside placer of the type here classed as eluvial.

A true bench placer may also occur along the valley slope below the line of present filling. Such a placer will have no surface topographic expression and may be discovered only by excavation. This type of buried bench placer has been found, for example, on Livengood Creek, in the Tolovana district of the Yukon, and on Anvil Creek, at Nome.

Closely associated with these buried bench placers are the deep channel placers, such as those found in the Tolovana and Koyukuk districts and especially in the Fairbanks district. At Fairbanks the richest and most extensive placers occur as deep channels lying on the bedrock floor, in what were formerly broad valleys with gentle slopes.[12] This ancient topography has been obscured by valley filling, consisting largely of talus from the adjacent valley walls. The overburden consists largely of silt, which ranges in thickness from 30 feet or more near the heads of the valleys to over 200 feet toward their mouths. These placers were evidently formed under physical conditions different from those of the present day, and they are properly termed ancient. Most of the Fairbanks placers belong to this ancient type, though in the headwater regions of the creeks there are some normal present-stream placers.

Much searching for underground channels has been done in the Fairbanks district. While extension of those already known is probable, the finding of new ones is unlikely. It should be remembered, however, that the finding of deeply buried channels is a

[12] Prindle, L. M., and Katz, F. J., A geologic reconnaissance of the Fairbanks quadrangle: U. S. Geol. Survey Bull. 525, pp. 92-140, 1913.

laborious task, and in some of the Yukon camps the possibilities of this work are by no means exhausted. The deep channels of Seward Peninsula are chiefly those at Nome and are of marine origin. There is in the Kougarok district [13] a deep deposit of well-rounded gravel near Dahl Creek. Here a shaft was sunk in April, 1905, to a depth of 187 feet in well-rounded quartz gravel that contained a little gold, but as bedrock was not reached the presence or absence of a pay streak was not determined. This indicates that even some of the well-known placer districts of Alaska have not yet been thoroughly explored for deep channels.

A special type of buried channel occurs in the Fairhaven district of Seward Peninsula. Here the overburden consists of comparatively recently extruded lava flows. These lavas, in part at least, flowed over gravel that carries some placer gold. [14]

Bench placers have in places been formed by a drainage system that has little or no relation to the present valley arrangement. These were the result of an older system of erosion and deposition. Although they belong to a different physiographic cycle, they do not differ in essence from such deposits in the deep channels of Fairbanks or the bench placers in the valleys of many other districts. Their most significant feature is that dissection of them may furnish the gold for the enrichment of the more recent placers, which will be discussed under re-sorted placers.

The high bench placers of the Nome district are examples of these types that have been extensively mined.[15] These placers have been mined chiefly by expensive underground-drifting methods. Were water available to hydraulic the entire deposit, an additional large quantity of placer gold could be mined.

Some high bench gravel has been found in the Ruby-Kuskokwim region, but so far as known no workable placers have been found in it.[16] A deposit of high bench gravel has also been traced east of and along Minook Creek, in the Rampart district.[17] This gravel is, locally at least, gold-bearing, but in the absence of water at high level it has been but little mined. Other high bench gravels have been reported in Alaska but have not been described in detail. The White Channel of the Klondike, on the Canadian side of the boundary, represents this type of rich placer deposit.

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[13] Brooks, A. H., The Kougarok region: U. S. Geol. Survey Bull. 328, p. 312, 1908.

[14] Moffit, F. H., The Fairhaven gold placers: U. S. Geol. Survey Bull. 247, pp. 31-35, 47-67, 1905.

[15] Collier, A. J., and others, The gold placers of parts of Seward Peninsula: U. S. Geol. Survey Bull. 328, pp. 198-209, 1908. Moffit, F. H., Geology of the Nome and Grand Central quadrangles: U. S. Geol. Survey. Bull. 533, pp. 101-108, 1913.

[16] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region: U. S. Geol. Survey Bull. 754, pp. 44-49, 1924.

[17] Hess, F. L., Placers of the Rampart region: U. S. Geol. Survey Bull. 337, pp. 64-98 1908. Eakin, H. M., A geologic reconnaissance of part of the Rampart quadrangle: U. S. Geol. Survey Bull. 535, pp. 31-32, 1913.

Beach placers.—The concentration of gold by wave action has taken place at many localities in Alaska. Most of the deposits thus formed are the result of a re-sorting of auriferous alluvium and therefore properly belong in what are here classed as re-sorted placers. The best-known and richest beach placers are those of Nome and Topkok, of Seward Peninsula.[18] At Nome the beach placers include both modern and ancient types.[19] The form of occurrence and genesis of the Nome beach placers have been fully described.[19a] The known beach placers of the peninsula are about mined out, though dredging ground at or near the ancient beach line still remains to be worked. At Topkok, where the only beach placers found are those of the present shore line, no beach placers have been found along the intermediate shore. Much prospecting has been done on the coastal plain at Solomon, but it has not disclosed an ancient beach,[20] though the search has by no means been exhaustive. Modern beach placers have been found at many places along the Pacific seaboard of Alaska. As early as 1891 beach placers were mined at Anchor Point, Cook Inlet, and they have since been mined at this and other localities of the vicinity.[21] A little beach gold was for many years mined on Popof Island, in southwestern Alaska,[22] and at several localities at the south end of Kodiak Island.[23] A little placer gold has been mined from the beach and south end of Middleton Island. About $200,000 worth of gold has been taken from the Yakataga beach placers during the 15 years of intensive mining.[24] A little beach gold has been won from the shore near Yakutat.[25] Valuable beach placers were long worked near Lituya Bay.[26] The total gold recovered from the Pacific coast beach deposits is from $500,000 to $1,000,000 in value. At none of these localities is there evidence of any reserves of placer gold, and at most of them the beach placers seem to be the result of wave cutting of material of glacial origin, in which the gold is undoubtedly widely disseminated.

[18] Collier, A. J., and others, The gold placers of parts of Seward Peninsula: U. S. Geol. Survey Bull. 328, pp. 151–165, 288–291, 1908.

[19] It is worthy of record that a geologic examination of the Nome region in 1899 led to the prediction of the discovery of ancient beach deposits in the coastal plain at Nome, which did not occur until several years later. Schrader, F. C., and Brooks, A. H., Preliminary report on the Cape Nome gold region, pp. 22–23, U. S. Geol. Survey Spec. Pub., 1900.

[19a] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, pp. 74–126, 1913.

[20] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula: U. S. Geol. Survey Bull. 433, pp. 207–217, 1910.

[21] Martin, G. C., Geology and mineral resources of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 110–111, 1915.

[22] Atwood, W. W., Geology of parts of Alaska Peninsula: U. S. Geol. Survey Bull. 467, p. 125, 1911.

[23] Maddren, A. G., The beach placers of the west coast of Kodiak Island: U. S. Geol. Survey Bull. 692, pp. 299–319, 1919.

[24] Maddren, A. G., Mineral deposits of the Yakataga district: U. S. Geol Survey Bull. 592, pp. 134–143, 1914.

[25] Tarr, R. S., The Yakutat Bay region: U. S. Geol. Survey Prof. Paper 64, pp. 165, 168, 1909.

[26] Brooks, A. H., and others, Report on progress of investigations of mineral resources of Alaska in 1906: U. S. Geol. Survey Bull. 314, pp. 64–65, 1907.

Glacio-fluviatile placers.—It has been noted that glacial scouring dissipates the alluvial gold of a region and is unfavorable to the process of placer formation by weathering and stream sorting, described above. It is true, however, that glacial erosion removes a large quantity of material, and if this is sorted by fluviatile action, placers may be formed. Gold has been found in unsorted glacial débris, and the washing of such material by wave or stream action may form workable gold placers. The floods that accompanied the retreat of the ice were favorable to stream sorting of this kind. The glaciated parts of Alaska are likely to contain placers of three types—(1) ancient placers, formed before glaciation and by chance preserved from ice scouring; (2) glacio-fluviatile placers, which resulted from flooding during the disappearance of the ice sheets; (3) placers formed entirely in postglacial time.

The glacio-fluviatile deposits include all those in which the débris from which the placers were formed by fluviatile or marine action was originally scoured from bedrock by glaciers. Examples of these deposits are found in the beach placers of the Pacific seaboard, as well as in all the districts lying in the glaciated areas of Alaska, including the Juneau [27] and Porcupine [28] districts of southeastern Alaska, the Nizina district [29] of the Copper River region; Kenai Peninsula [30]; the Yentna district [31]; the Turnagain Arm region [32]; the Kantishna region [33]; and the Chistochina region.[34]

Re-sorted placers.—There are many placers whose gold content has been enriched by the erosion and concentration of the gold of older placers. The most easily recognizable of these are formed by the dissection of bench placers and the concentration of their gold content in modern stream placers. Such action has been observed in the formation of re-sorted placers by the dissection of the high bench placers of Nome. A similar process in the formation of re-sorted placers from auriferous bench gravels is observable in the Glenn Creek region of the Hot Springs district of the Yukon.

The present placers and some of the ancient beach placers of the Nome region are good examples of re-sorted placers, enriched by the dissection of older fluviatile placers. There are many other re-sorted placers, all characteristically enriched by the reworking of older placers.

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[27] Spencer, A. C., The Juneau gold belt: U. S. Geol. Survey Bull. 287, pp. 77-85, 1906.

[28] Eakin, H. M., The Porcupine gold placer district: U. S. Geol. Survey Bull. 699, 1919.

[29] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district: U. S. Geol. Survey Bull. 448, pp. 98-108, 1911.

[30] Martin, G. C., and others, Geology and mineral resources of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 181-207, 1915.

[31] Capps, S. R., The Yentna district: U. S. Geol. Survey Bull. 534, pp. 47-72, 1913.

[32] Capps, S. R., The Turnagain-Knik region: U. S. Geol. Survey Bull. 642, pp. 174-187, 1916.

[33] Capps, S. R., The Kantishna region: U. S. Geol. Survey Bull. 687, pp. 76-98, 1919.

[34] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers: U. S. Geol. Survey Bull. 498, p. 79, 1912.

PRODUCTION

A large part of the Alaska placer gold reserves are in the semiarid parts of the Territory, where the annual precipitation ranges from 10 to 20 inches. In many districts even a wet season may not supply water enough to sluice all the gravel that otherwise could be profitably mined. If the winter snowfall is light, the spring freshets may not suffice to wash the auriferous gravel accumulated by the deep winter mining. Again, if the summer rainfall is below normal, open-cut mining may lag, because streams do not furnish the water needed for sluicing. On the average, an extra dry period occurs about once in three to five years, and this always curtails gold production. During the period of bonanza gold placer discoveries and development the total placer output (p. 9) did not reflect the abnormal reductions in output of individual districts because of dry seasons, for these were usually more than offset by the increases from other camps. Now that the gold all comes from placers that have long been known, a curtailment by dry weather greatly reduces the total output. In the summer of 1923 abnormally dry weather persisted in Seward Peninsula and in many parts of the Yukon basin, notably in the Innoko, Ruby, Hot Springs, Fairbanks, and Circle districts, and also in the Yentna district of the Susitna basin. That the drought was not universal in the Yukon is shown by the heavy rains of midsummer in the Eagle and adjacent districts. The net result was a decline of $787,000 in 1923, as compared with 1922. Indeed, had it not been for the increase in dredging, the decline in placer-gold output would have been much greater. Even dredge mining has been hampered notably in Seward Peninsula by lack of water.

Under present economic conditions many of the Alaska placer mines are operated at a small margin of profit. There is therefore danger that such a disastrously dry year may have a far-reaching effect on the industry by finally discouraging the operators of many small mines. Should a still larger percentage of small-scale operators withdraw from the industry, the more normal annual output of gold will not be restored until more gold dredges are built or some other form of cheap mining is developed. The statistics of the placer-mining industry in 1923, as compared with 1922, are shown in the following table:

Statistics of placer mining in Alaska in 1922 and 1923

Region	Number of mines				Number of miners				Value of gold produced		
	Summer		Winter		Summer		Winter		1922	1923	Decrease or increase, 1923
	1922	1923	1922	1923	1922	1923	1922	1923			
Southeastern Alaska	2	5	1	-----	3	12	2	-----	3,000	3,500	+500
Copper River region	8	9	5	3	91	86	18	11	165,000	144,000	−21,000
Cook Inlet and Susitna region	36	35	1	-----	174	180	2	-----	293,000	247,000	−46,000
Yukon basin	321	301	99	64	1,254	1,078	321	243	2,119,000	1,644,000	−475,000
Kuskokwim region	30	28	-----	2	137	106	-----	4	542,000	292,000	−250,000
Seward Peninsula	104	60	11	6	528	606	51	29	1,265,000	1,270,000	+5,000
Kobuk region	6	8	3	-----	11	13	8	-----	8,000	8,000	---------
	507	446	120	75	2,198	2,081	402	287	4,395,000	3,608,500	−786,500

Gold dredge mining was very successful in 1923, in spite of the checks caused by the very dry season. Dredging has been done in Alaska for 20 years, during which a constantly growing percentage of the Alaska placer-gold output has been obtained from this form of mining, as is shown by the following table:

Relation of recovery of placer gold per cubic yard to proportion produced by dredges in Alaska, 1911–1923

Year	Percentage of placer gold produced by dredges	Recovery per cubic yard			Year	Percentage of placer gold produced by dredges	Recovery per cubic yard		
		Dredges	Mines	All placers			Dredges	Mines	All placers
1911	12	$0.60	$3.36	$2.17	1918	24	$0.57	$1.84	$1.20
1912	18	.65	2.68	1.70	1919	27	.77	1.31	1.10
1913	21	.54	3.11	1.57	1920	29	.69	1.53	1.13
1914	22	.53	2.07	1.26	1921	37	.57	1.31	.88
1915	22	.51	2.33	1.29	1922	40	.55	1.29	.84
1916	24	.69	2.64	1.57	1923	51	.40	1.28	.60
1917	26	.68	2.21	1.40					

As shown in the subjoined tables, there were 25 dredges operated in 1923, of which 16 were on Seward Peninsula, 7 in the Yukon basin, and 1 each in the upper Kuskokwim and Susitna basins.

Gold produced by dredge mining in Alaska, 1903–1923

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
1922	23	1,767,753	3,186,343	.55
1923	25	1,848,596	4,645,053	.40
	----------	26,723,801	----------	----------

The gold dredges operated in 1923 are listed below.

Seward Peninsula:
- Council district:
  - Northern Light Mining Co., Ophir Creek.
  - Wild Goose Mining & Trading Co. (2 dredges), Ophir Creek.
- Fairhaven district: Alaska Dredging Association, Candle Creek.
- Kougarok district:
  - Alaska Kougarok Co., Taylor Creek.
  - Behring Dredging Corporation, Kougarok River.
- Koyuk district: Dime Creek Dredging Co., Dime Creek.
- Nome district:
  - Bangor Dredging Co., Anvil Creek.
  - Center Creek Dredging Co., Snake River.
  - Dexter Creek Dredging Co., Dexter Creek.
  - Hammon Consolidated Gold Fields (2 dredges), various creeks.
  - Julien Dredging Co., Osborn Creek.
- Solomon district:
  - Eskimo Gold Mining Co., Solomon River.
  - Iversen & Johnson, Big Hurrah Creek.
  - Shovel Creek Dredging Co. (Nylen, Hultberg, and others), Shovel Creek.

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

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

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

The dredges were operated about 120 days in the Nome and Solomon districts and for shorter periods in other districts of Seward Peninsula. The dredges at Fairbanks and Iditarod had a season of about 110 days; at McGrath it was 176 days. Many of the dredges, for various reasons, were not operated the full time, but the above figures give an approximate measure of the length of the dredging season.

There was a notable increase of investigations of gold-dredging projects. With the long experience in Alaska dredging, there is no reason why haphazard projects should be undertaken. Reliable facts on the cost of transportation, which is decreasing, are now available. The drill affords a means of determining the quantity of the placer and its gold contents. Drilling will also determine the physical character of the deposit and, if frozen, its adaptability to thawing by the injection of cold water. If the deposit is in a glaciated region it will also determine whether the placer includes glacial erratics. There is good reason to believe that gold dredging will greatly increase in Alaska, but it is certain that projects of this kind will be successful only if they are fully investigated in advance of the installation of a machine.

COPPER

Copper ores are widely distributed in Alaska and have been profitably mined in the Ketchikan, southeastern Alaska, Chitina, Copper River basin, and Prince William Sound districts. Very promising deposits of copper have also been found in the headwater region of White and Tanana rivers, but these are too remote from transportation to justify present development. With the present low price of copper, even ores available to tidewater or railroad can not be profitably mined unless they are of high tenor or can be developed on a very large and hence economical scale. Accordingly there has been of late little search for copper deposits, and the development of many promising and accessible ore bodies has been discontinued. It appears that during 1923 little work was done on the many scattered copper prospects lying within 20 miles of the Alaska Railroad or the Copper River & Northwestern Railway. In spite of this stagnant condition of Alaska copper development, the output of copper was greater in 1923 than in 1922, as shown in the subjoined table. Most of it came from the Bonanza, Jumbo, and Mother Lode, three large mines of the Kennecott group, in the Chitina Valley, and the Beatson-Bonanza, on Prince William Sound, belonging to the same company. As for many years, copper was also produced at the Rush & Brown mine, in the Ketchikan district of southeastern Alaska, and small amounts from other properties under development. Special mention should be made of the properties visited by F. H. Moffit, who reports as follows:

Underground exploration of the Green Butte group, in the Chitina region, was vigorously pushed in 1923, and some ore was hauled over the wagon road to McCarthy and shipped over the railroad. The ore is chalcocite and copper carbonate, similar to that of the Kennecott mines, and occurs in the Chitistone limestone near the contact with the Nikolai greenstone. Developments thus far made reveal the occurrence of ore in three beds of the limestone, aggregating 16 feet in thickness. W. A. Dickey continued the development of his copper deposit at Rua Cove, Knight Island, on Prince William Sound. The total length of drift and crosscuts on this ore body is now about 1,800 feet, which is much greater than the length erroneously reported by the Geological Survey last year. This deposit occurs along a fault zone which traverses a complex of greenstone and cherty or quartzose rock, possibly altered sediments, and consists principally of pyrrhotite with some chalcopyrite. The mine workings make entrance on the seaward slope of a mountain which rises steeply to the north of Rua Cove. Here the outcrop is traceable to a height of 750 feet above the mine level. The fault zone has been traced north of the mountain crest for a distance of more than a mile and reveals the presence of copper minerals at a number of places.

The occurrences of copper on Prince William Sound are described by Mr. Moffit in another section of this volume.

Copper, silver, and gold produced at Alaska copper mines, 1880, 1900–1923

Year	Mines operated	Ore mined (tons)	Copper		Silver		Gold	Total value of metals
			Pounds	Value	Fine ounces	Value		
1880	1	20	3,933	$826	----------	----------	----------	$826
1900	1	500	100,000	16,000	200	$124	$500	16.624
1901	2	1,350	270,000	44,000	500	300	1,100	45,400
1902	3	2,750	510,000	59,000	900	477	2,600	62,077
1903	4	9,000	1,730,000	224,510	2,500	1,350	10,000	235,860
1904	4	15,000	2,843,586	376,076	4,000	2,330	13,000	391,406
1905	8	52,199	3,481,771	542,155	30,090	18,292	35,370	595,817
1906	15	105,739	6,459,803	1,246,682	27,861	18,577	80,851	1,346,110
1907	13	98,927	6,308,786	1,261,757	52,056	34,357	93,858	1,389,972
1908	9	51,509	4,585,362	605,267	33,602	17,809	47,483	670,559
1909	7	34,669	4,124,705	536,211	22,549	11,726	41,638	589,575
1910	7	39,865	4,241,689	538,695	26,388	14,250	36,484	589,429
1911	8	68,975	27,267,878	3,408,485	320,114	169,660	86,569	3,664,714
1912	7	93,452	29,230,491	4,823,031	376,593	231,605	153,552	5,208,188
1913	6	135,756	21,659,958	3,357,293	273,179	165,000	132,000	3,654,293
1914	6	153,605	21,450,628	2,852,934	283,355	156,695	171,231	3,180,860
1915	14	369,600	86,509,312	15,139,129	897,839	455,204	153,121	15,747,454
1916	18	617,264	119,654,839	29,484,291	1,207,121	794,286	188,977	30,467,554
1917	17	659,957	88,793,400	24,240,598	1,041,153	857,911	265,900	25,364,409
1918	17	722,047	69,224,951	17,098,563	719,391	719,391	107,635	17,925,589
1919	8	492,644	47,220,771	8,783,063	488,034	546,598	63,795	9,393,456
1920	8	766,095	70,435,363	12,960,106	682,033	743,416	18,868	13,722,390
1921	6	477,121	57,011,597	7,354,496	544,311	544,311	11,689	7,910,496
1922	5	581,384	77,967,819	10,525,655	623,518	623,518	15,069	11,164,242
1923	----------	731,168	85,920,645	12,630,335	715,040	586,333	33,683	13,250,301
		6,280,096	837,007,287	158,109,158	8,372,327	6,713,520	1,764,923	166,587,601

SILVER-LEAD

As already noted, some galena ore was mined and shipped in 1923 from two properties, the Red Top lode and the Alpha mine, in the Kantishna district, but these ventures proved unsuccessful because of the high cost of transportation to the smelter. Some ores, rich in silver and lead, were also shipped from the Hyder district, on Portland Canal, and, as before, both silver and lead were produced from the Juneau gold mines. Most of the Alaska silver output is a by-product of gold and copper mining.

Lead produced in Alaska, 1892–1923

Year	Tons	Value	Year	Tons	Value
1892	30	$2,400	1909	69	$5,934
1893	40	3,040	1910	75	6,600
1894	35	2,310	1911	51	4,590
1895	20	1,320	1912	45	4,050
1896	30	1,800	1913	6	528
1897	30	2,160	1914	28	1,344
1898	30	2,240	1915	437	41,118
1899	35	3,150	1916	820	113,160
1900	40	3,440	1917	852	146,584
1901	40	3,440	1918	564	80,088
1902	30	2,460	1919	687	72,822
1903	30	2,520	1920	875	140,000
1904	30	2,580	1921	759	68,279
1905	30	2,620	1922	377	41,477
1906	30	3,420	1923	410	57,400
1907	30	3,180			
1908	40	3,360		6,605	829,414

TIN

There was no revival of tin mining in Alaska during 1923, in spite of the increased value of the metal. The only tin output of the year was that recovered incidentally to gold-placer mining in the Hot Springs district of the Yukon. This region is now accessible enough to lead to the hope that placer-tin mining might be justified. The heavy overburden makes prospecting for tin very difficult, and no bedrock source of the tin has yet been found. There was no tin mining in the York district of Seward Peninsula during 1923.

Tin produced in Alaska, 1902–1923

Year	Ore (tons)	Metal (tons)	Value	Year	Ore (tons)	Metal (tons)	Value
1902	25	15	$8,000	1914	157.5	104	$66,560
1903	41	25	14,000	1915	167	102	78,846
1904	23	14	8,000	1916	232	139	121,000
1905	10	6	4,000	1917	171	100	123,300
1906	57	34	38,640	1918	104.5	68	118,000
1907	37.5	22	16,752	1919	86	56	73,400
1908	42.5	25	15,180	1920	26	16	16,112
1909	19	11	7,638	1921	7	4	2,400
1910	16.5	10	8,335	1922	2.3	1.4	912
1911	92.5	61	52,798	1923	3	1.9	1,623
1912	194	130	119,600				
1913	98	50	44,103		1,612.3	995.3	939,199

PLATINUM METALS

Some 28 ounces of platinum and allied metals was recovered from gold placer mine concentrates obtained on Slate Creek, in the Chistochina district, Copper River region, and on Dime Creek, in the Koyuk district, Seward Peninsula. It was reported that small quantities of platinum occur in the placers of Alfred Creek, in the Nelchina region, and of Penny River, on Seward Peninsula. Since 1916 platinum metals have been recovered from placers only on Slate and Dime creeks, above mentioned, and on Boob Creek, in the Innoko district, and Bear Creek, in the Fairhaven district. Nowhere has placer platinum been found in sufficient quantities to make its recovery for itself alone profitable. Minute quantities of platinum are rather widely distributed in Alaska. The discovery of platinum deposits is very unlikely without a search specially directed toward this object.

The bedrock source of the alluvial platinum is not very definitely known. In general it is believed to have come from basic igneous rocks, which are usually dark green and have a high specific gravity. If such rocks are found, it will be advisable to examine the gravel derived from them carefully for traces of platinum.

The only known bedrock occurrence of the platinum and allied metals in Alaska is at the Salt Chuck mine, in southeastern Alaska. Here these metals occur in association with copper, in an ore body formed in basic igneous rocks.[35] Similar occurrences may be found elsewhere in the Ketchikan district. The Salt Chuck mine, containing palladium, platinum, and copper, was not operated during 1923 but will be reopened in 1924.

Platinum metals produced in Alaska, 1916–1923

Year	Crude ounces	Fine ounces	Value	Year	Crude ounces	Fine ounces	Value
1916	12.0	8.33	$700	1921	57.0	40.0	$2,670
1917	81.2	53.40	5,500	1922	39.0	28.30	2,830
1918	301.0	284.00	36,600	1923	37.0	25.90	3,004
1919	579.3	569.52	73,663				
1920	1,493.4	1,478.97	160,117		2,599.9	2,488.42	285,084

MISCELLANEOUS METALS

While war prices and demands prevailed for such metals as tungsten, antimony, chromite, molybdenite, and quicksilver, the search for and development of bodies of these ores was very active in Alaska. In 1923 this work, so far as reported, was entirely suspended, except that some residual scheelite (tungsten ore) was mined on Rock Creek, in the Nome district. A vein of scheelite, reported to be 5 inches wide, was discovered at the Apex-El Nido gold mine, in the Sitka district, during the year. The development of a bismuth-bearing lode in the Bonnifield district, south of Fairbanks, was continued.

In 1922 nickel was found on Snipe Bay, in the southern part of Baranof Island. This find, with the former discovery of nickel deposits on Chichagof and Yakobi islands, about 100 miles to the north, suggests that nickel may occur in a considerable zone and that a nickel-mining industry may be developed. (See a paper by A. F. Buddington elsewhere in this volume.) A little work was done at the Thrift mine and other quicksilver properties in the Iditarod-Kuskokwim region.

COAL

A new and valuable deposit of coal adjacent to the Alaska Railroad is described by S. R. Capps as follows:

This coal occurs in the Cantwell formation, which is widely distributed in the Alaska Range near the point where it is crossed by the railroad. The coal bed developed is itself of commercial value, and it is important to know that a new coal-bearing formation has been found near the railroad.

The McKinley Bituminous Coal Co. has this year opened a mine near the railroad track at mile 341. Here beds of coarse conglomerate, coarse sandstone, and shale cut by dikes and sills strike N. 70° E. and dip 70° N. A number of shallow excavations, now caved, show that the coal bed is continuous along the surface for about half a mile. At several places coal blossom shows at about 90 feet stratigraphically below the main bed, and there are other blossoms both

[35] Mertie, J. B., jr., Lode mining in Juneau and Ketchikan districts: U. S. Geol. Survey Bull. 714, pp. 121–125, 1921.

above and below this bed, so it is possible that there are other workable seams in the section. The bed that is being developed is paralleled on the hanging wall by a dark-colored igneous sill that averages about 30 feet in thickness and is separated from the coal by a thin shale, generally full of gouge, that is from an inch to 2½ feet thick. The footwall is a shale about 1 foot thick, overlying 3 to 4 feet of fairly hard coarse gray sandstone, which in turn overlies 80 to 90 feet of conglomerate. The intrusive sill makes an admirable hanging wall. Its lower surface rolls somewhat, but underground the dike is massive and little fractured and should stand with a minimum amount of timbering. The gouge in the hanging-wall shale shows repeated movements, in horizontal, vertical, and oblique directions.

The coal is bright, clean, and moderately fractured. The bed in the workings ranges from 5 to 6 feet in thickness. It is not a coking coal but appears to be of much better quality than any of the lignites of the Nenana field and to compare favorably with the best coal so far produced commercially from the Matanuska field. Locally the coal shows some evidence of coking from its close association with the overlying sill, but developments to date show only small areas so affected.

The mouth of the main entry is 1,200 feet west of and 300 feet vertically above the railroad at mile 341. It is now (August 17, 1923) 420 feet long, and there is a counter 380 feet long and 50 feet above the main entry. Chutes or raises are 50 feet apart. I estimate that there is now 7,000 to 8,000 tons of coal blocked out on four sides and ready to mine. An inclined tramway on a 14 per cent grade is being constructed from the mouth of the main entry to the railroad.

This is the first coal bed found on the north side of the Alaska Range that contains coal which is of high enough grade to be a good steam coal, and the mine should be able to supply the northern section of the railroad with steam coal, as well as develop a considerable market at Nenana and Fairbanks. The possibility is also suggested of good-grade coals being present elsewhere in the Cantwell formation. It is reported that in the course of further development work in this mine a fault was encountered that displaced the coal bed.

The following analyses of this coal have been made from samples supplied by the mine management. The analyses represent the coal as received.

Analyses of coal from Mount McKinley bituminous-coal mine

[By Bureau of Mines]

	1	2	3	4	5	6
Moisture	2.85	2.60	1.81	1.75	1.03	1.67
Volatile matter	24.08	23.76	24.05	25.35	25.18	25.42
Fixed carbon	63.77	61.38	58.55	57.87	53.76	61.18
Ash	9.30	12.26	15.59	15.03	20.03	11.73
	100.00	100.00	100.00	100.00	100.00	100.00
Calories	6,950	6,732	6,322	6,362	6,261	6,666
British thermal units	12,510	12,118	11,380	11,452	11,270	12,000
Sulphur	0.294	0.282	0.305	0.327	0.332	0.302

1. Bottom of bench counter.
2. Top of bench counter.
3. Full thickness of bench counter.
4. Full thickness of main gangway.
5. Top of bench main gangway.
6. Bottom of bench main gangway.

The surveys made in northern Alaska during 1923 under the direction of Sidney Paige[36] indicate that there is an area of at least 1,000 square miles underlain by coal between the Cape Lisburne coal field, long known, and Meade River, to the northeast. Most of this coal is too inaccessible to be available for present use. According to William T. Foran, a dozen beds of this coal, 4 to 10 feet wide, are well exposed on Kukpowruk River within 5 or 6 miles of the sea. These coal beds dip from 20° to 40°, are not faulted, and could easily be mined. The coal contains about 55 per cent of fixed carbon and is of about the same quality as the Corwin coal, on the Arctic, about 30 miles to the southwest. This coal could be brought down Kukpowruk River in shallow-draft barges and could be loaded on small vessels in the shelter of a lagoon at its mouth. The loading on small vessels would be better than at Corwin. This coal might find a market at Nome, which is now supplied by imported coal. The shipping season would, however, be limited to two or three months of the year. This coal would appear to be more accessible than the Corwin coal, of which 2,600 tons has been mined since 1880, chiefly by whalers.

Coal of the same quality has been mined on Wainwright Inlet, where the Alaska School Service has produced about 3,500 tons for the use of the neighboring native settlements.

Though some exploration of the high-grade coal of the Matanuska and Bering River fields was continued in 1923, it has not yet been proved that these fuels can be mined cheaply enough to find an export market, under present economic conditions. Meanwhile, evidence of the enormous reserves of lower-grade bituminous and lignitic coals in Alaska is accumulating each year. The use of Alaska coal for the needs of the Territory is expanding steadily. In 1923 a dozen small coal mines were operated in Alaska,[37] most of them on the Alaska Railroad, without which this coal would not be available.

[36] Paige, Sidney, and others, The Point Barrow region: U. S. Geol. Survey Bull. 772, 1925.

[37] The statistics of coal production in 1923 are furnished chiefly by B. D. Stewart, supervising engineer of the Bureau of Mines.

Coal produced and consumed in Alaska, 1880–1923

Year	Produced in Alaska, chiefly subbituminous and lignite		Imported from States, chiefly bituminous coal from Washington [a]	Total foreign coal, chiefly bituminous coal from British Columbia [a]	Total coal consumed
	Short tons	Value			
1880–1890	6,076	$37,205			
1891	1,083	6,291			
1892	871	5,093			
1893	923	5,372			
1894	488	2,765			
1895	1,687	9,290			
1896	712	4,142			
1897	2,673	31,393			
1898	2,652	27,201			
1899	2,264	22,836	10,000	[b] 50,120	62,384
1900	2,855	35,275	15,048	[b] 56,623	74,526
1901	2,740	29,843	24,000	[b] 77,674	104,414
1902	3,052	22,508	40,000	[b] 68,363	111,415
1903	2,717	21,302	64,626	[b] 60,605	127,948
1904	1,824	8,195	36,689	[b] 76,815	115,328
1905	4,334	15,070	67,713	[b] 72,612	144,659
1906	6,061	19,924	69,493	[b] 47,590	123,144
1907	10,689	55,770	46,246	[b] 93,262	150,197
1908	4,066	22,665	23,893	[b] 86,404	114,363
1909	3,430	16,350	33,112	69,046	105,588
1910	2,250	13,200	32,098	58,420	92,768
1911	1,850	11,690	32,255	61,845	95,950
1912	1,205	7,130	27,767	68,316	97,288
1913	2,312	13,290	69,066	56,430	127,808
1914	1,190	6,540	41,509	46,153	88,852
1915	1,629	6,653	46,329	29,457	77,415
1916	12,676	57,412	44,934	53,672	111,282
1917	54,275	268,438	58,116	56,589	168,980
1918	75,816	413,870	51,520	37,986	165,322
1919	60,894	345,617	57,166	48,708	166,768
1920	61,111	355,668	38,128	45,264	144,503
1921	76,817	496,394	24,278	33,776	134,871
1922	79,275	430,639	28,457	34,251	141,983
1923	119,826	755,469	34,082	43,205	197,113
	612,323	3,580,500	1,016,525	1,433,186	3,044,869

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

PETROLEUM

The only oil produced in Alaska in 1923 was obtained from a dozen small wells, one of which was drilled during the year on the single patented tract of petroleum land in Alaska, in the Katalla field. These wells are owned by the Chilkat Oil Co., which finds a ready local market for its product in the form of gasoline produced in its own refinery.

The search for oil has been continued in many parts of Alaska, but except in the Cold Bay field there has been no drilling in new fields during the year. Drilling was in progress during 1923 at the Pearl dome, 18 miles from the coast. Here the Associated Oil Co. sank two wells, about 500 feet (Finnegan claim) and 950 feet (Alaska Oil Co. claim) deep, but it suspended drilling in June. The Standard Oil Co., drilling on the same dome, reached a depth of 300 feet by August and is reported to have reached about 700 feet by November and 1,400 feet by March, 1924 (Lee claim). The company began the installation of a second drill in August (Lathrop claim). What is known of the geology and the results of the drilling still gives great encouragement to the finding of an oil pool on the Pearl dome. There are other structural features in the Cold Bay field that are favorable for oil, though the Pearl dome is believed to be the best one of which to make the first test.[38]

George C. Martin, who in 1923 hastily examined the Chignik region south of the Cold Bay field, reports that what he learned of the geology near Chignik is not favorable to the presence of petroleum. Kirtley Mather, who made a geologic survey of the northern part of the Alaska Peninsula, reports that some of the structural features and the formations are favorable to the presence of oil. A small seepage has long been known in the region near the mouth of Douglas River, which flows into Cook Inlet.

In 1923 Sidney Paige examined the oil seepages long known near Cape Simpson, about 50 miles southeast of Point Barrow, the northernmost point of Alaska. He reports[39] that there are two very large seepages emanating from small ridges about a mile apart and several miles from the coast. These are marked by flowing petroleum and cover many acres. There is a large accumulation of petroleum residue at these seepages. The surface exposures consist of clay shale with hard thin partings of calcareous shale, which lie nearly horizontal and are probably of Jurassic age. Mr. Paige and his two subparties explored a large area inland from the Arctic coast between Cape Beaufort on the south and Point Barrow and Cape Simpson on the north. He himself ascended Meade River for some 150 miles. These surveys indicate a wide distribution of what is believed to be the formation from which the Cape Simpson seepages emerge, which is probably of Jurassic age. These rocks are little disturbed near the north Arctic coast but are increasingly folded to the south, toward the mountains. No other seepages have been found, but what is known of the geology is not unfavorable to an oil field. This entire region lies in Naval Petroleum Reserve No. 4, and it was examined by the Geological Survey at the request and expense of the Department of the Navy.

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[38] Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 151–218, 1924.

[39] Paige, Sidney, Foran, W. T., and Gilluly, James, The Point Barrow region, Alaska: U. S. Geol. Survey Bull. 772 (in press).

Petroleum products shipped to Alaska from other parts of the United States, 1905–1923, 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
1922	15,441,542	1,436,050	2,095,675	345,400
1923	12,285,808	4,882,015	473,826	454,090
	296,867,513	33,091,456	17,285,684	5,044,914

[a] Compiled from Monthly Summary of Foreign Commerce of the United States, 1905 to 1923, Bureau of Foreign and Domestic Commerce.

STRUCTURAL MATERIALS

The quarrying of marble began in southeastern Alaska in 1901 and has been an important industry since 1908. Most of the marble produced has come from the north end of Prince of Wales Island, where the only large Alaska quarries are located, but there are many other places in the Panhandle where marble has been found. The only commercial gypsum deposit found in Alaska is on the eastern shore of Chichagof Island, in the Sitka district. Here gypsum has been produced every year since 1906. The value of the total output of marble and gypsum to the end of 1923 is about $2,700,000. These industries were operated on about the same scale in 1923 as in 1922.

REVIEW BY DISTRICTS

SOUTHEASTERN ALASKA

The value of the total mine products of southeastern Alaska was $3,084,389 in 1922 and $2,356,864 in 1923. The output of 1923 came very largely from five large and small gold and silver lode mines. Only one copper mine, the Rush & Brown, in the Ketchikan district, was operated throughout the year, but some copper was shipped from the Jumbo mine, in the same district. Shipments were also made from the Endicott mine at William Henry Bay, north of Juneau. In addition to the output of the lode mines, five small placer mines, a gypsum mine on Chichagof Island, and a group of large marble quarries near the north end of Prince of Wales Island were productive. The reduction in value of mineral output in 1923, as compared with the previous year, was largely due to the suspension of operations at the Chichagof gold mine in the Sitka district after July 1. The Alaska Juneau is now the only large mine in southeastern Alaska that has been continuously operated since it was first opened.

Production of Alaska Juneau mine, 1893–1923 [a]

Year	Ore (tons)			Metals recovered			
	Total	Fine milled	Coarse tailings rejected	Gold	Silver (ounces)	Lead (pounds)	Total value
1893–1913	507, 254	330, 278	176, 976	$707, 730	Lost in tailings		$707, 730
1914–1915	242, 328	239, 918	2, 410	251, 655	6, 192	117, 031	261, 326
1916	180, 113	180, 113	----------	115, 022	2, 844	61, 068	121, 379
1917	677, 410	677, 410	----------	429, 262	12, 248	296, 179	460, 666
1918	592, 218	574, 285	17, 933	430, 124	11, 828	273, 297	459, 445
1919	692, 895	616, 302	76, 593	499, 002	16, 431	359, 762	542, 714
1920	942, 870	637, 321	305, 549	732, 870	23, 348	487, 574	791, 390
1921	1, 613, 600	904, 323	709, 277	969, 703	40, 619	550, 913	1, 035, 251
1922	2, 310, 550	1, 108, 559	1, 201, 991	1, 296, 157	49, 404	687, 315	1, 388, 679
1923	2, 476, 240	1, 134, 759	1, 341, 481	1, 427, 199	41, 876	755, 423	1, 514, 774
	10, 335, 478	6, 403, 268	3, 832, 210	6, 858, 724	204, 790	3, 588, 562	7, 283, 354

[a] Compiled from published reports of mining company.

Some placer mining was done in the Silver Bow Basin, near Juneau, and a little beach mining at Yakataga. This work employed a total of 12 men. The most important gold and silver lode discoveries of the year were in the Hyder district, on Portland Canal, and on Chichagof and Admiralty islands. A new find of nickel on Snipe Bay, Baranof Island, indicates a probable southern extension of the nickel-bearing zone. These new discoveries are described by A. F. Buddington elsewhere in this volume.

COPPER RIVER BASIN

The only large operations in the Copper River region during 1923 were those of the three copper mines of the Kennecott group, already noted, as is also the continuation of the development of copper on the Green group of claims (p. 28). Work was continued at the Midas gold mine, in Chitina Valley. In 1923 mining was active in the Nizina and Chistochina placer districts and was continued in a small way in the Nelchina district. In this region a total of nine mines employing 86 men were operated and produced $144,000 worth of gold. In 1922 eight summer mines employing 91 men produced $165,000 worth of gold. In 1923 most of the gold produced came from three large hydraulic mines employing 75 men, which recovered on the average 81 cents' worth of gold to the cubic yard. These hydraulic mines were operated from 107 to 153 days.

PRINCE WILLIAM SOUND

In 1923, as in previous years, the only large mining operations on Prince William Sound were at the Beatson-Bonanza, on Latouche Island. Development was continued on the Rua Cove and other copper properties, as described by F. H. Moffit elsewhere in this volume. Some small operations were continued at the Tuscarora, near Valdez, the only productive gold lode mine on Prince William Sound during the year.

KENAI PENINSULA

In the summer of 1923 some 10 placer mines employing 55 men were operated on Kenai Peninsula and produced $38,000 worth of gold. The same district in 1922 contained 14 active placer mines employing 51 men and produced $40,000 worth of gold. The largest mines are those equipped with hydraulic plants on Crow, Canyon, Lynx, and Resurrection creeks, where the average recovery was about 30 cents to the cubic yard. Because of the very dry season most of these mines were operated less than 100 days. One coal mine was operated at Bluff Point, on Cook Inlet.

The following notes by S. R. Capps summarize the conditions of lode mining on Kenai Peninsula in the summer of 1923:

The Kenai Star mine, in the Palmer Creek basin, milled 80 tons of ore in the early part of the summer. The mill returns being unsatisfactory, the crew was put to prospecting for better ore and building an inclined track for hauling ore from the main tunnel to the crusher at the mill. It is reported that later in the summer the directors decided to close the mine. The mill was sold to the Lucky Strike mine, and plans were under way to remove it and reinstall it on the Lucky Strike this fall.

The Robin Red Breast prospect, of J. Kacerosky and H. W. Hargood, 800 feet east of the Kenai Star, has a tunnel 90 feet long on one level and another 54 feet long on another level. The owners are reported to have a large body of ore that assays well in gold. This ore body is 250 feet from an acidic dike that itself assays in gold. The same two men have a 5-foot prospect tunnel on the adjoining Esther claim, which is said to show a 2-foot quartz vein that carries sulphides and assays well in gold.

The Lucky Strike mine, of the Alaska Minerals Co., generally known as the Hershey mine, has developed an ore body which is a stockwork of thin quartz veins in slate, the ore zone ranging in width from practically nothing to 4 feet or more. The quartz is somewhat rusty and carries besides free gold arsenopyrite, pyrite, galena, and a little chalcopyrite. The relationship of quartz veins to acidic dikes is not shown in the mine, though such dikes crop out on the surface not far away, and the veins are almost certainly genetically related to them. The mine has approximately 800 feet of underground workings in three tunnels and crosscuts from them, in addition to about 100 feet of slopes. The present mill, a Gibson eccentric grinder, with a capacity of 3 tons in 24 hours, is to be enlarged this fall by the installation of a Hendy mill, of five 1,000-pound stamps, purchased from the defunct Kenai Star Co.

A. O. Robinson and C. P. Bowman have driven a 220-foot prospect tunnel into the east wall of the Palmer Creek canyon. The country rock, of slate and graywacke, strikes about north and dips 60° E. The tunnel is run on a streak of clayey gouge containing some quartz that cuts the slate and graywacke at a slight angle. An acidic dike in the slate and graywacke appears on the mountain above the tunnel, and the vein is thought to be genetically related to this dike. The quartz contains pyrite, arsenopyrite, galena, and locally free gold. The gold along the vein underground is of erratic distribution, and no body of pay ore had been uncovered when the examination was made.

SOUTHWESTERN ALASKA

The most important development in southwestern Alaska in 1923 was the drilling for oil on Cold Bay (p. 34). Probably a little beach placer mining was continued on the south end of Kodiak Island, but no report of it was received. A little alluvial gold has been found near Cape Kubugakli, as described by W. R. Smith elsewhere in this volume. This is the only place on Alaska Peninsula that placers have been mined. Some work was continued during the year on the McNeil copper property, described in another part of this volume by Kirtley Mather. Nothing new appears to have been found in the copper district of Iliamna Lake.

SUSITNA-MATANUSKA REGION

Productive mining in the Susitna-Matanuska region includes that of gold lodes in the Willow Creek district, placer mining in the Yentna and Valdez Creek districts, and coal in the Matanuska district. The total value of the mineral output in this region was $803,685 in 1922 and $955,062 in 1923.

WILLOW CREEK DISTRICT

By S. R. Capps

In addition to the six gold lode mines productively operated in the Willow Creek district during 1923, considerable search was made for ore bodies. The following notes on this work are not complete, being the hasty observations of a few days' visit, made in the fall of the year.

The old Gold Cord mine, on the C. B. Smith property, is at the head of the Fishhook Creek basin. This year arrangements were made to prospect this vein by a new management, under a five-year lease. The new company installed a 15-horsepower gas engine, compressor, and tool sharpener, also a 3-horsepower gas engine and ventilating fan and an assay shop. The main adit tunnel has been driven 575 feet. The lode includes irregular bunches that pinch and swell irregularly and is faulted along many planes, with a gouge. An open cut indicates another vein farther north that carries considerable chalcopyrite. At the time of visit no considerable body of milling ore had been blocked out. While this mine was leased to the Alaska Free Gold Mine Co. 1,600 tons of ore was mined and milled on Gold Creek, and from it $21,000 in gold was recovered.

Eleven tons of this ore milled separately yielded $225 in gold to the ton.

The Kelly Mines Co., whose property includes the old Independence, Alaska Free Gold, and Independence mines, milled no ore in 1922 or 1923. Everything on the Fishhook Creek side of the mountain was shut down at the time of visit, and operations centered on the Willow Creek side of the divide, where the main effort was directed to the running of a long adit tunnel to cut at depth the veins previously mined on the Fishhook Creek side. This adit was then in 975 feet and had cut several quartz veins that the manager believed he identified as those for which the tunnel was driven. The first vein, thought to be the Skyscraper vein, was cut at 760 feet from the portal. In a 30-foot drift along the vein it shows a few inches of quartz and gouge vein matter. At 850 feet from the portal what is identified as the Skyscraper vein was cut, and a 30-foot drift to the north on it shows a maximum of 9 inches of quartz but commonly much less. At 965 feet from the portal the tunnel cuts what is thought to be the Blacksmith Shop vein, which shows a maximum of over a foot of quartz and vein matter. These veins all strike about N. 10° W. and dip 30°–40° W. The meager gold content and the small size of the veins where cut by the adit tunnel are disappointing, but exploratory work along the veins is expected to show the usual swellings in the veins and to reveal minable ore shoots. Several faults were encountered in the adit tunnel, the amount of displacement of which has not yet been determined. The mine on the Willow Creek side is equipped with a 15-horsepower gas engine, a compressor, a 4-horsepower gas engine and ventilating fan, a hoist for steel from the blacksmith shop to the tunnel mouth, and three machine drills.

The Gold Bullion, Lucky Shot, and War Baby mines belong to the the Willow Creek Mines Co.[40] and are on Craigie Creek. The Gold Bullion was worked all winter. The mill started early in June and shut down on July 8 for the rest of the year. Ore was taken from No. 5 tunnel. There is a rich lode showing on the Willow Creek side of the divide, which is believed to be the outcrop there of the Bullion vein. The company intends sometime to drive through to cut this vein from the Bullion workings.

At the Lucky Shot mine during the winter 4 men worked in the upper (Hogan) level, and 11 men in the lower adit tunnel, which is 300 feet vertically below the Hogan level. The adit is 825 feet long, and at the breast the Lucky Shot vein was intersected. The lode there is 3 to 4 feet wide, including quartz and also vein matter. The quartz occurs in shoots as much as 3 feet wide. The Lucky Shot and War Baby mines are now worked as parts of the same mine, and the ore from both is taken to the Lucky Shot mill. In the Lucky Shot

[40] See U. S. Geol. Survey Bull. 607, pl. 3, 1915, and Bull. 712, fig. 5, p. 170, 1920.

mine development work has been carried out on three levels. The upper or 100-foot level has 50 feet of adit and 200 feet of drifts, the Hogan or 200-foot level 250 feet of adit and 600 feet of drifts, and the lower or 500-foot level 825 feet of adit and 150 feet of drifts. In addition there are considerable areas of stoped ground. The War Baby mine has 685 feet of adit and 200 feet of drifts on the lower (700-foot) level, 50 feet of adit and 80 feet of drifts on the second level, and 100 feet of adit on the upper level. A prominent fault, with a displacement of about 400 feet, lies between the adjoining Lucky Shot and War Baby claims. The new Lucky Shot adit encountered the vein mined above at about the calculated position, but on this lower level the ground is tighter and the vein is smaller than was expected. No good ore has yet been disclosed in these lower workings. In all the workings of these mines there is much evidence of movement along all the veins, with development of abundant gouge. In places the vein matter is largely crushed diorite and gouge, with little or no quartz. The diorite wall rock shows little mineralization.

Lee John, John Johnson, and E. Johnson have started to drive a crosscut tunnel on Shorty Creek, to tap what is supposed to be the extension of the Lucky Shot-War Baby vein.

The "Jap mine," operated by Hari Yago, is on upper Willow Creek, on the southeast slope of Bullion Hill. The property is developed by four adits 400, 100, 25, and 30 feet long. The veins revealed range from a few inches to 18 inches in width. No attempt was made to mine ore carrying less than $100 a ton in free gold. The property is equipped with a 1-stamp prospecting mill having a capacity of 200 pounds in 13 hours and an arrastre (now broken down), both operated by water power from Willow Creek.

The Gold Mint mine, on Little Susitna River, was closed in 1923.

At the Mabel mine, on Archangel Creek, 400 to 500 feet of new workings, mainly to the south along the vein, have been driven. Mining this year has consisted mainly of cleaning up ore from old workings, but some ore has been taken from the new south excavations. The mill was started June 3. The vein shows the same characteristics as heretofore, swelling from a thin seam to 6 feet of quartz within short distances. The workings have disclosed several faults of a few feet to 50 feet displacement. The material mined ranges from vein matter below mill grade to very high-grade ore. The present management is attempting to develop tonnage for future milling. Only one shift is worked in the mine and mill. A Denver Chile mill, operated by water power, and a gas engine and compressor are at the mine. The management contemplates moving the cable tramway from the gulch to a spur to the north, to avoid trouble with snow during winter operations.

The property of the Consolidated Gold Mines (formerly Matanuska Gold Mining Co.) is on Fairangel Creek. The main workings are at the old mine, where some rich ore is reported at the bottom of a 30-foot winze in the main tunnel. The mine has one vein 30 inches wide and another 16 inches wide. The company is contemplating putting in new machinery and driving a 500-foot tunnel, just back of the mill, to cut old ore bodies at depth. The old tunnel is now in about 500 feet and is expected at any time to cut a lode that crops out above it. On the Alaska-Willow Creek claim of this company, which is on the mountain slope east of Reed Creek, opposite the Mabel mine, an adit has been driven for 140 feet with the hope of striking a quartz vein that is exposed on the surface 240 feet above the tunnel, but it had not reached the vein at the time of visit. This company has made a new find on Craigie Creek, on the old Miller-Newman claims, which are reported to have an open cut 60 feet long on a vein showing from 4 to 10 inches of very rich quartz. The company is prospecting for the extension of this vein, with the purpose of running a tunnel to cut the ore body that is exposed on the surface but is now inaccessible.

The Fern Gold Mining Co.'s property is on the east spur of the mountain between Fairangel and Archangel creeks. The mine and mill operated last winter and until late in June, since when the mill has not been operated. The No. 1 adit is now in 700 feet, with 50 feet of crosscuts. The No. 2 adit, 180 feet below, was at the time of visit 245 feet long, and the company hopes to cut the ore body at about 550 feet from the entrance. Only development work is being done at present. The mine is equipped with a Denver Chile mill, a 25-horsepower semi-Diesel engine, and a cable tramway from the mine to the mill.

The Opal prospect, owned by Dave Skarstad and Leonard Laubner, includes four claims surveyed for patent last year. The main adit is in 200 feet, with 100 feet of drifts. At the breast of the main adit the vein, exposed on the surface above, was cut, showing a maximum of 2 feet of quartz. It contains free gold, and the tenor is said to be high in places. It shows some faulting, and the vein zone contains much gouge. Another vein, encountered at 52 feet from the portal, shows 14 inches of vein matter and 4 to 5 inches of quartz, but the tenor is low.

The Homebuilder prospect on Reed Creek is being explored by Paul Hanson and Ernest Richter. On this prospect a series of open cuts show a vein zone as much as 5 feet wide, which contains quartz and mixed vein material. The quartz shows considerable pyrite and is said to yield good gold prospects by panning. The vein strikes N. 70° E. and dips 35° NW. A projected 600-foot adit tunnel, now in 140 feet, it is hoped will cut the vein 300 feet below the surface workings.

Mike Sherry has a prospect on the west side of the Reed Creek valley about a mile north of the Homebuilder. He is reported to have an adit in 120 feet, of which 30 feet was driven this year. This adit is said to show a small quartz vein at the face.

Gold and silver produced at lode mines in the Willow Creek district, 1908–1923

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	937.00
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
1922	7	7,242	11,513.25	238,000	1,500.00	1,500.00
1923	6	9,132	8,622.29	178,238	912.00	748.00
	------	86,018	114,612.43	2,363,235	10,287.27	8,048.98

PLACER MINING IN THE YENTNA DISTRICT

In 1923 21 summer mines employing 98 men were operated in the Yentna district and produced $189,000 worth of gold. An output of $223,000 worth of placer gold was made in 1922. The decrease is entirely due to the lack of water, which seriously hampered all hydraulic mining and even curtailed dredging on Cache Creek, the largest operation on that stream. The principal mining operations included one dredge and eight hydraulic plants; the other mines were worked with pick and shovel. It is estimated that a total of 398,000 cubic yards of gravel was sluiced, yielding an average of 47 cents' worth of gold to the cubic yard. A description of a Tertiary placer in the district is given by Mr. Capps on pages 53–61.

MISCELLANEOUS MINING IN THE REGION

About half a dozen placer mines were operated in the Susitna region besides those of the Yentna district. Some coal was mined at a few localities in the Matanuska field; the Evan Jones mine was operated throughout the year. A new copper (chalcopyrite) bearing lode was reported 10 miles east of Matanuska station. In August, 1922, Arthur Moose Johnson discovered an ore body carrying ruby silver about 10 miles east of Chulitna, a station on the Alaska Railroad. This deposit is in a region geologically unsurveyed, but the ore is said to be associated with igneous dikes. The ore body is reported to be large, and the assays made by the Bureau of Mines from the samples submitted by the owner showed a high silver content and some gold. The property, called the Mint, is on Portage Creek and is the first one reported from Alaska carrying ruby silver.

YUKON BASIN

GENERAL FEATURES

The first gold placers to be mined in the Alaska Yukon were those on Fortymile River in 1886. Alluvial gold mining has ever since been the dominating industry of the Yukon. Since 1903 some gold-lode mining has been done in the Fairbanks district, and since the building of the Alaska Railroad some coal has been mined in the Nenana field. The only other mining in the Alaska Yukon was a small production of lead, silver, copper, tin, tungsten, antimony, and platinum. The total mineral output is as follows:

Mineral production of the Yukon basin, Alaska, 1886–1923

	Placer mines		Lode mines		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
Gold..........fine ounces..	6,577,870	$135,975,000	66,923	$1,382,934	6,644,793	$137,357,934
Silver..............do....	1,120,256	691,199	264,055	262,886	1,384,311	954,085
Coal..............tons..					116,561	594,295
Lead, copper, tin, antimony, tungsten, and platinum..............						549,880
		136,666,199		1,645,820		139,456,194

In 1923 there were 301 summer and 64 winter placer mines, 3 gold lode mines (Fairbanks district), 2 silver-lead deposits (Kantishna district), 3 placer mines producing some tin (Hot Springs district), and 2 coal mines (Nenana field) that were productive in the Alaska Yukon. The total value of their output is as follows:

Mineral production of the Yukon basin, Alaska, in 1923

	Placer mines		Lode mines		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
Gold....................fine ounces..	79,528	$1,644,000	1,250	$25,844	80,778	$1,669,844
Silver..........................do....	11,106	9,106	17,194	14,099	28,300	23,205
Coal, lead, copper, and tin..............						182,547
		1,653,106		39,943		1,875,596

GOLD PLACERS

As shown by the subjoined table, placer mining greatly decreased in 1923 compared with 1922, in part because of the exhaustion of the rich deposits on which most of the Yukon districts have largely depended to maintain their gold output, but mainly because of the exceptional dryness of the season, which cut down the stream flow so greatly as to produce a shortage of water for sluicing. This dearth of water was notable in the Fairbanks, Rampart, Circle, Richardson, Ruby, Innoko, Iditarod, and Koyukuk districts. Indeed, the aridity persisted over all the Yukon basin, except in the Eagle and Fortymile districts. In the Seventymile Valley of the Eagle district unusual floods wrecked much of the mining equipment. In most of the Yukon districts there is a great need for wagon roads, which will lower the cost of transportation and therefore of mining. The search for placers suitable for dredging is being extended to nearly all the Yukon districts. In 1923 two dredges were operated in the Fairbanks district, two in Innoko, two in Iditarod, and one in Circle.

Placer gold produced in Yukon basin, 1922 and 1923, by districts

District	Value of gold		Summer				Winter			
			Mines		Miners		Mines		Miners	
	1922	1923	1922	1923	1922	1923	1922	1923	1922	1923
Fairbanks	$693,000	$603,000	62	62	392	313	27	21	108	115
Iditarod	280,000	228,000	14	20	126	118	1	-----	10	-----
Tolovana	221,000	164,000	26	18	132	76	12	8	61	45
Innoko (including Tolstoi district)	224,000	153,000	18	21	62	75	4	2	6	8
Circle	121,000	114,000	15	18	42	64	8	6	16	8
Ruby	123,000	72,000	24	28	67	80	13	4	39	8
Hot Springs	55,000	62,000	25	17	61	53	3	1	9	2
Fortymile	50,000	53,000	24	28	52	59	18	14	33	25
Chandalar	83,000	42,000	4	4	15	7	1	2	10	12
Koyukuk (including Indian River district)	132,000	37,000	36	16	106	33	10	4	25	17
Chisana	29,000	23,000	9	9	25	22	-----	-----	-----	-----
Eagle	24,000	23,000	14	11	28	35	-----	-----	-----	-----
Rampart (including Gold Hill district)	18,000	16,000	14	6	25	14	2	2	4	3
Richardson (Salcha-Tenderfoot)	2,000	16,000	3	5	6	41	-----	-----	-----	-----
Bonnifield	10,000	13,000	7	13	24	41	-----	-----	-----	-----
Kantishna	32,000	13,000	14	13	60	19	-----	-----	-----	-----
Marshall	22,000	12,000	12	12	31	28	-----	-----	-----	-----
	2,119,000	1,644,000	321	301	1,254	1,078	99	64	321	243

About 2,000,000 cubic yards of gravel was sluiced in the Yukon districts during 1923, and the average value of gold recovered was 82 cents to the cubic yard. The first gold was mined at Fairbanks in 1903. The total output since then, by creeks, is as follows:

Approximate distribution of placer gold produced in Fairbanks district, 1903–1923, by sources

Cleary Creek and tributaries	$23,252,000
Goldstream Creek and tributaries	15,286,000
Ester and adjacent creeks	11,497,000
Dome and Fairbanks creeks	16,711,000
Vault Creek and tributaries	2,733,000
Little Eldorado Creek	2,380,000
All other creeks	717,000
	72,576,000

Most of the placer gold produced at Fairbanks during the summer was mined by two dredges, 21 drifting operations, 10 steam scrapers, and 12 small hydraulic plants. The 62 summer mines and the 21 winter drift mines excavated about 524,000 cubic yards of gravel that was sent through the sluice boxes, which averaged about $1.15 worth of gold to the yard.

The second largest producer of the Yukon basin was the Iditarod district, where the largest output came from the two dredges, which with nine hydraulic plants, one steam scraper, and two open-cut mines excavated about 624,000 cubic yards of gravel, which averaged 37 cents in gold to the yard. In the Tolovana district seven summer drift mines, five hydraulic mines, and eight winter drift mines worked 59,000 cubic yards of gravel, yielding an average of $2.77 of gold to the cubic yard. The placer-mine production and the number of plants operated in the smaller Yukon districts are presented in the table on page 45.

LODE MINING

During 1923 there was no important advance in the discovery or development of lode deposits in the Yukon basin. As already shown (p. 13), only three auriferous lodes were productive, and these in only a small way, at Fairbanks. There was some systematic prospecting of the auriferous quartz veins in the Iditarod district. Work was continued on the Arnold quartz claim, in the Marshall district.

KUSKOKWIM BASIN

Kuskokwim River, second in size of Alaska streams, drains a vast area between the mountains bordering the Pacific and the Yukon Valley. Its drainage basin is estimated to include over 50,000 square miles, less than a third of which has been surveyed. The Kuskokwim basin, though off the main route of travel, is not difficult of access. Small ocean vessels may enter the mouth of the river and run up to Bethel, 50 miles from the sea, and thence the journey may be continued up the river by steamers at least as far as Berry's Landing, a distance of about 400 miles from tidewater. Some of the southern tributaries are also in part navigable for small boats. Three small river steamers give communication with Bethel, where the ocean boats deliver their cargo.

McGrath, the largest settlement on the upper river, may be reached by winter trail from Ruby, on the Yukon, a distance of about 170 miles. This trail is now being made into a wagon road, of which about 70 miles is completed. Formerly mail was carried to McGrath either from the mouth of the river in summer and by dog team from Fairbanks, by way of Lake Minchumina, in winter or from Seward by way of Rainy Pass. Now the mail is brought by airplane from Nenana, on the railroad. The radio station keeps McGrath in constant communication with the outside world.

The earlier visitors to the Kuskokwim basin were attracted by the fur hunt, which continues to be an important industry. There are considerable areas of arable and grazing lands in the upper Kuskokwin basin, and potatoes and other hardy vegetables may in favorable seasons be raised along the river nearly to its mouth. There are also large areas of reindeer pastures within the Kuskokwim basin. Much salmon is preserved for local food along the lower course of the Kuskokwim.

Some quicksilver-carrying lodes were the first mineral deposits of the Kuskokwim to attract attention. They were known as early as 1880 and were explored prior to 1898. The Parks quicksilver prospect, near Kolmakof, on Kuskokwim River, about 15 miles above Georgetown, was discovered in 1906, and between that date and 1914 it produced about 700 pounds of the metal.[41] Later better reducing equipment was installed, and developments have continued in a small way up to the present time. There appears to have been a small output of quicksilver, which found a market in Alaska placer-mining camps until 1921. An extension of the mineralized zone was made evident by the opening of a quicksilver deposit on Montana Creek, a tributary of Iditarod River,[42] about 40 miles northwest of the Parks property, where some quicksilver was produced.

Placer gold was first found in this region in the Goodnews Bay district, adjacent to Kuskokwim Bay, in 1900, and during the next six years the prospector extended his search northward, gradually disclosing a not very well defined auriferous zone, which includes the Goodnews Bay, Tuluksak-Aniak, Georgetown, and McGrath (McKinley) districts. This zone crosses Kuskokwim River at Georgetown and north of that merges into a gold-bearing zone of the Iditarod, Innoko, and Ruby districts. As in other parts of Alaska, this auriferous zone is marked by a line of intrusions. In 1917 another locus of intrusion was found near a granite contact, in the headwater region of Nixon Fork, a tributary of Takotna River, which joins the Kuskokwim at McGrath. The granite of Nixon Fork is a small area, but its axis of intrusion seems to be marked by another granite stock which is 15 miles to the north. The extension of this axis of intrusion to the southwest goes into an unmapped area. Seventy miles to the east lies the field of intrusion following the crest line of the Alaska Range, along the margin of which some metallized rock has been found. The above outline of the distribution of gold shows a broken yet well-marked axis of granite intrusion extending through the heart of the Kuskokwim basin; another one, 50 miles to the east, has been traced only a short distance.

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[41] Smith, P. S., and Maddren, A. G., The quicksilver deposits of the Kuskokwim region; U. S. Geol. Survey Bull. 622, p. 274, 1915.

[42] Brooks, A. H., The Alaska mining industry in 1921: U. S. Geol. Survey Bull. 739, p. 13, 1923.

It has thus far been impossible to obtain accurate statistics of mineral production and mining operations in the Kuskokwim region. The incomplete returns from mining operations have been supplemented by estimates made on the best information available in compiling the following table, the errors in which must be charged to those miners who have failed to furnish the information requested each year.

Estimated value of placer gold produced in the Kuskokwim region, 1908–1923

Year	Number of mines	Number of men	Value of gold	Year	Number of mines	Number of men	Value of gold
1908			$3,000	1917	23	78	$100,000
1909			5,000	1918	19	87	100,000
1910			15,000	1919	22	104	350,000
1911			25,000	1920	32	125	305,000
1912			35,000	1921	31	106	520,000
1913	16	50	50,000	1922	30	137	542,000
1914	25	80	100,000	1923	30	110	292,000
1915	25	80	100,000				
1916	20	70	80,000				2,622,000

The first placer gold reported from the region was that mined in 1908, though there was probably some output in earlier years. Most of the output in the first years of known production came from the Goodnews Bay and Tuluksak-Aniak districts; later the annual output was greatly swelled by contributions from the camps farther north, notably from the McGrath district, where rich placers were opened up on Candle Creek. In 1917 a dredge was installed on these deposits, and in the last few years it has been operated very successfully. This and other mining on Candle Creek has placed the district in the front ranks of Alaska placer producers. The searching out of dredging ground is not the most important event in the Kuskokwim placer district. In 1917 a rich gold lode (Crystal) was discovered in the Nixon Fork district, near which a few placer mines had been developed. The ore occurs in limestone near the margin of a granite stock.[43] This property was subsequently taken over by the Treadwell Yukon Co. (Ltd.) and developed as the Nixon Fork mine. Some ore was shipped down Kuskokwim River, 12 miles distant. A 10-stamp mill was installed in 1921 and was operated in 1922 and 1923.

The Nixon ore contains, besides gold and silver, about 2 per cent of copper. A copper deposit occurs in the Russian Mountains, west of the lower Kuskokwim, lying along a margin of a granite intrusion.[44] This ore contains chalcopyrite and arsenopyrite. A stibnite and gold bearing vein has been found in the same mountains. Stibnite also occurs in association with the quicksilver deposits of the lower

[43] Martin, G. C., Gold lodes in the upper Kuskokwim region: U. S. Geol. Survey Bull. 722, pp. 146–161, 1922.

[44] Maddren, A. G., Gold placers of the lower Kuskokwim: U. S. Geol. Survey Bull. 622, p. 359, 1915.

Kuskokwim Valley, already referred to, and realgar-bearing lodes have been found in the same area and elsewhere in the Kuskokwim region. Small areas of coal land are widely distributed in the Kuskokwim basin. Some of the coal is of high bituminous grade, and much of it is lignitic. An extensive coal field is reported in the basin of Big River, a tributary of the South Fork of the Kuskokwim. The very fragmentary information given above is included because it comes from many reports of the Geological Survey.

SEWARD PENINSULA

The most important event of the year in Seward Peninsula was the launching at Nome early in June of the two great gold dredges of the Hammon Consolidated Gold Fields. These machines are 115 and 140 feet in length, with digging ladders over 70 feet long, and are equipped with buckets of 9 cubic feet capacity. Their successful operation for a year marks a new epoch in Alaska dredge mining.

It has long been known that the coastal plain, at places stretching inland a distance of over 4 miles and traceable for at least 7 miles parallel to the coast, was auriferous and in many places contained rich placers.[45] Though the bonanza placers, especially those occurring in the several beach deposits, have been largely mined out, most of the auriferous gravel of lesser gold content is still undisturbed. This area of at least 28 square miles is the largest body of auriferous gravel known on the peninsula. This enormous bulk of gravel may not all be classed as gold placers, but drilling can determine what percentage of it contains workable placer ground. The use of heavier equipment and cold-water thawing, by lowering operating costs, will make available to profitable mining a greater percentage of the auriferous gravel than that previously estimated.

The reports of the Geological Survey show the very wide distribution of gold placers and the much wider distribution of auriferous gravel in Seward Peninsula. Nearly 20 years ago the facts then available about the occurrence of gold placers on Seward Peninsula were summarized, and the opinion was ventured that they contained gold to the value of $265,000,000 to $325,000,000.[46]

According to the original estimate, the creek placers carried about $50,000,000 worth of gold, and the coastal-plain and high bench placers, chiefly in the Nome district, were credited with placer reserves valued at about $215,000,000. Since this estimate was made about $50,000,000 in gold has been mined from Seward Peninsula placers. Crude as the original estimates of gold reserves were, the facts accumulated during the 20 years of mining do not lead to a modification of them. The mining of the coastal-plain placers has

[45] Moffit, F. H., Geology of the Nome and Grand Central quadrangles: U. S. Geol. Survey Bull. 533, pl. 3, 1913.

[46] Brooks, A. H., Outline of economic geology [Seward Peninsula]: U. S. Geol. Survey Bull. 328, pp. 111–138, 1908.

now been undertaken, but the mining on a large scale of high bench gravels has not yet begun.

The discovery of gold placers in the Buckland River basin was reported in 1922. This find was made by a native on what is called Koo-o-puk Creek, tributary to Buckland River, about 20 miles from tidewater and 25 to 35 miles east of Candle. In 1923 a number of miners reached the creek, and some gold was mined. This region has not been examined by the Geological Survey, and there is no information on the geology of the occurrence, but the discovery suggests an extension of the gold belt.

The metalliferous lodes of Seward Peninsula, including gold, silver, copper, antimony, lead, and tin, are not without promise,[47] but under present costs of operation and value of metals they are not likely to excite interest. Indeed, in 1923 there was no mining on the peninsula except that of placers and a small coal mine operated in the Fairhaven district. The discovery of large areas of bituminous coal on the Arctic coast (see p. 33) raises the question whether some of the mineral fuel brought to Nome (3,384 tons of coal in 1923) might best be supplied from this source. Some platinum was recovered from the gold placer mines of Dime Creek, in the Koyuk district.

The 16 dredges operated in Seward Peninsula in 1923 (see p. 27) were distributed by districts as follows: Nome, 6; Solomon, 3; Council, 3; Kougarok, 2; and Fairhaven, 1. One was also installed on Dime Creek and was operated for a short time before the end of the season. The value of gold recovery to the cubic yard varied with different dredges, from 13 to 90 cents; the average was 35 cents. The machines that were well equipped worked from 81 to 132 days. Some of the dredges were hampered by shortage of water due to the unusually dry season. This shortage also greatly curtailed all other forms of placer mining, as shown in the subjoined table. Had it not been for the increased gold output from the dredges, the production of 1923 would have been less than that of 1922.

Placer gold produced in Seward Peninsula in 1922 and 1923, by methods of mining

Method	Mines		Men		Value of gold		Gravel sluiced (cubic yards)		Value of gold recovered per cubic yard	
	1922	1923	1922	1923	1922	1923	1922	1923	1922	1923
Dredging	15	16	151	388	$609,859	$1,017,620	1,574,454	2,921,629	$0.39	$0.35
Hydraulic mining (includes all operations where any water is used to move gravel to sluice box)	24	16	192	144	426,671	179,207	468,147	148,740	.91	1.20
Open-cut mining (other than by hydraulicking and dredging)	59	24	136	47	117,736	21,883	39,972	11,148	3.00	1.96
Drifting	17	10	100	56	110,734	51,290	21,118	10,093	5.24	5.08
	115	66	579	635	1,265,000	1,270,000	2,103,691	3,091,610	------	------

[47] Cathcart, S. H., Metalliferous lodes in southern Seward Peninsula: U. S. Geol. Survey Bull. 722, pp. 163-261, 1922. Steidtmann, Edward, and Cathcart, S. H., Geology of the York tin deposits: U. S. Geol. Survey Bull. 733, 1922.

Placer gold produced in Seward Peninsula, 1922 and 1923, by districts

District	Value of gold		Summer				Winter			
			Mines		Miners		Mines		Miners	
	1922	1923	1922	1923	1922	1923	1922	1923	1922	1923
Nome	$485,000	$598,000	26	15	164	363	3	3	16	6
Solomon and Casadepaga	111,000	89,000	14	7	61	39	------	------	------	------
Koyuk	109,000	59,000	11	9	78	41	4	2	25	20
Council	375,000	360,000	11	4	89	37	1	------	3	------
Kougarok	32,000	50,000	11	9	35	40	------	------	------	------
Fairhaven	150,000	107,000	26	9	93	69	3	1	7	3
Port Clarence	3,000	7,000	5	7	8	17	------	------	------	------
	1,265,000	1,270,000	104	60	528	606	11	6	51	29

KOBUK REGION

Alluvial gold was reported in the Kobuk River basin as early as 1898, when the widespread Klondike excitement attracted gold seekers to many of the most remote parts of Alaska. Most of those going to the Kobuk left the following year, but a few remained and mined a little gold. The Shungnak district, in the Kobuk region, was the scene of the earliest mining, and by about 1907 more systematic development was begun, notably on Dahl Creek. The metallized areas near Shungnak, as determined by discoveries of gold, both in bedrock and in gravel, included an area about 10 miles square. Here the country rock comprises schist, slate, and limestone, with some igneous intrusives.[48] Some copper-bearing lodes have been found in this district, on which underground work has been done. From July to September Shungnak can be reached by river steamer from Kotzebue Sound, a distance of about 200 miles.

In 1910 gold placers were found on Squirrel River, which flows into the Kobuk about 60 miles from the sea. Kiana, at the mouth of Squirrel River, is the distributing point for the district and has a radio station. The geology of this district is similar to that of the Shungnak district, but no copper has been reported in it. In the Squirrel River district most of the placer mining has been done on Klery Creek, where gold has been found both in the creek and in the bench gravels. As shown by Smith's survey, the geology is much the same throughout the Noatak-Kobuk region, and there is no inherent reason why auriferous gravel should not occur at other localities than those described. Indeed, such deposits have been discovered and some placer gold has been mined on Agnes Creek, tributary to Ambler River in the Kobuk basin, and on Lucky Six and Midas creeks, in the upper Noatak basin. Some coal has been mined for local use on Kobuk River.

Mining in the Kobuk region was long limited to very small operations, consisting chiefly of open-cut work during the short summer

[48] Smith, P. S., The Noatak-Kobuk region: Geol. Survey Bull. 536, 1913.

season. A little deep placer mining has been undertaken in the region.

In 1922 and 1923 a hydraulic plant was installed on California Creek, in the Shungnak district. This installation, which was completed in 1923, includes a 2-mile ditch, 3,000 feet of pipe line, and a hydraulic elevator and is to be operated in 1924. This will be the first mining on a large scale in the entire region.

The statistics of gold production are very incomplete, but the figures given in the subjoined table are as accurate as may be had from the data in hand. The figures presented for the years since 1908 are based, so far as available, on the output of the individual mines, but as the returns are not complete, they have been supplemented by data obtained from various sources and are largely the estimates of local residents. Among those to whom special acknowledgment should be made are Mr. Lewis Lloyd, of Shungnak, who for 15 years has supplied the Geological Survey with valuable information about mining in the Kobuk region; and Messrs. M. F. Moran, Geo. L. Stanley, James C. Cross, and F. R. Ferguson, from whom important information has also been obtained.

Estimated value of placer gold produced in the Kobuk region, 1898–1923

Year	Mines	Men	Value of gold	Year	Mines	Men	Value of gold
1898–1902			$5,000	1914	7	15	33,000
1903			2,000	1915			20,000
1904			5,000	1916			20,000
1905			5,000	1917	17	25	25,000
1906			5,000	1918	19	49	15,000
1907			5,000	1919	16	40	25,000
1908			5,000	1920	12	19	8,000
1909			12,000	1921	13	25	7,000
1910			30,000	1922	9	19	8,000
1911	7	53	35,000	1923	8	13	8,000
1912	6	28	25,000				
1913	5	15	35,000				338,000

AN EARLY TERTIARY PLACER DEPOSIT IN THE YENTNA DISTRICT

By Stephen R. Capps

LOCATION AND GENERAL GEOLOGY

The Yentna gold-placer district lies at the western edge of the Susitna basin, on the southeastern flank of the Alaska Range, in south-central Alaska. It has been the scene of moderately active placer mining since the first discovery of gold there in 1905, and up to the end of 1923 it had produced about $1,500,000 in placer gold. Most of this gold has come from the basins of Cache and Peters creeks and their headward tributaries.

The general geology of the district in which the gold-placer deposits occur can be stated in fairly simple terms. This portion of the flank of the Alaska Range is composed mainly of a thick series of argillite, slate, and graywacke, of Mesozoic age, which have been highly deformed and considerably metamorphosed and are intruded, at a distance of 10 miles west of the placer mines, by large masses of granitic rocks. A few acidic dikes cut the slate and graywacke in the vicinity of the mines. The Mesozoic slate and graywacke are hard rocks and form high mountain ridges that border the basin of Cache Creek and upper Peters Creek both to the northwest and southeast. They show some mineralization, chiefly by disseminated cubes of pyrite. They contain abundant gash veins, stringers, and bunches of quartz, most of which is almost devoid of metallic minerals. A few quartz veins that carry gold in appreciable amounts have been found, and some fragments of vein quartz thickly studded with gold have been recovered from the sluice boxes by the miners. Many of the placer-gold nuggets contain some vein quartz, so there can be little doubt that the original source of the gold was in quartz veins carrying free gold.

Next younger than the Mesozoic slate-graywacke series is a series of gravel, sand, clay, and lignite beds that are correlated with the Kenai formation, of Eocene age. These partly indurated materials lie unconformably upon the Mesozoic slate and graywacke, are themselves considerably warped and deformed, are easily eroded, and so are now preserved only where their deformation has depressed them into synclinal basins in which erosion has been of only moderate severity.

The long time interval between the Eocene and the Pleistocene is not represented by recognized deposits in this district. This entire part of Alaska was heavily glaciated in Pleistocene time. Ice erosion greatly modified the preexisting topography, carved deep glacial troughs along the valleys of the main streams within the mountains, removed great quantities of the easily eroded Tertiary beds, and left a widespread mantle of glacial till and outwash gravel in the lowlands. In the Cache Creek and Peters Creek basin the ice erosion was severe, and large amounts of Eocene material were removed by glacial scour, but the position of the basin, bordered on the northwest and southeast by high mountain ridges and lying at right angles to the direction of the main ice movement in Kahiltna and Tokichitna valleys, gave it some degree of protection from glacial scour and prevented the complete removal of the relatively soft Eocene beds. The surface formation in much of the basin is now glacial till, which in places is known to be over 80 feet thick. This till is a characteristic deposit of unassorted stiff blue clay, studded with boulders and angular fragments of a wide variety of rocks.

Since the withdrawal of the glacial ice the streams have vigorously intrenched themselves into the basin filling of Eocene beds and the overlying glacial till and gravel, and they now occupy rather narrow, steep-walled cayons from 100 to 300 feet deep. The placer mining has been done mainly along the floors of these canyons. In general the bedrock beneath the stream gravel consists of the sand, gravel, clay, or coal beds of the Eocene series, but in places the streams have cut through to or into the harder Mesozoic slate and graywacke.

The location of the bedrock source of the placer gold has been open to question. No quartz veins capable of yielding the large amount of placer gold that the camp has produced and the additional large amount that still remains unmined have been found. The writer has expressed the belief[1] that the gold was originally derived from small, discontinuous quartz veins in the Mesozoic slate and graywacke, the veins being genetically related to the intrusion of these sediments by acidic igneous rocks, and this conclusion is confirmed by the present investigation.

PLACER DEPOSIT

In 1911 miners on Dollar Creek, a tributary of Cache Creek from the northwest, noticed while working upstream that the gold content of the stream gravel diminished rapidly above a certain point in the stream valley. In prospecting to discover the cause for this termination of the pay streak, a body of pebbles and subangular fragments of white quartz was found on the east wall of the valley, and this deposit was found to contain gold in minable amounts. At the time of the writer's first visit to the district, in 1912, only a small cut had

[1] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, p. 49, 1913.

been made at that place, and the conclusion,[2] based on the small exposures then accessible, was that the mining operations had uncovered a preglacial channel of Dollar Creek, buried beneath glacial till, and that the abundant quartz fragments and pebbles indicated the presence somewhere not far away of a considerable vein of gold-bearing quartz.

The Yentna district was visited by J. B. Mertie, jr., in 1917. By that time a large excavation has been made on the east bench of Dollar Creek, and a similar deposit had been opened and mined on Thunder Creek. Mertie[3] has described these deposits in some detail, and the following description has drawn freely on his observations, supplemented by those of the writer, who revisited the district in the summer of 1923. A third locality, in the upper valley of Willow Creek, in which ancient deposits of white quartz gravel,

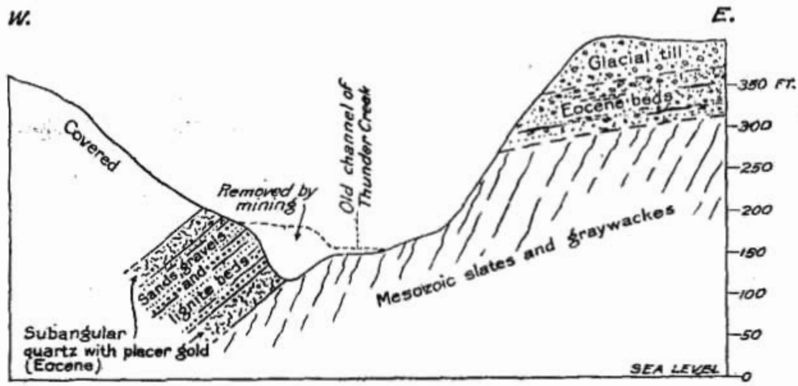


FIGURE 1.—Generalized cross section of Dollar Creek valley, showing geologic conditions at the placer mines.

unrelated to the present drainage lines, were proved to contain gold in paying quantities, extends the belt in which such deposits are known to a northeast-southwest length of 11 miles. The miners have been keenly alive to the commercial importance of these ancient gold-bearing gravels, and in the early months of 1923 they submitted a petition to the Geological Survey to send a geologist to the district, in order that he might study these deposits and advise them as to the source of the gold and the probable extent of the deposits. In response to this petition the writer spent a week in the district in August, 1923.

The largest exposure of the ancient gold placer is on Dollar Creek, about 4 miles above the mouth of that stream. There, on the east canyon wall, the placer-mining operations have opened a cut that

[2] Capps, S. R., op. cit., pp. 62–63.

[3] Mertie, J. B., jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 249–251, 252–254, 1919.

has a face over 1,500 feet long and averages over 100 feet high. The section exposed is shown in Figure 1. The sharply incised valley of Dollar Creek was cut through the surface layer of glacial till, through the Eocene deposits of poorly rounded quartz, assorted gravel, sand and clay lenses, and thin lignite beds, and into the underlying Mesozoic slate and graywacke. The Mesozoic beds, striking about N. 25° E. and dipping from 60° E. to 90°, are seen to contain abundant bunches and gash veins of quartz, most of which seems to be devoid of mineralization. In the valley of Dollar Creek the slate and graywacke are hard, fresh, and unweathered, but on the old surface from which the overlying Tertiary beds have been removed by mining there is evidence of long-continued weathering and decay, the graywacke having broken down into incoherent sand and the argillite and slate into clay. There can be no doubt that before the beginning of Tertiary deposition here the older Mesozoic rocks had been subjected during a long period to surface weathering and erosion, in which the surface was reduced and the exposed rocks were deeply weathered and decomposed.

The Tertiary deposits, of Kenai (Eocene) age, lie unconformably upon the weathered and decomposed surface of the Mesozoic slate and graywacke. The lower portion of the Eocene beds, in places having a thickness of 60 feet, consists primarily of subangular or partly rounded fragments of quartz, with some imperfectly rounded graywacke fragments, and a smaller number of well-rounded pebbles of quartz and graywacke, the pebbles and fragments all embedded in a bluish-white clayey matrix that is itself composed largely of broken vein quartz and siliceous clay. This quartzose stratum is gold bearing throughout, though there is a main concentration of gold on or near the slate-graywacke bedrock, and other minor concentrations occur on the upper surfaces of clayey bands and lignite beds. Conformably above the quartzose stratum there is a varying thickness of well-rounded gravel, and this is succeeded above by a 50 to 80 foot layer of blue glacial till which itself carries some gold.

In mining these claims the entire body of Eocene materials and the overlying glacial till are washed down with hydraulic giants, operating under a head of about 200 feet, and put through the sluice boxes. Both Eocene materials and glacial till are closely compacted and tenacious and yield to the hydraulic stream with difficulty. Under the influence of the weather, however, the material slowly disintegrates and may then be sluiced readily. The gold recovered is conspicuously rough and angular and in general shows the crystalline outlines of the vein quartz crystals in which it was embedded. Very little of it shows much evidence of stream wear and smoothing, and it has certainly been transported only a very short distance from its bedrock source. It ranges in coarseness from tiny colors to nuggets having a value of as much as $90. The gold assays about $17.60 an ounce. The sluice-box concentrates contain large amounts of pyrite carrying much gold, as well as magnetite, ilmenite, zircon, garnet, and cassiterite. As the materials sluiced include a large quantity of glacial till that contains material of widely diversified origin, it is impossible to be certain of the bedrock origin of many of these sluice-box concentrates.

Another locality at which the basal Tertiary materials have been mined for their placer gold is on Thunder Creek, about a mile above the mouth of that stream. Figure 2, a section of the stream valley at that place, shows a close similarity to the conditions on Dollar Creek illustrated in Figure 1. At the workings of 1923 the underlying slate-graywacke bedrock is overlain unconformably by 60 feet or more of Tertiary sediments that include at their base a deposit of

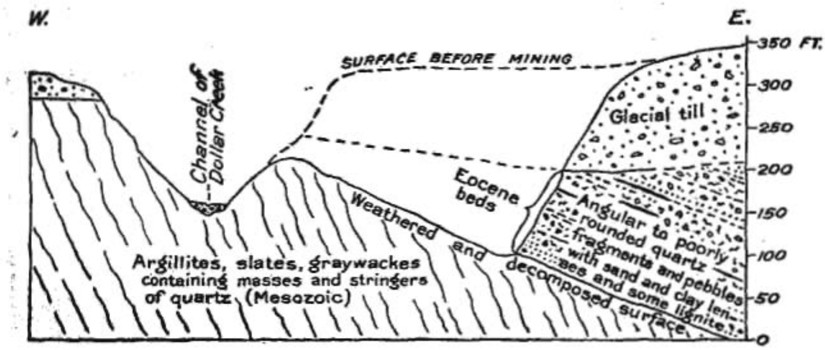


FIGURE 2.—Generalized cross section of the valley of Thunder Creek, showing stratigraphic relations of Mesozoic beds, Eocene deposits, and glacial till.

subangular quartz fragments with a few rounded quartz pebbles, embedded in a matrix of white clayey fragmental quartz and siliceous clay. This deposit is succeeded above by sand, clay, gravel containing lignite seams and fragments, and at about 50 feet above the base of the Tertiary by another quartzose bed, the materials of which are more perfectly rounded than those of the lower quartzose layer. The surface portion of the underlying slate and graywacke is deeply weathered and decomposed, contains numerous quartz bunches and gash veins, and shows evidence of having been long subjected to atmospheric disintegration before it was covered by the Tertiary sediments. The placer gold recovered is sharp and rough and shows almost no indication of having been transported far by streams. The principal gold concentration occurs in the basal portion of the lower quartzose stratum, or in the surface of the underlying decomposed slate and graywacke. A little gold is found in the Tertiary beds higher in the section, and a notable concentration in the upper quartzose bed. The gold is coarse, nuggets worth as much as $96 having been recovered. The gold assays $18.10 an ounce. The Tertiary beds on this creek have been mined for their gold content for several years by hydraulic methods, but the tenacious character of the beds makes them difficult to break down and limits the quantity that can be disintegrated and sluiced. Both the Mesozoic slate and graywacke and the Eocene beds are cut by faults, most of which are of small displacement. The character of the quartz fragments in the bedded Eocene deposits is strikingly like that of the gash veins and bunches in the underlying Mesozoic slate and graywacke. Most of the quartz is almost entirely lacking in visible mineralization, although on this creek a number of pieces of quartz thickly studded with gold have been found in the sluice boxes.

A third locality at which the quartzose beds at the base of the Tertiary sediments have been mined for their gold content is on the head of Willow Creek, a tributary of Cottonwood Creek, which joins Peters Creek just above the canyon through which that stream crosses the Peters Hills. At the extreme head of the Willow Creek basin, where numerous small streams drain the steep eastward slope of the Dutch Hills, there is a deposit of white, well-rounded gravel in a white siliceous clay matrix that contains sufficient placer gold to justify mining. The stratigraphic relations at this place are much less plain than on Thunder and Dollar creeks, for the deposit has been greatly confused and disturbed, probably by landslides. Nevertheless, from the prevailing association of the quartz-gravel deposit with a decomposed phase of the Mesozoic slate and graywacke, it is evident that here also the quartz gravel represents the oldest Tertiary beds at this place, though here both the quartz fragments and the associated placer gold are more rounded and worn and show evidence of having been transported farther from their source than in the Tertiary quartzose deposits on Thunder and Dollar creeks.

SUMMARY OF PERTINENT FACTS OF OBSERVATION

As a result of a study of the three localities at which the ancient quartzose deposits have been mined for their placer gold, a few general statements may be made as to the character and stratigraphic relations of these deposits. The quartzose deposit lies at the base of the Eocene formation, at its unconformable contact with the eroded and deeply weathered Mesozoic slate and graywacke. This series of Mesozoic rocks is highly folded and deformed, the beds generally dipping at high angles, and carries abundant gash veins and bunches of quartz that is similar in appearance to the great volume of quartz present in the Eocene beds. These quartz lenses and bunches are for the most part nearly devoid of mineralization, but it is likely that there are present other small veins, possibly of different age, that carry abundant free gold. Fragments of such veins have been found in the sluice boxes.

The lowest portion of the Eocene formation is composed mainly of quartz fragments that, on Thunder and Dollar creeks, are for the most part subangular or only partly rounded. This quartz is partly disintegrated and breaks up easily into fine angular fragments. A few well-rounded pebbles were seen at these places, and on Willow Creek the material is noticeably more worn. The pebbles and subangular fragments lie in a tenacious white siliceous clay, full of fine fragments of quartz. From the base of the Eocene series upward the proportion of quartz in the deposit decreases, and sand, clay, and lignite beds occur. Locally quartzose beds recur at intervals in the lower portion of the Eocene series. Some small faults, of a few feet displacement, cut both the Mesozoic and the Tertiary beds.

Placer gold occurs in small amounts through the basal portion of the Eocene series on Dollar, Thunder, and Willow creeks, but the principal concentration is found within the lower 2 feet of the basal quartzose bed, or on the surface of the underlying decomposed slate and graywacke. There is some concentration also upon the upper surface of clay and lignite beds and in the layers of fragmental quartz that occur higher in the section. The gold itself is coarse and remarkably rough and angular, showing the imprint of the vein-quartz crystals in which it was originally embedded. Since it was released from the parent quartz veins it obviously has not been transported far by streams to the quartzose beds in which it is now found. The angular to subangular character of the quartz fragments in the quartzose beds also indicates that this material has undergone only a small amount of stream handling and transportation.

Since their deposition the Eocene beds have been warped into irregular basins, so that dips in all directions may be found. The whole district was overridden, during Pleistocene time, by a thick body of glacial ice that eroded away large quantities of rock. In places where the Eocene beds had been warped and folded the domes and anticlines have been planed off by the glaciers, and the Eocene beds and also some of the underlying Mesozoic materials have been removed. The whole surface was covered by a sheet of glacial till that in places reaches a thickness of 80 feet. This till carries some gold, though generally in too small quantities to justify mining unless the material overlies richer deposits that are to be mined anyway.

From the facts just cited it is possible to reconstruct the series of events that took place in this district and gave rise to these interesting placer deposits. The major events in the series are believed to be as follows:

1. In the time preceding the deposition of the earliest Tertiary beds of the Cache Creek district the land surface was composed

of Mesozoic slate and graywacke that contained abundant quartz veins and bunches, most of which carried little gold, but some of which presumably carried free gold in considerable amounts. The surface of this group of quartz-bearing sediments was exposed to atmospheric weathering and erosion for a long time, was reduced to mild relief, and was covered by an accumulation of residual quartz that had weathered out from the slate and graywacke. Along with the quartz was a residual concentration of gold, freed from the rocks and the gold-bearing quartz veins by their disintegration.

2. In early Tertiary time certain deformations of the land surface took place that rejuvenated the drainage, and the residual surface accumulations of quartz and gold were carried from the elevated areas to near-by lowlands and there deposited.

3. Later in Tertiary time, the supply of residual quartz in the highlands having been largely exhausted, the streams attacked the underlying slate and graywacke. More slate and graywacke pebbles appeared in the gravel, and gravel deposits alternated with sand, clay, and lignite beds. All the clastic materials contained a little gold, but notable concentrations were formed only in the basal quartzose layer, on the top of clayey beds, or in later beds of fragmental and partly rounded quartz.

4. After the deposition of the Eocene beds was completed they were warped into irregular basins.

5. In Pleistocene time a great glacier advanced through this district, deeply eroded all the surface formations, and removed great quantities of Eocene and older materials, in places planing the Eocene beds entirely away and cutting into the underlying slate and graywacke. Later the glacier deposited a thick layer of glacial till over the surface of the lowland. This till contained the gold of those parts of the basal Eocene that the glacier had eroded and also the gold of any stream placers that had been eroded by the ice and incorporated in the till.

6. After the retreat of the ice the present streams began to intrench themselves into the glacial deposits, and they have now succeeded in many places in cutting through the till and the underlying Eocene beds and locally into the Mesozoic slate and graywacke. In so doing they have concentrated in their beds the gold that was distributed through the glacial till and the Eocene deposits and that which occurred in the quartz veins in the Mesozoic slate and graywacke.

CONCLUSIONS

It has been generally believed by the miners that the Eocene quartzose beds are old stream-channel deposits and that the angular character of the quartz and the gold indicate the presence somewhere in the vicinity of large auriferous quartz veins. Such an origin also implies that the quartzose deposits have long, narrow outlines and are of sharply limited area. The writer's concept—that the quartzose deposits are bedded deposits, coextensive with the base of the Eocene formation, and that the quartz is derived by weathering from the Mesozoic slate and graywacke, which contain a multitude of small bunches and veinlets—does not support the expectation that large gold quartz veins will be found. It does imply, however, that the quartzose beds have a much wider distribution than they would have if they were proved to be stream-channel deposits. It is not to be expected that the basal Eocene quartzose beds will everywhere contain placer gold in minable amounts, for their gold content at any particular place has been determined by the gold tenor of the quartz veins in the small area that supplied the materials of the deposit. Nevertheless, the knowledge that the basal Eocene quartzose beds contain placer gold in paying quantities over a rather wide area greatly increases the area favorable for prospecting, and those localities where the Eocene sediments are in contact with the Mesozoic slate and graywacke deserve prospecting with care.

15288°—25†——5

ADMINISTRATIVE REPORT

By Alfred H. Brooks

The systematic investigations and surveys of Alaska mineral resources began in 1898 and therefore in 1923 had been carried on for a quarter of a century. The great task before the Geological Survey was to determine the distribution and forms of occurrence of the valuable minerals of a region including 586,400 square miles, which was difficult of access and about which very little was then known. Most of the coast line had been fairly well charted by the Coast and Geodetic Survey, but inland Alaska was but imperfectly known by the explorations of a few pioneers. The Geological Survey had in 1895 and 1896 made a hasty exploration of the mineral resources of the Pacific seaboard and of the Yukon placer districts. Only the courses of the larger rivers were known, and no instrumental surveys had been made of inland Alaska. No understanding of the mineral deposits could be had except by the preparation of a geologic map, and the making of such a map required first the making of topographic surveys.

The basal plan of the first few years of work was to extend a network of exploratory surveys over the Territory, which would block out its larger physical features. This type of work was followed by areal surveys on a scale of 4 miles to the inch, which was adopted as the standard of the geologic and topographic maps of Alaska. Areas of special economic importance were to be mapped on a scale of 1 mile to the inch as fast as the appropriations permitted. On the average, it now costs about $10 a square mile to survey the topography and geology of Alaska; the detailed surveys will cost $30 to $50 a square mile.

Standard geologic and topographic maps have now been completed of about 200,000 square miles. At least half of the unsurveyed area is so inaccessible that its mapping may be deferred, but there are areas covering about 200,000 square miles of which geologic and topographic maps are needed to determine mineral resources that may possibly be of great importance. At the rate of progress in the past, it will require 50 years to complete this preliminary work. This estimate takes account of the fact that there are many districts which should be surveyed in the same detail as that used for the standard maps made in the States, as well as subjected to special geologic study in addition to the geologic mapping.

The need of geologic surveying as a basis for industrial development is so generally recognized that it requires no argument. It is especially important in new lands, however, to furnish the scientific facts on which to assure an orderly industrial development and to avoid the hit or miss policy which has been so often disastrously employed. In Alaska, too, there is the special Federal interest in the task because of the large expenditures on the Government railroad, which must find its main support from the production of mines. This interest calls for an early survey of the region tributary to the Alaska Railroad. It is evident then, that the parts of Alaska that should first be surveyed are the accessible parts, which will include the Pacific slope as well as the regions opened up by the railroad. Among these are the Alaska Peninsula and a belt to the north, which includes possible petroleum and coal resources, also a large unmapped area stretching westward from the head of Cook Inlet to Kuskokwim River and a tract lying south of Tanana River, between Delta River and Mentasta Pass, which is known to include some metal deposits. In northern Alaska a survey of the unmapped Buckland and Selawik basins is also believed to be important. The completion of the geologic mapping of southeastern Alaska is urgently needed.

Alaska's potential water power is estimated to aggregate about 2,500,000 horsepower, of which some of that on the Pacific slope is of immediate economic importance. The facts needed for utilization of water power in addition to topographic surveys are stream-gaging observations extending through a long period of years. The Geological Survey began this work in 1906 by measurements of stream volume in Seward Peninsula and later extended these measurements to other inland placer districts as well as to water powers of the Pacific seaboard. The most important of these were records for five years in southeastern Alaska, obtained before 1920, when the work was stopped on account of lack of funds. It is needless to say that if the potential water powers of Alaska are to be utilized, further expansion of such surveys is essential.

A retrospect of the accomplishments during 25 years of investigations in Alaska will show that these reflect great credit on the many who have taken part in the task. Alaska's geography, geology, and resources—thanks to the work of the geologist and the engineer—have become well known, and many of the details are recorded in maps and publications.[1] It is, however, evident that if this vast land and its resources are to be fully utilized by the large population it can support, the task of its survey and investigation is but fairly well begun.

In 1923 ten parties were engaged in surveys and investigations in Alaska. Of these, seven operated under the appropriation of $75,000

[1] The Geological Survey has published over 420 maps and 383 reports treating of Alaska.

for investigating the mineral resources of Alaska and included in their personnel 7 geologists, 2 topographers, and 11 recorders, rodmen, packets, cooks, and other helpers. Five of these parties were engaged in geologic work, and two were combined geologic and topographic parties. Three combined geologic and topographic parties were engaged in surveying Petroleum Reserve No. 4, on the northern coast of Alaska. This work was done under a grant of $75,000 to the Department of the Interior from the Department of the Navy. These three parties included 3 geologists, 2 topographers, 1 topographic assistant, and 17 rodmen, boatmen, packers, cooks, and other helpers.

Allotments for salaries and field and office expenses, field season of 1923

	1922-23	1923-24
Professional salaries		$28, 887
Field expenses	$14, 100	14, 000
Clerical salaries and other office expenses		6, 870
Office of Director		10, 992
To be allotted to field work, 1924		14, 251
	14, 100	75, 000

This statement includes only the appropriation made for the investigation of Alaska mineral resources; the other grants from naval appropriations and from funds for public-land classification are referred to below.

Allotments of naval fund, field season of 1923

Professional salaries	$12, 411
Field expenses	39, 877
Miscellaneous expenses, including clerical salaries	1, 900
Office of Director	1, 512
Allotted to field work, 1924	19, 300
	75, 000

The following grants have been made for the classification of the Alaska public lands and have been entirely devoted to the surveys of petroleum lands: 1921, $12,000; 1922, $2,000; 1923, $6,000.

The allotments shown in the subjoined tables as made to different kinds of work and to different regions are only approximations. To determine the precise 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 table shows, in a general way, however, on what project the funds have been spent. The geologic surveys include work that is used in the classification of public lands, which, as already shown, has in part been paid for from another appropriation for that purpose. These additional grants are not included in these totals and have all been spent on petroleum lands. They increase the allotment shown in these tables for geologic work in the first and for similar work on the Alaska Peninsula in the second.

Approximate allotments to different kinds of surveys and investigations, field season of 1923

	1922-23	1923-24
Special investigation of geology and mineral resources		$10,990
Geologic reconnaissance surveys	$10,000	15,130
Topographic reconnaissance surveys	4,100	7,500
Map compilation		2,200
Collecting mineral statistics		1,560
Administration of Alaska branch, including clerical salaries and miscellaneous expenses		12,377
Office of Director		10,992
To be allotted to field work, 1924		14,251
	14,100	75,000

Approximate geographic distribution of allotments for investigations in Alaska, field season of 1923

	1922-23	1923-24
Special investigation of geology and mineral resources	$2,935	$4,150
Southeastern Alaska	1,600	3,870
Prince William Sound	860	5,000
Alaska Railroad region		2,600
Alaska Peninsula	4,780	14,500
Yukon basin	3,925	3,500
Map compilation		2,200
Mineral statistics		1,560
Administration of Alaska branch, including clerical salaries and miscellaneous office expenses		12,377
Office of Director		10,992
To be allotted to field work, 1924		14,251
	14,100	75,000

The following table shows the progress of investigations in Alaska and the annual grant of funds since systematic surveys were begun in 1898.[2] A varying amount is spent each year on investigations of geology and mineral resources the results of which can not be expressed in terms of area.

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

Progress of surveys in Alaska, 1898–1923

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)	Lines of levels	Bench marks set	Gaging stations maintained part of year	Measurements of stream volume
		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	75,000		3,500			1,200					
1919	75,000		2,700			2,300				19	
1920	75,000		1,480			770				19	
1921	[b] 75,000		2,130	150		300	205				
1922	[b] 75,000		4,000			4,300					
1923	[b] 75,000		8,570			6,530					
	2,011,189	73,200	123,665	5,657	51,680	163,430	3,936	462	74		
Percentage of total area of Alaska		12.48	21.09	0.96	8.81	27.87	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] In 1921–1923 additional funds were available; see p. 65.

The chief Alaskan geologist was engaged in Alaska work until June 21, 1923, when he left for Seattle, Wash., on administrative duty. From July 1 to October 10 he was absent as an official delegate to the Pan-Pacific Science Congress in Australia. His time in the Washington office was divided as follows: Geology and geography of Alaska, 61 days; progress report, 19 days; press bulletin, 8 days; mineral statistics, 24 days; reading and revising reports of others, 25 days; field plans and orders, 30 days. The balance of office time was devoted to miscellaneous administrative duties.

On June 21, 1923, S. R. Capps took over the administrative duties of the branch, previously performed by G. C. Martin, Mr. Capps then becoming acting chief Alaskan geologist in the absence of the chief. In addition to doing his own geologic work, he devoted 125 days in the office to administrative work. Miss Lucy M. Graves, chief clerk, acted as chief of the branch during part of the field season. Miss Erma C. Nichols devoted about two-thirds of her time to collection and coordination of mineral statistics.

R. H. Sargent continued to supervise topographic surveys and map compilation. He devoted 112 days of office time to administrative work.

A. F. Buddington spent from May 22 to September 14 in the continuation of his investigation of geology and mineral resources of southeastern Alaska. Special attention was given to the Hyder district and to the nickel deposits of the Sitka district.

F. H. Moffit was engaged from June 1 to September 15 in a continuation of the study of the copper deposits of Prince William Sound and incidentally thereto mapped the geology of about 400 square miles on a scale of 4 miles to the inch.

S. R. Capps was engaged during the month of July in continuing his study of the metal deposits of the region tributary to the Alaska Railroad.

R. H. Sargent, with Kirtley F. Mather, geologist, carried a reconnaissance survey from Kamishak Bay to Katmai during the period included between June 21 and August 28. This party mapped an area of 3,150 square miles topographically and 2,200 square miles geologically, both on a publication scale of 4 miles to the inch.

R. K. Lynt, with Walter R. Smith, geologic aid, mapped an area of 1,300 square miles topographically and 1,000 square miles geologically, lying between Katmai on the north and Cold Bay on the south. This work was done for publication on a scale of 4 miles to the inch.

George C. Martin devoted the time from July 18 to August 28 to a continuation of the study of the stratigraphy of Alaska Peninsula. He gave special attention to the Cold Bay petroleum field and to the Chignik district.

J. B. Mertie, jr., carried a geologic reconnaissance survey from Beaver, on the Yukon, to the Chandalar district. Later he studied the geology along the Yukon between Beaver and the Tanana. The total area investigated by him included about 4,000 square miles, of which about half was new mapping.

Sidney Paige led an expedition to investigate the oil resources of Naval Petroleum Reserve No. 4. The field work began about July 15 and ended about September 9. The northern party, including Sidney Paige, geologist, and E. C. Guerin, cadastral engineer, worked from Wainwright around Point Barrow to Dease Inlet and thence up Meade River about 150 miles. The northeastern party, including James Gilluly, geologist, and J. E. Whitaker, topographic assistant, went overland from Peard Bay down to Inaru River and explored Topagarok River for 40 miles. The southern party, including

William T. Foran, geologist, and Gerald FitzGerald, junior topographer, landed near Cape Beaufort and surveyed the shore line north to Icy Cape. It mapped Kukpowruk River inland for 35 miles, Kokolik River for 25 miles, and Utukok River for 40 miles and explored the lower part of Wainwright Inlet.

The Paige expedition in all mapped 2,150 square miles, but the exploration has thrown much light on 10,000 square miles in northern Alaska. The surveying was done chiefly on a scale of 1:96,000, but as the maps will be published on a scale of 4 miles to the inch, it is here classed as reconnaissance work.

C. Arthur Hollick completed his studies of the Alaska Tertiary flora, and the resulting manuscript will soon be submitted.

James McCormick was employed in the Alaska branch for a part of the year in preparing a revision of the geographic dictionary of Alaska.

During 1923 the Survey issued two complete bulletins relating to Alaska—Bulletin 739, "Mineral resources of Alaska, 1921," by Alfred H. Brooks and others, and Bulletin 745, "The Kotsina-Kuskulana district, Alaska," including topographic maps, by F. H. Moffit and J. B. Mertie, jr.; also two separate chapters from Bulletin 755, "Mineral resources of Alaska, 1922," by Alfred H. Brooks and others. Bulletin 754, "The Ruby-Kuskokwim region, Alaska," by J. B. Mertie, jr., and G. L. Harrington, was issued in March, 1924. The manuscripts of four reports—on the Mesozoic stratigraphy of Alaska, by G. C. Martin; the Upper Cretaceous flora of Alaska, by Arthur Hollick, with a description of the Upper Cretaceous plant-bearing beds, by Geo. C. Martin; the Point Barrow region, Alaska, by Sidney Paige, William T. Foran, and James Gilluly; and Aniakchak Crater, Alaska Peninsula, by W. R. Smith, are nearly ready for the printer. The usual annual review of the mining industry of Alaska was issued on December 31, 1923.

The following Alaska maps were published in 1923: A new map of Alaska on a scale of 1 to 2,500,000, a relief map of Alaska on a scale of 1 to 2,500,000, and a new edition of the index map of Alaska on a scale of 1 to 5,000,000. The following maps have been issued in 1924: "Northwestern part of Naval Petroleum Reserve No. 4, Alaska," surveyed for the Department of the Navy by the Department of the Interior, on a scale 1 to 500,000, issued in April; "Cold Bay-Chignik, Alaska Peninsula," on a scale of 1 to 250,000, in April; "Iniskin Bay-Snug Harbor district, Cook Inlet region, Alaska," on a scale of 1 to 250,000, in May; and the topographic map of the region tributary to the Alaska Railroad, on a scale of 1 to 250,000, in three sheets (Seward to Matanuska coal field, Matanuska coal field to Yanert Fork, and Yanert Fork to Fairbanks) in June and December.

MINERAL INVESTIGATIONS IN SOUTHEASTERN ALASKA

By A. F. Buddington

FIELD WORK

Since 1921 the writer has been engaged in a study of the geology and mineral deposits of southeastern Alaska. The field work in 1921 and 1922 was devoted chiefly to the Wrangell district. A part of the results have already been published,[1] and a more complete report is in preparation. In 1923 the investigation was given a rather broader scope, and mineral deposits in many widely separated districts were examined. These studies yielded much information, which, it is believed, is of immediate practical value to the mining industry. For this reason it is here presented, even though the mapping of the geology necessary for a full understanding of the occurrence of ores in the district examined is by no means complete. Therefore, the statements here made must be taken as a record of progress rather than of final results. This report will deal chiefly with the gold and silver deposits of the Hyder district and the copper and nickel ores of Chichagof and Baranof islands. The results of examinations of other widely distributed mineral deposits will also be included.

The writer was engaged from May 21 to August 10, 1923, in geologic mapping of the northern portion of Prince of Wales Island, in the Ketchikan district, and of the mainland from Port Houghton to Taku Inlet, in the Juneau district. From August 10 to September 15 he made an examination of mineral developments in the Sitka, Petersburg, Hyder, and Ketchikan mining districts.

The writer is indebted to his assistants, C. M. Deming and George A. Wiggan, for consistent efficient aid, and to Mr. Wiggan for notes on the topography of Texas Creek, the description of the Cripple Creek prospect in the Hyder district, and other data. He is also under obligations to Walter C. Waters, of Wrangell, for very satisfactory services as navigator, and to Government officials in Juneau and many men connected with mineral development in

[1] Buddington, A. F., Mineral resources of the Wrangell district: U. S. Geol. Survey Bull. 739, pp. 51–75, 1923.

southeastern Alaska. He specially acknowledges assistance and information from Messrs. Metzger, of the Alaska Juneau Co.; Cann and White, of the Apex-El Nido Co.; S. H. P. Vevelstad, D. W. Yates, and Gudmund Jensen, of Juneau; and Hardy Haughn, H. Tanner, Jack Littlepage, Daniel Bayne, C. Carlson, and J. H. Hewitt, of Hyder.

RECENT DISCOVERIES OF ORES

Several new discoveries of mineral deposits have been made in southeastern Alaska during the last three years. In the Sitka district veins of high-grade free-milling gold have been discovered and prospected on Lisianski Inlet, Chichagof Island, and a mill for their treatment is now being constructed by the Apex-El Nido Mining Co. Veins of similar type are being prospected by the Pinta Bay Mining Co. near Pinta Bay. Nickeliferous pyrrhotite deposits have been found on Tenakee Inlet and at several places on Yakobi Island.

A nickeliferous pyrrhotite lode has also been found on Snipe Bay, Baranof Island, and barite veins have been located along the southwest side of Saginaw Bay and Keku Straits, on Kuiu Island, all in the Petersburg district. The Helm Bay King Mining Co. is prospecting a newly discovered gold lode in the Ketchikan district.

In the Hyder district the discovery in July, 1923, of a strong quartz vein well mineralized with galena carrying silver on the West Fork of Texas Creek resulted in a stampede of prospectors to this district. About 30 reached this area, and by the middle of September about 100 claims had been recorded, and 11 prospectors were still in the field. Veins containing gold, lead, silver, and copper, medium-grade gold-silver veins, and low-grade silver-lead and copper deposits have been located. Quartz porphyry sills, similar to those in which occur the ores of the famous Premier mine, in British Columbia, have been found on the east side of Salmon River in American territory and are being prospected. In September rich pockets of ore carrying much gold had been found in them, but no commercial ore body.

In the Juneau district, near Hawk Inlet on Admiralty Island, a number of large, strongly defined quartz veins are being prospected on the Charles Williams property. One workable shoot, 18 feet in width, of low-grade gold ore has been proved by the present developments. Numerous other veins show indications that warrant the continuation of prospecting for similar ore shoots. These veins are similar in type to those which are being prospected by the Admiralty-Alaska Co. on Funter Bay and form a southward extension of the belt in which they occur.

HYDER DISTRICT

INTRODUCTION

Many factors have worked together to maintain interest in the possibilities of mining development in the Hyder district. These include the continued success of the Premier mine; the extensive prospecting and development work being carried on along Big Missouri Ridge in the adjoining part of British Columbia; the discovery on the American side of mineralized felsite or porphyry sheets similar to those in which the ores of the Premier mine occur; the maintenance of prospecting, to an extent in excess of that required for assessment work, on many properties along the Salmon River valley; and the new strikes along Texas Creek. In the spring of 1923 the United States Forest Service began the construction of a prospectors' trail from Salmon River near Ninemile to Behm Canal by way of the West Fork of Texas Creek, Chickamin Glacier, and the Chickamin River valley. It was expected that this trail would be completed in 1924 and would have a length of 48½ miles. The Forest Service also expects to have a pack trail for horses completed from the Salmon River bridge near Ninemile to the Chickamin Glacier by the fall of 1924 and proposes in the future to build a trail up the south fork of the Chickamin, running almost east, across the divide at the head of Dolly Varden Creek and down the valley of that creek to Portland Canal. Another trail up the Le Duc River valley is also proposed. These trails will help to open up this area for systematic prospecting.

A preliminary examination of the geology of the Hyder district was made in 1920 by L. G. Westgate.[2] Much light has also been thrown on the geology of the district by the detailed studies made by the Canadian geologists in the adjacent region across the international boundary.[3]

In 1923 the writer spent from September 8 to 15 in a reconnaissance of new ore discoveries along the Salmon River valley, especially those on the West Fork of Texas Creek along the route of the recently constructed Government trail. Between Westgate's examination in 1920 and the time of the writer's visit no very large new body of ore had been found or productive mine developed. New veins of ore have been discovered, however, and the results have been of such a character as to warrant continued work. It is probable that one or more mines will be developed from the prospects in the

[2] Westgate, L. G., Ore deposits of the Salmon River district, Portland Canal region: U. S. Geol. Survey Bull. 722, pp. 117–122, 1922.

[3] Schofield, S. J., and Hanson, G., Geology and ore deposits of Salmon River district: Canada Geol. Survey Mem. 132, Ottawa, 1922.

Hyder district. The location of the prospects on the American side of the boundary and of the more prominent prospects on the Canadian side is shown in Plate I.

TYPES OF MINERAL DEPOSITS

In the following table are grouped the present available data on the mineral veins of the Salmon River and Texas Creek districts in British Columbia and Alaska. The data for the Canadian deposits have been taken from the report by Schofield, and those for the Salmon River district from the report by Westgate and from the writer's own observations, more particularly on Texas Creek. It must be recognized that in view of the slight development of most of the veins and the lack of intensive study, any grouping that may be made is tentative and is offered only for what suggestive value it may have. Several known veins do not conform in detail to all the characters of any one of the groups.

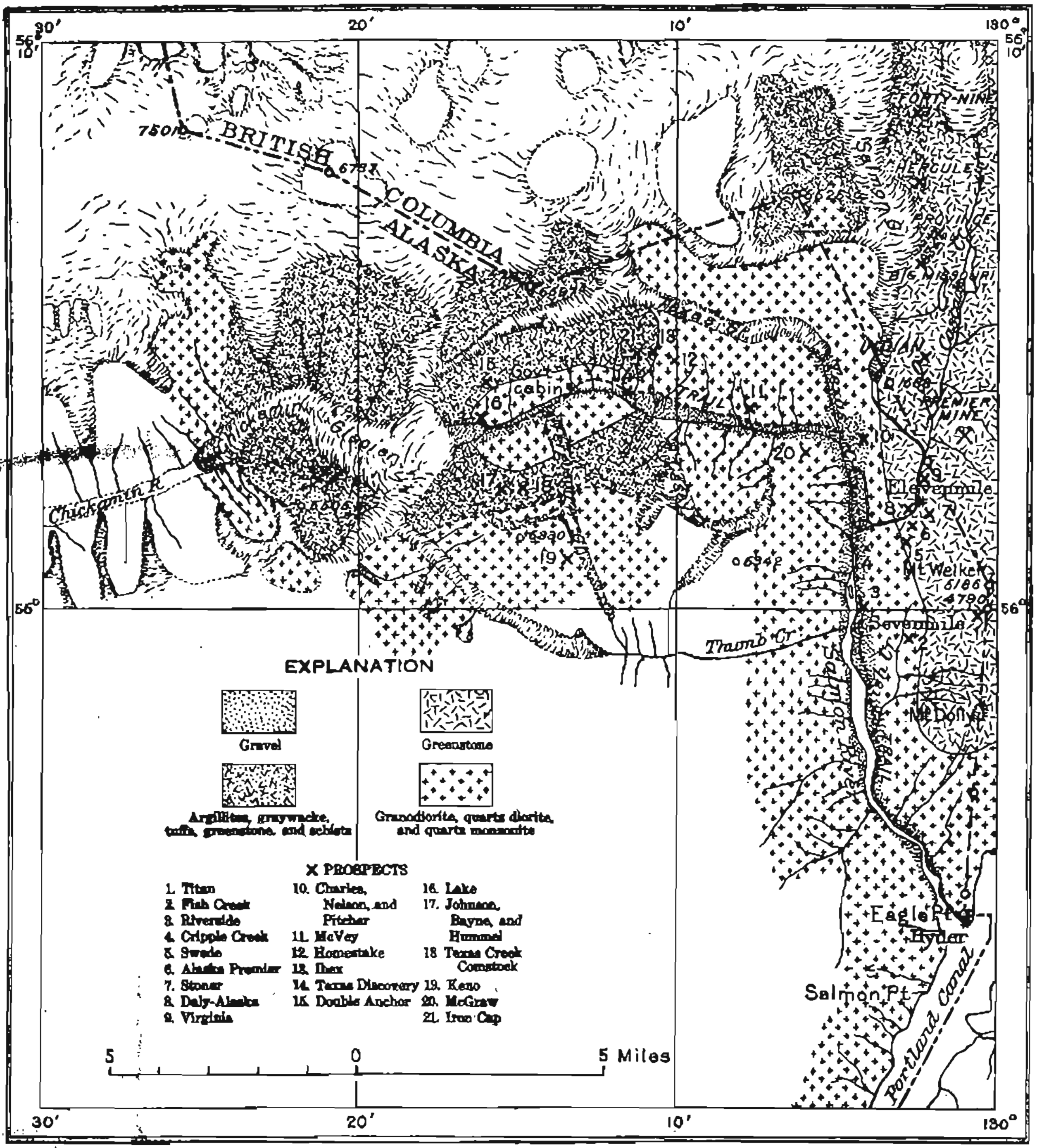
Types of mineral deposits on Texas Creek, Alaska, and in Salmon River district, Alaska and British Columbia

[—, Major mineral, or important ore mineral; +, an important mineral in some veins, in others a minor accessory]

Mode of occurrence	Country rock[a]	Pyrite	Galena	Sphalerite	Chalcopyrite	Tetrahedrite	Rich silver minerals	Pyrrhotite	Examples
Quartz veins and veinlike replacement deposits.	Quartz porphyry *sills* and their contacts with tuff.	—	—	—	—	—	—		Premier, B. C., and certain ore bodies in the Forty-nine, Big Missouri, and Mineral Hill.
	Quartz porphyry (felsite).	—	—	—	+			+	Alaska-Premier, Titan.
	Quartz porphyry *	—							An ore body of the Premier, B. C.
Replacement and disseminated deposits.	Schistose tuff and fine tuffaceous conglomerate.*	—	—	—	+				Big Missouri; Hercules, Forty-nine, Province.
	Greenstone	—	—	—	+			+	Virginia group, Elevenmile, Stoner, Swede group.
	Greenstone	+	+		+			—	Certain bodies at Elevenmile, Virginia group, Fish Creek.
Quartz fissure veins	Granodiorite (one prospect in tuffs).	—	—		+				Riverside group, Jackson & Hummel, Reno, Cripple Creek, Texas-Discovery, Lake.
	Granodiorite	+	—	+	+	—			Fish Creek.

[a] An asterisk (*) indicates types found on Canadian side; after Schofield.

On the American side mineral deposits are found in country rock of four general types—quartz porphyry, greenstone, granodiorite, and sedimentary beds. At the Alaska-Premier and Titan and perhaps at one of the Stoner groups of claims sheets of quartz porphyry (greenish felsite) similar to that at the Premier mine in British Columbia are being prospected. The mineralization in this rock on the Alaskan side differs in that the rich silver minerals, such



GEOLOGIC SKETCH MAP OF HYDER DISTRICT

as argentite, pyrargyrite, stephanite, and native silver, have not been found. High gold returns, however, have been obtained from local pockets, particularly rich in sphalerite, and some bodies with low tenor in gold have been found, but as yet no commercial ore body.

Within the greenstones local pockets giving high-grade gold assays, samples reported to give very high silver assays, and mineralized bands of low to medium grade containing mainly silver, gold, and lead have been found. There are many mineralized streaks in the greenstones, but no extensive prospecting has been done on them and no commercial ore body has yet been developed.

Most of the development work in this region so far has centered on the quartz fissure veins in granitoid rock. The granitoid rocks vary from granodiorite to quartz-hornblende diorite. The term granodiorite will be used as a general descriptive name for them where accurate determination has not been made. The fissure veins occur along the east side of Salmon River and both sides of the West Fork of Texas Creek. Veins of similar character and mineralization are also found in the andesitic tuffs at the Texas Creek Comstock group, on the south side of the West Fork of Texas Creek, and in banded argillite and quartzite at the Ibex prospect, on the north side of the West Fork of Texas Creek.

The available data on the strike and dip of the veins suggest the possibility that there may be two groups—one whose strikes vary between N. 30° W. and N. 60° W., with dips of 45°–70° NE., and another whose strikes vary between N. 15° E. and N. 10° W., with dips of 30°–70° E. The former are the most numerous, and the latter are prominent in the vicinity of the Homestake-Ibex groups on Texas Creek. Faults that offset the veins with small displacements are not uncommon, and at several localities the veins are cut by dikes.

With respect to the sulphide mineralization, most of the veins may be divided into two groups, one of which is characterized by the predominance of galena and pyrite, and the other by galena associated with tetrahedrite, chalcopyrite, and other sulphides. The veins of the second group carry more silver than those of the first. This difference is in accordance with Schofield's statement that wherever tetrahedrite is present the ore carries much silver. Veins of transitional character between the two groups occur, such as the "cross" vein at the Riverside group and some veins on the Texas Creek Comstock claims, where chalcopyrite in considerable quantity is associated with the pyrite and galena. Pyrite and sphalerite occur in practically all the veins in varying amounts, but galena appears to be the predominant sulphide. The sulphides occur concentrated in shoots within or along the vein.

The continuity of the veins and the quality of their mineralization is, of course, a most important consideration. Some of them, as exposed at the surface, are several hundred feet long and pinch abruptly or are displaced by faulting. In some places the fissure persists beyond the vein matter. Other veins have been proved to have a minimum length of 600 or 700 feet, with their total length undetermined. One vein on the Riverside group appears to have been traced for nearly 2,100 feet and to crop out at altitudes from 200 feet up to 900 feet. The tunnels at an altitude of about 250 feet on this vein, so far as explored, show the vein to consist only of stringers of quartz in schistose granodiorite. Developments have not proceeded far enough to give an adequate idea of precisely what may be expected. For this reason the deductions of Knopf[4] from his study of the development of the quartz veins which occur in granite rocks of the Berners Bay region are of interest here and are quoted:

> It has been pointed out in previous pages that the veins were formed by the movements of the walls past each other along gently sinuous fractures. Pinches and swells are therefore encountered on the levels along the strike of the veins. Similar variation is to be expected vertically, also, although development has not yet been sufficiently extensive to demonstrate this as a law.
>
> Inasmuch as narrow portions of the fissures are commonly occupied by masses of schistose diorite which are here and there interlaced with quartz stringers, such schistose zones are worth exploring or drifting on in the chance of striking other valuable ore bodies. This possibility was forcibly illustrated at the Jualin mine, where an 18-inch zone of crushed diorite of most unpromising appearance opened out when followed along the strike into a strong and valuable ore body. That this is no infallible rule, however, is clearly demonstrated by certain fruitless attempts that have been made under its guidance. In the most conspicuous example 500 feet of tunnel was drifted along in a schistose zone in the diorite without encountering a ledge. The probability of striking an ore body is apparently strongest in those belts of crushed or sheared diorite that are penetrated by quartz stringers.
>
> On the whole, the downward persistence of fissuring would seem to be proved by the deep-seated origin of the vein-forming solutions, as shown by their mineralization.

Westgate has described five veins at the Fish Creek claims which, to judge from the claim map, constitute a group lying within a radius of 500 feet. Other veins are found on the same group of claims but at greater distances. All the veins show a similar type of mineralization with shoots carrying much silver. At the Riverside property three veins lie within a width of 600 feet and likewise show among themselves a similar type of mineralization but different from that of the Fish Creek group, though the two groups are only a little over a mile apart. The Ibex and Homestake veins, on

[4] Knopf, Adolph, Geology of the Berners Bay region, Alaska: U. S. Geol. Survey Bull. 446, pp. 37–38, 1911.

the north side of Texas Creek, are similar to each other in type of mineralization. The occurrence of several veins in a group at the Fish Creek and Riverside claims suggests that probably new veins with similar mineralization will be found in the vicinity of the Homestake and Ibex veins.

The metallized veins are known to occur throughout a vertical range of nearly a mile, from an altitude of 200 feet at the Riverside group to 5,000 feet on the Texas Creek Comstock claims, on the West Fork of Texas Creek. The sulphides of the veins are believed to be primary, and no evidence of enrichment has been found. From these two facts it is probable that the same general quality of mineralization of the veins persists in depth and that if any change occurs it is one arising from peculiarities of original deposition. The mineralization of the quartz fissure veins agrees essentially with the statement made by Westgate[5] with respect to the mineralization in the Salmon River district in general.

PROSPECTS NEAR SALMON RIVER

TITAN

The writer did not visit the Titan group of claims, and the following data were furnished by S. P. Fitzgerald, one of the stockholders. The property is about 4½ miles by trail from the intersection of the Fish Creek trail and the Salmon River road. It comprises 10 claims located in 1917 and held by the Titan & Salmon River Syndicate. The developments consist of 400 feet of tunnel, started in the fall of 1922 at an altitude of 2,950 feet, and a short crosscut from the tunnel that is reported to have cut 12 feet of quartz running about $4 in gold and 6 ounces of silver to the ton. The quartz is sparsely mineralized with galena, pyrite, and sphalerite. The country rock is quartz porphyry, similar to the type found at the Premier mine and the Alaska-Premier prospect. Rich stringers are reported to have been found in the porphyry, picked specimens of which assayed as much as 4½ ounces in gold to the ton.

FISH CREEK

Developments on the Fish Creek property up to 1920 have been described by Westgate.[6] Since his report was written the main work done has been the prospecting of a new vein on the Olympia Fraction claim. The vein is a metallized quartz fissure vein in quartz-hornblende diorite and has been exposed by a series of trenches along its strike for a length of about 300 feet. At each end it tapers off abruptly, though the fissure continues in each direc-

[5] Op. cit., p. 131.
[6] Op. cit., pp. 134–138.

tion. The vein strikes about N. 60° W. and dips 50° NE. The vein matter breaks freely from the wall rock, and the walls show marked slickensiding. A narrow dike of dense black lamprophyre cuts the vein.

At the longest surface trench the vein is from 4 to 6 feet wide and consists of quartz with 5 per cent or more of disseminated sulphides and with stringers of solid sulphides so localized as to constitute rich ore shoots. The gangue is mostly quartz, with some calcite and brown siderite. The sulphides include galena, tetrahedrite, chalcopyrite, pyrite, sphalerite, and rarely a little arsenopyrite. The tetrahedrite occurs in solid streaks as much as 2 inches wide and is rich in silver. Forty tons of sorted ore taken from the surface trench is reported to have averaged about $90 to the ton.

At an altitude of about 2,800 feet a crosscut tunnel 125 feet long was driven to intersect the vein. Near the end of the crosscut a winze was sunk on the vein for 42 feet and a drift run along the vein to the southeast for 120 feet. In the drift the vein ranges from 2 to 5 feet in width and locally contains inclusions of the wall rock. In the winze the vein is reported to narrow and the tenor to decrease. It is reported that 55 tons of sorted ore was taken from the drift and shipped and that it averaged about $90 to the ton.

About 30 feet below this tunnel another tunnel was started on a fissure and driven for a total length of about 400 feet. The fissure on which the tunnel was started did not lead to the vein sought, but a short crosscut made from the tunnel intersected the vein, and then a drift was run back along the vein for about 50 feet, and from its face a raise was opened to the upper tunnel.

SWEDE

The Swede group is reported to comprise six claims on the mountain side about a mile south of Elevenmile. These claims were not examined by the writer but are reported to be similar in type to the Daly-Alaska prospects.

ALASKA-PREMIER

The Alaska-Premier group (not to be confused with the Premier mine, which is on the Canadian side of the boundary) comprises 25 claims between Elevenmile and Fish Creek. The general country rock is greenstone with intercalated beds of slate and graywacke. Three sheets of felsite (quartz porphyry) cut the greenstone and the sediments. Present developments are being directed toward finding an ore body within two of these sheets. The northern sheet, on the Alaska claim, is about 40 feet thick, strikes about N. 60° W., and dips 50° E. A short prospect tunnel 15 feet long, at an altitude of 1,400 feet, has been driven on a mineralized streak in the sheared felsite. Veinlets of quartz several inches thick, with pyrite, sphalerite, galena, and a little pyrrhotite and carrying considerable gold, have been found. On the Ready Money claim the second sheet of felsite is being prospected. Open cuts have been made, and a tunnel is being driven. At about 40 feet above the tunnel an open cut was made on a very rich pocket of mineralized, veined, and altered felsite. The rock is shattered, veined with quartz, and much silicified. Veinlets and blebs of sulphides occur throughout the pocket and comprise pyrite, sphalerite, galena, and a little pyrrhotite and chalcopyrite. As much as 35 ounces of gold to the ton is reported to have been obtained on assays of selected specimens. A crosscut tunnel at an altitude of about 1,300 feet is being driven to cut the felsite sheet. On September 9, 1923, the tunnel was in about 200 feet and had cut about 30 feet of felsite. The country rock at the entrance to the tunnel is a dark-gray to brown hornlike stone of uncertain origin. The tunnel passed through about 50 feet of a light-colored diorite porphyry dike which does not show at the surface. The whole zone of felsite is fractured, and the fractures are faced with small pyrite cubes. These small cubes are also disseminated throughout the felsite. Rarely a bleb of pyrrhotite occurs. Such rock is reported to average $2 to $3 in gold and about 1 ounce of silver to the ton.

RIVERSIDE

The Riverside group of claims is on the east side of the Salmon River road a little beyond Sevenmile, at an altitude of about 260 feet. The property consists of ten claims under development by Strong, Barber & Black. The developments consist of about 2,400 feet of underground workings and numerous trenches and strippings at the surface, made since September, 1922. Three quartz fissure veins in grandiorite are being prospected, known as the Ickis vein, Cross vein, and Southeast vein or "main lead."

The Ickis vein has been prospected by three tunnels, the lowest one about 15 feet long, the middle one about 20 feet long and 35 feet higher (now covered by the dump from the upper tunnel), and the upper one about 70 feet above the lowest tunnel and 500 feet long. In the upper tunnel the vein is about 20 inches wide at the face and is reported to be 4 to 5 feet wide in front of the entrance, now covered by the dump. The tunnel was driven on the vein, which narrows to a stringer a fraction of an inch wide at about 200 feet from the entrance and does not thicken again within the length of the tunnel. The vein within the tunnel averages about 8 or 10 inches in width, with local pinches. The country rock is a shattered, slickensided gneissoid granodioritic rock. The vein occupies a fissure and consists of quartz with local bunches strongly mineralized with pyrite and galena and rarely with sphalerite. The vein has a general northwest strike, though varying considerably, and a steep northeast dip. Assays as high as $20 to the ton in gold, silver, and lead are reported. The vein matter breaks free from the walls. Stringers (droppers) of quartz several feet long offshoot into the wall rock.

The Cross vein was cut in the underground workings when a crosscut was driven from the drift on the Ickis vein with the intention of reaching the Southeast vein. It is intersected about 600 feet from the entrance of the tunnel, and drifts have been driven on it for about 150 feet to the south and for about 60 feet to the north, to a point where it pinches out; from this point the tunnel has been continued northward to the extension of the Southeast vein. The southerly 100 feet of the vein ranges from 8 inches to 3 feet in width, but the southernmost 25 feet is sparsely mineralized and carries only a little gold. In the drift north from the crosscut tunnel the vein is also narrow but is better mineralized with sulphides. The 50 feet of the vein immediately south of the crosscut tunnel ranges from 18 inches to 3 feet in width, is well mineralized with sulphides, and carries gold, reported to average locally $40 to the ton. At 50 feet in from the crosscut tunnel a 20-foot raise and a 40-foot winze have been opened on the vein. The vein maintains a width of about 2 feet in the raise but narrows to 6 or 8 inches in the winze. The vein as thus exposed in the tunnel is about 210 feet long; the northerly three-fourths is well mineralized with sulphides and carries a good metal content, and the other fourth has sparse sulphides and a low metal content, mainly gold. The southern termination of the vein is not shown. About 150 feet of the vein, as developed in the tunnels, is considered workable. The sulphides comprise pyrite, galena, and chalcopyrite, with rare sphalerite. The vein is in part frozen to the walls (granodiorite). It strikes about north and dips 30° E.

By September, 1924, continued prospecting of this vein had developed new ore shoots, and it was planned to install a 50-ton mill using both tables and flotation to treat the ore. Three shoots of ore have been found in drifting on the vein at the level of the crosscut tunnel—a small one north of the crosscut tunnel, the one described above south of the crosscut tunnel, and a new 70-foot shoot 150 feet farther south. About 150 feet of sparsely metallized quartz intervenes between the two main shoots. The southernmost ore shoot in turn gives way to quartz metallized with pyrrhotite and other sulphides but of low tenor. A winze has been sunk on the vein from the tunnel level 140 feet to a lower level, where drifts have been run on the vein for a length of 180 feet, and 110 feet to a still lower level, where drifting is in progress. On the first level below the tunnel 50 feet of fine ore has been exposed which averages over 3 feet in width, ranging from 2 to 5 feet, and is reported to average $46 a ton in value, ranging from $36 to $100 per ton. The ore averages about $7 or $8 to the ton in gold and 1 ounce of silver to 1 per cent of lead. A sample from the muck pile of both the upper and lower levels, which included some rock, yielded about 25 per cent concentrates. The pyrite concentrate obtained by separation on tables gave 0.56 ounce of gold and 10.40 ounces of silver to the ton, 4.4 per cent of lead, 37.4 per cent of iron, and 0.4 per cent of insoluble matter. The galena concentrate gave 0.40 ounce of gold and 58 ounces of silver to the ton, 74 per cent of lead, 4 per cent of iron, and 1 per cent of insoluble matter.

The Southeast vein or "main lead" has been developed by two adits and a drift over 400 feet long from the crosscut tunnel. The crosscut intersects the vein at about 800 feet from the entrance. The vein here consists of quartz stringers, locally widening to several feet, in a very highly mashed, minutely plicated schistose granodiorite. A 70-foot raise showed similar material. A lens of solid pyrite several inches wide was found. About 60 feet above the main tunnel the vein crops out on the hillside, and an adit about 300 feet long, known as the Lindeborg tunnel, has been driven on it. Some inclusions of schistose granodiorite occur within the vein. In the Lindeborg tunnel the vein averages about 3 feet in width and is reported to average about $14 a ton. The vein is cut by two dikes of dark andesite porphyry, and the tenor is reported to decrease near the dikes. The sulphides are pyrite and galena, usually localized in bands, with here and there a little sphalerite and chalcopyrite. About 90 feet below the Lindeborg tunnel is another adit about 150 feet long driven on the vein. At the portal of the adit is a 2-foot quartz vein, which pinches markedly about 50 feet in. Stringers of quartz occur in the adjacent country rock, and stringers and veins of quartz are found along the remainder of the drift. There is here no well-defined persistent mineralized vein, but sulphides, mainly pyrite and galena, are present locally in considerable quantity. At the surface numerous trenches and strippings have exposed quartz with sulphides for a length of about 1,800 feet up to an altitude of 900 feet. The amount of sulphides varies considerably. Layers of solid galena several inches thick and carrying considerable silver are found here and there. At one cut the quartz vein is 5 feet wide and contains 18 inches of steel galena reported to assay 27 ounces of silver to the ton. The present workings thus show a better-defined vein with higher metal content in the outcrop and the upper (Lindeborg) tunnel than in the lower tunnels. In the lower tunnels the vein has more of the nature of a stringer lead in schist, with thick bunches of quartz and small local pockets of sulphides. Several dikes of andesite porphyry cut the granodiorite and the vein. The vein matter breaks freely from the walls.

At an altitude of about 550 feet about 40 feet of vein matter is exposed, consisting in part of solid milky-white quartz and in part of a brecciated granodiorite with quartz veinings. A grab sample of this quartz is reported to show a little gold, though it carries practically no sulphides.

CRIPPLE CREEK

The Cripple Creek group of claims is on the south bank of Salmon River just above Texas Creek and just below the bridge across Salmon River at Tenmile. The group comprises four claims. The developments consist of an adit 45 feet long with a 15-foot open cut at the portal, an 8-foot drift to the west from the breast of the adit, four small prospect holes, and strip pits along the projected strike of the vein. An upper vein of quartz has been stripped for 150 feet.

The adit was driven on a vein zone lying along the contact between a sheet of granodiorite and greenstone and consisting of two veins, one on the footwall of the adit and the other on the hanging wall, with a barren zone of fractured greenstone between them. The lower vein is exposed for 65 feet, and the upper vein for 45 feet, pinching out within 20 feet of the breast of the adit. From the breast a drift was driven 8 feet to the west on the lower vein without reaching the end of the vein zone. In the open cut the vein zone is exposed for a width of 13 feet and consists of a massive vein of quartz 4 feet wide with numerous smaller stringers in fractured greenstone. In the drift the strong quartz vein splits into a vein zone of small quartz stringers in brecciated and fractured greenstone. A little pyrite was noted in the drift, scattered through the greenstone in disseminated grains. No sulphides were noted in the massive quartz, though it has iron and copper stains in the open cut.

The upper vein has granodiorite on the hanging wall; all the footwall has been cut away, but to judge from the rock exposed in the breast, it was an altered and brecciated greenstone. The vein consists of quartz bordered by several smaller stringers of quartz in the hanging wall. The main vein ranges from a few inches to 2 feet in width and averages 11 inches. On the footwall side of this vein were noted two small seams of sulphides, one about 2 inches wide exposed for about 6 inches, the other about 1 inch wide and traceable for 5 feet. Both of these stringers carried rather coarsely crystalline galena, with a little pyrite and sphalerite. Scattered through the quartz vein are sparse grains of pyrite, galena, and chalcopyrite. Specimens of solid galena 3 to 4 inches wide are common on the dump.

About 200 feet above the road is a solid mass of quartz which has been exposed by stripping for about 150 feet. The quartz vein is about 4 feet wide and is contained in granitic work, probably the sheet that partly parallels the adit on the lower vein zone. No sulphides were noted in this vein. The lower vein strikes northwest and dips 70° N.; the upper vein strikes northeast and dips 40° E.

STONER

The Stoner group of claims adjoins the Elevenmile group and is held by H. B. Stoner. About 300 feet above the Hoosier tunnel on the Elevenmile claims, at an altitude of 1,360 feet, 15 feet from the boundary line of the Elevenmile group, an open cut was made. This cut is about 40 feet wide and is in either silicified greenstone or a felsite sheet. More careful examination would be necessary to determine which. Dikes of andesite porphyry are found on each side of the open cut. Fine pyrite cubes are disseminated throughout the rock, and locally there are little threads and veinlets of fine granular galena. Calcite veinlets are common. The best assays are reported to be about half an ounce of gold to the ton.

DALY-ALASKA

The Daly-Alaska group of claims is also known as the Elevenmile and as the New Alaska group. The claims are near Elevenmile, on the Salmon River road.

The writer is indebted to B. W. McDougall for information about the property. The group comprises 11 claims and is equipped with a 25-horsepower Fairbanks-Morse oil engine and compressor. An average of about 16 men were employed between March and August, 1923. Since Westgate's report was written about 380 feet of underground workings have been driven. At an altitude of about 150 feet above the camp on Salmon River a 58-foot shaft was started on a mineralized streak in greenstone and sunk vertically. From the bottom of the shaft a 70-foot crosscut was driven; from this crosscut a drift 62 feet long was run on a mineralized streak, and from the end of the drift 44 feet of crosscut. The mineralized zone consists of broken and silicified greenstone, with quartz veinings and streaks of sulphides.

A short distance northeast of the Daly shaft a crosscut was driven for about 150 feet in a southeast direction and intersected some rich but narrow sulphide stringers.

Many small open cuts have been made on mineralized outcrops above the entrance to the Larson tunnel. Near the bed of a creek, at an altitude of about 600 feet, two open cuts have been made on a mineralized shear zone in the greenstones. There is a 3-foot vein here, streaked with stringers of fine granular galena, pyrrhotite, and sphalerite, with some chalcopyrite and pyrite, together with calcite and quartz veinlets and some sulphides. The sulphides may form about 20 per cent of the zone. The vein strikes about N. 80° W. and dips 60° S., and it is reported to average about 30 to 40 ounces of silver to the ton. In another open cut on the same zone, about 10 feet above, the sulphides consist mainly of pyrite with local sphalerite stringers that give high assays in gold.

Samples are reported to have been obtained that yielded assays of silver as high as 500 ounces to the ton. A polished specimen reported to be of the high-grade type was examined under the microscope and found to comprise pyrrhotite, sphalerite, and pyrite, with a little chalcopyrite, galena, and tetrahedrite. The tetrahedrite occurs as small blebs in the sphalerite and as minute veinlike stringers. Its reaction with potassium cyanide suggests that it is the silver-bearing variety, freibergite. Moil samples as much as 30 inches in width are reported to have yielded 20 to 30 ounces of silver to the ton. Work is being continued to prove whether or not a definite ore body exists on the property.

VIRGINIA

The writer did not see the workings at the Virginia group, and William Bunting is authority for the following description. The group comprises six claims staked in 1919 on the Salmon River road near the international boundary. Work was begun in 1920, and the developments consist of 600 to 700 feet of tunnel and crosscuts. In this work a zone 50 feet wide, of which 12 to 16 feet is mineralized with sulphides, was crosscut. The ore is said to average about $4 to $5 a ton, mainly in gold. Selected samples have yielded as high as 4½ ounces of gold to the ton.

TEXAS CREEK BASIN

MINERAL DISCOVERIES

Chapin[7] reported in 1916 that several claims had been staked on Texas Creek and that the ore bodies were said to be quartz veins carrying seams of tetrahedrite penetrating granite and pegmatite but had been only slightly prospected. For a number of years little was done in this part of the district. On June 12, 1923, interest was

[7] Chapin, Theodore, Mining developments in southeastern Alaska: U. S. Geol. Survey Bull. 642, p. 98, 1916.

renewed by the staking of claims along the line of the Government trail in the West Fork of Texas Creek valley by Smith, Davidson, and Ferguson. This interest was intensified by the staking, by J. Neary and J. Jackson, on July 23, of a claim still farther up the valley on a large, well-defined quartz vein carrying galena and some pyrite and chalcopyrite. This find attracted about 30 prospectors into this part of the district, and by the middle of September about a hundred claims were recorded and 11 prospectors were still in the field. As little has been printed about this part of the district, its features will be described in some detail.

TOPOGRAPHY

Texas Creek flows almost due south from its source in Texas Glacier to its junction with Salmon River. The West Fork enters the main creek about 2½ miles above its mouth, after flowing almost due east for about 10 miles from the divide at the Chickamin Glacier. The West Fork is fed mainly by streams originating in two glaciers on the south side—Casey Glacier, about 5 miles from the mouth, and Ferguson Glacier, at 8 miles. Many small tributaries flow into the creek, chiefly from the north side.

The valley of the West Fork is essentially a glacial U-shaped, flat-floored valley, covered with a veneer of coarse gravel. It rises gradually, at a rate of about 200 feet to the mile, from an altitude of about 600 feet at its mouth to about 2,600 feet at its head. At about 3 miles and 6 miles from the mouth postglacial gorges have been cut in the valley floor for about 1,000 yards and 600 yards and to depths of about 350 and 200 feet, respectively.

Casey Glacier occupies a great cirque basin and is highly crevassed and broken up; Ferguson Glacier is a "through" glacier, extending across the divide at the head of the narrow valley which it occupies and into a small tributary valley of Thumb Creek, which empties into Salmon River opposite Sevenmile. Ferguson Glacier is retreating, and the old rough moraines extend in front of the present ice for half a mile or so, forcing the West Fork of Texas Creek to flow against the cliffs on the north side of the valley.

Chickamin Glacier is likewise in retreat, and a conspicuous terminal moraine has been left about three-fifths of a mile below the present ice front. Between the terminal moraine and the ice front is a lake; and a narrow, higher-level lake terrace fringes the basin on either side.

Along the sides of the main valley gravel terraces and alluvial fans occur at considerable altitudes above the present bed of the main creek. Such forms are also characteristic of the valley of Ibex Creek, where along the west side a gravel terrace or bench of hard-pan, in part roughly stratified and in part of slide material, extends nearly to the head. The terrace is maturely dissected by the many tributary streams, which have cut a succession of gulches. The cutting of postglacial gorges and the lowering of its bed by Texas Creek evidently resulted in a quickening of erosion and marked downcutting by its tributaries all along the line, leaving the old gravel deposits as terraces along the mountain sides. Along the Salmon River road up the hill from the Daly-Alaska camp, near Elevenmile, there are exposed well-stratified clay and sand up to an altitude of about 450 feet. These deposits were probably laid down in marine waters and therefore indicate an uplift of at least 450 feet since the retreat of the glaciers there.

The valley of the West Fork of Texas Creek is bordered on both sides by steep, rugged mountains, ranging in altitude from 4,500 to about 6,400 feet. Up to altitudes of about 3,000 feet the hills are timbered with hemlock and spruce of good grade, in quantity adequate for all mining and building demands. No examination was made as to the possibilities of developing water power, but the two gorges and the gradient of the main stream and tributaries suggest that sufficient for all needs could be developed.

GEOLOGY

On the accompanying map (Pl. I) the areal geology of the region east of Salmon River is taken from the map by Westgate; that shown of the region west of the river was sketched in by the writer from distant views and is therefore only a rough approximation. The fact which it is desired to emphasize is that the contact of the coast-range batholith and the sediments to the west is not "smooth and flowing" but irregular and that belts of metamorphosed andesitic tuff, graywacke, slate, and associated greenstone and argillite are found on the American side of the boundary and afford many contacts near which promising prospects have already been located and near which others may be sought. Many prospects other than those described and located on the map have been staked but are not included here for the reason that in the short time available the writer was unable either to visit them or to get accurate information about them.

The granitoid rock along Texas Creek, as along Salmon River, ranges from a granodiorite to a quartz-hornblende diorite and is intruded by numerous dikes of light-colored rock, including granodiorite porphyry, granite porphyry or granophyre, and aplite, and by dikes of dark-colored rock, including andesite and andesite porphyry. Similar dikes are found in the sedimentary beds.

The rock forming the mountain between the Homestake and Ibex groups of claims is a granodiorite consisting by volume of about 60 per cent of plagioclase, 16 per cent of quartz, 12 per cent of orthoclase, and 12 per cent of hornblende, with accessory magnetite, titanite, and apatite. The hornblende is partly or completely altered to chlorite, biotite, epidote, zoisite, and ilmenite. The plagioclase is flecked with sericite, and the quartz shows strain shadows or is recrystallized under nonuniform pressure. The rock at the Keno group of claims is of similar character, except that the percentage of postassic feldspar (microcline) is less (about 6 per cent). At the Lake claims the rock is a quartz diorite with only a trace of orthoclase. Muscovite in large flakes is present and has resulted from the replacement of some of the ferromagnesian minerals. All the rocks show the effect of strain in the crushing of the quartz, also the effects of alteration whereby the plagioclase has been partly altered to sericite and the hornblende has been altered to chlorite with associated epidote, ilmenite, and magnetite. The potassic feldspars, orthoclase and microcline, are predominantly fresh and unaltered.

At the Ibex claims a light-colored dike of pinkish hue occurs in the argillite. This rock was examined in thin section and is a granite porphyry. It consists of abundant small crystals of quartz, orthoclase, plagioclase, and hornblende, in a granophyric groundmass. Aplite and andesite dikes are common in the tuff beds on the south side of Texas Creek.

PROSPECTS

CHARLES, NELSON & PITCHER

Westgate[8] has described a prospect held by Charles, Nelson & Pitcher 2 miles above Salmon River on the east side of Texas Creek.

SNYDER

Ray Snyder holds claims just off the trail along Texas Creek about halfway between the bridge across Salmon River and the cable crossing on Texas Creek. At an altitude of about 600 feet a small open cut has been made on a vein in granodiorite porphyry. The vein strikes N. 25° W. and dips 40° E. It is about 3 feet thick and consists of a shattered zone in the granodiorite with reticulating veinlets and stringers of quartz aggregating 12 to 14 inches in width. The quartz is in part heavily metallized with galena, pale resin-colored sphalerite, a little chalcopyrite, and sparse tetrahedrite. Several open cuts and strippings have been made in the vicinity on small quartz stringers, but the veins exposed do not appear to be persistent.

[8] Westgate, L. G., op. cit., p. 139.

McVEY

The writer was shown specimens of ore by Daniel McVey, reported to come from a vein not yet recorded but staked in a gulch about 2 miles up the West Fork trail. The vein is reported to be a quartz fissure vein in granodiorite, mineralized with pyrite, galena, and chalcopyrite.

HOMESTAKE AND IBEX

The Homestake and Ibex groups of claims are held by J. H. Hewitt and C. Carlson. A cabin has been built at an altitude of about 2,300 feet, about 8 miles by trail from the bridge over Salmon River at Ninemile. Trails have been cut to both groups of claims, but practically no work has been done on the veins.

The Homestake group comprises six claims. The vein is in the face of a bluff on the east side of a gulch at an altitude of about 3,500 feet. The vein strikes about N. 15° E. and dips 45°–50° E. It has been traced for a length of 250 feet or so. The northern 150 feet is strongly metallized, but the southern 100 feet is milky-white quartz with very sparse metallization. The width of the vein ranges from 4 to 5 feet. The vein pinches abruptly at the north end, and its projected line of extension is covered by snow. At the south end the vein is covered for a short space by débris and does not show in the bluff to the south. This may be due to offsetting by faulting. In the ore shoot bands of solid sulphide (almost wholly steel galena) occur in widths up to a foot.

The sulphides on these claims consist predominantly of dense steel galena with some pyrite and chalcopyrite and locally a trace of sphalerite. The pyrite and chalcopyrite usually occur together as small eyes or streaks within the galena and together with the quartz give a banded character to the vein. Under the metallographic microscope the pyrite appears in part as much fractured granular aggregates in a meshwork of chalcopyrite and in part as cubes and corroded grains disseminated through narrow streaks within the galena. The quartz is in part broken up and veined and corroded by the galena. The galena appears to belong to a later stage of mineralization than the quartz and pyrite-chalcopyrite aggregates.

Through the courtesy of Dr. J. Austen Bancroft, assays on three samples (Nos. 1, 2, and 3 in the following table) from this vein, made for him by the Granby Co., are given below, together with an assay (No. 4) made for the writer by E. T. Erickson in the chemical laboratory of the United States Geological Survey.

Assays of samples from vein on Homestake group

	1	2	3	4
Lead.........per cent..	43.8	5.5	62.0	65.75
Copper.........do....	1.0	.84	.9	1.95
Zinc.........do....	....	1.2	.0	9.22
Silver.........ounces per ton..	5.8	1.3	13.1	9.22
Gold.........do....	.26	.22	.18	.06

1. 12 feet south of discovery post. Width of 20 inches.
2. About 25 feet south of discovery post. Width of 5 feet.
3, 4. Picked samples of galena.

The Ibex group comprises four claims. The vein is exposed on both faces of a small, deep, steep-sided gulch at an altitude of about 3,700 feet, on Ibex No. 1 claim. The country rock consists of thin-bedded gray to black argillite and quartzite, cut by dikes of granite porphyry and granodiorite. The vein is exposed for about 100 feet in length and 75 feet difference in altitude. It pinches and swells but is 15 inches to 2 feet in width for considerable portions. At the bottom of the gulch about 18 inches of sulphide ore with only a little quartz gangue is exposed. The sulphides here consist almost wholly of interbanded pale-colored sphalerite and coarse-grained galena. The vein is cut by a dike of granite porphyry and is offset along the dike. In the face of the north wall of the gulch the vein is again offset by faulting. The vein is a fissure vein striking about N. 5° E. and crossing the bedding of the banded argillite and quartzite. It dips steeply to the east.

Some of the ore is banded with streaks of galena, pyrite, chalcopyrite, light-colored resinous-lustered sphalerite, and tetrahedrite. Several small specimens were examined with the metallographic microscope. The pyrite is the earliest mineral of crystallization and occurs as grains or aggregates in a meshwork of chalcopyrite. The sphalerite is of later crystallization than the chalcopyrite, and veinlets of sphalerite cross the pyrite-chalcopyrite streaks. All three of the earlier minerals are broken and veined by galena, and some corrosion of the sphalerite by galena has taken place. The relations of the galena and tetrahedrite are somewhat indeterminate, but the tetrahedrite appears, in part, to have finished crystallization later than the galena, and in part it occurs as blebs in the galena and may be of contemporaneous crystallization. The tetrahedrite tends to occur as veinlets in or along the borders of the sphalerite.

A high content of silver, copper, and lead is reported to have been shown by assays of picked specimens from this vein.

SILVER STAR

The Silver Star claim was staked by McVey & Connors. It is about 950 feet in altitude above the Government trail, between the

Texas Discovery and the trail that turns off to the Homestake and Ibex groups. The vein is in a shear zone in granodiorite, striking about N. 10° E. and dipping 55° E. At the surface there is a 2-foot shear zone with abundant stringers of metallized quartz. The quartz is, in general, sparsely to heavily metallized with pyrite and galena. Picked samples from this vein are reported to have yielded an ounce of gold to the ton.

SILVER COIN

The Silver Coin claim was staked by Paul Meagher and Ray Snyder. It is on the east side of the western gulch tributary to that on which the Homestake is located and is about 700 feet in altitude above it. The vein is in granodiorite and is about 50 feet in length. It strikes N. 5° W. and dips 45° E. The northern 25 feet of the vein consists of a shoot of ore which widens abruptly from a few inches at the north to 5 feet on the south. At the south end it passes into practically barren milky-white quartz. The quartz splits into stringers, and an extension to the south can not be traced. The quartz vein zone at the south end has no well-defined hanging wall or footwall and is 10 feet or more thick. The quartz stringers appear to stop abruptly down the dip. It was not ascertained whether this is due to pinching or to a fault. The granodiorite shows many slipping planes, and along the footwall of the ore shoot these are coated with malachite. The metallized shoot of the vein consists of quartz heavily metallized with galena and a little pyrite and chalcopyrite.

EVENING STAR AND MORNING STAR

The Evening Star and Morning Star claims were staked by McVey & Connors on August 20, 1923. The two claims are on the east side of the creek just east of the cabin of Carlson & Hewitt and about 150 feet in altitude above it. Only a small open cut had been made on the vein. This shows a zone of shattered granodiorite with stringers of fine-grained to dense steel galena of the type found in the Homestake vein and stringers of quartz as much as 9 inches in width. The vein is otherwise covered along its strike.

TEXAS DISCOVERY

The Texas Discovery claim was staked June 22, 1923, on the West Fork of Texas Creek at an altitude of about 1,900 feet, about 5 miles by trail from Texas Creek. The vein is a heavily metallized quartz vein in a shear zone in granodiorite. It strikes about N. 30° W. and dips 45°–60° NE. The metallic minerals consist of galena and pyrrhotite; galena and pyrite; or galena, pyrrhotite, pyrite, and sparse chalcopyrite. The vein ranges from 1 to 14 inches in width and pinches out at the northwest end. An assay of a picked sample is reported to have given 30 per cent of lead and $22 in gold and $6 in silver to the ton.

Another vein is reported to have been found higher up on the slope.

DOUBLE ANCHOR

The Double Anchor group comprises four claims lying on the north side near the head of the West Fork of Texas Creek, recorded July 28, 1923. They are said to be held by Frey, Goldborgh & Davidson. No information regarding the nature and exact location of the prospect was obtained.

LAKE

The Lake claim was located on July 27, 1923, and lies on the trail near the head of the West Fork of Texas Creek at an altitude of 2,500 feet. The vein is a quartz fissure vein in quartz diorite, heavily mineralized along the footwall with galena and pyrite; the galena is predominant. The vein is 11 inches wide, strikes N. 35° W., and dips 60° E. No work has been done on the property.

TEXAS CREEK COMSTOCK

The cabin for the Texas Creek Comstock group of claims lies on the south side of the West Fork trail about 11 miles from the Salmon River bridge. (See fig. 3.) The original claim was located July 15, 1923, and is known as the Joe-Joe claim. It is at an altitude of about 4,700 feet. Subsequently 14 additional claims were staked in the vicinity and were known as the Jackson-Hummel group. Subsequently new claims were staked, and together with a claim held by Johnson, Bryne, and Hummel and those previously staked, comprising 20 in all, were grouped as the Texas Creek Comstock.

Veins are exposed at a number of places on these claims, but they have not been developed, and only further exploration and more intensive study can determine whether they represent faulted portions of a few veins or many different veins. In general character they are alike, being quartz fissure veins mineralized with galena, pyrite, and a little chalcopyrite and having a general northwest strike and steep northeast dip. The veins occur both in granodiorite, which forms the lower slope of the mountain ridge, and in metamorphosed graywacke and tuff, which form the upper half of the ridge. Dikes of andesite porphyry and aplite cut both the granodiorite and the sediments.

On the Joe-Joe claim the mineral deposit is a metallized quartz fissure vein in metamorphosed tuff and graywacke with thin layers of gray slate. The slate strikes N. 85° E. and dips 60° S.; the vein strikes N. 35° W. and dips steeply northeast. The vein ranges from 6 to 11 feet in width, and the mineralized ore shoot from 5 to 8 feet. Sparsely mineralized white quartz veins, as much as 4 feet in width and with inclusions of country rock, occur in the footwall of the vein. Many narrow gash veins of white quartz are found within a zone several feet wide in both the hanging wall and the footwall of the upper portion of the vein. One quartz vein offshooting from the main vein into the footwall is exposed along the

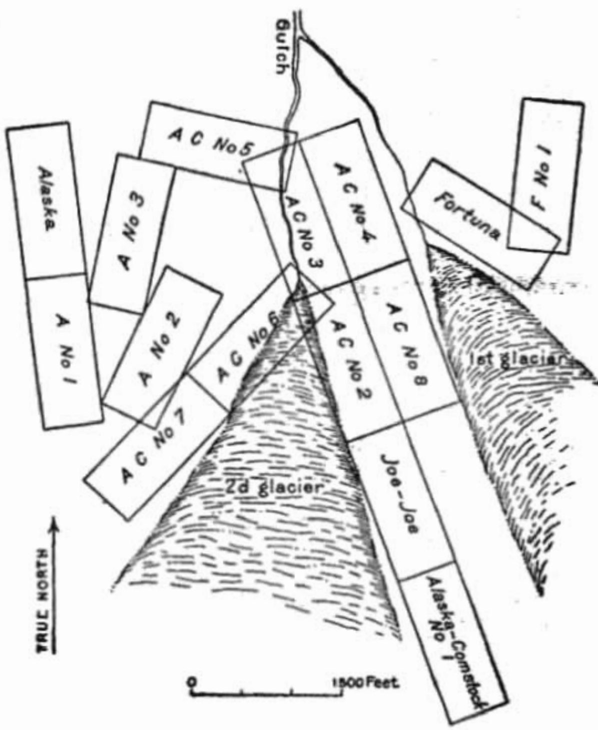


FIGURE 3.—Sketch map of portion of Texas Creek Comstock group of claims, West Fork of Texas Creek

strike for about 20 feet, is from 9 to 18 inches wide, and carries some sulphides, predominantly galena with considerable pyrite and chalcopyrite. The main vein is exposed for a difference in altitude of 60 feet and appears to be offset by faults at each end.

At an altitude of about 4,830 feet is a mineralized quartz vein striking N. 15° W. and about 10 to 15 inches wide, which may be the faulted continuation of the lower vein.

Below the discovery stake on the Joe-Joe property is a dike of light-gray andesite porphyry, which at the west turns and strikes N. 50° W. Along this portion, which strikes northwest, at the contact of the dike and the sedimentary rocks, a quartz vein is exposed for a length of about 100 feet. The vein has an average width of about 4 feet, but it widens at one place to 8 feet and at another consists for a length of 6 feet of several stringers of quartz in a schistose pyritized country rock. The vein pinches abruptly at the southeast end and is covered toward the northwest. The lower portion of the vein is predominantly milky-white quartz; the upper portion is mineralized with heavy bands of galena, pyrite, and chalcopyrite.

At an altitude of about 4,260 feet, near the east side of the second glacier, is a quartz vein mineralized with considerable galena and a little pyrite and chalcopyrite. The vein strikes north, dips 35° E., has an average width of about 2 feet, and is exposed along the strike for 30 feet.

Also near the east side of the second glacier, at an altitude of about 4,115 feet, is a quartz vein 16 to 24 inches wide, heavily mineralized with sulphides in the upper portion but consisting almost wholly of pure-white quartz farther down the hill. Local layers, as much as 10 inches thick, of solid galena with some pyrite are present.

At an altitude of about 3,980 feet, just at the edge of the ice, a quartz vein is exposed for a length of about 30 feet. It has an average width of about 15 inches and is well mineralized with galena and a little pyrite and chalcopyrite. Several dikes of granodiorite cut the metamorphic sediments here, and the vein cuts rock of both types. Its south end is cut off as if by a fault. The vein strikes N. 35° W. and dips 65° NE.

At an altitude of 3,900 feet, in a gulch just west of the second glacier, several trenches have been made on quartz fissure veins in granodiorite. These veins are from 8 to 20 inches in width and carry the usual mineralization. A 2-inch quartz vein with molybdenite occurs in the granodiorite in the gulch below the second glacier.

Mr. Hummel furnished the following data on assays made by the Granby Smelting Co., of Anyox, B. C., of samples from the claims lying between the two glaciers:

Assays of samples from Texas Creek Comstock group

	1	2	3	4	5
Silver ounces per ton	5.7	16.9	2.0	3.6	16.1
Gold do	.01	.18	.05	Tr.	.03
Copper per cent	0.61	0.58	0.06	0.14	0.17
Lead do	5.6	72.8	3.8	4.5	28.4
Zinc do	1.8	.0	1.2	.0	2.6

1. Across 1 foot of 30 foot vein at lowest showing on hill.
2. Across 1 foot next to last showing down, Comstock No. 2.
3. Across 56 inches, 10 feet above discovery post, Joe-Joe claim.
4. Across vein.
5. Picked samples, high grade, from Joe-Joe claim.

JOHNSON-BAYNE-HUMMEL

The Johnson-Bayne-Hummel claim, which is undeveloped, is near the head of the West Fork of Texas Creek, on the south side, at an altitude of 4,900 feet, at the foot of the third small glacier west of Ferguson Glacier. The mineralized rock consists of a fissured zone in slate, graywacke, and tuff from 3 to 6 feet wide, with stringers of quartz from a fraction of an inch to a foot wide. The quartz is locally heavily mineralized with galena and pyrite. The veins can not be traced far, as they pinch out in one direction and pass under the glacier in the other. There is considerable mineralized float in the adjacent moraine on the glacier, including one boulder of quartz 3 by 1¼ feet, very heavily mineralized with galena, pyrite, and chalcopyrite.

KENO

The Keno group of claims, staked in August, 1923, comprises nine claims on the west side of Ferguson Glacier, at altitudes of about 4,000 feet, about 3 miles south of the West Fork of Texas Creek. The mineral prospects are several quartz fissure veins in granodiorite. A small open cut has been made on one of the veins, which in the cut is 3 feet wide and is mineralized with sparse pyrite. The vein has been traced up the hillside for 400 feet by trenches and natural exposures, through a difference in altitude of about 200 feet. The predominant vein matter is milky-white quartz with sparse sulphides. Through the center of the vein is a band several inches wide of quartz heavily mineralized with streaks of solid sulphides in which galena predominates. A specimen sample of this mineral shoot is reported to assay 0.6 ounce of gold and 3 ounces of silver to the ton and 48 per cent of lead. A specimen of the prevailing white quartz of the vein was assayed by E. J. Erickson in the chemical laboratory of the United States Geological Survey and yielded a trace of gold and 0.08 ounce of silver to the ton. The vein strikes N. 40° W. and dips 80° NE. Locally it pinches to a few inches, but generally it is from 2 to 4 feet in width. Small inclusions of the wall rock are found here and there in the vein. The walls are slickensided, and the quartz breaks clean. The wall rock appears to be unsheared but shows considerable alteration to epidote.

Another vein, at an altitude of 4,440 feet, 7 inches to 2 feet wide, is exposed for about 30 feet along the strike. It is of similar character to the one just described, strikes N. 60° W., and dips 70°–80° NE.

McGRAW

Chapin [9] in 1916 indicated on his map the location of a prospect on Texas Creek known as the McGraw but did not describe it.

[9] Chapin, Theodore, Mining developments in southeastern Alaska: U. S. Geol. Survey Bull. 642, p. 95, 1916.

IRON CAP

Five claims known as the Iron Cap group lie west of the Ibex group and run parallel to the West Fork of Texas Creek. David McVey says that the vein is a band in the argillite carrying chalcopyrite and pyrite disseminated and in threads and that a sample gave an assay 0.04 ounce of gold and 6.28 ounces of silver to the ton and 2 per cent of copper.

NICKEL-COPPER DEPOSITS

DISCOVERY

The first nickeliferous mineral deposit found in southeastern Alaska was that of the Alaska Nickel Mines, located in 1911 on the outside coast of Chichagof Island between Portlock Harbor and Lisianski Strait. From 1915 to 1918 some prospecting and sampling of this property was carried on. In 1921 S. H. P. Vevelstad located 40 claims on nickeliferous lodes about 14 miles to the north, on Yakobi Island, in the vicinity of a valley basin known as the Bohemia Basin, whose mouth is on Lisianski Strait, about 2¼ miles southwest of Miner Island. In 1923 Vevelstad also located one claim near Surge Bay and two claims south of Takanis Bay, both on the west side of Yakobi Island. In 1922 I. Myre Hofstad located four claims on a nickel-copper lode lying on the north side of Snipe Bay, on the west coast of Baranof Island, about 100 miles southeast of the Alaska Nickel Mines property. A. Lagergren has claims on a nickel-copper prospect on Tenakee Inlet, Chichagof Island (Pl. II).

The Admiralty-Alaska Co. has also found a nickeliferous deposit on its property near Funter Bay, Admiralty Island.

These successive discoveries have aroused renewed interest in the subject, and it is very probable that other masses of gabbro and norite, with which the nickel is uniformly associated, will be found on Chichagof and Baranof islands.

ALASKA NICKEL MINES

The property of the Alaska Nickel Mines was not visited by the writer, and the description which follows is taken from the report by Overbeck.[10]

LOCATION

The claims of the Alaska Nickel Mines lie on the outside coast between Portlock Harbor and Lisianski Strait. The principal prospects are on Fleming Island, a small tidal island, about 25 miles by water northwest of Chichagof. The property in 1917 consisted of 18 claims and two fractions. The original

[10] Overbeck, R. M., Geology and mineral resources of the west coast of Chichagof Island: U. S. Geol. Survey Bull. 692, pp. 125–133, 1919.

locations were made in 1911, and a relocation was made in 1915. The company holding the property was called the Juneau Sea Level Copper Mines until 1917, when the name was changed to the Alaska Nickel Mines. * * * A wharf site and power site have been located by the present company.

GENERAL CHARACTER OF THE DEPOSIT

Exposures of rock in this part of the coastal plain are confined to the seashore, for everywhere else the rocks are concealed by a heavy growth of vegetation and by swamps. Three outcrops, heavily stained with iron, were noted on the shore. These outcrops form irregular areas whose maximum diameter is about 70 feet and project somewhat above the surrounding rock. The extreme outcrops are about a mile apart. The northwest cropping shows limonite, and although no sulphides were seen it is probable that they would be found under the leached zone. The 180-foot shaft was sunk beside the central outcrop, and ore is reported on the 180-foot level. No work has been done on the southeast outcrop, but the ore minerals are found on the surface. At a number of other places the ore minerals have been found disseminated through the country rock in small amounts, but it is not yet known whether this type of so-called "disseminated ore" can be handled profitably. Two of the principal outcrops are close to the contact between the igneous rock in which the ore bodies occur and the quartz-mica schist which these igneous rocks intrude. The northwest outcrop is several hundred feet from the contact; the central outcrop is a few feet from the contact; and the southeast outcrop also may be near a contact, but the heavy cloak of vegetation conceals the rock a few feet away from the outcrop. From the surface outcrops, then, it would appear that the distribution of the ore bodies is to some extent related to the contact between the igneous body and the schist. Most of the "disseminated ore" has been found near the contact, but some of it is farther away from the contact than are the two main outcrops. The only chance for underground observation was in the 80-foot level of the central outcrop. The shaft is in light-colored diorite that is free of ore minerals. The drift for about 30 feet from the shaft is in barren hornblende gabbro, but the last 20 feet are in massive ore. The contact between the barren rock and the ore-bearing portion appears to be an irregular line. There is a rather rapid transition from barren rock to rock in which there are a few disseminated sulphides and then to massive ore. The change does not appear to occur progressively but irregularly. In the face of the tunnel and in a crosscut near the face are some blocks of barren rock, but the drill holes in the face of the main tunnel are apparently in sulphides. Some movement has taken place in this tunnel, but its extent is not known. The 180-foot level could not be visited, but it is reported that ore was encountered on this level. The report that a clay gouge occurs in this level indicates that movement has taken place. The presence of niccolite on the 180-foot level indicates a secondary origin for some of the ore on that level.

MINERALOGY

The chief metals that may be of commercial importance found in this deposit are copper and nickel. Assays furnished by the company show small amounts of gold and silver. The principal sulphide minerals are pyrrhotite, chalcopyrite, and pentlandite. In the hand specimen of the rock chalcopyrite and pyrrhotite are the only minerals that can be recognized, but in a polished specimen of the ore the pentlandite can be plainly seen. A few specimens of niccolite have been obtained from both levels. The niccolite is a secondary mineral and lines crevices in the country rock. Insufficient underground work has been done to afford data on the relative abundance of the ore minerals. In some hand specimens chalcopyrite is more abundant than pyrrhotite; in other specimens the reverse is true. * * *

PETROGRAPHY

The deposits are found in a body of medium to coarse grained igneous rock that shows considerable variation in type—variations that extend all the way from granite to gabbro. This igneous body intrudes quartz-mica schist, which is supposed to be the metamorphic phase of the graywacke that occupies much of the west coast of Chichagof Island. * * * In general, a gradation in rock type from more acidic away from the contact to less acidic near the contact appears to exist. That this gradation is due entirely to differentiation, however, is doubtful; for the most acidic bodies of rock, such as those in Cautious Pass and those in Mirror Harbor, seem to be later than the diorite and intrusive in it. The acidic dikes are definitely later than the diorite and norite. * * * The smaller light acidic dikes and bodies that cut the diorite are aplites and granites. * * * The rock that makes up most of the intrusive body falls under the general term of diorite. * * * The most basic of the rocks—hornblende gabbro and norite—are found close to the outcrops of the ore bodies. A common rock of characteristic appearance that occurs near the ore bodies is a very coarse-grained hornblende gabbro or norite. The rock weathers to large rounded boulders with rough and pitted surfaces. Small amounts of ore minerals scattered in blebs are seen at some places in these rocks. * * * A specimen of rock from the 80-foot level, about 10 feet from the shaft, is a dark-greenish medium-grained hornblende gabbro. * * * A specimen of the "disseminated ore" is a dark-brown fairly coarse grained rock. It consists chiefly of hornblende, pyroxene, and feldspar, together with disseminated pyrrhotite and chalcopyrite and a little biotite. The hornblende is brownish and strongly pleochroic. The pyroxene is orthorhombic; it occurs in lath-shaped crystals rounded at the ends and has altered somewhat to hornblende. * * * Most of the opaque minerals replace and are definitely later than the principal silicates in the section. The replacement of the pyroxene by sulphide is particularly evident. The opaque minerals also occur as grains in the original minerals. Nickel was found in this specimen. * * *

A polished surface of the ore shows pyrrhotite, pentlandite, and chalcopyrite. * * * At no place in a dozen specimens examined could any decisive evidence as to the relative time of formation of the sulphides with reference to one another be obtained. * * * They are, however, definitely later than the original silicates.

DEVELOPMENTS

S. H. P. Vevelstad furnished the writer with a copy of a report made by J. C. Rogers for the International Nickel Co. in 1917. The following data are quoted or summarized from this report:

A 6 by 8 foot shaft was sunk 175.5 feet, the first level being at 75.5 feet. The 75-foot level has 62 feet of drift northwest of shaft, 4 feet of drift southeast of shaft, and 5 feet crosscut, giving a total of 71 feet, of which 37 feet is in ore. The 175-foot level has 51 feet of main drift, 15 feet of drift southeast, and 14 feet northwest, giving a total of 80 feet. The character of the rock here is different than on the 75-foot level, the north and south drifts being in the brecciated mass between slips or shear zones. * * * The 75-foot level at present shows a maximum ore body of 37 feet by 10 feet, inclosed at one side and ends but open on the remaining side, as massive ore extends to the end of the drift on the left-hand side.

The width of the ore as sampled in the 75-foot level ranges from 2.2 to 7.8 feet and averages about 5 feet. The nickel content ranges from 1.85 to 5.05 per cent, and copper from 0.4 to 4 per cent, with an average of 3.42 per cent of nickel and 1.58 per cent of copper over 37 feet of drift. Sulphur ranges from 8.3 to 25.3 per cent, and silica from 16.1 to 38.05 per cent. Four assays are given for widths ranging from 1.1 to 7.9 feet on the 175-foot level which show nickel from 1.65 to 5.7 per cent and copper from 0.4 to 2.3 per cent; the narrower widths gave the higher assays. Rogers states also that the rock on the 175-foot level seems to have no direct connection with the ore above.

BOHEMIA BASIN

GENERAL FEATURES

Bohemia Basin, on Yakobi Island, is a flat-floored valley that extends from Lisianski Strait due southwest for about 2¼ miles and rises gradually from sea level to a height of about 500 feet. The mouth of the basin, on Lisianski Strait, is about 2¼ miles southwest of Miner Island (Pl. II). At the head of the basin the mountains rise abruptly on all sides, except for a low narrow pass at an altitude of about 550 feet on the northwest side, which leads into Takanis Bay.

Two groups of claims have been located around this basin. The Bohemia group, 14 in number, lie at the head of the basin; and the Tasmania group, 16 in number, on the ridge along the northwest side. A blazed trail leads from the cabin just south of the mouth of the creek that drains the basin to the entrance of a tunnel on the Bohemia claims, about 2½ miles to the southwest, at an altitude of about 900 feet.

Good harborage is available on Lisianski Strait, and there is adequate timber for all purposes necessary for mining development.

One day and a half was spent in examining the deposits in the vicinity of this basin. The geology is complex, and the time spent was too short to permit more than a hasty survey of the general relations.

The nickeliferous deposits are located within a mass of gabbroic rock which appears to be of roughly elliptical shape and to have a width of about 1⅘ miles and a length of about 2 miles, the longer diameter oriented in a northeasterly direction. Bohemia Basin has been carved out of this mass by processes of weathering and river and glacial erosion. The mountains (altitude about 2,500 feet) that form the rim of the basin consist of a bright-colored granitoid rock ranging from typical quartz diorite to a diorite with only a little quartz, and similar rock occurs at the mouth of the basin on Lisianski Strait. Gabbroic rock faces the inner slopes of the mountains and occurs in scattered outcrops projecting above the surface veneer of vegetation that covers most of the floor of the basin. It is possible, however, that the gabbroic rocks do not form as large a mass as that suggested and that diorite forms a part of the covered area. The gabbroic rocks are of extremely varied character and comprise such facies as hornblende gabbro, norite hypersthenite or segregations of hypersthene, and amphibolite resulting from the alteration of hypersthenite. The concentration of sulphides, so far as observed by the writer, is restricted to the norite.

From the top of the hill at the head of the basin a dozen rusty spots within the gabbroic mass may be seen. Only three of these were visited.

The rusty-weathering sulphide-bearing zones of the Bohemia claims lie within a mass of norite, perhaps 1,000 feet across, which is bordered on the west and southwest by hornblende gabbro and on the southeast by quartz-bearing diorite. (See fig. 4.) The extension of this mass to the northeast is covered by vegetation. The rusty zones lie near the border of the norite and strike approximately parallel to the contacts. A gulch lies along the center of the norite embayment, and the rusty zone on the east side of the gulch strikes about N. 80° E., and that on the west side of the gulch about N. 45° E. The most conspicuous rusty zone lies on the southeast side of the gulch and can be traced southwestward up the gulch for about 40 yards and in a general easterly direction from the gulch for about 100 yards. Several other rusty layers are also exposed here. Within a zone about 40 yards wide are layers of massive sulphide, rock with disseminated blebs of sulphide, and bands of barren norite. The zone dips steeply south. The developments consist of a 65-foot tunnel started to crosscut the sulphide-bearing zone about 200 feet below the outcrop. The inner 10 feet of the tunnel is in norite with disseminated sulphide; the remainder in practically barren norite except for a streak with disseminated sulphides near the entrance. Slippage planes and slickensided surfaces are common in the rocks exposed in the tunnel. A sample of the rock with disseminated sulphides, taken from the dump, averaged about 4.25 per cent of sulphide. The tunnel has been driven only far enough to enter the disseminated-sulphide zone, and not far enough to cross it completely.

Several open cuts have been made on rusty zones on the northwest side of the gulch and show similar conditions.

Very little prospecting has been done on the Tasmania group of claims. In the first rusty zone to the northeast on this group of claims, at an altitude of about 1,700 feet, lenses of solid pyrrhotite a yard in diameter are found in a band of norite carrying disseminated sulphides.

PETROGRAPHY

No systematic study or geologic map was made of the mass of rock in which the nickel deposits occur, but the following detailed observations on the character and relations of the rocks near the Bohemia tunnel and of two specimens from the Tasmania claims are recorded for the significance they have in allying the deposit with the similar type found at the Alaska Nickel Mines, at many

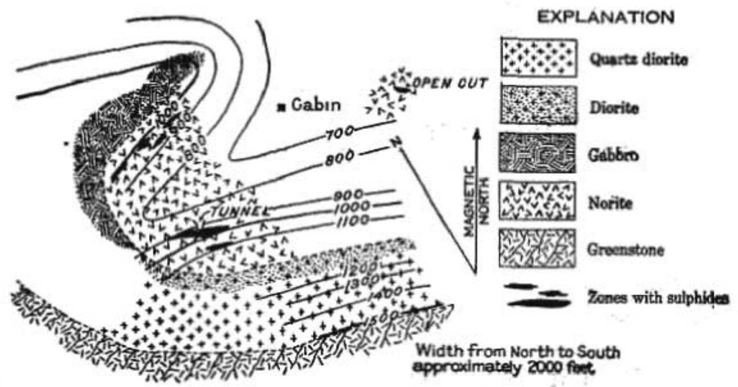


FIGURE 4.—Sketch map showing geology of nickeliferous sulphide-bearing zone, Bohemia Basin, Yakobi Island

places in Norway and Sweden, and on a much larger scale at Sudbury, Ontario. The mineral percentages are given by volume as determined by the Rosiwal method.

A specimen of the greenstone country rock in the mountain above the Bohemia tunnel is found to consist predominantly of actinolite in a groundmass of quartz and chlorite. Magnetite occurs in disseminated grains, and there is a little pyrite. The rock is an actinolite schist.

At an altitude of about 1,550 feet, 100 feet from the contact with the greenstone in the same mountain, the intrusive igneous rock is a light-colored quartz diorite, consisting of about 57 per cent of plagioclase, 19 per cent of quartz, 14 per cent of hornblende, 9 per cent of biotite, and 1 per cent of apatite and magnetite. The plagioclase is zoned and ranges in composition from calcic oligoclase to sodic labradorite averaging an andesine. About 500 feet of quartz diorite intervenes between the greenstone and the norite, but the rock adjacent to the norite is much more basic than the rock near the greenstone and is a quartz-bearing diorite. A small depression lies along the contact of this rock and the diorite at an altitude of about 1,100 feet. A specimen taken from the south side is found to consist of 57 per cent of plagioclase ($Ab_{60}An_{40}$, andesine), 34 per cent of hornblende, 8 per cent of quartz, and a little magnetite and apatite.

On the north side of the depression is an outcrop of medium-grained rock composed of a light-greenish fibrous mineral. This rock is found in thin section to consist predominantly of a fibrous colorless amphibole (uralite) and a little plagioclase feldspar. The feldspar is fresh but is crossed by veinlets of a fibrous mineral. The rock is probably a very highly altered phase of the norite.

Fresh specimens of norite from the inner end of the tunnel on the Bohemia claims were taken from the dump for examination. The rock is medium grained and is composed predominantly of bronzite with intermingled white feldspars and in part with disseminated small blebs of sulphides. The norite was estimated from the hand specimen to consist of about 20 to 30 per cent of plagioclase and the remainder pyroxene (almost wholly bronzite) and accessory minerals. The facies with disseminated sulphides has less feldspar, possibly about 12 per cent, and about 4 to 4.25 per cent of pyrrhotite, pentlandite, and chalcopyrite, the pyrrhotite predominating. In thin section the rock is found to consist predominantly of bronzite with associated labradorite feldspar and minor amounts of monoclinic pyroxene, hornblende, olivine, and sulphides and a trace of secondary biotite and interstitial quartz. The bronzite is colorless and only faintly pleochroic and is a variety rich in the enstatite molecule (86 per cent $MgSiO_3$). The olivine occurs as corroded rounded remnants of larger grains, inclosed wholly in bronzite. The labradorite ($Ab_{35}An_{65}$) is in part of simultaneous crystallization with the bronzite and in part interstitial and later in crystallization than the bronzite. The hornblende is pale brown to green, is primary, and occurs as grains of contemporaneous crystallization with the bronzite and locally as peripheral borders to it. The pyrrhotite (with some chalcopyrite and pentlandite) forms small irregular blebs along the borders between the other grains, locally sending off threadlike veinlets between or across the other minerals. The sulphides appear to be primary and not secondary infiltrations or injections, and the chalcopyrite and pentlandite are everywhere associated with the pyrrhotite grains.

A specimen of rock taken 20 feet from the inner end of the tunnel is a fine-grained norite consisting of 56 per cent of pyroxene (predominantly hypersthene), 39 per cent of labradorite ($Ab_{25}An_{75}$), and 5 per cent of hornblende. Accessory apatite, pyrrhotite, and chalcopyrite are present. The hypersthene is in part fresh, in part altered to brownish and greenish hornblende and fibrous uralite. The feldspar is fresh and unaltered. The brown hornblende is primary and intergrown peripherally with the hypersthene, as in the coarser facies. The rock is much more altered than the coarser rock.

Noritic pegmatite veins are also found. A typical specimen consists of labradorite and hypersthene, the latter in crystals averaging an inch in length.

A specimen of norite with disseminated sulphides, from an altitude of about 940 feet on the opposite side of the gulch from the Bohemia tunnel, is a uniform dark green-gray medium-grained olivine-bearing hypersthenite or hypersthene segregation. It consists almost wholly of hypersthene, with a very little monoclinic pyroxene and about 10 per cent of olivine. Only a trace of feldspar is present. The olivine occurs as corroded grains within the pyroxene, and the sulphides as blebs along the borders of the grains. Veinlets of fibrous serpentine (bastite) with center zones of opaque grains cross the olivine grains and to a lesser extent the pyroxene. The serpentine is later than the pyrrhotite, as the veinlets locally swing around the borders of the sulphide grains.

The hill on the opposite side of the gulch from the Bohemia tunnel is made up of hornblende gabbro with a faint gneissic structure due to alternating laminae of more hornblendic and more feldspathic character. The specimen studied consists essentially of 53 per cent of labradorite feldspar ($Ab_{40}An_{60}$), 44 per cent of hornblende, and 2 per cent of quartz with accessory apatite, pyrrhotite, and chalcopyrite. A few of the hornblendes show unreplaced remnants of pyroxene. The sulphides occur as grains in the hornblende, which is not the mode of occurrence in the noritic rocks. At the head of the gulch the gabbro is darker and carries more hornblende.

Only two specimens from the Tasmania claims were examined. One of them is a uniform dark green-gray medium-grained rock weathering with a reddish hue. It consists of about 75 per cent of pyroxene in a much altered condition and 25 per cent of labradorite. The pyroxene (probably hypersthene) is almost entirely altered to a microcrystalline aggregate of talc and fibrous uralite. The plagioclase feldspar is partly replaced by chlorite along its borders but is otherwise fresh. A trace of accessory pyrrhotite and secondary iron ores is present. The other specimen is a quartz-bearing diorite which occurs as a dike in the norite. It consists of 61 per cent of andesine feldspar ($Ab_{57}An_{43}$), 30 per cent of hornblende, 7 per cent of quartz, and 2 per cent of orthoclase, magnetite, apatite, and zircon. The three minerals last named are abundant as scattered mineral crystals.

METALLIC MINERALS

The metallic minerals comprise essentially the three primary minerals pyrrhotite, pentlandite, and chalcopyrite and the secondary minerals formed by descending surface waters, bravoite (?), and marcasite. The pentlandite and bravoite (?) can not be distinguished from the pyrrhotite in the field.

An effort was made to determine the chemical composition of the pentlandite in the "disseminated rock" on the Bohemia claims. Several hand specimens of the "disseminated norite" from the Bohemia tunnel were crushed, and the sulphides picked out by hand. The sulphides were then ground in a mortar and the pyrrhotite separated with an electromagnet. The pyrrhotite was found to be only weakly magnetic, but the pentlandite is nonmagnetic. Only 300 milligrams was thus obtained, and the amount of impurity could not be determined. A little pyrrhotite was probably present.

Chemical analysis of pentlandite from Bohemia claims

[Analyst, A. H. Phillips]

	1	1a	1b
Insoluble matter	5.83		
Cu	2.70		
Ni	21.28	24.65	0.420
Fe	35.10	37.88	.678
S (by difference)	35.09	37.47	1.170
	100.00	100.00	

1. Nonmagnetic concentrate from sulphides of disseminated norite, Bohemia claims, Yakobi Island, Alaska.
1a. Composition of pentlandite calculated free of chalcopyrite and silicates.
1b. Atomic ratio.

As shown by the atomic ratios the mineral conforms within the limits of error to the formula for pentlandite—(Ni, Fe)S—with a ratio for iron to nickel of about 5 to 3 or a little less. In physical properties the mineral is similar to the pentlandite of the Sudbury district, Ontario.

Specimens from three different localities on the Bohemia claims consisting of norite or hypersthenite with disseminated sulphides were studied with regard to the interrelations of the metallic minerals. The sulphides comprise pyrrhotite, pentlandite, and chalcopyrite. The pyrrhotite predominates, but the pentlandite forms a considerable proportion of the blebs. None of the pentlandite showed any trace of alteration, even on surfaces only half an inch below the weathered surface. The pentlandite and chalcopyrite occur predominantly along the borders of the sulphide blebs. The pentlandite occurs as grains which usually show straight-line borders against the pyrrhotite, suggesting the traces of crystal faces. The pentlandite and chalcopyrite show mutual relations to each other. The chalcoyprite shows in part mutual relations to the pyrrhotite and in part straight-line borders, suggesting crystal faces. In one sulphide bleb a veinlet of pentlandite crosses its full length and cuts the pyrrhotite. All three minerals appear to belong to the same period of mineralization, the pentlandite and chalcoyprite perhaps beginning early and finishing late. A second generation of pentlandite is present in small amounts. It replaces the pyrrhotite locally along the borders of the chalcopyrite and the first-generation pentlandite and occurs in needle-like shapes along cracks or in patches with deeply serrate borders. An alternative explanation for the mineral relations shown is that the pentlandite and chalcopyrite are both later than the pyrrhotite and that the crystal faces of the pentlandite against the pyrrhotite are the result of replacement. This is a complex interpretation for which there does not seem to be any supporting evidence.

The sulphides of the outcrop of the ore lens above the Bohemia tunnel show very considerable alteration. Microscopic study of polished specimens of the outcrop sulphides shows that the pyrrhotite is locally replaced by veinlets of marcasite and that there is practically no pentlandite in the ore but a new nickel mineral resembling bravoite. The supposed bravoite occurs in granules of equidimensional to stringer-like form. The equidimensional grains show definite straight-line borders against the pyrrhotite and appear to be the traces of crystal faces. Only a trace of pentlandite was found in the specimens examined, but the form of the secondary mineral grains resembles the mode of occurrence of the primary pentlandite grains in the sulphide blebs of the "disseminated rock," and it is probable that the new nickel mineral is secondary after original pentlandite.

Several polished specimens from the outcrop of a 3-foot mass of solid sulphide on the Tasmania claims were examined with the microscope. The minerals comprise pyrrhotite, pentlandite, a secondary nickel mineral, chalcopyrite, and marcasite. The secondary nickel mineral for the most part forms a much interrupted skeletal network to the pyrrhotite grains. In part it occurs as grains of about the same size as those of the pyrrhotite. Some of these grains are irregular-shaped, with apophyses running out as tentacles between the adjoining pyrrhotite grains. Almost all the secondary nickel mineral contains residual remnants of partly replaced pentlandite. It is no doubt secondary after pentlandite and formed by descending surface waters. The marcasite is similarly secondary after the pyrrhotite, forming an irregular network of replacement veinlets in the pyrrhotite. In part the replacement of the pyrrhotite by marcasite starts from the borders of the nickel mineral and works inward, but the nickel mineral itself shows only a trace of replacement by the marcasite. The secondary nickel mineral resembles bravoite in its appearance and properties.

A mineral which resembles bravoite in is chemical and physical properties forms the chief nickel mineral in the outcrop of the sulphide deposits associated with peridotite on Canyon Creek, a tributary of Copper River.[11] The writer separated the pyrrhotite from the nickel mineral with an electromagnet. An analysis of this concentrate (which is itself slightly magnetic), made by A. H. Phillips, showed the nickel mineral to be a disulphide of iron and nickel—$(Fe, Ni)S_2$—and to consist essentially of about 24.81 per cent of nickel, 20.68 per cent of iron, and 54.51 per cent of sulphur. The chemical formula, the physical properties, and the microchemical reactions are all similar to those of bravoite, with which it is believed to be identical. The nickel mineral, secondary after pentlandite and associated with marcasite that replaces pyrrhotite, at the Bohemia and Tasmania claims likewise is similar in physical properties and microchemical reactions to bravoite and is believed to be this mineral. Chemical analyses, however, are needed to verify this inference.

In the following table are given assays of two specimens of ore (Nos. 1 and 2) from the claims in the Bohemia Basin, made for the writer by E. T. Erickson, in the chemical laboratory of the United States Geological Survey. No. 1 came from an outcrop above the Bohemia tunnel; No. 2 from a 3-foot mass of solid sulphide on the Tasmania claims. Assays Nos. 3 and 4 were furnished by Mr. Vevelstad and were made for him by I. F. Laucks (Inc.) and the British American Nickel Corporation (Ltd.), respectively, from specimens on the Bohemia claims.

Assays of specimens of ore from claims in Bohemia Basin

	1	2	3	4
Nickel per cent	1.72	4.09	2.18	2.45
Copper do	.89	.82	1.55	.68
Gold ounces per ton			.01	
Silver do			.07	
Metals of the platinum group do			.005	

[11] Overbeck, R. M., Nickel deposits in the lower Copper River valley: U. S. Geol. Survey Bull. 712, pp. 91–98, 1919.

SNIPE BAY.

In 1922 I. Myre Hofstad located a group of four claims on Snipe Bay, Baranof Island, about 45 miles south of Sitka. They are in the first bight inside the entrance to Snipe Bay, on the north side, in a gulch at an altitude of about 450 feet. A bare rusty spot can be plainly seen from the bay. Snipe is a good harbor and is used during the summer by many fishing boats.

The sulphides occur within a mass of gabbro or amphibolite which is intrusive into argillaceous and quartzose schist. Only a small mass of gabbro is exposed in the gulch, and its extension to the north-northwest is obscured by vegetation. At an altitude of 400 feet the contact between the gabbro and schist cuts across the bedding of the schist at an angle of about 35°, the schist striking northwest and dipping steeply northeast. The gabbro is exposed along the bed of the gulch up to an altitude of 500 feet. Schist with a general north-northwest strike is exposed locally on each side of the gulch, bordering the gabbro. Above 500 feet the hilltop is too thickly covered with vegetation to follow the continuation of the gabbro. The relations would suggest that the gabbro is a lens, dike, or sheet, striking more or less parallel to the schist and terminating with a blunt end on the south-southeast, where the contact is exposed in the gulch at an altitude of 400 feet. The possibility that this sharp crosscutting contact is due to faulting was considered, but no positive evidence of faulting was found. The exposures, however, are too much weathered and too obscure to warrant a positive statement. Along this contact the gabbro mass is about 50 feet wide. Where examined across the strike, several feet up the gulch from the contact, the gabbro along the northeast and southwest sides showed disseminated blebs and veinlets of sulphides, with a central zone of about 7 feet of solid sulphide. In the disseminated-sulphide rock chalcopyrite generally predominates, although associated with pyrrhotite in variable amounts, and locally pyrrhotite is predominant. In the solid sulphide zone pyrrhotite predominates but is associated with accessory chalcopyrite. Here and there small pyrite cubes form veinlets facing fracture surfaces in the gabbro and locally extend into the schist. Chalcopyrite veinlets are also found. The solid pyrrhotite is coarse grained. Farther up the gulch the gabbro is poorly exposed, but layers of solid fine-grained pyrrhotite, disseminated rock, and barren gabbro are found. Mr. Hofstad reports that he has traced gabbro outcrops intermittently for a distance of over 2 miles and that an outcrop occurs on the ridge above the claims.

Only one specimen of the gabbro mass was examined in detail. This particular rock is a hornblende-magnetite gabbro or amphibolite, consisting of about 49 per cent of brown hornblende, 29 per cent of magnetite, 11 per cent of plagioclase, 8 per cent of chloride, 2 per cent of pyrrhotite, and 1 per cent of zoisite. The magnetite and zoisite are inclosed poikilitically in the hornblende and plagioclase and are disseminated throughout the rock in well-crystallized grains. The pyrrhotite is later than the magnetite, locally forming a groundmass for it.

The sulphides comprise pyrrhotite, chalcopyrite, pentlandite, and a nickel mineral secondary after pentlandite. The chief nickel mineral is not identifiable with the naked eye. The specimens of ore obtained were so weathered that good polished surfaces suitable for microscopic examination could not be prepared. A mineral of white color with reflected light appears, however, to lie between the grains of pyrrhotite. It gives similar reactions to the chief nickel mineral in the surface outcrops of the Bohemia Basin deposits of Yakobi Island and may be bravoite. The chalcopyrite is in grains associated with the pyrrhotite.

A specimen from the 7-foot mass of solid coarse-grained pyrrhotite (No. 1 in the subjoined table) and a grab sample of the metallized gabbro (No. 2) were analyzed by E. T. Erickson in the chemical laboratory of the United States Geological Survey, and the results are given below. Mr. Hofstad furnished a copy of a report on an assay made for him by the Tacoma smelter (No. 3).

Assays of specimens from Snipe Bay prospect

	1	2	3
Nickel...per cent..	3.57	0.43	2.62
Copper...do....	2.87	3.44	2.6
Gold...	Trace.	None.	....
Silver...ounces per ton..	.06	.13	....
Platinum...	Trace?	....	....

BIG LEDGE

The Big Ledge claim, formerly known as the Mosquito Ledge, is on Tenakee Inlet about 1¾ miles west of the tip of East Point, about half a mile from the beach on the east side of a gulch at an altitude of 450 feet. It is held by Alfred Lagergren. Practically no development work has been done on it. The mineral deposit is in a gabbroic or diabasic dike about 20 feet wide intrusive into conglomerate. About 6 feet of the central part of the dike is sheared and highly fractured and weathers conspicuously rusty from the oxidation of disseminated sulphides. Rare metallized quartz and calcite stringers also occur in this zone. There is a conspicuous gouge on the west wall of the vein. Stringers of solid pyrrhotite as much as 6 inches in width are present but sparse. The predominant sulphide is pyrrhotite in a disseminated form. There is a little chalcopyrite. A little pyrite occurs along fracture faces. The whole dike shows marked slickensiding on close-spaced fractures, but the intervening rock itself appears to be fresh. The dike has not been traced along the strike, and it is entirely covered.

A specimen from the claim was furnished by Mr. Vevelstad. It is a gabbroic rock heavily metallized with sulphides rich in chalcopyrite and pentlandite. The sulphides comprise pyrrhotite, chalcopyrite, pentlandite, a nickel mineral secondary after pentlandite, a little pyrite, and a trace of sphalerite. The chalcopyrite, pyrrhotite, and pentlandite appear for the most part to be contemporaneous in origin, and they corrode and replace the silicates. The chalcopyrite and pyrrhotite occur in veinlike forms, each with small veinlike blebs of the other and with associated pentlandite. The pentlandite occurs in veinlike forms and in grains and is apparently essentially contemporaneous in origin with the chalcopyrite and pyrrhotite, though it may have crystallized somewhat later than part of the pyrrhotite. In specimens of solid sulphide pentlandite forms half the mass. It is partly or completely altered to a secondary nickel mineral. A trace of sphalerite veins the chalcopyrite. A little pyrite in veinlike form locally replaces the pyrrhotite and chalcopyrite. The pyrite and the secondary nickel mineral were probably formed by descending surface waters. The secondary nickel mineral has similar properties to the bravoite of the Canyon Creek nickel prospect, in the Copper River basin, and to the secondary nickel mineral in the outcrops of the other nickeliferous sulphide masses in the Sitka district. Pentlandite also occurs in the quartz-calcite veins.

BALDY LODE

Three claims known as the Baldy Lode group were located in 1923 by Alfred Lagergren and O. Winerman on Tenakee Inlet, on the east side of Chichagof Island. They are at an altitude of about 2,500 feet, about 3 miles west of the east point of Tenakee Inlet, in a saddle of a hill marked 2,800 feet on the coast chart.

The mineral deposit, located as a possible nickeliferous lode, lies at the contact between a mass of granular intrusive rock on the southeast and marble on the northwest. A rusty oxidized mass is exposed at the contact for a width of about 20 feet. The minerals comprise a coarse-grained mixture of pyrite, magnetite, garnet, pyroxene, scattered rosettes of hematite, and a little quartz. Each of the minerals is locally well crystallized. Only a small open cut has been made on the deposit, and along the strike the contact of the intrusive rock and the marble is covered. The intrusive rock near the contact is a diorite consisting by volume of about 66 per cent of andesine feldspar, 30 per cent of hornblende, 4 per cent of magnetite, and accessory microperthite and apatite. A specimen of what appears to be the same intrusive mass from the first point east of Lagergren's ranch on Tenakee Inlet is a granodiorite containing 47 per cent of andesine, 16 per cent of quartz, 16 per cent of microperthite, 12 per cent of hornblende, 8 per cent of biotite, and 1 per cent of magnetite, apatite, titanite, and zircon, by volume. There appears to be a mountain of relatively clean marble here. It is medium grained, with coarsely crystalline veinings. It is reported that two outcrops of contact-metamorphic mineral deposits are found at the southwest corner of the hill of marble and that they carry considerable pyrrhotite. Another claim is located on them.

A specimen from this lode was examined by E. T. Erickson in the chemical laboratory of the United States Geological Survey, and he states that no nickel was found in it. Nickel does not normally occur in a contact-metamorphic deposit of this type. The writer examined with the metallographic microscope several specimens collected from the outcrop and could find no nickel mineral but saw a little chalcopyrite, which is a common ore mineral in contact deposits. This deposit is not of the same type as the nickeliferous deposit on the coast of Tenakee Inlet, known as the Big Ledge.

ADMIRALTY-ALASKA

Nickeliferous pyrrhotite has been found on the War Eagle Extension claim No. 2 of the Admiralty-Alaska group, Funter Bay, Admiralty Island. At an altitude of about 1,650 to 1,700 feet a dike of olivine diabase of troctolite-like character with a high percentage of disseminated sulphides has been exposed by trenching. This dike is highly oxidized and weathered and has a characteristic nodular or spheroidal appearance. Only one wall of the dike is exposed. The country rock consists of white quartzite schist and graphitic black phyllite. The dike is exposed in a small steep gulch, along which it has been trenched for a difference in altitude of about 50 feet. There appears to be about 50 feet of the width of the dike exposed. The disseminated sulphides are almost wholly pyrrhotite with a little chalcopyrite and pentlandite. Probably stringers of solid sulphide are also present, but the rock is too deeply weathered to find them. Assays of specimens made for Mr. Pekovich, of the company, gave the following results:

Assays of specimens from War Eagle Extension No. 2

Gold .... ounces per ton..	0.10	0.03
Silver .... do....	.30	Trace.
Nickel .... per cent..	1.18	.54
Copper .... do....	1.98	1.25

ECONOMIC ASPECTS

The nickel ore at the Alaska Nickel Mines at a depth of 175 feet carries from 1.65 to 5.70 per cent of nickel; and to judge from Overbeck's descriptions the nickel mineral is practically all pentlandite. Pentlandite is a primary mineral, and it is probable that there has been little or no increase in nickel content here as a result of enrichment.

Only specimens from the surface outcrops of the sulphide masses at Snipe Bay, Yakobi Island, and Tenakee Inlet are available. In the outcrops the nickel minerals are almost wholly secondary, formed by supergene (descending) surface waters. A little original pentlandite is present, but the predominant nickel mineral is believed to be bravoite or a mineral resembling bravoite.

The replacement of pentlandite by bravoite need not necessarily involve an increase in the percentage of nickel, though local enrichment may occur. The formation of bravoite appears in general to have been restricted to the alteration of a single mineral, pentlandite. Assays for nickel on specimens from the outcrop are comparable to those obtained from the primary ore of the Alaska Nickel Mines. Unusually high nickel assays obtained locally at or near the surface may be the result of enrichment. It is the writer's opinion, however, that the primary pentlandite ore will be found at a very shallow depth below the surface and that the percentage of nickel to the total sulphides present will prove to be similar to that of the freshest samples from the outcrop. A considerable fluctuation in the percentage of even a primary ore shoot must be expected from place to place.

The nickel deposits are still in the prospecting stage, and a brief discussion of the possibility of finding other deposits in southeastern Alaska and of the characteristics of similar deposits elsewhere is given below.

The nickel-bearing sulphide deposits are associated with norite at the Bohemia Basin, with norite and hornblende gabbro at the Alaska Nickel Mines, and with hornblende gabbro (practically amphibolite) at Snipe Bay on Baranof Island. Diorite is an associate of the gabbro and norite at both the Chichagof Island localities. Another mass of diorite whose affinities are with the gabbros is mapped by Overbeck near the southwest entrance to Lisianski Strait. Two known masses of gabbro thus lie northwest of that at the Alaska Nickel Mines. The Snipe Bay mass lies 100 miles to the south. It therefore seems highly probable that other masses of gabbroic character, which would warrant prospecting for nickel-copper deposits, occur on Baranof and Chichagof islands between these localities.

The sulphides of the "disseminated" type of rock are believed to belong to the last stages of normal magmatic crystallization. The solid sulphide masses have, at least in part, been formed through segregation, transfer of material, and veinlike replacement of the silicates. The ore at Tenakee Inlet was formed essentially later than the consolidation of the associated igneous rock, in a sheared zone, and in part comprises quartz-calcite fissure veins carrying pentlandite.

In southeastern Alaska nickeliferous pyrrhotites have been found only on Chichagof and Baranof islands and their neighboring islands and on Admiralty Island, though masses of pyrrhotite are common at many of the ore deposits in the area. Three analyses of pyrrhotite from contact-metamorphic copper deposits in the Ketchikan district, made by George Steiger for F. E. and C. W. Wright, show only 0.1 to 0.2 per cent of nickel, a trace of cobalt, and no platinum or gold.

At a copper prospect on a fissure vein at Port Houghton, in the Juneau district, pyrrhotite is the major sulphide; yet the vein matter yielded only a doubtful trace of nickel. Similarly the pyrrhotite of ore lenses in schist at the Khayam mine, on Skowl Arm, Prince of Wales Island, and at the Virginia prospect, in the Hyder district, shows no nickel.

The essential similarity between the geology of the deposits at the Alaska Nickel Mines and the great deposits at Sudbury, Ontario, has been set forth by Overbeck. The Sudbury igneous mass crops out in the shape of an elliptical ring with a longer diameter of 35 to 40 miles and a maximum shorter diameter of about 16 miles. The width of the ring itself, as exposed at the surface, is in general from 2 to 3½ miles. The following statements with respect to the proportionate relation between the amount of nickel-copper ore and the volume of the norite and the occurrence of a higher percentage of nickel and copper in the sulphides of the disseminated type of rock as contrasted with the massive sulphides are of interest.[12]

> The quantity of sulphides which may be expected to occur at the contact of the nickel-bearing intrusive is roughly proportional to the volume of the adjacent norite. The surface expanse of the nickel-bearing intrusive and its thickness as shown by the dip at the contact both go to show what the volume of tributary nickel-bearing intrusive may be. * * * The pure sulphide concentrates of the ores, if made, would have practically a uniform content of 7 to 8 per cent combined metals. In the hanging wall, however (disseminated ore with about 1 per cent of nickel), where the processes of mineralization would naturally be more erratic, the sulphide concentrates would have a combined metallic content of 13.42 per cent. The solid masses of pyrrhotite contain less copper than the rocky ores.

[12] Roberts, H. M., and Longyear, R. D., Genesis of the Sudbury nickel-copper ores: Am. Inst. Min. Eng. Trans., vol. 59, pp. 40–41, 1918.

The gabbro masses, so far as exposed, on Baranof and Chichagof islands, however, are more closely allied in size with gabbro bodies carrying nickeliferous sulphide zones, such as that at the Friday claim, at Julian, Calif.; the old Gap mine, in Lancaster County, Pa.; and the many masses in Norway and Sweden. J. H. L. Vogt has made a careful study of the Norwegian deposits, and some of his conclusions are summarized here.[13]

The numerous nickel-pyrrhotite deposits found in different countries and especially in Canada, Norway, Sweden, Pennsylvania, in the Monte Rosa district of Piedmont, etc., in their mineralogical and geological relations form a sharply defined group. The most important characteristic common to them all lies in their occurrence within or at the margins of gabbro masses, chiefly norite. * * *

Of about 50 nickel-pyrrhotite occurrences distributed over Norway, the greater number occur in fresh unaltered norite which carries diallage, sometimes olivine, and at other times quartz, the latter association forming quartz norite. Some of them, however, occur in gabbro more or less greatly uralitized, the pyroxene being so greatly altered that the rocks were formerly regarded as gabbro-diorite and later as uralite gabbro. * * * The variety of gabbro which favors the nickel-pyrrhotite deposits is therefore one which carries hypersthene.

In a more recent paper[14] he writes:

Segregations of nickel pyrrhotite are very common in norites, and in Norway alone, inclusive of some rather small deposits, 37 separate bodies of norite (and peridotite) are known to be accompanied by nickel pyrrhotite. The deposits that are associated with quite small bodies of norite and peridotite are themselves of very small dimensions. The large deposits always accompany large intrusive masses, especially of norite. However, it must not be concluded that all large norite masses must be accompanied by large deposits of nickel pyrrhotite, or that the deposits which accompany large norite bodies are themselves necessarily large.

Vogt cites as an example the norite mass at Erteli, Norway, which has an area of about 240,000 square yards and from the ore bodies of which has been produced about 110,000 tons of nickel ore containing 1,250 tons of nickel and 600 tons of copper.

As another example may be cited the Gap mine, in Lancaster County, Pa. This mine was actively operated from 1863 to 1885 and was for a time the chief nickel producer of its day, but after the development of the nickel deposits in New Caledonia and Sudbury it was closed. Its total production was from 4,000,000 to 4,500,000 pounds of nickel.[15] The ore as mined ran about 1 to 3 per cent of nickel and one-third to one-fourth as much copper. The deposit is described by Kemp[16] as pyrrhotite carrying pentlandite

[13] Beyschlag, F., Vogt, J. H. L., and Krusch, P., Ore deposits, pp. 280–281, 1914.

[14] Vogt, J. H. L., On the content of nickel in igneous rocks: Econ. Geology, vol. 18, p. 334, 1923.

[15] U. S. Geol. Survey Mineral Resources, 1882–1886.

[16] Kemp, J. F., The nickel mine at Lancaster Gap and the pyrrhotite deposits at Anthony's Nose, on the Hudson: Am. Inst. Min. Eng. Trans., vol. 24, pp. 620–633, 888, 1895.

and chalcopyrite and occurring on the borders of a lens of amphibolite or hornblendic rock which yields evidence that it is an altered gabbro or norite or peridotite. This lenticular mass or stock is about 1,500 feet long and 500 feet in maximum width and is an intrusion in mica schist.

Vogt [17] also states that

> For the larger noritic nickel deposits in Norway and Sweden, it appears that the highest percentage of nickel is found in the norite richest in hypersthene, the lowest percentage of nickel in the norite relatively poor in hypersthene, and intermediate percentages of nickel in the rocks having an intermediate content of hypersthene. In other words, the percentage of nickel in the sulphides is dependent essentially on the content of hypersthene (or hypersthene plus diallage, primary amphibole, and biotite) in the rock.

The nickel content of the sulphide ores was also found to increase with the percentage of magnesium oxide in the rock. As previously stated, the norites adjacent to the ore at the Bohemia and Tasmania claims are hypersthene segregations in which the hypersthene is rich in magnesia (80 to 86 per cent $MgSiO_3$). These data are therefore favorable indications of the nickel percentage in the sulphides, if Vogt's conclusions are of general application. At the Snipe Bay locality the rock appears to be made up largely of hornblende, which according to Vogt is likewise a favorable indication for the percentage of nickel in the sulphides.

For purposes of comparison, the nickel and copper content of ores from representative mines in Canada is given below. These data are taken from the report of the Royal Ontario Nickel Commission.

Mine	Nickel	Copper	Production to end of 1915 (tons)	Reserves (tons)
Creighton	4.4	1.5	4,611,577	10,000,000
Crean Hill	2.9	1.5	[a] 660,000	2,000,000
Frood Extension	2.0	2.0		500,000
Garson	2.4	1.7	872,179	
Levack	3.2	1.5		4,500,000
Victoria	1.6	3.3	619,612	

[a] Sorted ore.

There had been smelted in the Sudbury district up to the end of 1916 10,322,515 short tons of ore averaging 2.76 per cent of nickel and 1.7 per cent of copper. The total ore smelted in Ontario [18] during the five years from 1916 to 1920 was 6,568,457 tons. The value of the total imports of nickel for consumption in the United States for the five years from 1918 to 1922 amounted to $36,291,077.[19]

[17] Op. cit., p. 348.
[18] Ontario Dept. Mines, Thirteenth Ann. Rept., pt. 1, 1921.
[19] U. S. Geol. Survey Mineral Resources, 1922, pt. 1, p. 67A, 1923.

GOLD DEPOSITS IN SITKA DISTRICT

LISIANSKI DIORITIC STOCK

GENERAL FEATURES

The outstanding finds of new mineral deposits in the Sitka district in the last few years have been made within a complex mass of intrusive igneous rocks that occurs in the northwestern part of Chichagof Island. As mapped by Overbeck[20] (see Pl. II), this mass extends in a northwesterly direction from the head of Hooniah Sound parallel to Lisianski Inlet almost to Cross Sound.

Overbeck reports that the gold prospect on Yakobi Island, northwest of Miner Island and in the Lisianski dioritic stock, was located about 1887. In 1917 this prospect was relocated and a new find was made on the north side of Stag Bay about a quarter of a mile northwest of the cannery. In October, 1919, J. H. Cann staked the Apex vein, in the mountains between Lisianski Inlet and Stag Bay, from which very rich gold assays were obtained. This discovery incited renewed prospecting in this vicinity, and many other claims have since been located within this mass, the most recent in 1923 near the head of Hooniah Sound.

No careful examination has been made of the igneous rock composing the stock, but at the Apex-El Nido and Paramount prospects it is a diorite. A specimen obtained near Vevelstad's cabin on Lisianski Strait is a quartzose diorite, and another from the mountain back of the Bohemia claims is a quartz diorite. At the Pinta Bay prospects the country rock is an albite-quartz diorite, and Overbeck reports a similar rock on Lisianski Strait northwest of Miner Island. Local masses of hornblendite are found along Lisianski Strait and at the Apex workings. Aplite and porphyry dikes are common near the Apex-El Nido workings.

The variation from diorite through quartz diorite to albite-quartz diorite (or soda granite), the local included masses of hornblendite, and the aplite dikes are all features which are common to some of the outlying stocks of the Coast Range batholith on the mainland. Overbeck concluded that the mass belonged to the Coast Range group of intrusives.

The rock in the vicinity of each of the prospects is in general in a very highly shattered condition. This is confirmed by the microscopic evidence, which shows all the minerals much broken, veinlets of chlorite with a little associated ilmenite and locally abundant epidote, and secondary aggregates of calcite and sericite. The original quartz shows strain phenomena or has been crushed and

[20] Overbeck, R. M., U. S. Geol. Survey Bull. 692, pl. 2, 1919.

recrystallized with a sutured interlocking texture. Green slickensided surfaces are developed on a minute scale. Shear zones with ground-up altered rock powder of a greenish hue are common. In superficial appearance they resemble dikes, but their association with fissured zones suggests their origin. Veinings of white zoisite and yellow-green epidote are common.

The gold deposits are predominantly quartz fissure veins in diorite or hornblendite or in aplite-like dikes that are intrusive into both these rocks. The aplite-like dikes are intensely altered near the veins. Dikes of unaltered aplite and of porphyry are both found in the vicinity. One small "stockwork" has been found at the El Nido group of claims. Both the Apex and the El Nido veins are for the most part in aplite dikes. Of eight veins on which observations were made, all have strikes between N. 15° E. and N. 60° E., averaging about N. 45° E. The veins dip from 50° to 80° and are equally divided between easterly and westerly dips. They may vary considerably, both in direction and in degree of dip. Like most other fissure veins, they pinch and swell, ranging from only narrow stringers to veins 7 feet in width. At the Apex-El Nido workings they average from 1½ to 2½ feet. The El Nido vein has been traced for more than 1,000 feet along the strike, and the Apex vein for more than 2,000 feet. Both veins are exposed through a vertical distance of more than 600 feet.

The veins range from milky-white quartz with free gold and only a trace of sulphides to quartz with local pockets of almost solid arsenopyrite as much as 2 feet in width. In general the sulphide mineralization is slight. Arsenopyrite predominates, and pyrite, galena, sphalerite, chalcopyrite, gold, locally scheelite, and rarely tetrahedrite constitute the other metallic minerals.

In the Apex and El Nido veins most of the gold is invisible to the eye. The rich shoots yield gold when the quartz is crushed and panned. In all the veins coarse flakes are often found. At the Apex and El Nido veins pyrite and arsenopyrite impregnate the wall rock, which consequently carries a little gold.

The gangue is uniformly a milky-white granular quartz, with here and there a little sericite and calcite and numerous vugs lined with quartz crystals.

The phenomena at the Apex and El Nido workings suggest that the sulphides (in particular the arsenopyrite) and the gold in part crystallized contemporaneously with the quartz, but that in part the quartz veins were crushed along slickensided surfaces and that solutions circulating along them introduced new sulphides (including arsenopyrite) and gold.

The gold deposits within this mass of diorite bear a very striking resemblance to the deposits found within the Jualin diorite in the Berners Bay district, which has been described by Knopf,[21] and within the augite diorite stock on the east side of the Coast Range batholith, described by McCann.[22]

The "stockwork" at the El Nido group of claims is apparently similar to that of the Eureka and Kensington mines, in the Jualin diorite, though it is smaller and the quartz veins are mineralized with a higher percentage of sulphides.

Within the diorite of Lisianski Strait mineralized quartz veins are exposed throughout a vertical range of 2,000 feet. The characteristics of the fissures, of the mineralization, and of the alteration of the wall rock are all such as are common to veins formed at intermediate to high temperature and relatively great depth. High metal content has been found both at the surface and as deep as 300 feet below the outcrop. Although there may be some enrichment (perhaps in part mechanical) at or very near the surface, the presence of primary high-grade ore shoots is assured, and conditions in depth may be judged from conditions near the surface.

The Apex and El Nido veins show a sheeted or ribbon structure parallel to the walls. The character of the veins within the Lisianski stock is insufficiently well known to determine whether or not this structure has any significance. The following quotation from McCann[23] shows its importance in the Bridge River area, British Columbia:

> Most of the important veins in the augite diorite, however, show pronounced sheeting or ribbon structure parallel to the walls, each band being separated by a film of finely pulverized sulphides, and sometimes there is a film of gouge made of carbonates, sericite, and chlorite along these planes. In places where the different bands have slickensided surfaces exceedingly thin films of gold, also striated, coat the surfaces. The banding may have been caused originally by local concentration of sulphides, producing a somewhat banded structure. Such mineralized portions may then have formed lines of weakness along which subsequent movement within the veins took place, the sulphides being pulverized and later recrystallized in part, producing the ribbon structure now observed. * * * Only those veins which show ribbon structure formed in this way have been found to contain "bonanzas," although massive quartz veins, in which such banding is absent, contain fine specks of gold disseminated through them. Movement of a similar character has been noted in the gold-quartz veins of Grass Valley, Calif., and elsewhere.

APEX-EL NIDO

The Apex-El Nido mine, on Chichagof Island, is on Cann Creek, which enters Lisianski Inlet from the south about 5 miles southeast

[21] Knopf, Adolph, Geology of the Berners Bay region, Alaska: U. S. Geol. Survey Bull. 446, 1911.

[22] McCann, W. S., Geology and mineral deposits of the Bridge River map area, British Columbia: Canada Geol. Survey Mem. 130, 1922.

[23] Idem, pp. 59–60.

of Miner Island (fig. 5). The veins lie on the mountain slopes about 1¾ miles from the beach, at the back of a glacial basin whose floor is at an altitude of about 760 feet. The following description of the early development is abstracted from the annual reports of B. D. Stewart, mine inspector, for 1920, 1921, and 1922.

The Apex vein was located by J. H. Cann in October, 1919, and the El Nido vein, about 1,600 feet east, in June, 1920. The Apex group of claims was bonded to the Chichagof Mining Co., and development work started early in the summer of 1920 and continued through most of 1921. The company drove about 30 feet of drift alongside the vein at an altitude of 1,227 feet and completed over

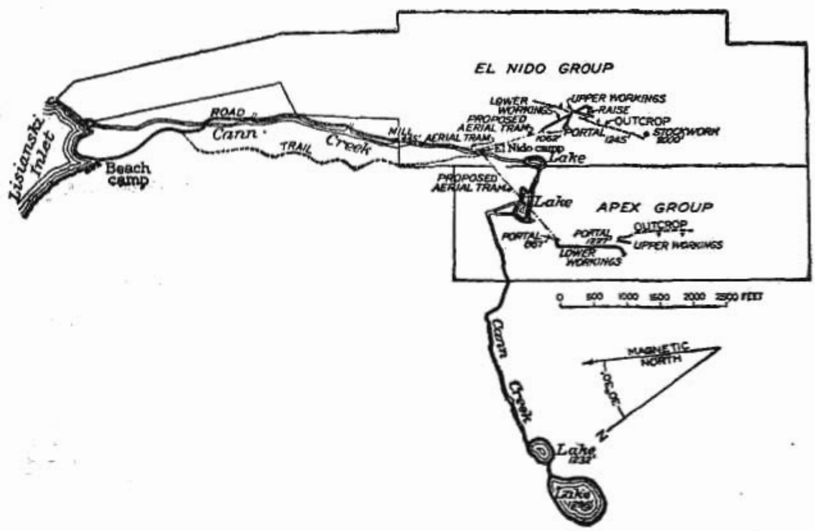


FIGURE 5.—Sketch map of Apex-El Nido gold claims, Chichagof Island

1,400 feet of tunnel, with the portal at an altitude of 867 feet, intended to crosscut to the vein. The vein was not cut as soon as was hoped; and for this and other reasons the company released its option on the property. Meanwhile, J. H. Cann and his associates were at work during 1921 in the development of the El Nido vein and drove 273 feet of crosscut tunnels and 320 feet of drifts.

In 1922 Cann and his associates extended the drift on the Apex vein for 110 feet and drove 1,100 feet of crosscut tunnels, drifts, and raises on the El Nido vein. In 1923 the Apex and El Nido groups of claims were consolidated under the name Apex-El Nido Mining Co. Work was continued on the crosscut tunnel to the Apex vein, and preparations were being made to drive a raise to intersect the vein. On Cann Creek at an altitude of 450 feet a 10-stamp mill was being erected, and the United States Forest Service completed a corduroy road about a mile in length from the beach to the mill site. A tractor and trailer are used to haul supplies from the beach to the mill site. Tramways are contemplated from the upper camp (altitude about 800 feet) to the tunnels on the El Nido and Apex veins. There is already an aerial tram from the upper camp to the mill site. A 12 by 12 inch Blaisdell compressor, driven by a 6-foot Pelton water wheel under a 310-foot head, supplies air for the machine drills.

The Apex group includes 12 claims, on which there are a series of quartz fissure veins. The country rock is diorite, with a small local mass of hornblendite in the mountain above the Apex workings and intrusive dikes of aplite. The outcrop of the Apex vein is extraordinarily well exposed. It stands out boldly in a bare cliff face several hundred feet high, is traceable across a bench about 600 feet above the tunnel almost continuously for 200 yards to a talus slide, reappears in the face of another high cliff at the back of the talus, and can be seen extending upward in the cliff for several hundred feet. Two other quartz veins, which have not been sampled, are exposed in this cliff, one on the east and the other on the west. They are essentially parallel in strike and dip. The Apex vein is reported to have been traced for over 2,000 feet from the tunnel. The vein in general strikes northeast and dips 50°–80° NW. In width it pinches and swells from several inches to 5 feet. Where exposed in the drift tunnel for a length of 140 feet it ranges from 9 inches to 4 feet and is reported to average 31 inches. At the surface above the tunnel the average width for 100 feet is 19 inches.

The vein occupies a well-defined, persistent fracture and cuts across several varieties of igneous rock, including diorite, hornblendite, and aplite; the aplite occurs as dikes in the diorite and hornblendite. The wall rocks adjacent to the vein are intensely altered and are impregnated with disseminated sulphides. An average sample of 15 inches of the footwall in the drift at an altitude of 1,227 feet is reported to have yielded $2.48 in gold to the ton. The intensity of alteration diminishes gradually away from the vein.

Adjacent to the vein the hornblendite is bleached and altered—the hornblende to a pale-brown hue and the interstitial feldspar to a dull white. In thin section the hornblende is found to be altered to a cloudy unidentifiable aggregate with many veinlets of calcite. The feldspar is altered to sericite. The wall rock at the entrance to the drift is a very highly altered phase of the diorite in which calcite and chlorite form the major secondary minerals, associated with a little quartz and sericite and disseminated pyrite.

On a level with the drift and 5 feet distant is a mineralized quartz vein averaging 8 to 12 inches in width. The whole zone between these two veins carries disseminated pyrite, and about 8 inches of the hanging wall of the Apex vein and 5 inches of the footwall of the upper vein has considerable disseminated sulphides. An almost vertical stringer, 9 inches wide, offshoots from the Apex vein about 100 feet above the tunnel and pinches out about 50 feet below its level. At 20 feet east of this stringer is another quartz vein about 10 inches wide, which pinches out about 65 feet below the tunnel level but extends upward to the top of the cliff. Several other narrow quartz veins carrying a little sulphide were noted in the hill above the tunnel.

The vein matter ranges from half sulphides to sparse sulphides both across the strike and along it, but on the average the sulphides form only a small percentage of the vein. The minerals include arsenopyrite, pyrite, sphalerite, chalcopyrite, sparse tetrahedrite, and free gold. Arsenopyrite is greatly predominant. Stewart reports that from the base of the outcrop to a height of at least 150 feet visible free gold was plentifully scattered over the surface of the vein. The gold occurs in very fine particles rather evenly distributed within the quartz, and pieces the size of a pinhead are occasionally seen.

The gangue is almost wholly a milky-white quartz. Quartz crystals lining small pockets in the vein are common, and here and there a little calcite is present, or little patches of sericite. Slickensided surfaces are common within the vein.

The El Nido group of claims joins the Apex group on the east and comprises 18 claims, including a power site and a mill site. The El Nido vein is a quartz vein filling a fracture in an aplite dike, which is intrusive into the diorite country rock. The vein strikes northeast and dips 50° E. Northwest of the workings the vein is near the footwall of the aplite dike, but toward the southeast it gradually works up toward the hanging wall, and at an altitude of about 1,650 feet, in the gorge of a small stream, it passes completely out of the aplite dike into the diorite for a distance of about 15 feet, pinching to several inches in width, and then returns to the aplite dike and widens again.

The aplite dike ranges from several feet to 20 feet or more in width, and the vein from 6 inches to 7 feet. Above the workings, for a length of 182 feet, the vein averages about 2½ feet in width. In the drift on the lower workings the usual width is not over 16 inches, though locally it swells to 7 feet. The vein was followed by the writer from a trench about 150 yards northeast of the tunnel for over 1,000 feet to a gorge at an altitude of about 1,650 feet. There is a covered space here, and several quartz veins are found on the opposite side. One of these may represent the continuation of the El Nido vein.

The developments consist of a 775-foot crosscut tunnel to the vein at an altitude of 1,002 feet, a 100-foot drift on the vein, and a raise on the vein to the upper workings, about 200 feet above. Another crosscut tunnel at an altitude of 1,245 feet has been driven about 225 feet to intersect the vein, and about 320 feet of drift run to the southeast on the vein.

The vein matter consists almost wholly of milky-white quartz. Here and there is a little calcite, and eyes or films of scaly pale-green sericite are common, as well as pockets lined with quartz crystals. Much of the quartz shows slickensided surfaces, and the sulphides are mostly localized there, though stringers and disseminated grains of original intergrowth with the quartz also occur. The quantity of metalliferous minerals is small. They include arsenopyrite, sphalerite, pyrite, free gold, scheelite, and a trace of chalcopyrite. Arsenopyrite predominates. The scheelite is pale yellow and occurs as disseminated grains and in narrow bands parallel to the vein walls.

Microscopic examination of a thin section of the vein from the lower workings shows it to consist of granular quartz with thin shear zones of crushed and recrystallized denticulate-textured quartz, associated with newly introduced sulphides and lenticles of sericite.

The diorite at the mouth of the lower tunnel on the El Nido workings is a dark green-gray rock with white plagioclase crystals. In thin section the rock is seen to consist of veined and shattered plagioclase in a groundmass of secondary minerals which are probably, in part, alteration products of hornblende. The plagioclase is a calcic andesine and is partly fresh and unaltered but is veined with films of chlorite associated with a little epidote and is locally altered to calcite. The veinlets and irregular areas of secondary minerals in the groundmass consist of altered plagioclase, with associated chlorite, epidote, and a little ilmenite, partly altered to leucoxene.

The aplite dikes at both the El Nido and the Apex veins are so altered that in the specimens taken their original character is not discernible. The rock consists of secondary alteration minerals, such as sericite, calcite, quartz, and chlorite, associated with quartz and altered feldspar and a little ilmenite and impregnating sulphide. Fresh specimens of similar dikes at the head of Cann Creek proved to be aplites or trachytes of both sodic and potassic character.

About a quarter of a mile southeast of the El Nido workings, at an altitude of 2,000 feet, there is a pear-shaped stockwork of brecciated altered diorite with many stringers and wide veins of quartz. The stockwork is about 20 by 35 feet, and the reticulating quartz veins form the larger part of the mass. The veins range from a fraction of an inch to 4 feet in width and carry a considerable percentage of coarse pyrite and the blackjack variety of sphalerite. The included fragments of diorite are altered and impregnated with pyrite. A gulch has been cut in the stockwork and is partly filled with snow, so that part of the mineral deposit is covered. Altered rock can be traced for at least 100 feet up this gulch along the continuation of the fracture on which the stockwork is located. The stockwork was apparently formed along a zone of local abrupt change of direction along the fracture or where the continuation of the fracture was slightly offset. Subsequent movement along the fracture produced at this point a fissured, brecciated zone in which the quartz veins were deposited. The fissure strikes northeast and has a steep southeast dip. The longer axis of the stockwork has a northwesterly strike. The veins on the north and west sides are essentially parallel to the borders, but those on the south side strike at an angle to the borders.

It is reported that a 13-foot sample across part of the stockwork, consisting of about 30 per cent of diorite and 70 per cent of quartz stringers from 2 to 16 inches wide, averaged $6.82 in gold and 0.44 ounce of silver to the ton. Another sample 16 feet in width is reported to have averaged $19.85 in gold to the ton.

R. F. Hill, of Juneau, prepared a report on this property for the company in which the following assay figures are given: The average value of the ore as exposed in the adit on the Apex lode is about $40 a ton, with variations from $5 to $55. The average value of 100 feet of the surface outcrop above the adit is $94.50. It is estimated that 4,000 tons of ore, with an assay value of $57, is developed between the outcrop and the adit, and that in addition 10,000 tons of ore of milling grade can reasonably be considered as in sight along the extension of the vein. On the El Nido vein, Hill estimates, there is 4,500 tons of ore with an average assay value of $33 a ton developed between the outcrop and the upper drift, and 4,000 tons of milling grade is blocked out by the upper and lower drifts and the connecting raise.

Assay values of more than $500 a ton are reported to have been obtained from samples of the surface outcrop.

PINTA BAY

The Pinta Bay Mining Co. controls four groups of claims. One is the group of seven copper claims northwest of Baker Peak, described by Overbeck.[24] Assessment work only is now being done on them. Another group of claims is located on a gold quartz vein at the head of Deep Bay. This was not visited. The workings are said

[24] Op. cit., pp. 121–122.

to comprise a crosscut tunnel 110 feet long and 18 feet of drift on a quartz vein in black slate. Free gold is reported to occur in the quartz.

The group of claims which are now under process of development comprises nine claims lying about 4½ miles north of the head of Pinta Bay, on the northeast side of a flat-floored basin at an altitude of about 750 feet. They were located in 1922 by Cox Brothers, Bolyan & Loeberg. Development work was begun the same year. A light narrow-gage 30-inch track with 12-pound rails is being built to the mill site, which lies near the tunnel entrance, 4½ miles from the beach at the head of Pinta Bay. All but three-fourths of a mile was finished in August, 1923, and it was expected that the whole job would be completed by the end of September. The railroad is being built to furnish a means of taking in a compressor and the mill parts. The equipment includes a sawmill, run by a Fordson tractor engine, which is used for sawing out ties for the railroad and lumber for the mill, and a Fordson tractor and trailers for hauling supplies on the railroad. The tractor is specially built and slung on flanged wheels. There is a very good water-power site on the creek entering Pinta Bay, and the basin at the head of the railroad offers every advantage for a mill site and camp. From 25 to 30 men have been working since May 1, 1923.

Two veins are being prospected on this group of claims. A tunnel 30 feet long has been driven on vein No. 1, and trenches have exposed it at the surface for a length of over 200 feet and for a vertical distance of 50 feet. The portal of the tunnel is at an altitude of about 800 feet. The vein is a quartz fissure deposit, predominantly in a gneissoid albite-quartz diorite but locally in aplite. The wall rock is only slightly altered, though impregnated with disseminated sulphide near the contact. The vein strikes about northeast and dips 70° NW. It is displaced in two places by faults, one resulting in an offset of the southwestern part about 20 feet to the northwest and the other resulting in an overlap of several feet. The vein matter is almost wholly milky-white quartz. Open spaces lined with quartz crystals are common. A little dolomite is present. Sulphides in general are sparse but locally occur in vein form or as disseminations. Arsenopyrite predominates, but sphalerite, galena, free gold, and a little pyrite and chalcopyrite are also found. The vein ranges from 6 to 18 inches in width; in the tunnel it is about 10 to 14 inches. The vein matter breaks free from the walls, and there is a persistent clay gouge 1 to 1½ inches wide on the hanging wall, which carries free gold. The projected strike of the vein toward the northeast carries it into greenstone immediately beyond the present exposure. At the entrance to the tunnel there is about 4 feet of altered and silicified greenstone, which occurs as an inclusion in the quartz diorite. The greenstone is traversed by veinlets of quartz and of pyrrhotite and chalcopyrite.

No. 2 vein lies about 300 feet to the southeast, strikes about northeast, and dips 80° SE. This vein is a quartz fissure vein which cuts across greenstone, cherty quartzite, and siliceous limestone at an angle to the bedding. At an altitude of about 1,050 feet a 28-foot crosscut has been driven in the siliceous limestone to intersect the vein. Several quartz stringers were cut, also the main vein, which is here about a foot wide. The vein is exposed by trenches and strip pits at the surface for a length of 40 feet. It ranges in width from 6 to 8 inches and carries a little disseminated sphalerite, galena, free gold, and a trace of pyrite, in a gangue of quartz. Just northwest of the limestone bed a trench has exposed a quartz stringer in greenstone which lies in the general direction of the strike of the vein. About 1,500 feet to the southeast a trench has exposed about 2 feet of quartz in gneissic quartz diorite. The quartz here has a more glassy luster, typical of high-temperature veins associated with pegmatite dikes.

Samples across No. 1 vein are reported to average from $2 to $22.60 to the ton, the latter for a 16-inch width. A sample from No. 2 vein gave $4.90. Higher assays are reported from some specimens. Coarse gold has been found in both veins.

The fourth group of claims, known as the south-side group, lies about 1 mile southeast of the tunnels at the head of the railroad. L. S. Robe, superintendent, reports that the mineral deposit there is a vein of quartz 20 inches wide exposed for 300 feet. A tunnel 8 to 10 feet long has been driven on the vein. No assays have been made, but the material is reported to pan well.

PARAMOUNT

The Paramount group is reported to include nine claims held by Schotter, Dodge & Borland, located in 1920. They lie along a gulch about 1⅕ miles southeast of the point between Lisianski Strait and Lisianski Inlet. Assessment work only was done during 1923, and the veins are not sufficiently developed to give an adequate idea of their character.

At altitudes of 150 to 200 feet a quartz fissure vein in diorite has been exposed intermittently for a length of 400 feet. It ranges in width from a few inches to several feet, but in the higher measurement lenses of the country rock are included. Float believed to come from this vein is reported to carry free gold, and low assays in gold are yielded by the quartz. The vein strikes about N. 15° E. and dips 55° W. A good trail has been built from the beach to this prospect, a distance of about 500 yards. The vein matter is milky-white quartz with practically no sulphides.

These claims were restaked in 1924 and the name changed to the Goldwan group.

Another vein occurs on the west side of the gulch at an altitude of 940 feet, where it is exposed in a cliff. This vein is in an intensely sheared and altered zone of diorite. It strikes northeast and dips 58° W. The wall rock adjacent to the vein shows slickensided surfaces on a minute scale and veinings of siliceous and epidotic material. The vein is a quartz fissure filling from 1 inch to 11 inches wide where exposed in the gulch and averaging about 6 inches. It is exposed for a length of about 50 feet in the gulch and for a vertical distance of 40 feet. It is reported to extend up a small boulder-filled tributary gulch to the top, where it is somewhat wider. The vein matter is milky-white quartz with rare sulphides (only pyrite being noted) and a little calcite and aggregates of sericite. Several feet below the vein is a black schist zone several inches wide resembling a dike but probably only a sheared phase of the diorite. It is reported that assays of picked samples showed as much as $60 a ton in gold.

OTHER CLAIMS

Other claims within the dioritic stocks are those of Lee H. Wakefield, A. Nilsen, S. H. P. Vevelstad, the Etna group, and the two prospects described by Overbeck.[25] Wakefield owns three claims and a fraction of another, parallel to the Apex group. They were staked in 1920, and only assessment work has been done on them. Nilsen's group comprises two claims staked in 1923 on the south side of Lisianski Inlet near Junction Island. The Vevelstad claims are on Yakobi Island. The Etna group comprises five claims held by J. H. Cann, on the south side of Stag Bay about 1½ miles from the entrance. The vein is reported to average 16 to 18 inches in width, to have been exposed by stripping for 150 feet, and to carry a medium gold content.

HIRST-CHICHAGOF MINE

The geology of the Hirst-Chichagof property has been described by Overbeck.[26] It lies on the northwest side of Doolth Mountain, at the head of Mine Cove on Chichagof Island, and comprises a group of ten claims with mill site. The property is equipped with a 10-stamp mill, operated by three Fairbanks-Morse Diesel engines of 10, 25, and 50 horsepower, and one Wilfley table. In August, 1923, five stamps

[25] Op. cit., p. 121.
[26] Op. cit., pp. 116–118.

were running and 20 men were employed. The underground workings have now a total length of about 3,130 feet. They include three tunnels with portals at altitudes of 95, 270, and 450 feet.

The lower tunnel is now in about 1,700 feet and is being driven forward along a new ore shoot discovered in August, 1923. This ore shoot, which is at present being stoped, has a length of about 200 feet and an average width of 27 inches on the lower level, a length of 200 feet and an average width of 24 inches on the middle level, and a length of 175 feet and an average width of 27 inches on the upper level. The lower and upper levels are 340 feet apart. The shoot has been stoped out between the lower and middle levels and for about 60 feet above the middle level. A raise is being driven from the middle level to the upper one preparatory to stoping the remainder of the lens. The gross value is reported to average about $11 to the ton. About 70 per cent of the value is recovered in the mill, and the concentrates are shipped to Tacoma.

On the lower level, 280 feet from the end of the ore shoot just described, the beginning of a new ore shoot had just been found at the time of the writer's visit. The shoot widened to 30 inches within 8 feet and is 33 inches wide at the face of the drift, 38 feet from the beginning of the shoot. The vein lies in black slate about 5 feet above a greenstone sheet, with about 5 feet of black gouge lying between the greenstone and the vein. The vein matter is milky-white quartz with graphitic films and a little disseminated pyrite. Very fine free gold is disseminated through the quartz. The vein strikes about N. 35° W. and dips steeply southwest.

GOLD PROSPECTS ON WINDHAM BAY, JUNEAU DISTRICT

About three-fifths of a mile in a straight line from the head of Windham Bay is a mineral belt along which prospecting has been continued in recent years. This mineralized belt occurs in general within the green schist series but may itself be in intercalated beds of black slate and quartz schist. The original nature of the country rock could not be positively identified, but it now occurs as a white sericitic siliceous schist The quartz stringers are abundant and range generally from a fraction of an inch to several inches in width. In addition, rich high-grade quartz stringers are found, especially in the upper or southeastern portion of the belt. These are mineralized with galena, sphalerite, and free gold. In the schist pyrite and pyrrhotite comprise the disseminated sulphides.

Helvetia.—The Helvetia Mining Co. holds 13 claims along this belt on the northwest side of Spruce Creek. An adit has been driven in along a high-grade stringer 25 feet in length, and another 350 feet in length cutting the formation at an angle. The 350-foot adit exposed about 200 feet of slightly mineralized quartz stringers in schist, but it is reported that assay returns did not warrant further development with a small-scale plant.

Alaska Peerless.—On the southeast side of Spruce Creek, along the same mineralized band, the Alaska Peerless Co. took over four claims from Robert Durer in 1915. Two of these claims lie along a vein which is being prospected for a low-grade ore body. A tunnel about 80 feet in length, at an altitude of 850 feet, had been driven on the vein by the Helvetia Mining Co. in 1904. The Alaska Peerless Co. from 1916 to 1922 extended this tunnel to a total length of about 475 feet. At about three-fourths of this length from the portal a crosscut about 160 feet long has been driven across the vein without exposing any definite lateral walls. The vein consists of quartz stringers in a sericitic quartz schist. The rock in the hanging wall seems to be a dark sheared slate. The vein is slightly mineralized with sulphides. Pyrite is most common and is locally slightly cupriferous. Free gold occurs in some stringers. The vein as exposed in the tunnel and crosscut was assayed in 1919 and is reported to have shown an average low-grade value for the full width of 160 feet. At an altitude of about 1,100 feet the Alaska Peerless Co. has driven another tunnel about 50 feet long on the same vein, exposing rock of similar character. Stringers of high-grade ore occur here.

Yates, Rowe, and Jensen.—Southeast of the claims held by the Alaska Peerless Co., one claim and a fraction along the same vein are held by Mrs. D. W. Yates. On this property the vein has been exposed by several trenches, and at an altitude of about 1,360 feet a 35-foot tunnel, driven between 1917 and 1922, crosscuts a portion of the vein. At the entrance to the tunnel a fissure vein of quartz cuts diagonally across the formation and constitutes a high-grade stringer from 7 to 18 inches in width. In the tunnel minute pyrite cubes are conspicuously disseminated throughout several bands of the quartz-veined schists. One of these bands is 4 feet wide.

Adjoining the Yates claims on the southeast are three claims along the same belt, held by R. V. Rowe. In 1922 a crosscut of 80 feet is reported to have been made on the Fairview claim in order to intersect a high-grade stringer 9 to 12 inches wide, at a depth of about 60 feet below the outcrop. The stringer is reported to have been traced at the surface for a length of about 500 feet and is continued by a series of offset veins for 200 feet more.

Adjoining Rowe's property on the southeast along the same belt are two claims held by Gudmund Jensen. The vein here is reported to be 110 feet wide and over 2,000 feet long and to consist of quartz stringers in schist. Small ledges and stringers flank the main vein for 100 feet on the hanging-wall and footwall sides. A high-grade stringer is found on No. 1 of the Great Mine group, on the east side of the main vein or "big ledge." On a third claim, to the east, practically at the crest of the mountain, a 20-foot shaft has been sunk by Jensen on a rich stringer of free gold. Additional claims were located on this belt in 1923.

Independent Mining Co.—The Independent Mining Co. holds two groups of claims at the head of Windham Bay. One of these groups is on the north side of the bay about a quarter of a mile from the town of Windham. The vein consists of an intimate network of quartz stringers in a brecciated greenish to light-colored sericitic phyllite. The included fragments of the country rock are partly or completely altered and silicified, so that the whole mass forms a single unit with respect to weathering processes and to mining. An open cut has been made on the vein for a length of 15 feet, and it has been traced from tidewater up the hillside to a height of about 100 feet. In the face of the open cut the vein is about 6 feet wide. Sulphides are disseminated throughout the vein and comprise pyrrhotite, pyrite, and a little sphalerite. Assays are reported to have shown medium-grade value.

The second group comprises eleven claims on the south side of the bay about a quarter of a mile west of Windham. A tunnel near sea level has been driven alongside the vein for 150 feet with several crosscuts to cut the vein. At the entrance the vein system consists of two veins of "stringer lead" type, each about 5 feet wide and separated by 2 feet of schist. The veins consist of stringers of quartz with intervening leaves of schist. About one-third of the length from the portal the vein is 9 to 10 feet wide, consisting of quartz stringers with leaves of schist; about two-thirds of the length from the portal the stringers come together to form a strong vein about 5 feet wide, which pinches abruptly at the end of the tunnel to a stringer several inches wide. The vein is in green chloritic schist and carries a little sulphide.

At an altitude of about 375 feet an adit about 60 feet in length has been driven along an intersecting vein system in black slate. The veins are of the stringer type, are from an inch to a foot thick, and lie in part at an angle to the cleavage. Locally the veins have beautifully crystallized quartz and calcite in pockets and along fissures at an angle to the bedding. The stringers are not as abundant as in the lower tunnel, but high gold assays are reported from some of the stringers, which are mineralized with pyrite, sphalerite, galena, and free gold.

HELM BAY KING GOLD MINE, KETCHIKAN DISTRICT

The prospect of the Helm Bay King Mining Co. lies on the west side of Helm Bay, on Cleveland Peninsula, in the Ketchikan district about a mile from the head of the bay. The original claim was located in 1921. This was purchased by the company, and three additional claims were staked. The developments consist of a shaft 45 feet deep and numerous crosscuts and trenches to trace the vein. The equipment comprises a blacksmith shop, a 5-foot Huntington mill with 4 by 8 inch plates, an 18-foot Wilfley-Dodge rock breaker, one 15-horsepower and two 10-horsepower water wheels operating under a 250-foot head, and a 416-foot aerial tram. A corduroy trail leads from the beach to the mill at an altitude of 125 feet. The shaft starts at an altitude of about 300 feet, one-third of a mile from the beach.

There are two veins, the Alaska and Bonanza. The Alaska was the only one under development in 1923. It lies along a shear zone in greenstone and consists of quartz veinlets, mostly of a crosscutting gash type, associated with some lenses parallel to the foliation. The quartz is milky white and carries a little calcite and locally chlorite. Sulphides are rare and consist mostly of chalcopyrite with a trace of galena. Rarely coarse flakes of free gold are found along the borders between the quartz and the schist. Pyrite in small cubes as much as a quarter of an inch in diameter is disseminated through the schist. Usually the cubes are surrounded by a bleached sericitic halo. The most heavily mineralized schist layers are almost wholly bleached and sericitized. About three-fourths of the vein zone is schist and one-fourth quartz. The ore at the bottom of the shaft for a width of 8 feet is reported to have an average value of $14 in gold to the ton. The Alaska vein zone strikes northwest and dips on the average about 75° SE. The Bonanza vein is reported to strike at an angle to the Alaska.

COPPER PROSPECTS IN JUNEAU DISTRICT

PORT HOUGHTON

Near the head of Port Houghton on the mainland there is an old copper prospect on the southwest slope of the mountain spur that runs out from the south side into the bar separating the salt lake from the main arm. A slough is shown on the chart on the south side of the arm just west of the bar. The prospect is reached by a trail starting on the east bank near the head of the slough and running about a mile to the prospect. The main tunnel opening is at an altitude of about 750 feet. There is a cabin 35 feet lower.

The ore deposit is a metalliferous fissure vein lying along a shear zone between a light-colored rusty-weathering quartz-feldspar schist and a black hornblende schist. The vein strikes N. 50°–55° W. (magnetic), parallel to the schistosity, and dips 70°–80° W. At or near its outcrop the vein has been developed along the strike for a length of about 150 yards by three open cuts and two short adits, all of which crosscut the vein. The uppermost opening is about 70 feet above the lowest open cut. In addition an adit tunnel about 110 feet long and 60 feet below the outcrop has been driven into the face of the hill to crosscut the vein. A drift about 115 feet long follows the vein from this tunnel. It is possible that the vein has been traced farther than is indicated by the open cuts, as the work was done years ago and the continuation of the vein is obscured by forest litter.

In the open cut about 50 yards south of the tunnel opening the vein is about 6 feet thick in the upper portion but pinches to 2 feet at the base. A narrow breccia zone and a pegmatite vein with a quartz-muscovite mass occur in the hanging wall. In the adit just above the tunnel the width of the metalliferous zone is about 9 feet; in the next adit, about 30 yards north-northwest, it is about 10 feet wide; and 25 yards farther north-northwest it is about 12 feet wide with the hanging wall not shown. At about 25 yards beyond is an open cut in the hornblende schist of the footwall that shows only narrow lenses of mineralization. In the breast of the drift along the vein from the tunnel about 1 foot of ore is exposed in the hanging wall.

The ore consists of pyrrhotite, pyrite, magnetite, and chalcopyrite intergrown with the gangue minerals, which are predominantly quartz, garnet, and amphibole. The garnets are from one-eighth to one-fourth inch in diameter and have fair crystal forms. The amphibole is light green and occurs in long fibrous sheafs and bundles similar to actinolite, locally forming the predominant gangue mineral. Under the metallographic microscope the sulphides and magnetite are seen to occur as grains with irregular rounded borders intergrown with the gangue minerals, or as stringers interleaved with the gangue minerals. The metallic minerals and the gangue minerals belong for the most part to the same period of formation, though in part the sulphide minerals occur along fractures in the gangue minerals, indicating a later crystallization.

The magnetite shows a well-developed octahedral parting and modified crystal outlines. Many of the grains contain abundant small inclusions of pyrrhotite arranged along parting planes or fractures. Rarely a trace of chalcopyrite is associated with this pyrrhotite. Locally pyrite surrounds magnetite grains or is molded against them. It thus seems certain that the magnetite was the earliest metallic mineral to begin crystallization. Much of the pyrite shows a rough crystal form with relation to other minerals, and it may have been the second mineral to start crystallizing. The chalcopyrite is in part intergrown with the other minerals and in minor part appears to be interstitial, indicating that it may have finished crystallizing later than the other metallic minerals.

The character of both the metalliferous and the gangue minerals proves that the vein belongs to the high-temperature type. The relations of the vein to the wall rocks indicate that it has been formed through fissure filling rather than by replacement. The presence of so much garnet and amphibole, however, makes it appear that there may have been considerable solution and reaction with the wall rocks, particularly with the footwall hornblende schist. Lenticular veins of quartz, very rich in garnet and sparingly metallized, occur here and there in the ore vein, and in some places lenticular veinlets of glassy quartz are very abundant in the schist.

A small grab sample across the vein at one of the adits, including both rock and ore, gave the following results on assay: Copper, 1.34 per cent; gold and nickel, doubtful traces; platinum, none.

TRACY ARM

A copper prospect on Tracy Arm was relocated by Eugene Owens in 1922 and 1923. The prospect comprises three claims known as Neglected Prize Nos. 1, 2, and 3. It is about a mile south of the point at the first elbow on Tracy Arm. The trail runs from the west side of the first gulch east of the point to a shaft at an altitude of about 800 feet.

The vein lies within a narrow belt of aplitic injection gneiss which is bordered on the east by the quartz diorite of the Coast Range and on the west by a sheet of quartz diorite intruded into schist. The vein is parallel to the foliation of the gneiss and consists of sulphides with intermingled quartz and remnants of included country rock. The relations are those common to veins injected along foliation planes or deposited in a fissured zone in gneiss. The walls are not sharply defined, for veinlets of sphalerite, pyrite, and chalcopyrite, with a quartz gangue, are found in the wall rock.

The vein lies in a belt of timber and is covered with a veneer of vegetation and forest litter for its whole length, except where uncovered by prospect pits. A shaft 16 feet deep has been sunk on the vein, and it has been exposed by six prospect pits to the southeast and three to the northwest for a total length of over 500 feet. Neither end is shown. The vein is reported to range from 3 to 6 feet in width. Sulphides predominate over gangue and comprise pyrrhotite, sphalerite, chalcopyrite, pyrite, and a few veinlets of secondary marcasite. The gneiss is a siliceous variety consisting of quartz and feldspar with a little biotite.

Assays across the collar of the shaft are reported to run 5.6 per cent of copper and 7.3 per cent of zinc. Assays of samples from the full width of the vein in the prospect pits are reported to range from 1.5 to 4.1 per cent of copper and from 4.7 to 14.6 per cent of zinc.

POINT ASTLEY

The Point Astley property lies in the cove just east of Point Astley on Holkham Bay. The original claims are reported to have been staked as early as 1897. They were prospected by the Oceanic Mining Co. and are described by C. W. Wright,[27] as follows:

> The deposits here lie in the slate-greenstone belt, though not far to the southwest is an intrusive mass of gray diorite over a mile in width, which has probably played no small rôle in the deposition of the ores. Around this intrusive mass many of the sediments have been altered to quartzites and calcareous schists rich in mica.
>
> Irregularly distributed along the schistosity of this country rock there has been an introduction of sulphides, accompanied by quartz and calcite, with no apparent channels to which the metalliferous solutions were confined. This sort of filling has produced a mineral belt a few hundred feet wide and several hundred feet in length, within which occasional seams rich in silver and copper are encountered.
>
> The minerals are in the main bornite, pyrite, sphalerite, galena, and native silver. The proportions of the metals in these ores do not correspond to those of any other deposits in the Juneau belt.

Under the name of the Alaska Copper Mining Co. further prospecting was carried on between 1916 and 1920.

Development work has been done on two veins. One vein lies within green chloritic schist, which has probably resulted from the metamorphism and shearing of surface volcanic rocks. Some of the beds show evidences of an original fragmental character and were probably volcanic breccias; others may be tuffs and flows. The vein consists of quartz stringers in the green schist, together with mineralized schist. It is exposed along the shore at low water. Just back from tidewater an inclined shaft dipping 45° NE. has been sunk and a 100-foot crosscut run to intersect the vein in depth. A second shaft 300 feet to the southeast was sunk 60 feet and a crosscut run 40 feet to cut the vein. At 900 feet southeast of the second shaft a third shaft has been sunk 100 feet and a crosscut of 90 feet made to intersect the vein. It is reported that

[27] Wright, C. W., A reconnaissance of Admiralty Island, Alaska: U. S. Geol. Survey Bull. 287, p. 45, 1906.

three veins were encountered in this work, 8, 2, and 6 feet wide, and that an 18-inch streak of high-grade ore occurred along the footwall. The shafts were flooded at the time of the writer's visit.

A tunnel about 20 feet long cuts the other vein near the shaft just above tidewater. The vein is about 20 feet wide here and occurs in black slate. It consists of many quartz veins from a fraction of an inch to several inches in width, with bleached and mineralized muscovite schist leaves (possibly altered recrystallized slate). Almost all the sulphides occur in the intervening schist layers. The hanging wall appears to grade into the slate through a bleached and altered slate with sparingly disseminated sulphides. The ore in general is thinly banded and appears as alternating leaves or seams of metallized schist and milky-white quartz. A little less than 3 feet above the footwall a 10-inch layer of limestone with disseminated bands of sulphide is intercalated in the vein. The vein appears to pinch out about 20 yards to the northwest but is reported to extend southward into the mountain.

About 15 or 20 feet below the main vein is a stringer of ore about 1½ feet thick along which a short drift has been driven.

The metallic minerals of the vein in the slate comprise pyrite, sphalerite, bornite, galena, a trace of chalcopyrite, and a little chalcocite, covellite, and native silver. The ore is banded with alternating seams in which one or more of the minerals pyrite, bornite, and sphalerite predominate.

A specimen of ore which probably came from one of the shafts was examined with the metallographic microscope and showed the following phenomena: The predominant mineral is pyrite, which occurs in good euhedral crystals, and only rarely do the other minerals form reentrant angles in its crystal faces. The other primary sulphides, sphalerite, bornite, and galena, bear essentially mutual relations to each other, though the bornite and galena may in part be later than the sphalerite. Blebs of galena, sphalerite, and bornite occur in the pyrite; of galena and bornite in the sphalerite; and of galena and sphalerite in the bornite. The galena alone appears to be free of other minerals, and though it is commonly associated with the bornite in mutual relations it may overlap the bornite a bit, and a portion of it be a trifle younger. The bornite shows incipient alteration to chalcocite and covellite, and the galena is likewise partly replaced by a little chalcocite and covellite. The chalcocite and covellite are of secondary origin and due to descending surface waters. A bare trace of chalcopyrite occurs as minute grains in the bornite. The predominant ore consists of banded gangue and seams of sulphides, predominantly pyrite, with considerable sphalerite and a little galena and bornite.

Native silver is reported to occur locally in the veins but was not seen by the writer. Assays show that the high silver content is uniformly accompanied by high copper content. Bornite is the rich copper mineral, and the presence of secondary chalcocite and covellite in the bornite suggests the necessity for considering the hypothesis that the native silver may likewise be due to descending waters and may therefore not persist in depth. The bornite, sphalerite, galena, and chalcopyrite are definitely primary.

A specimen from the outcrop of the vein in the green schist is found to comprise the sulphides pyrite, chalcopyrite, and sphalerite. The sphalerite and chalcopyrite are contemporaneous in crystallization, but they show corrosion effects against the pyrite. All the minerals are primary.

MAGNETITE AT SNETTISHAM

The northern part of Snettisham Peninsula, on the mainland in the Juneau district, is composed of a mass of diorite and hornblendite about 2¾ miles wide, as exposed along the coast at the entrance of Port Snettisham. The eastern 1½ miles of this mass is hornblendite with associated variants. The most marked characteristic of this hornblendite mass, as of all the other masses of hornblendite in southeastern Alaska, is a rapid and large-scale variation in its texture. The predominant rock, however, is a black medium-grained variety composed almost wholly of hornblende, with accessory magnetite, apatite, and plagioclase. Coarse-grained pegmatitic variants occur within the mass and may consist of long columnar hornblende, of hornblende and biotite, of hornblende and pyroxene, of pyroxene and magnetite, or of magnetite alone. Here and there chlorite in large well-crystallized plates is intergrown with the other minerals. Rarely an epidote veinlet cuts the pegmatite veins. The hornblendite is intruded by dikes of diorite and of aplite. Narrow vein dikes of white albite occur sparingly, and rarely one composed almost wholly of pink orthoclase is found.

About 100 yards east of the first point opposite the post office at Snettisham there is a 6-foot vein of practically solid titaniferous magnetite. An open cut has been made on this vein, and in 1918 4 or 5 tons of ore was shipped to the Treadwell mines. It is reported to have carried 4 or 5 per cent of titanium.

A small specimen of the magnetite ore was polished and examined with the metallographic microscope. It consists of granular magnetite with accessory ilmenite and silicates. The ilmenite occurs almost wholly in grains from 0.2 to 1 millimeter in diameter with mutual boundaries against the magnetite, whose grain diameters are from

0.5 to 1.5 millimeters. The very small ilmenite grains occur along the boundaries of the magnetite. Ilmenite also occurs as thin microscopic lamellae parallel to the octahedral parting planes of the magnetite. Nonmetallic microscopic intergrowths of rodlike forms and rows of dots also occur along the octahedral parting planes of the magnetite, but with their pattern oriented at an angle of 45° to that of the ilmenite. The ilmenite, in the form of grains, constitutes about 8 per cent of the ore.

The country rock adjacent to the 6-foot vein is a medium-grained hornblende pyroxenite consisting of about 56 per cent of pyroxene, 26 per cent of brown hornblende, 14 per cent of magnetite, and 4 per cent of apatite. The magnetite with the associated apatite predominantly forms an interstitial mesh to the pyroxene and hornblende and rarely occurs as inclusions in the ferromagnesian minerals. The apatite is almost wholly associated with the magnetite and in part occurs as perfect crystals within it.

A most significant piece of evidence as to the probability of there being very large masses of titaniferous magnetite within the body of the hornblendite has been furnished by N. H. Heck,[28] of the United States Coast and Geodetic Survey. He shows that a map of the magnetic lines in this vicinity made by the steamer *Explorer* proves the existence of a pronounced center of local magnetic disturbance in the vicinity of Snettisham. Though apparently unaware of the existence of the magnetite prospect just described, Heck drew the following significant conclusions:

> The natural question is, What causes this great disturbance of the compass, which is felt over an area of 20 square miles of land and water and is strong over an area of 8 square miles? There is a gold mine in the vicinity, and it is safe to say that it is caused by associated minerals. Whether there is a large mass of the useful iron ore magnetite, and whether, if so, it is workable, is a matter for the future. It is certain that there is an immense mass of magnetic material.

The presence of the titaniferous magnetite vein just described suggests, in part, what the probable character of the "immense mass of magnetic material" may be.

Knopf[29] has described titaniferous magnetites in similar hornblende-pyroxene rocks near Haines, in the Skagway district. The ore there, however, occurs for the most part as disseminated deposits. A sample of ore from the Haines prospect crushed to 100-mesh and separated magnetically is reported to contain 3.91 per cent of titanium dioxide.

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[28] Heck, N. H., Where the compass fails to guide: Sci. Am., March, 1923, p. 192.

[29] Knopf, Adolph, The occurrence of iron ore near Haines: U. S. Geol. Survey Bull. 442, pp. 144–146, 1910.

WHITING RIVER SILVER PROSPECT

A silver prospect on which some work has been done in past years lies near Whiting River, which flows into Port Snettisham, on the southeast side of an ice-capped mountain ridge. (See fig. 6.) This prospect has been known since 1896 and has been relocated again and again. Its inaccessibility is a drawback. A skiff with outboard motor may, with care, be taken upstream 5 miles from Whiting Point to the cabin of Gudmund Jensen, at the head of a slough. From the cabin a blazed trail leads along the northerly side of a brook and two small lakes nearly to the head of the second lake. Then it turns up the right-hand side of a gulch to timber line and crosses a small valley filled with large boulders to a conspicuous

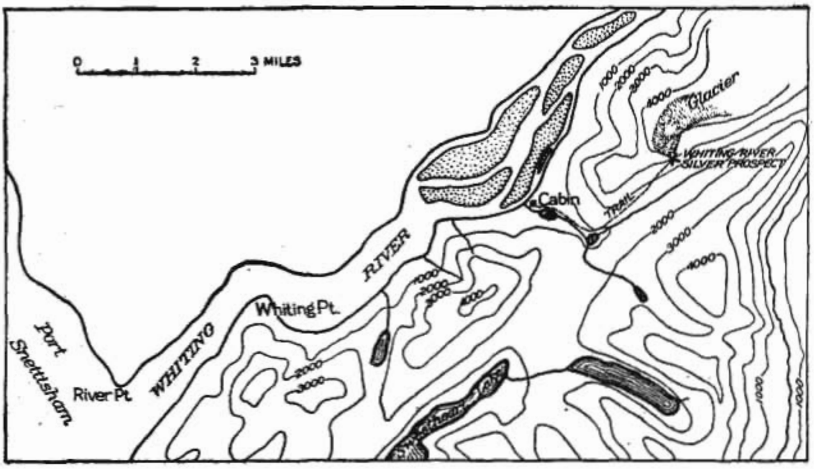

FIGURE 6.—Sketch map showing location of Whiting River silver prospect, near Port Snettisham

goat trail, which goes up the face of the mountain to the prospect. The prospect is about 3½ miles from the cabin, on the east side of a brook draining from a glacier, at an altitude of 2,800 feet.

A small open cut has been made on the vein, and a tunnel started to crosscut the vein below the outcrop. The tunnel is 118 feet long but is reported not to have been driven far enough to reach the vein. The vein is a quartz fissure vein in a wide belt of coarsely crystalline dolomite which lies within the usual quartz diorite of the Coast Range. At the face of the open cut the vein is 40 inches wide. Along the footwall there is about 10 inches of almost solid sulphides, and the rest of the vein contains several per cent of sulphides. The sulphides comprise arsenopyrite, pyrite, galena, sphalerite, and chalcopyrite. Arsenopyrite is predominant. It is reported that very high assays for silver have been obtained from selected specimens and that moderate assays are common.

The writer had no opportunity to make a careful geologic examination of this prospect. Superficial observations suggest that the vein is offset by faulting. Quartz porphyry dikes are found in the dolomite, and the mineral deposits are probably genetically connected with the magma that gave rise to the dikes.

BARITE IN PETERSBURG DISTRICT

In the Petersburg district barite was discovered on the northwest end of Kuiu Island, in the vicinity of the Keku Islets, and along the west shore of Saginaw Bay (fig. 7). Three claims were located by Hungerford and two by Barrows in 1923 on the veins about 4 miles southeast of Point Cornwallis. Opposite a small island a series of conglomerate and volcanic rocks, including rhyolitic tuffs, breccias, and flows, crop out along the shore. They are much broken up, shattered, and fissured. The stronger fissures have in general a northerly strike, but they are irregular in trend, with many subsidiary fractures. The veins filling the fissures range from a fraction of an inch to 4 or 5 feet in width and pinch and swell markedly along the strike. One strong vein, from a fraction of an inch to 2 feet wide, can be traced 200 feet. Minute veinlets of barite fill short gashes throughout the volcanic rocks. The barite is usually of coarse, lamellar character and has a pinkish hue. A few veins are pure white and translucent and have a radiate columnar structure.

The felsite breccias are also found on the north end of the west side of the long island about 3 miles southeast of Point Cornwallis. Veinlets of barite several inches wide are common here. Opposite this island on Kuiu Island the felsite volcanic rocks and conglomerate are overlain by basaltic volcanic rocks with many veinlets of brilliant red jasper.

At the east end of the eastern island of a pair of long islands about 7 miles southeast of Point Cornwallis barite veins are exposed along a fissured zone in limestone. This zone is the result of faulting between greenstone and limestone. Along it are wide veins of chalcedony with drusy quartz crystals lining the many open spaces and locally associated with barite. Veins of chalcedony as much as 10 feet wide were seen here. In part the veins follow the contact of basalt dikes that are intrusive into the limestone. Many barite veinlets occur in the limestone, but they are usually not over several inches wide and where wider pinch and swell abruptly. Locally traces of galena and pyrite are associated with the barite. Calcite is also common in the barite and chalcedony veins. The barite is white and in tabular crystals adjacent to limestone fragments.

On the southwest side of Saginaw Bay, just about midway between the head and the mouth, is a small cove in which an old cabin and piling still stand. Silurian limestone beds crop out here, and for a considerable distance to the south they are fractured across the bedding and the fissures are filled with coarse lamellar barite of a pinkish hue. These veins range from mere facings of the fractures and short irregular veinlets to well-defined veins an inch to a foot in width, but most of them are narrow. Barite veinlets were also noted in the limestone beds to the north of the cove.

At the tip of the west headland of Saginaw Bay barite veins occur in abundance in a series of interbedded volcanic conglomerates of reddish and greenish hue, similar to those on Keku Straits. The

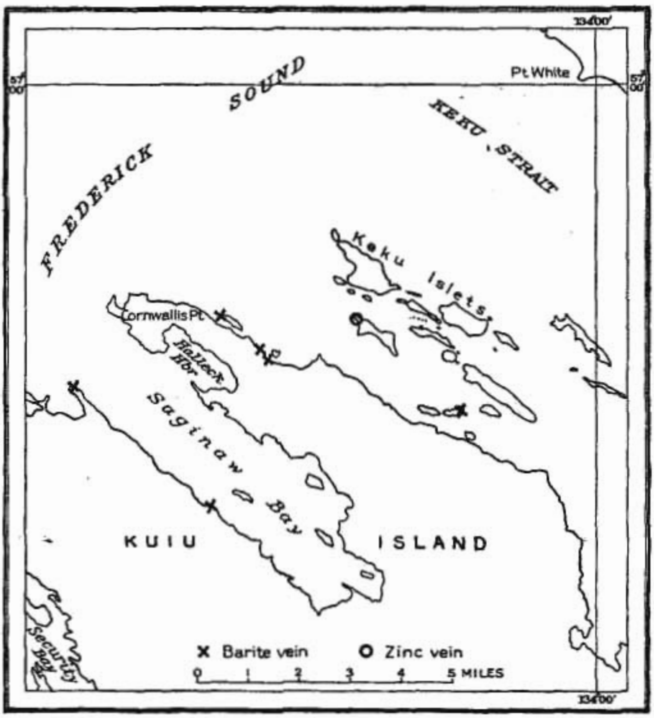

FIGURE 7.—Map showing location of mineral deposits at northwest end of Kuiu Island.

veins are from an inch to a foot in width, and the main fissures strike about N. 35° W.

The origin of the veins is not evident. Basalt dikes, however, are found in their vicinity, and there is a possibility that the mineralization followed the intrusion of these dikes and was effected by solutions that originated in the same underlying magma as the dikes and deposited their dissolved mineral matter in the fissured volcanic rock, conglomerate, and limestone. The structure of the veins and the association of chalcedony with the barite at one locality suggest that they are of the low-temperature, low-pressure, near-surface type. The zinc veins of ladder type in the basalt dikes on the Keku Islets are probably of similar origin and belong to the same period of mineralization.

A large volume of barite is present in the veins along the southwest sides of Keku Straits and Saginaw Bay, but the mineral matter as exposed is distributed in a great number of gash veins instead of being concentrated in strong, well-defined fissures. It is possible, however, that as the mineralization was so extensive prospecting may discover veins of commercial size.

Other deposits of barite in southeastern Alaska are found on the Castle Islands, in Duncan Canal, Kupreanof Island,[30] and at Lime Point, on Prince of Wales Island.[31] Claims on the Castle Islands have been patented by the Alaska Treadwell Gold Mining Co.

Narrow stringers of barite are also found just south of Bibora Point, on the southeast end of St. Ignace Island, which lies off the west coast of Prince of Wales Island. They consist of white lamellar barite in beds of sandstone and conglomerate.

KEKU ISLETS ZINC VEIN, PETERSBURG DISTRICT

A metalliferous vein with a mode of occurrence unusual in the Petersburg district is found on one of the Keku Islets, off the north end of Kuiu Island. The islet is the large one due south of the northwesternmost large islet of the group. (See fig. 7.)

The islet is for the most part formed of gently warped interbedded sandstone and conglomerate. The pebbles in the conglomerate are chert, limestone, and fragments of other rocks. Traces of carbonized plant remains are found in the sandstone. Basalt dikes are common on the island. The age of the sedimentary beds is uncertain, but the geographic location and the presence of a few intercalated limestone beds suggest that they are Carboniferous. The dikes may be either Mesozoic or Tertiary but are probably Tertiary.

Many of the dikes are crossed by fractures filled with calcite, but these fractures are usually lacking in metalliferous minerals, and there has been little or no alteration of the wall rock. One such dike, however, is crossed by metalliferous veinlets adjacent to which sulphides have been locally introduced into the country rock. This dike is on the west side of the northwest side of the northwest tip of the island, about 150 yards south of the point. The dike strikes about N. 60° W. and cuts across the conglomerate beds, which strike about N. 15° W. It is exposed along the beach for a length of about 150 yards. At the south end it is about 7 feet wide, but

[30] Burchard, E. F., A barite deposit near Wrangell: U. S. Geol. Survey Bull. 592, pp. 109–117, 1914. Buddington, A. F., Mineral deposits of the Wrangell district: U. S. Geol. Survey Bull. 739, pp. 72–73, 1923.

[31] Chapin, Theodore, Mining developments in southeastern Alaska: U. S. Geol. Survey Bull. 642, p. 104, 1915.

toward the northwest it splits, and the two parts are separated by a band of conglomerate. One offshoot maintains about the same width as the original; the other widens from about 2 feet to 7 feet. The fresh basalt is a normal black felsitic rock, consisting of interlocking labradorite laths and pyroxene in ophitic texture. Titaniferous magnetite, commonly in skeleton crystals, is a common accessory. Some interstitial quartz and microperthite are present.

The dike and its branches are broken by fractures oriented roughly at right angles to the walls, somewhat after the fashion of the rungs of a ladder. These fractures are filled with sphalerite, and the wall rock adjoining the fractures is altered and bleached white. As seen in thin section, this alteration has consisted in the partial replacement of the feldspars by calcite and the alteration of the groundmass of the rock, with separation of many discrete particles of magnetite. The pyroxenes are as fresh as in the unaltered rock. The sphalerite veinlets are from a fraction of an inch to an inch wide and from a foot to several feet apart. The altered zones are in places as much as a foot wide and include veinlets of sphalerite aggregating several inches. Locally the sphalerite impregnates the altered rock. The veinlets are confined almost exclusively to the dikes and rarely cross the contact into the country rock, though they occur along the contact of the dikes with the sediments.

Locally adjacent to the dike are lenses of minutely brecciated flinty or cherty quartz with interstitial fillings and veinings of pyrite and marcasite. The pyrite was evidently earlier than the marcasite, as the marcasite forms the central portions of the veinlets and the pyrite the walls. Some of the pyrite veinlets have drusy surfaces coated with minute pyrite octahedra. Both the chert and the pyrite-marcasite veinlets have in turn been minutely brecciated and fractured, and the fissures have been filled with sphalerite similar to that which fills the fractures in the dikes. Only a trace of pyrite occurs with the sphalerite that fills the fractures in the dikes. Pyrite occurs sparingly, however, as an accessory mineral in the altered wall rock adjacent to the veins. Only a little gangue, mostly calcite and locally flamboyant quartz, is associated with the sphalerite in the veinlets.

A sample of the vein matter of the sphalerite veins was assayed and yielded 37.4 per cent of zinc, 0.24 ounce of silver to the ton, and a doubtful trace of gold. A sample of the cherty pyritic vein matter adjacent to the dike was assayed for gold with negative results. These results indicate that the occurrence is of scientific interest only, as it is the only one yet found in these districts where ore minerals are positively associated with intrusive rocks that do not belong to the Coast Range group.

THE OCCURRENCE OF COPPER ON PRINCE WILLIAM SOUND

By Fred H. Moffit

INTRODUCTION

The copper deposits of Prince William Sound attracted the attention of prospectors as early as 1897, when the properties of the Alaska Commercial Co. on Landlocked Bay, the Gladhaugh mine at Ellamar, and the Big Bonanza mine on Latouche Island were staked. Doubtless many deposits of copper minerals were known to the natives and perhaps to a few traders long before that time, yet little if any effort was made to investigate them. Interest in copper grew rapidly after 1897, but not until 10 years later did it reach its high point. By 1907 the number of men engaged in mining copper and in the search for copper in this region had increased many times, and the amount of money invested in such enterprises had reached large proportions. Furthermore the possibilities of the Sound region for producing copper had been presented to investors in many places outside of Alaska, so that the interest in it was by no means local. After 1907, however, the less favorable financial situation, the failure of most of the prospects to become mines, and finally the World War made the raising of money for developing copper properties difficult and reduced prospecting almost to the vanishing point. The only place where copper is now being produced on Prince William Sound is at the mines of the Kennecott Copper Corporation on Latouche Island.

The copper deposits of the Sound have been studied by many persons representing either the Federal Government or private investors, and a considerable literature on the subject has accumulated. This was summarized by Johnson [1] in a report published in 1915. Several papers dealing with the geology and copper resources of Prince William Sound or of particular districts in it have appeared since that time, notably papers by Johnson [2] and Bateman.[3]

[1] Capps, S. R., and Johnson, B. L., The Ellamar district, Alaska: U. S. Geol. Survey Bull. 605, pp. 52–61, 1915.

[2] Johnson, B. L., Mining on Prince William Sound; The gold and copper deposits of the Port Valdez district, Alaska: U. S. Geol. Survey Bull. 622, pp. 131–188, 1915. Mining on Prince William Sound, Alaska: U. S. Geol. Survey Bull. 642, pp. 137–145, 1916. Mining on Prince William Sound; Copper deposits of the Latouche and Knight Island districts, Prince William Sound: U. S. Geol. Survey Bull. 662, pp. 183–220, 1917. Mining on Prince William Sound; Mineral resources of Jack Bay district and vicinity, Prince William Sound: U. S. Geol. Survey Bull. 692, pp. 143–173, 1919.

[3] Bateman, A. M., Geology of the Beatson copper mine, Alaska: Econ. Geology, vol 19, pp. 338–368, 1924.

The writer visited all the better-known copper deposits of Prince William Sound in 1923 and spent some weeks in studying the general geologic relations of the ore deposits to the rocks inclosing them. This paper therefore contains some new material, although it has drawn freely on the earlier observations of other workers, especially those of Johnson. It is written for the purpose of presenting information regarding the character of the copper deposits but is not intended to give descriptions of individual properties except so far as such descriptions illustrate principles which it is desired to make clear. It will be fully evident to the reader that many problems regarding both the general geology and the ore deposits still remain to be solved.

Prince William Sound lies at the most northern extension of the Gulf of Alaska. It is almost shut off from the Pacific by a chain of large islands extending southwestward across its south side. Numerous smaller islands are scattered through it, especially on the west side, where Knight Island, Latouche Island, and various other less well-known islands are situated. The shore line is long and intricate, for the sides of the Sound on the east, north, and west are a succession of deep bays and narrow inlets shut in by rugged mountains from which scores of glaciers descend. The country surrounding the Sound is all mountainous, and the higher part is covered by snow and ice. The greatest relief is found along the north side, where the tallest peak in this part of the Chugach Range reaches a height of over 13,000 feet and the crest line of the range is over 10,000 feet. The relief of the country east and west of the Sound and of the larger islands is less but is measured in thousands rather than hundreds of feet.

The whole of Prince William Sound was once filled with glacial ice, which doubtless covered the smaller islands and possibly may have pushed out to sea beyond Montague and Hinchinbrook islands. Presumably the gathering ground for the ice was in the highlands surrounding the Sound. Only the higher peaks could have risen above the ice surface at the time of maximum glaciation. At a later time Montague Island and the other islands to the west, which may have been entirely covered when the ice was thickest, were above the ice surface and directed the southward-moving currents through the passages that separate them. The passage between Montague and Hinchinbrook islands possibly served as another outlet at that time. Eventually, however, the supply of ice from the mountains diminished, and the glaciers were reduced to their present condition. Glaciation had a prominent part in giving their present form to the mountains and is of importance to the miner and student of ore deposits because glacial ice stripped away any oxidized ores that may have existed in preglacial time and protected the remaining ores from further oxidation for an indefinite time.

Prince William Sound is now characterized by an abundant precipitation, which in unusual years like 1912 has been known to amount to nearly 200 inches. Precipitation takes the form of snow in the winter. The snowfall is heavy, and the snow hangs on mountain sides and in many gulches till the early part of the summer—in fact, the highest ridges north of the Sound are above snow line the year round. The temperature is more moderate than that of interior Alaska, being neither hot in summer nor intensely cold in winter. These conditions are believed to have prevailed since the great glaciers disappeared, and in consequence oxidation of the ore bodies since then has been slight.

GEOLOGY

General features.—The rocks of Prince William Sound are dominantly sedimentary but locally include dark-colored, more or less altered lava flows and intrusive rocks, commonly termed greenstones, and a few relatively small areas of granite. Light-colored porphyritic dikes, probably related to the granite, intrude the sedimentary rocks of the northern part of the Sound in many places. The sedimentary rocks are in the main closely folded graywacke and slate showing a varied degree of metamorphism, which is more noticeable on the north and west sides of the Sound than on the east side and on the large islands of the south side. Beds of conglomerate and of limestone are interstratified with the slate and graywacke in a few places, but limestone in particular is uncommon.

The sedimentry rocks of the Sound were separated by the early workers in the district into two "series" or groups designated the Valdez "series" and the Orca "series." This separation is indefinite, and its accuracy has been questioned, but it is accepted here for the present as being probably correct in a broad way. Schrader[4] states that the Valdez "series" or group may be only a more highly metamorphosed phase of the Orca "series" but that because of lithologic differences it seems desirable to distinguish the two by different names. The stratigraphic and structural relations of the Valdez and Orca groups are still undetermined, yet there is evidence to support the reversal of the relative ages assumed by Schrader and the assignment of at least a part of the Orca group to the Paleozoic era and of the Valdez group to the Mesozoic era. They may be as widely separated as the Silurian and the Cretaceous.

[4] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 408, 1900.

Orca group.—The rocks that have been designated the Orca group are typically displayed on the shores of Orca Bay. These rocks consist dominantly of black and gray slate interbedded with graywacke or arkose. The slate in most places has a fair cleavage but in some places lacks the cleavage and may be called argillite. The graywacke varies widely in color and in composition. It is a dense quartzitic sandstone made up of angular fragments of quartz, feldspar, and dark minerals. The proportions of the constituents vary, however, and in many places the dark minerals are so much reduced in relative quantity that the rock is distinctly lighter in color and may be called an arkose.

The beds of the slate and graywacke range in thickness from less than a foot to 100 feet or more, although the beds of graywacke are commonly not over 50 feet thick and in general are much less. Thick beds of slate are more common than thick beds of graywacke. Nearly everywhere the bedding is conspicuous, so that strike and dip observations are easily made, although structure is hard to determine because of close folding, overturning of folds, drag folds, and the scarcity of beds that can be correlated. The shore lines give excellent and almost continuous exposures. One type of exposure is a succession of alternating slate and graywacke in approximately equal proportions, or with graywacke predominant, in beds about a foot thick, more or less. Another type shows one or more thick beds of graywacke, vertical or dipping at a high angle, flanked by interbedded graywacke and slate and finally by slate alone. Beyond the slate is interbedded slate and graywacke and finally graywacke again. The succession of changes is rhythmical like waves on the sea and may all take place in 100 yards or less but is repeated over and over. This transition is gradual. The change from the graywacke begins with beds of graywacke of diminishing thickness separated by slate beds of increasing thickness which finally replace the graywacke entirely. These successive alternations of thick beds of graywacke with slate separated by interbedded thin slate and graywacke represent either similar conditions of sedimentation repeated with much regularity, or possibly in places a repetition of beds due to close folding.

Several prominent beds of conglomerate appear in the Orca group at different localities on the Sound. A few beds of dark impure limestone are also known. Occasionally scattered pebbles are seen in the slate, or the graywacke is coarse grained and becomes a grit or even a fine conglomerate.

The areas mapped as Orca sedimentary beds include dark-colored igneous rocks, described on page 145, and at least one area of granite, which lies on the east side of the Sound between the heads of Sheep Bay and Port Gravina.

The Orca rocks are closely folded and faulted, yet the regional metamorphism of the rocks of the southern part of Prince William Sound is not pronounced. The age of these rocks is not known, but fossils collected from Montague Island in 1923 suggest that they are Paleozoic and may be as low in the Paleozoic as Silurian or Devonian.

Valdez group.—The rocks in the vicinity of Port Valdez are chiefly thin-bedded slate and graywacke, but they are more metamorphosed regionally than the rocks of Orca Bay and show other differences. In places the rocks of this type are less thinly bedded than the sedimentary beds of Orca Bay, and the bedding is less conspicuous. Moreover, in the district north of Valdez and on the west side of the Sound the graywacke contains a larger proportion of dark particles and has less the appearance of sandstone than much of the graywacke or arkose of the southern part of the Sound, yet in the vicinity of Ellamar and elsewhere are slate and graywacke in alternating thin beds where the graywacke includes light-colored feldspathic sandstone like some of that in the Orca group. Locally the slate and graywacke are metamorphosed to a degree that would warrant calling them schists. The Valdez rocks, in spite of their slightly greater metamorphism, show little if any more folding than the Orca rocks. Like the Orca rocks, they were originally gray or black muds and feldspathic sands with more or less dark minerals. They were cemented and folded and metamorphosed to form the present beds. They were derived from older rocks which were undergoing weathering so rapid that the resultant sands and finer particles were not greatly oxidized and were not worn sufficiently to destroy their general angular form.

The age of the rocks about Port Valdez is not known. Fossils have been collected at a number of places from rocks regarded as belonging to the Valdez group. They are not diagnostic but make the Paleozoic age of the rocks seem doubtful and indicate rather that they may eventually be shown to be Mesozoic, possibly Cretaceous.

Greenstones.—The term "greenstone," so frequently used in describing the geology of Prince William Sound, is applied to certain altered igneous rocks, including lava flows that welled out over the surface from vents in the crust; tuffs and agglomerates; and other igneous rocks, subordinate in amount, that were intruded into the crust as dikes, sills, and larger masses of less regular form. The two outstanding localities where greenstones are abundant are Knight Island and the vicinity of Landlocked and Boulder bays, both of which were centers of volanic activity where lava flows, tuffs, and agglomerates were especially developed. Centers of less importance are Glacier Island and the south end of Elrington Island. The intrusive greenstones, although occupying less area than the flows and other extrusive forms, are more widely distributed and are particularly abundant in the islands between Latouche and the mainland.

The greenstones as described by Johnson[5] range in color from light gray through shades of green to greenish black and show a wide range of texture. Some are of fine, even grain; others are coarse grained. The diabasic texture is common. Both porphyritic and nonporphyritic lavas are found, and also amygdaloidal lavas in which the vesicles have been filled with epidote, quartz, and chlorite, as well as ellipsoidal lavas.

The greenstones appear to be differentiates from a single magma but range in composition from that of andesite and diorite to that of gabbro, diabase, and peridotite. In most places they are considerably altered. Calcite resulted from the alteration of the more feldspathic (dioritic) varieties, and calcite, sericite, chlorite, epidote, quartz, and leucoxene from that of the more basic varieties. Shearing and chemical alteration by circulating waters changed the greenstone locally to chloritic schist or brought about epidotization or silicification.

A most noticeable feature of many of the lava flows is the ellipsoidal or pillow structure. This is well developed in the Ellamar district and especially on Knight Island, where the bare ledges of the mountains and the shores of the north end of the island display the ellipsoidal structure on a large scale and in many places suggest the appearance of giant conglomerates because of it.

The greenstones with some possible exceptions are thought to belong to one period of volcanism, although they were not formed simultaneously. Repeated intrusions and extrusions of molten magma took place, so that earlier flows and dikes are cut by younger dikes, and new lava flows were poured out over older flows. Because of the uncertainties regarding the age of the sedimentary rocks, the age of the greenstones is also in doubt. All the sedimentary rocks of the district are cut by greenstones and are therefore older than the greenstones. This suggests a possible Cretaceous or later age for the greenstones, if the Valdez group is correctly interpreted as being in part Cretaceous.

Brooks[6] regards the last two great epochs of diastrophism affecting Alaska as having been in Jurassic or Cretaceous and post-Kenai (Eocene) time. These two epochs of diastrophism were times of great igneous activity and are most significant in relation both to the tectonic history of Alaska and to the formation of many of the

[5] Johnson, B. L., unpublished manuscript.

[6] Brooks, A. H., Outline of tectonic history of Alaska (in preparation).

ore deposits. So far as the evidence is known at present, the greenstones of Prince William Sound may belong to the earlier rather than the later of these two epochs, but they can not now be assigned definitely to either.

CHARACTER OF THE SULPHIDE DEPOSITS

FORM OF THE SULPHIDE BODIES

The copper deposits of Prince William Sound are simple in form and in mineral composition, and all with the possible exception of a few in the vicinity of Cordova belong to one general type. They consist of copper and iron sulphides, notably chalcopyrite, pyrite, and pyrrhotite, deposited from mineralized solutions along fault planes or fracture planes in fault zones, or of these same sulphides disseminated through the country rock adjacent to such planes. Ordinarily veins of sulphides and disseminated sulphides are associated together in the same deposit. The vein deposits are of tabular or lenticular form. The disseminated ore bodies, on the other hand, are irregular in form and variable in copper content. The disseminated sulphide minerals are present as a multitude of veinlets or as grains replacing minerals of the rock between veinlets. As a rule the boundary line between disseminated ore and waste rock is not evident to the eye and is determined only by systematic mine sampling, for the quantity of the replacing sulphides ordinarily varies inversely with the distance from the more open channels of the mineral-bearing solutions, and the ore body grades finally into barren rock. In the ideal case a perfect gradation exists from ore with a maximum of metallic sulphides to country rock. In many deposits good evidence may be found to show that the mineral-bearing solutions made their way along openings, such as fault planes and joint planes, which they found available and deposited their sulphides either in these openings or in the adjacent rock walls. The sulphide bodies or veins along the fault planes are probably in part a filling of open cavities but may be much more largely formed by the replacement of beds particularly susceptible to replacement, or of wall rock and the fragmental material in the fault zone.

Possibly the walls of the fault may have been separated or forced apart as the vein grew, so that large open cavities did not exist at any time, or it may be that the pressure of the solutions was sufficient to support the walls of cavities along the fault planes and allow the formation of cavities of considerable size. Although they were probably formed at the same time by the same solutions, the veins and the disseminated sulphides were deposited under somewhat different conditions. The massive tabular bodies of sulphides were deposited by solutions having considerable freedom of movement along channels that followed the fault or fracture planes. The resulting sulphide bodies, although limited in extent and varying in width, are practically continuous. The disseminated ores, on the other hand, were deposited from solutions that made their way through the intricate channels formed by a multitude of tiny openings in shattered country rock. The solutions followed even microscopic openings and not only filled open cavities but took into solution the minerals of the rock itself and replaced them with metallic sulphides and gangue. The circulation of such solutions must have been much less rapid than that of the solutions in the trunk channels along the faults. It is readily seen that the form of the disseminated deposits produced under such conditions is likely to be far less regular in outline than that of the vein deposits.

The location of most of the ore bodies is evidently dependent on faults that cut the country rock. These faults provided the channels by which the mineralized solutions made their way toward the surface from the depths, and their shattered walls were especially subject to the attack of the solutions. The weakness of the rocks adjacent to faults finds topographic expression in hundreds of places on Prince William Sound in depressions produced by the more rapid weathering of the fractured rock of the fault zones.

In a few places, however, the rock of the fault zone was cemented with material that made it more resistant than the adjacent country rock, and an elevation rather than a depression marks the location of the fault. A few prospectors have made extensive use of the topographic expression of faults in their search for ore bodies.

OXIDATION OF THE ORE BODIES

The copper deposits of Prince William Sound show only surface oxidation. Enrichment or impoverishment of the deposits through alteration due to oxidizing surface waters is not recognized, and the ore bodies are seemingly unchanged from their original condition. If an oxidized zone were ever present, it was completely removed from all the known ore bodies during the time when the region was covered with glacial ice, and a new oxidized zone has not been formed, for oxidation since the retreat of the ice has not been sufficient to affect more than the surface of exposed ore bodies. This condition is in strong contrast with that of the copper deposits at Kennicott, where a considerable proportion of the ore mined from the lowest levels yet reached, 1,750 feet, is carbonate ore. The condition of the copper deposits of Prince William Sound in preglacial time is not known. Possibly they were below sea level and were not subject to oxidation. Whether this is true or not, it is probable that glacial erosion was profound and was competent to remove a considerable thickness of oxidized ores if any existed. The present climate is cool and damp and not calculated to promote rapid oxidation of rocks or ores. Probably similar climatic conditions or possibly conditions even less likely to promote oxidation have prevailed since the time of maximum glaciation.

MINERALS OF THE COPPER DEPOSITS

The usual minerals associated together in the copper deposits of Prince William Sound are a few metallic sulphides and a much smaller number of gangue minerals. The more common valuable minerals are pyrite, pyrrhotite, chalcopyrite, chalmersite (cubanite), sphalerite, galena, and quartz. Gold and silver in varying amounts are present. These minerals may be regarded as typical of the Prince William Sound copper deposits with the exception of a few prospects near Cordova, where the more abundant copper sulphide is chalcocite rather than chalcopyrite and is accompanied by a little native copper. Chalcopyrite and chalmersite (cubanite) are the only copper minerals among those listed as typical of the Sound deposits which are of present or probable future commercial importance, although several other copper minerals have been recognized. It is of considerable interest that nickel has been reported from the copper deposits at four or five localities.

The occurrence of copper sulphides and other associated minerals of the Ellamar district was described by Johnson,[7] and as the minerals of that district are typical of the other copper deposits of the Sound the list prepared by him is presented here with slight modification.

Minerals occurring in the ore deposits of the Ellamar district

Mineral	Composition	Occurrence
Arsenopyrite	FeAsS	Associated with other sulphides at old Alaska Commercial Co.'s property, Landlocked Bay.
Azurite	$2CuCO_3.Cu(OH)_2$	Oxidation product of the copper sulphides.
Calcite	$CaCO_3$	Gangue mineral of the ores.
Chalcopyrite	$CuFeS_2$	Principal copper-bearing mineral of the ores.
Chalmersite	$CuFe_2S_3$	Intimately associated with chalcopyrite at Threeman Mining Co.'s mine on Landlocked Bay and elsewhere.
Chlorite	Complex hydrous silicate of Fe, Mg, and Al.	
Copper	Cu	Oxidation product of copper minerals of ore.
Epidote	Complex hydrous silicate of Ca, Al, and Fe.	A gangue in some of the ores.
Galena	PbS	One of the sulphides of the ores. Not very common.
Gold	Au	Present in most of the ores. Relationship unknown.
Limonite	$2Fe_2O_3 3H_2O$	Oxidation product of iron minerals.
Malachite	$CuCO_3.Cu(OH)_2$	Oxidation product of the copper sulphides.
Pyrite	FeS_2	Abundant ore mineral at some prospects.
Pyrrhotite	$FeS(S)x$	Abundant ore mineral at most prospects.
Quartz	SiO_2	Gangue mineral of the ores.
Silver	Ag	Presence in ores shown by assays.
Sphalerite	Zn(Fe)S	A common ore mineral.

[7] Capps, S. R., and Johnson, B. L., The Ellamar district, Alaska: U. S. Geol. Survey Bull. 605, pp. 68–72, 1915.

Several other copper sulphides, such as bornite, chalcocite, and covellite, the sulphantimonide tetrahedrite, and the oxide melaconite, together with sulphides of other metals, as marcasite and stibnite, and the carbonates siderite and ankerite have been reported from different parts of Prince William Sound. The presence of one or two of these minerals, however, has not been confirmed.

The primary ore minerals and those of later origin are listed by Johnson for the Ellamar district as follows:

Primary	*Secondary*
Native metals:	Native metal:
Gold, silver.	Copper.
Oxide:	Oxide:
Quartz.	Limonite.
Sulphides:	Sulphide:
Arsenopyrite, chalcopyrite, galena, pyrite, sphalerite, chalmersite (cubanite).	Chalcocite (?).
	Carbonates:
	Malachite, azurite.
Carbonate:	
Calcite.	
Silicates:	
Chlorite, epidote.	

The sulphide minerals are of present commercial value only for the copper which they contain and for the gold and silver associated with them. Chalcopyrite is the important copper mineral of all the copper deposits. The pure mineral contains 34.5 per cent of copper, but as chalcopyrite is invariably associated with one or more of the other sulphides the richest ore bodies contain only a fraction of this amount of copper. Chalmersite, or cubanite, the other copper mineral, contains 23.5 per cent of copper when pure and has been an important constituent of the copper ore shipped from Landlocked Bay. Chalmersite has a wide distribution in the Prince William Sound region and has been recognized at various places. It is present in the ores from Latouche Island but is of little importance in the copper production of that place.

Pyrite is present in all the ore bodies, and pyrrhotite is usually present also. Pyrrhotite is more abundant than all the other sulphides in some localities. At the Beatson mine, on Latouche Island, it is the most abundant mineral of a solid vein of sulphides, in places 10 feet thick, along the Beatson fault, which forms the hanging wall of the ore body. This vein, however, has a low copper content and is not mined. Pyrrhotite is abundant at other localities on Latouche Island and on Knight Island. Arsenopyrite is reported from a few places, as at Landlocked Bay, yet it has been recognized more frequently in the gold deposits of Prince William Sound than in the copper deposits.

Sphalerite appears to be present in practically all the copper deposits in the form of small crystals or grains scattered through other sulphides, and at the Ellamar mine it forms veins which are gold bearing. Galena also has been noted at several localities, both in the rough hand specimen and in polished surfaces examined under the microscope. It is much less common than sphalerite and has no commercial value.

Gold and silver are shown by the assays and are recovered from the ores treated at the smelter, but they have not been recognized by the eye in hand specimens from any of the deposits. Probably they are present as native metals in pyrite or some other sulphide.

The principal gangue mineral accompanying the metallic sulphides is quartz, which is commonly found intergrown with the massive sulphides of the veins and as replacement quartz in the country rock that contains disseminated sulphides. Like the sulphides it filled cavities and replaced original constituents of the rock itself. Calcite and ankerite are associated with the ores in places. Chlorite and epidote were also formed in some of the veins by chemical reactions between the mineralized solutions and the wall rocks.

Although the copper deposits do not show more than superficial oxidation several secondary minerals are seen on some of the outcrops of the ore bodies. Among these are native copper, chalcocite (?), malachite, and azurite. Melaconite and one or two other minerals are also reported, and it is probable that a detailed study of the copper deposits would extend the list of copper and associated minerals.

ORIGIN OF THE ORE DEPOSITS

The copper deposits of Prince William Sound exhibit an association of metallic sulphides classified by Lindgren[8] as belonging to the metalliferous deposits formed at intermediate depths by ascending thermal waters and in genetic connection with intrusive rocks. Such deposits are supposedly formed by alkaline waters at depths ranging from 4,000 to 12,000 feet and at temperatures ranging from 175° to 300° C. The pressure of water at such depths, calculated as hydrostatic pressure, ranges from 140 to 400 atmospheres, but the actual pressure may be greater if the water and gases do not have free communication with the surface. The pyritic replacement deposits are divided by Lindgren into (1) those associated with certain silicates such as amphibole, pyroxene, epidote, tourmaline, and garnet, part of the sulphide being present as pyrrhotite, and (2) those associated with calcite, barite, and quartz as gangue minerals. Deposits of the first class indicate considerably higher temperature

[8] Lindgren, Waldemar, Mineral deposits, 2d ed., pp. 546–549, 635–637, 1919.

and probably greater depth than those of the second class. Lindgren says of the second class, "The ores, while consisting mainly of pyrite or pyrrhotite, derive their value from a small percentage of chalcopyrite; there are usually minute quantities of gold and silver, and frequently also zinc blende and a little galena; other sulphides are rare." This description applies well to most of the copper deposits of Prince William Sound.

A direct genetic relationship between the copper-bearing sulphide bodies and intrusive igneous rocks has not yet been demonstrated for this district. It is a notable fact, however, that almost every known copper deposit of southern Alaska, including Prince William Sound and the Copper and Susitna river basins, is either in the altered igneous rocks usually designated greenstones or in the sedimentary rocks in the vicinity of such igneous rocks. The deposits, however, are younger than the rocks that inclose them and were not formed till the greenstones had solidified and had been more or less deformed and faulted. Students of ore deposits of the kind under consideration have long been inclined to the belief that they are genetically connected with the intrusion of igneous rocks and were deposited from mineral-bearing solutions which originated in the molten magma or in some localities from mineralized solutions stimulated to circulation by the heat of the magma. If the deposits of Prince William Sound were derived from such a source and have some intimate connection with the greenstones, as seems highly probable, it is reasonable to suppose that the extrusion or intrusion of the greenstones and the deposition of the sulphide bodies were expressions of deep-seated igneous activity such as is already known to have occurred in parts of the Sound, and that although they are phases of one geologic event they differ somewhat in time, the formation of most of the greenstones coming first.

Johnson[9] has stated his conclusion regarding the relation of the copper-bearing sulphide bodies and the greenstones as follows:

> The close association of the ore deposits and the greenstones and the character of the mineral association in the ore deposits point thus to a close relationship between the copper deposits and the greenstones, and it is therefore suggested here that the copper deposits of these islands are attributable to hot, alkaline copper-bearing solutions of magmatic origin deriving their heat and metallic content from the same parent magma as the greenstones, circulating through fissure and shear zones in both greenstones and sedimentary rocks throughout much of the period of igneous activity and immediately thereafter.

The copper deposits of Ellamar and Latouche, because of their production and commercial importance, have been more carefully studied than the other deposits of the Sound. No mining has been done at Ellamar for several years, and the mine is filled with water

[9] Johnson, B. L., unpublished manuscript.

and is inaccessible. The areal geology of the district was mapped in detail, however, by Capps and Johnson during the productive days, and the mine was studied by Johnson.

The country rock inclosing the ore body at Ellamar consists predominantly of soft black slate with which are interbedded black limestone, dark-colored argillite, and a few beds of fine-grained graywacke. No igneous rocks are known in the mine or nearer than the greenstone lava flows north of Gladhaugh Creek, nearly half a mile away. The ore body consists of two parts[10]—(1) a large lens of solid pyrite, forming the hanging wall for (2) smaller, closely packed parallel lenses, consisting largely of other sulphides. A series of polished specimens of the ores of the district, studied by Johnson, showed the primary sulphide minerals chalcopyrite, chalmersite (cubanite), pyrrhotite, pyrite, sphalerite, and specks of a bright reflecting mineral that possibly is galena. Johnson[11] says of these sections:

> The order of deposition of the various sulphides is well brought out by this metallographic study. Pyrite, where present, was invariably the first mineral to be deposited. This was true in all sections in which pyrite was visible. It was followed later by the deposition of the other sulphides, which in most places appear to have been deposited contemporaneously. At the Ellamar mine, however, tiny veinlets of chalcopyrite with a little sphalerite cut earlier sphalerite.
>
> In the ore from the mine of the Threeman Mining Co. on Landlocked Bay a slightly different order of deposition occurs—contemporaneous chalcopyrite, galena, and an unknown sulphide, which are definitely later than the pyrrhotite in the ore. The chalcopyrite and the unknown sulphide occur intimately intergrown. In polished specimens from the old Alaska Commercial Co.'s property a little arsenopyrite is present and appears to have been the first sulphide to form. No pyrite was seen in the specimen of this ore which was examined.
>
> Naturally most interest attaches in an investigation of this sort to the occurrence of the economically important metals, which are copper, silver, and gold. One of the results of this investigation has been to show that the copper occurs apparently as a definite mineral, chiefly chalcopyrite, and not chemically combined with pyrite. This agrees with the conclusions of Simpson on the copper ores of Butte, Mont., and with Finlayson on the pyritic deposits of Huelva, Spain.
>
> The pyrite, under the metallographic microscope, is shown definitely to be of a slightly earlier generation, cut and replaced by the later chalcopyrite. The massive pyrite lens of the Ellamar mine shows very little copper content in assays. Metallographic examinations of the pyritic ore invariably show the copper content to be contained in the later chalcopyrite. Qualitative tests on a pale brass-yellow sulphide intimately associated with the chalcopyrite at the mine of the Threeman Mining Co., on Landlocked Bay, show that this mineral has apparently a low copper content. A careful determination of this mineral[12] is being made. No other primary copper-bearing minerals are found in the

[10] Johnson, B. L., op. cit. (Bull. 605), p. 91.
[11] Idem, p. 71.
[12] This mineral is now known to be chalmersite.—F. H. M.

ores, and no evidence of any copper silicates were seen in any of the ores or rocks examined in the Ellamar district.

Gold has not been observed in any of the specimens examined. Its presence in both copper and gold ores of the district, however, is amply proved by the results of assays. The Ellamar mine, formerly chiefly a copper producer, has in recent years produced large quantities of gold. This metal is also found in the Threeman ore. Though it is not definitely known that the gold occurs native, no tellurides or other gold minerals are known to occur in this district, and by analogy it is presumed, until further evidence is produced, that here, as in other parts of the Pacific coast region where similar genetic relationships exist, the gold occurs native.

Assay returns show the presence of silver in the gold and copper ores of the Ellamar district, but the metal has not been seen in any specimen examined. Inasmuch as all lode gold contains some alloyed silver, a part at least of the silver in the ores of the Ellamar district is presumed to occur alloyed with the gold of the lodes. No silver minerals have been found in this district.

The country rock of the Beatson mine at Latouche consists of interbedded slate and graywacke, with graywacke predominating. The graywacke is made up of angular fragments of quartz, feldspar, and dark minerals, including fragments of slate. Unlike the slate, it has no well-developed cleavage. In addition to the slate and graywacke, two other rocks are notable in the mine. They are a green chloritic schist which caves badly in mining and a very hard cherty or flinty rock which does not conform to the bedding of the slate and graywacke but crosses them irregularly and it appears to be an alteration product of the country rock. Similar cherty or flinty rocks are associated with the copper deposits at other places on the Sound. Another rock of much interest in the mine is a dark basic dike which resembles the graywacke. This dike was brought to the writer's notice by Dr. Bateman, who determined it to be an altered lamprophyre. It cuts the graywacke in the ore zone and is made up of alteration products of olivine in a matrix completely altered to calcite, chloritic material, and sericite. Basaltic hornblende, magnetite, and apatite are present. Limestone is not known in the mines at Latouche, but beds of light-gray siliceous limestone were disclosed by the shaft on the property of the Reynolds Alaska Development Co. at Horseshoe Bay, 3 miles south of Latouche.

Bateman[13] found on examination of polished specimens of the Latouche ore that the sulphides present are pyrite, pyrrhotite, chalcopyrite, chalmersite (cubanite), sphalerite, and galena, associated with quartz and a little siderite (ankerite?) as gangue minerals. Chalcopyrite constitutes about half the total quantity of sulphides and pyrrhotite and pyrite the other half. Sphalerite is widely distributed, although present in small quantity. Chalmersite is rare. Pyrite was the first sulphide to form, and the remaining sulphides

[13] Bateman, A. M., Geology of the Beatson mine, Alaska: Econ. Geology, vol. 19, pp. 354–357, 1924.

were practically contemporaneous, occurring singly or in combination. Quartz and chalcocite, quartz and pyrrhotite, or quartz alone are as common as mixtures of chalcopyrite, pyrrhotite, and quartz. Inclusions of chalcopyrite in pyrrhotite are almost as common as inclusions of pyrrhotite in chalcopyrite, yet there seems to have been a tendency for the pyrrhotite to form earlier. Veinlets of chalcopyrite cutting pyrrhotite or of pyrrhotite cutting chalcopyrite are not present. Sphalerite occurs as numerous small blebs or grains of microscopic size within pyrrhotite or chalcopyrite or by itself in quartz. It commonly contains specks of chalcopyrite that are visible only with higher powers of the microscope. In general the sphalerite is slightly earlier than the chalcopyrite and pyrrhotite, although the specks of chalcopyrite may be older than the sphalerite. Chalmersite (cubanite) is associated with pyrrhotite and chalcopyrite, occurring with both sulphides and in quartz adjacent to the other sulphides. The grains are without regular outlines and appear to have been formed simultaneously with the chalcopyrite and pyrrhotite. The principal gangue mineral is quartz, although siderite (ankerite?) is present in small amount, and chlorite, which is conspicuous in some of the country rocks, may have been introduced in part at the time of metallization. Quartz occurs as veinlets and irregular grains and was introduced before and with the sulphides. The gangue quartz is mostly of irregular form, although having crystal outlines in places, and is clear and thus distinguishable from the original quartz in the graywacke, which shows strains and inclusions. The continuity of the quartz veinlets is broken by sulphides in many places, and the plates show embayments where the quartz was replaced by sulphides. Most of the quartz appears to have replaced the country rock.

The similarity of mineral associations of the copper deposits of Prince William Sound and their common apparent connection with certain kinds of igneous rocks immediately suggest the probability that these deposits had a common origin and that although they may not have been formed simultaneously they nevertheless belong to one period of mineralization. The rare mineral chalmersite had formerly been found at only one locality outside of Prince William Sound,[14] and only in small quantity at that locality, the Morro Velho gold mine, in Brazil. More recently, however, it has been found at other localities in the United States and Canada. It occurs at many widely separated localities in Prince William Sound and was present at Landlocked Bay in sufficient quantity to be an important constituent of the ore shipped from the property of the Threeman Mining Co. It is probable that other localities for the

[14] Johnson, B. L., Preliminary note on the occurrence of chalmersite, $CuFe_2S_3$, in the ore deposits of Prince William Sound, Alaska: Econ. Geology, vol. 12, p. 519, 1917.

mineral will be found. This feature alone suggests a relationship between the copper deposits. Another tie appearing to indicate a relationship between the copper deposits of the Sound is the metal nickel. This metal was revealed in assay samples from Latouche[15] and is also reported from a number of places on Knight Island.[16] These reports are not sufficiently definite to form the basis for any general conclusions, but as nickel is always associated with basic igneous rocks the suggestion immediately arises that the solutions which formed the copper deposits at Latouche originated from a basic magma and that a similar condition holds for the other similar deposits.

The causes that lead to the deposition of the metallic sulphides in such large tabular or lens-shaped bodies as those at Ellamar, Latouche, Horseshoe Bay, Rua Cove, and elsewhere in this region are difficult to determine. Johnson[17] found that white calcite and metallic sulphides had replaced beds of original black limestone in the Ellamar mine. Limestone is not known in the Beatson mine, at Latouche, and if the hanging-wall vein has replaced limestone or other calcareous rocks the replacement is complete and has left no trace of the original beds. Moreover, Bateman regards the chloritic schistose rock adjacent to the great fault of the Bonanza mine, rather than limestone beds, as having had a prominent part in controlling the deposition of the copper and iron sulphides. Limestone is interbedded with the slate and graywacke at Horseshoe Bay, but the great sulphide body there is not known to be formed by replacement of limestone, and this mode of formation seems improbable, for no limestone beds of such thickness have been discovered anywhere in Prince William Sound. Limestone, furthermore, could hardly have had a part in the formation of sulphide deposits in the greenstones, although the greenstones are in places interbedded with sediments that may have had calcareous members, or they may themselves have contained sufficient secondary calcite to influence the deposition of the sulphides.

It would appear, therefore, that although some of the copper sulphide bodies, and the most valuable at that, may have resulted from the replacement of limestone or calcareous beds, some more general cause for the deposition of most of the deposits must be sought. This cause may have been the changes of temperature or of pressure in the mineralized solutions or the chemical reaction between solutions of different composition.

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[15] Lincoln, F. C., The Big Bonanza copper mine, Latouche Island, Alaska: Econ. Geology, vol. 4, p. 209, 1909.

[16] Johnson, B. L., Copper deposits of the Latouche and Knight Island districts, Prince William Sound: U. S. Geol. Survey Bull. 662, p. 203, 1917.

[17] Capps, S. R., and Johnson, B. L., The Ellamar district, Alaska: U. S. Geol. Survey Bull. 605, p. 92, 1915.

AGE OF MINERALIZATION

The age of the rocks of Prince William Sound is undetermined, and this statement applies equally well to the copper sulphide deposits, for no direct evidence that would restrict the age of the deposits within narrow limits has been found. A few facts bearing on the problem can nevertheless be stated.

The sulphide deposits of Knight Island are cut by dikes of greenstone, which are necessarily younger than the deposits and than the greenstone inclosing the deposits. Similarly the disseminated ore body of the Beatson mine at Latouche incloses a lamprophyre dike which cuts mineralized graywacke and is much altered but contains no sulphides [18] and consequently is thought to be later than the mineralization. These two occurences lead to the conclusion either that the deposition of the copper minerals took place in the midst of a protracted epoch of volcanism, for the earlier rocks were faulted and penetrated by the mineral-bearing solutions before the dikes were intruded, or that the earlier greenstones and the later greenstone dikes belong to two distinct periods of volcanism. The writer is inclined toward the first view.

Some of the deposits, such as those at Ellamar and Latouohe, are in rocks that have been regarded as belonging to the Orca group. Others, like that of the Midas mine, on Port Valdez, are in rocks of the Valdez group. This would signify that the sulphide deposits are younger than the youngest of the sedimentary beds, provided they belong to one period of mineralization, as appears to be probable. As the Valdez rocks, which formerly were considered older than the Orca group, are now thought to be Mesozoic and probably in part Cretaceous, a Cretaceous or later age for the copper deposits is suggested. In this connection, however, it should be stated that, as was pointed out previously, the copper deposits in the vicinity of Cordova show an association of minerals different from that which is typical of the other deposits in the Sound region and that this fact suggests a possible difference in age.

According to Brooks [19] the epoch of diastrophism which first outlined the Pacific Mountain system of Alaska involved the folding of beds of Lower Cretaceous age. He assigns to this epoch a Jurassic or Cretaceous age, regarding its greatest intensity as having occurred in late Jurassic time. This epoch of diastrophism was the epoch of greatest metallization in Alaska. It was followed in post-Kenai (Eocene) time by another epoch of widespread igneous intrusion, which was also a period of metallization, more localized but of greater intensity than that of the Mesozoic. The copper sulphide

[18] Bateman, A. M., Geology of the Beatson copper mine, Alaska: Econ. Geology, vol. 19, p. 347, 1924.

[19] Brooks, A. H., Outline of the tectonic history of Alsaka (in preparation).

deposits of Prince William Sound are thought to have originated in one of these two periods of mineralization, but a definite assignment can not now be made.

CONCLUSIONS

The copper sulphide deposits of Prince William Sound are of a simple type, involving a comparatively few characteristic minerals, one of which, chalmersite, is elsewhere of rare occurrence, although it is widespread in this district. They are commonly associated with greenstones and are believed to have been deposited from hot solutions at intermediate depths. The solutions originated from a basic rather than an acidic magma, and their principal channels of circulation were governed by faults or fault zones. The deposits are either tabular or lenticular bodies, deposited along fault planes by the filling of cavities and the replacement of the walls, or disseminated bodies of sulphides, deposited in part as veinlets in a multitude of small fractures and in part as grains or small irregular bodies replacing the country rock adjacent to faults. Oxidation of the sulphide bodies is superficial, and if a zone of oxidized vein material were ever present it has been completely removed by glaciation. It follows, therefore, that little change in the character of the ore bodies, other than the differences that may have existed at the time of deposition, should be expected as mining is carried to lower depths. The ore bodies for the most part are of low grade, and the surface exposures are a fair indication of what may be expected below.

Prospectors who are seeking to trace out the continuation of an ore body will do well to study the topography of the vicinity of the known body, for in many places the fault or fault zone that directed the mineral-bearing solutions has been particularly susceptible to weathering and is plainly expressed in the surface topography by gulches, notches on ridges, or other depressions.

MINERAL RESOURCES OF THE KAMISHAK BAY REGION

By Kirtley F. Mather

INTRODUCTION

Kamishak Bay is a broad indentation at the north end of the Alaska Peninsula, near the mouth of Cook Inlet, at the northeast end of Shelikof Strait. The area surveyed in the exploration upon which this report is based includes the entire shore of the bay, except its extreme southeastern portion, and extends westward about halfway across the peninsula. It includes much of the previously unmapped country south of Lake Iliamna and north of the Katmai National Monument.

As thus defined, the Kamishak Bay region lies between latitude 58° 20′ and 59° 20′ north and longitude 153° 35′ and 154° 45′ west. It includes about 2,500 square miles, as indicated on the accompanying map (Pl. III). A more complete report with topographic and geologic maps will be published later.

Field studies in this region were made during the summer of 1923 by a party consisting of R. H. Sargent, topographic engineer in charge; K. F. Mather, geologist; and four assistants and camp hands. The party landed at Iliamna Bay on June 16. Geologic and topographic mapping of the area was completed on August 28, when a junction with another party in charge of R. K. Lynt, topographic engineer, and W. R. Smith, geologist, was effected near the mouth of Savonski River. The two parties reached Kanatak on September 9 and sailed from Kodiak on September 23. The primary aim of the expedition was to make a reconnaissance map of previously unexplored territory. The short time available and the necessities of travel through a region whose major geographic features were unknown made it impossible to extend the geologic work to certain localities where essential data might have been obtained. For this reason most of the geologic boundary lines indicated on the accompanying map are generalized.

Although not far removed from customary routes of travel, the Kamishak Bay region is really very inaccessible. There are no docks or regular ports of call within or near the mapped area. The several bays are notably poor harbors, unprotected from the fierce winds that accompany the numerous storms along this coast, and many of them are so situated that entry or exit is safe only during times of comparative calm. As a rule, the large passenger boats that ply between Seattle and the head of Cook Inlet and Kodiak Island will put in at Iliamna Bay to discharge and take on passengers. Here they drop anchor a mile or more from shore, and the transfer must be made in small boats. The journey between Seattle and Iliamna Bay occupies about 10 days.

Kamishak Bay has never been adequately charted, and none of the larger passenger ships will enter, although it is stated that there is good anchorage in the lee of the Nordyke Islands. Small gasoline-propelled launches are accustomed on occasion to cross the inlet from Seldovia and at high tide enter McNeil Cove, near the head of Kamishak Bay. Seldovia is 90 miles from McNeil Cove and is a regular port of call for all steamers entering Cook Inlet. About seven or eight days is required for the journey from Seattle to Seldovia. It is also possible to obtain motor-boat transportation from Kodiak, about 100 miles from Kamishak Bay and 10 or 12 days' journey from Seattle.

The region under discussion is almost entirely uninhabited. Charles McNeil occupies a comfortable log cabin near the mouth of McNeil River. No other white man lives within the area shown on the accompanying map, although there are white residents a few miles north of its boundary, at the head of Cottonwood Bay and at Iliamna village. One family of Aleut natives lives at Chenik, and two families occupy cabins at Amakdedori.

PHYSIOGRAPHY

Topography.—The coast of this portion of the Pacific Ocean is deeply embayed and very irregular. Ursus Cove and Bruin Bay are fiords from whose shores the land rises steeply to mountainous heights. Although made irregular by many coves and other indentations, the southwest shore line of Kamishak Bay fringes lower and less rugged land. The mountains there are distant 2 or 3 miles from the strand.

The half of the Alaska Peninsula that is nearer the Pacific Ocean than Bering Sea consists of rugged mountains rising to altitudes of 3,500 to 4,500 feet near the south end of the Chigmit Range. These mountains are maturely dissected by numerous streams and everywhere display the results of strong glacial action. The multitude of lakes and ponds west and northwest from Kamishak Bay constitute the most obvious result of glaciation but are no more impressive than the many U-shaped valleys in which the intertributary spurs have been truncated by ice.

West and northwest from the long belt of mountainous country the surface drops abruptly away to the lowlands that border Bristol Bay. Here the relief is slight, and there are few hills more than 400 feet in altitude. Several large lakes occupy the deeper depressions of the undulating plain. Among these Kukaklek Lake is the only one within the area surveyed by this expedition, although Iliamna Lake borders the area on the north.

The southeast margin of the Kamishak region encroaches upon the northwest flanks of the Aleutian Mountains, which extend in a broad arc as a line of snow-capped and glacier-clad peaks from the Katmai National Monument northeastward to Cape Douglas, at the southeast corner of Kamishak Bay. This line of extinct or recently active volcanoes includes Mount Douglas, at the north, with an altitude of 7,000 feet; Four Peaked Mountain, next in line, 6,800 feet; Kukak Volcano, 6,600 feet, still emitting a slender plume of steam from a vent near its summit; Mount Steller, 7,450 feet; and Mount Denison, 7,560 feet, near the extreme south margin of the area.

The largest stream in this region is Savonoski River, which has its sources among the glaciers on the flanks of the Aleutian Range near the south margin of the area and empties into Naknek Lake and thus is eventually tributary to Bering Sea. Next in size is Kamishak River, which flows northward and receives the water of the Little Kamishak just before it debouches into Akumwarvik Bay, at the extreme southwest corner of Kamishak Bay. The only other streams of sufficient size to cause the traveler to worry concerning fords are McNeil River and Paint River, both of which flow in a general easterly direction and enter Kamishak Bay along the west shore.

Climate.—The climate of the region adjacent to Kamishak Bay is not severe, although it is by no means uniformly pleasant. There is abundant precipitation of snow during the winter and of rain during the summer. Except at the higher altitudes frosts are rare between June and September. During the growing season an extremely heavy stand of grass develops, so that meadows and hillsides have a luxuriant mantle of grass 3 to 6 feet tall by the later part of August. Along the shore the beach grass continues to grow even during the winter, so that it is reported to be possible to winter horses and other stock at a few sheltered localities.

The region is almost devoid of trees. Cottonwoods are confined to the valley flats of such rivers as the Savonoski and the Kamishak, and spruce trees grow only near the shores of Lakes Kahkonak and Naknek. Nearly everywhere there is an abundant growth of alders, which form dense thickets on many hillsides. Above an altitude of about 2,500 feet the only vegetation is reindeer moss and similar elements of the tundra flora.

The alders and scanty groves of spruce and cottonwood are sufficient to supply fuel only for preliminary exploratory development. Mine timbers would have to be transported many miles. Fuel for use during a drilling campaign in opening new oil fields must also be imported from other regions. In this connection the presence of coal along the shores of Kachemak Bay near Seldovia is worthy of note.

GEOLOGY

The Kamishak Bay region embraces two sharply defined geologic provinces, separated by a line that follows the major fault plane indicated on the accompanying map (Pl. III) as extending in a general southwesterly direction from a point near the mouth of Bruin Bay to a point near the middle of Alinak Lake. Because of the sharp contrast between these two provinces each will be described as a geologic unit.

NORTHWESTERN AREA

That portion of the Kamishak Bay region to the northwest of the major fault plane reveals geologic features practically identical to those in the Iliamna region,[1] at the north. There are considerable areas of metamorphosed sediments, probably of Paleozoic age, that were intruded by great masses of molten magma, which now appear at the surface over large areas as coarsely crystalline gray granite. The same granite batholiths intrude a thick series of volcanic beds—tuffs, agglomerates, and lava flows—of early Mesozoic age. All these older rocks are cut by a number of dikes, most of which are basaltic. Resting unconformably upon the eroded surface of these older formations there are at many localities patches of bedded volcanic rocks of Tertiary age. These include basaltic lavas and tuffs. Stream alluvium, glacial moraines, and landslide débris are the most abundant products of Quaternary time.

Gneiss, quartzitic schist, and quartzite.—The oldest rocks of this region are highly metamorphosed sediments, which now appear as gneiss, mica schist, and quartzite. They are identical in appearance and composition to similar rocks described by Martin and Katz in their report on the adjacent area at the north. These rocks are admirably exposed in the drainage basin of Paint River near the center of the mapped area. They are likewise crossed by Dream Creek a short distance west of Lake Gibraltar. At that locality

[1] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, 1912.

they appear at the surface throughout a long, narrow belt of territory which has a general easterly trend and probably curves southward to coalesce with the Paint River area, as indicated on the accompanying geologic map. Another mass of similar quartz-rich metamorphic rock forms the foundation beneath the volcanic ridge which culminates in the Seven Sisters, 7 miles northwest of Bruin Bay. Still another area of similar rocks was noted near the center of the peninsula, between Ursus Cove and Bruin Bay.

These rocks vary greatly in texture and composition from place to place. The coarse-grained varieties are generally light in color and show rather definite gneissoid banding. They are composed of quartz, feldspar, biotite, and hornblende, with minor amounts of various accessory minerals. The banding of these gneisses shows great variability in width, direction, and intensity, with no definite trend.

The finer-textured members of this series are quartzitic and chloritic schists, carrying a minor amount of dark-colored hornblende and feldspar. At places they show a strong resemblance to bedded rocks, and everywhere the schistosity is well displayed. Where crossed by Paint River a short distance above the mouth of Kenty Creek, these schists have a northeasterly strike and a dip of 20°–50° NW. In many places they are cut by stringers, dikes, or irregular intrusive bodies of granite, which is differentiated from the gneiss and schist on the map only where it occurs in large bodies.

The only evidence available concerning the age of these metamorphic rocks is their degree of metamorphism. As stated by Martin and Katz,[2] the evidence seems to indicate that these rocks must belong well down in the Paleozoic or possibly in part below it. They display many characteristics closely comparable to those of the metamorphic rocks of pre-Cambrian age in the Laurentian region of Canada.

Crystalline limestone and calcareous schist.—There is a single area of lime-rich metamorphic rocks near the head of Paint River which is of especial interest because of its relation to the copper properties described below. These rocks are intimately associated with the gneiss and quartzitic schist that surround them. It is possible that they represent merely the higher members of the same series, preserved at this locality because it is approximately in the trough of a great synclinal fold. The series as exposed along the forks of Paint River includes thin-bedded black quartzitic schist, much fractured and with many seams and veins of calcite, which has healed most of the fractures; thin-bedded quartzite of light flesh tint or milky appearance; white crystalline limestone or marble,

[2] Op. cit., p. 32.

which weathers to a yellowish red; and a red calcareous conglomerate, lime indurated and considerably altered by pressure and heat.

These calcareous rocks are so intimately associated with the quartzitic schist and gneiss described above that there can be little doubt as to the accuracy of their reference to the same general terrane. They are therefore presumably of Paleozoic age.

Kamishak chert.—The Kamishak chert, of Upper Triassic age, is typically exposed on the west shore of Kamishak Bay in a long, irregular belt extending northeastward from the southeastern shore of Bruin Bay. This occurrence has been described in detail by Martin and Katz.[3] The formation is in intrusive contact with granitic rocks along the northwest margin of the belt of outcrop. This belt is terminated along the southeast by the major fault plane above referred to.

Porphyries and tuffs.—The western foothills of the mountains west of Kamishak Bay and at least part of the adjacent lowlands are composed of bedded volcanic rocks which are probably the equivalent of the formation described by Martin and Katz[4] as Lower Jurassic (?) porphyries and tuffs. These rocks embrace a great variety of tuffs and flows and include many intrusive sills and dikes. Most of the beds weather to a light-gray or pinkish-gray surface. Characteristically, close inspection shows numerous phenocrysts of lath-shaped white feldspar and irregular grains of greasy or glassy quartz, set in a dense matrix of dark-greenish material. The matrix in some of the rock appears to be chiefly glass but in most of it is an andesitic or basaltic rock. Other beds show abundant crystals of hornblende and a few of biotite occurring as phenocrysts with quartz and feldspar. Most of the beds of this volcanic series are tuffs rather than flows, if the powdery appearance of the matrix gives a correct idea of their origin.

The entire series is distinctly silicic, and most of the porphyries would fall within the range of a latite. There are, however, especially in the upper part of the series, some flows and tuffs that approximate andesite and basalt in composition.

The varying resistance of these flows and tuffs results in the development of slopes composed of successive ledges rising steplike from valley floor to hilltop. The beds display dips of varying amount and direction but rarely pitch at steeper angles than 10°. In general they have a northeast strike and a regional dip toward the northwest. The series of silicic volcanic rocks must be at least 2,500 feet in total thickness. Between Gibraltar Lake and Funnel Creek, where this terrane controls the topographic development, the land is a submaturely dissected plateau. Broad, flat-topped mesas

[3] Op. cit., pp. 47–50.

[4] Idem, pp. 50–59.

are separated by steep-walled canyons. The mesa and plateau summits at many places coincide with the surface of a resistant lava flow.

The relations between this volcanic series and the granite that borders it on the east and southeast are well displayed in the cliff overlooking the landslide mass a mile northeast of Mirror Lake, as well as in the valley of the stream flowing westward from the pass at the head of North Fork of Paint River. At each of these two localities it is clear that the granite is intruded into the volcanic rocks.

The volcanic series appears to rest unconformably upon the eroded surface of the gneiss and schist, which crop out in a small area near the upper end of Kukaklek Lake. The reference of these rocks to the Lower Jurassic is in perfect keeping with all the facts observable in this area.

Tuxedni formation.—The rocks here identified as representing the Tuxedni sandstone consist of a variable series of sediments and extrusive volcanic rocks that forms the shore of Kamishak Bay in the vicinity of Amakdedori, a short distance north of Chenik. As exposed in the cliffs both north and south of the alluvial flat at the mouth of Amakdedori Creek, these rocks include a series of sediments about 500 feet thick, which comprises dark carbonaceous shale, sandstone, grit, and volcanic tuff. Both above and below these clastic beds there are lava flows composed of dense basic rock.

The conglomerates in this formation are generally only a few inches thick and occur at wide intervals among the sandy beds. Most of the pebbles are small, not over 1 or 2 inches in diameter. There is, however, one conglomeratic zone 10 to 20 feet thick in which the boulders are from 4 inches to a foot in diameter. These particular beds appear to be water-laid volcanic agglomerates. The pebbles and boulders scattered throughout this variable formation are chiefly basic volcanic rocks or porphyries; no granite boulders were noted.

Some of the more calcareous beds are crowded with fragments of shells, chiefly pelecypods, with a few belemnites. Most of these shells were mashed and jammed together by the waves while the sediments were being accumulated. At many places throughout the thickness of this formation there are sills and dikes of granodiorite, which in the smaller bodies is somewhat porphyritic.

Where exposed along the shore near Amakdedori these beds dip 40°–60° SW. and in general strike approximately N. 25° W. The exposure in the sea cliff is terminated both north and south of Amakdedori by the major fault plane, which here is inclined at an angle of about 45° NW., so that the beds of the Tuxedni formation with the included intrusive rocks are thrust forward from the northwest upon the younger formations, which form the tip of the peninsula south of Bruin Bay and the shore of Kamishak Bay near Chenik.

The fossils collected from this formation about 2 miles north of Amakdedori have been examined by T. W. Stanton, who has submitted the statement given below. His correlation would place the beds in the Middle Jurassic.

12101. About 2 miles north of Amakdedori, on west shore of Kamishak Bay; collected by K. F. Mather, 1923:

Inoceramus ambiguus Eichwald. Three small specimens.
Grammatodon? sp.
Trigonia sp.
Astarte sp., large form.
Elongate pelecypod resembling a solenid.

This small assemblage of fossils seems to belong to the fauna of the Tuxedni sandstone.

Granitic rocks.—The greater part of that portion of the Kamishak Bay region situated northwest of the major fault plane above referred to is underlain by granitic rocks of considerable diversity. Granite of varied texture and composition, granodiorite, and quartz diorite have not been differentiated on the accompanying map. Their occurrence is an extension of the outcrop area of similar rocks in the south margin of the Iliamna region, between Iliamna Lake and Cook Inlet. The variety of granites and associated rocks falls within the range of the "granitic rocks" described by Martin and Katz.[5]

In general, these rocks are characterized by a light to dark gray color and a wide variety of texture. In the coarse-textured varieties crystals of white feldspar and dark mica as much as half an inch in length are common. Irregular grains of greasy or glassy quartz fill the interstices between the feldspar laths. The coarse-grained granite is generally deeply weathered, and surfaces that not long ago were ice smoothed are now rough and irregular.

Elsewhere the granite is of much finer texture, displaying few crystals more than 2 millimeters in greatest dimension. The mineral composition of the rock is, however, much the same, regardless of the dimensions of individual crystal grains.

These rocks are obviously intrusive into the older formations described above. At some localities the contact between granite and schist is a zone 100 yards or more in width in which the schist is impregnated with stringers and lenses of granite, for the most part in the form of narrow dikes oriented parallel to the planes of schistosity. Ordinarily, such contact zones are places of weakness, marked by gulches or sharp topographic change.

[5] Op. cit., pp. 74–77.

As pointed out by Martin and Katz in their report on the adjacent Iliamna region, these granitic rocks must be in large degree if not entirely of Lower or Middle Jurassic age. It can not be definitely affirmed that the granodiorite sills intruded into the Tuxedni formation are offshoots from the main granite batholith, but that conclusion is a very reasonable one. The large number of huge granite boulders in the Chisik conglomerate, of the Upper Jurassic, may be interpreted to mean that the granitic intrusions had ceased before the end of Middle Jurassic time. In all probability the granitic rocks in this and adjacent portions of the Alaska Peninsula are the result of several intrusions closely associated in time but distributed at intervals throughout the Lower and Middle Jurassic epochs.

Tertiary volcanic rocks.—The western slopes of the Chigmit Mountains north of Kukaklek Lake display a number of isolated remnants of a once very widespread series of basaltic flows and tuffs. Erosion remnants cap the summits of several of the plateaus in the general vicinity of Gibraltar Lake. The jagged ridge west of Bruin Bay, which culminates in the Seven Sisters, is another outlying patch of the same series. The north and west shores of Lake Khakonak are formed in part of similar rocks, which extend thence to the west and northwest for many miles.

These basaltic rocks are in many places porphyritic, with tiny phenocrysts of plagioclase feldspar, augite, and magnetite embedded in a matrix which is generally either microcrystalline or a devitrified glass. On the ridge west of the north end of Lake Khakonak the basaltic flows are underlain by tuffs and thin calcareous sediments, which are evidently the basal members of the Tertiary volcanic series. Everywhere these rocks rest unconformably upon the eroded surfaces of the older terranes.

No fossils were obtained from the basal beds above referred to, but in the neighboring region to the north small collections of fossil plants were found in two localities. As reported by Martin and Katz,[6] these fossils indicate the Tertiary age of the containing beds. Doubtless the basalts of the Kamishak Bay region were contemporaneous with those of similar nature that occur near Iliamna Lake.

SOUTHEASTERN AREA

That portion of the Kamishak Bay region which lies between the major fault plane and the northwestern flank of the Aleutian Range is underlain by sedimentary rocks of Upper Jurassic age. Although these rocks amount to at least 6,000 feet in total thickness, only two formations could be differentiated in the reconnaissance mapping that

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[6] Op. cit., pp. 81, 82.

served as a basis for this report. These represent the Chisik conglomerate and the Naknek formation, which are widespread throughout the northeastern part of the Alaska Peninsula and have been described repeatedly by earlier workers in neighboring localities. Strata that appear to underlie the Chisik conglomerate crop out at one locality on the shore of Kamishak Bay, and these beds are tentatively identified as a part of the Chinitna shale.

Chinitna shale.—Rocks that are believed to be the oldest now exposed in the southeastern part of the Kamishak Bay region were observed on the shore of Kamishak Bay 2 miles north of Chenik. At that locality there is a closely compressed anticlinal fold, along the crest of which these rocks are elevated above sea level and in consequence appear in the sea cliff and wave-cut tidal flat.

The strata thus exposed are thin-bedded dark argillaceous shale, including a few thin layers of light-colored limestone. These thin calcareous beds are composed almost entirely of very much elongated lenses, which may be in large part of concretionary origin. They have a distinctly yellowish tinge on weathered surfaces. The inclosing beds of shale reveal no fossils but are evidently very rich in carbonaceous matter. They are generally dark gray or almost black and display fairly regular and closely spaced bedding planes.

The lithologic character of these rocks is apparently identical to that of the upper portion of the Chinitna shale in the Iniskin Bay district, a few miles to the northeast of Kamishak Bay, as described by Moffit.[7] Their relations to the coarse conglomerate of the Chisik formation make it clear that these beds are either beneath the Chisik or included in its basal portion. Somewhat similar beds of shale are known to occur as lenses in the lower part of the Chisik conglomerate near Horseshoe Cove, but the shale at that locality does not contain included beds of lenticular limestone. Again, the thickness of the shale at the locality north of Chenik is much greater than that of any of the shales known to occur within the Chisik conglomerate. All available evidence, therefore, is in harmony with the conclusion that the beds exposed at the crest of the anticline near Chenik are the uppermost layers of the Chinitna shale.

As noted by Moffit, the Chinitna shale is of Upper Jurassic age. It is known to be several hundred feet in thickness and at one locality reaches a maximum of 2,300 feet, but less than 200 feet is exposed on the shore of Kamishak Bay.

Chisik conglomerate.—The west shore of Kamishak Bay from a point 2 miles north of Chenik southward to the mouth of Kamishak River is formed of comparatively flat-lying beds of Chisik conglomerate. The same formation extends far up the valley of Little

[7] Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, pp. 123–124, 1923.

Kamishak River and reappears along the upper courses of Strike Creek and other streams that drain the region east and northeast of Alinak Lake.

The Chisik conglomerate is well displayed in the remarkable cliffs that rise sheer from the water's edge to heights of several hundred feet along the shore of the peninsula between McNeil and Horseshoe coves. The rocks here exposed are practically all conglomerate of varying texture and composition. Among the boulders there are specimens of all the various kinds of granitic and metamorphic rocks that now form the mountains west of Kamishak Bay. Some of the boulders and blocks of granite are as large as 8 by 10 by 15 feet. Some are angular and little rounded; others are considerably waterworn. In general the bedding is extremely irregular, and many lenses of sandstone or shale are intercalated with the thicker beds of conglomerate. Two zones of fine-grained thin-bedded blue-black clay shale from 25 to 50 feet in thickness were noted in the headland. These zones are several hundred feet below the top of the formation; each is underlain by coarse conglomerate. One seam of lignite, 2 or 3 inches thick, is exposed in the points on either side of Horseshoe Bay in the midst of the conglomerate beds.

There is abundant evidence that this formation was accumulated in a piedmont coastal strip not unlike that present at the same place to-day. At certain points the shale lenses are much contorted or fill hollows between reefs of conglomeratic débris. In all probability much of the coarser material was supplied by glacial streams issuing from rugged mountains not far distant from the shore. No glacial markings were found upon any of the boulders, but their huge size and angular appearance suggest transportation by other agencies than running water and swift currents.

The entire formation approximates 1,000 feet in thickness. At its top there is a transition zone between it and the overlying Naknek formation. These conglomerates are beyond doubt the equivalent of the beds in the Iliamna region described under this same name by Martin and Katz.[8] These rocks have also been more recently studied by Moffit,[9] who described their occurrence on the peninsula between Iniskin Bay and Oil Bay, about 35 miles northeast of Chenik.

Naknek formation.—Flat-lying beds of the Naknek formation are widespread throughout the drainage basins of Kamishak and Savonoski rivers. This formation was named by Spurr[10] from its occur-

[8] Op. cit., pp. 68–69.

[9] Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, pp. 117–132, 1923.

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

rence in the vicinity of Naknek Lake, a short distance southwest of the area now under consideration. Exposures of the same formation in the Cold Bay district, 120 miles to the southwest, along the Pacific shore of the peninsula, have recently been described by Capps.[11]

Near the mouth of Kamishak River the conglomeratic beds of the Chisik formation blend upward into the basal sandstones of the Naknek, without a marked plane of separation. Successively higher beds in the series show progressively smaller pebbles until the whole displays the texture of a sandstone rather than a conglomerate. These basal Naknek sandstones aggregate 250 to 400 feet in thickness and are grayish-brown arkosic sands, generally poorly cemented in irregular beds of varying thickness, ranging from less than an inch to 1 or 2 feet. They are much cross-bedded, and there are many lenses or laminae containing scattered pebbles, some of which are an inch or more in diameter.

These basal sandstones are overlain by 1,200 to 2,000 feet of brown and gray sandstone of much finer texture, interbedded at short intervals with sandy, nonfissile shale. A characteristically dirty greenish tint is displayed on freshly broken surfaces of the sandstone, but the shale is more commonly grayish drab, much of it with a greenish cast. In the midst of this part of the formation in the Kamishak Valley there are two or three beds, 1 to 3 feet thick, of loose pebbly conglomerate carrying a great variety of pebbles similar in composition to those in the Chisik conglomerate. At similar horizons, as well as higher in the Naknek formation, thick lenses of fairly coarse conglomerate, similar to the basal Chisik beds, were noted in the lower part of the Savonoski Valley. Presumably the thick conglomerates in Mount Katolinat, a short distance southwest of the mouth of Savonoski River, represent the recurrence of similar or equivalent conditions not unlike those which produced the subjacent Chisik conglomerate.

About 2,000 feet above the base of the Naknek formation there are scattered layers of dark bluish-gray limestone which weathers to a rusty yellowish brown. These layers are more or less lenticular and rarely attain greater thickness than a foot or so. The sandstones at about the same level as these beds of limestone are commonly concretionary, certain layers being crowded with calcareous concretions of about the same composition as the limestone beds.

Higher members of the Naknek formation form the divide between the Kamishak and Savonoski drainage basins and make many of the rugged hills in the vicinity of that divide. The great

[11] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 101–105, 1923.

variability of the beds is in keeping with the arkosic nature of the sands and the presence of numerous lenses of grit and pebbles. About 4,000 feet above the base of the Naknek formation there is a rather uniform change in composition. Rocks aggregating between 1,000 and 2,000 feet in thickness and occurring above that plane may be described as essentially dark-gray to black nonfissile shale carrying many thin layers of gray sandy shale and many nodules or lenses of very dark limestone. These strata are likewise included within the Naknek formation, which thus attains a thickness of 5,000 or 6,000 feet in this region.

All the beds of the Naknek formation, except possibly the arkosic basal sandstones, carry an abundance of fossils, most of which are shells of a single species of pelecypod, which belongs to the genus *Aucella*. Other pelecypods, as well as belemnites, are, however, not lacking. These fossils indicate the Upper Jurassic age of the formation.

Cenozoic volcanic rocks.—The peaks forming the portion of the Aleutian Range that traverses the southeast corner of the Kamishak Bay region are composed of volcanic rocks. Basaltic lava flows and tuffs of varied composition rest unconformably upon the eroded surface of the Naknek formation. Apparently this locality during Tertiary time was the site of great eruptive activity. Lavas welled up through vents and poured out on the surface. Explosive débris was hurled upward and contributed to the building of volcanic cones. The transfer of lava from its subterranean reservoirs to the surface seems to have been accomplished without notable deformation of the Naknek strata. Numerous dikes cut these sedimentary beds at several localities in and near the line of volcanoes and have altered the older rocks in a narrow zone closely adjacent to the fissures through which the lava moved.

Since the construction of Kukak Volcano, Mount Steller, and Mount Denison these volcanic cones have been deeply sculptured by streams and glaciers. At present the base-level of erosion in this part of the region is several hundred feet below the surface on which the lavas and tuffs were piled. In consequence the upper reaches of Savonoski River and its tributaries expose a considerable thickness of Naknek beds beneath the Tertiary volcanic rocks. While erosion was thus biting deep into the foundations of these mountains volcanic activity was frequently renewed. The later eruptions have occurred at no remote date in Quaternary time. About 12 miles northwest of Kukak Volcano there are volcanic rocks extruded within the valley of Savonoski River, and their base is only slightly above the modern flood plain of that stream. Kukak Volcano itself is still emitting gases that form a slender plume of smoke issuing from a vent near the summit of the mountain.

METALLIFEROUS DEPOSITS

So far as known, deposits of the metalliferous ores in the Kamishak Bay region are confined to the northwestern part of the area mapped. Here the igneous activity has been so intense as to justify expectations of workable deposits of such metals as gold, silver, and copper. On the other hand, the volcanic activity in the southeastern part of the area has evidently been so superficial as to give slight warrant for the hope that any workable deposits of precious or semiprecious metals have been formed there.

At numerous localities near the contact between the granitic batholiths of the Chigmit Mountains and the invaded country rock there is evidence of slight mineralization. Iron and copper sulphide minerals have been noted in sufficient quantity to lead to the opening of several prospect pits. In the basin occupied in part by Mirror Lake there are two or three places from which specimens impregnated with sulphide ores have been collected. The andesitic and latitic lavas exposed in the high cliff overlooking the landslide mass 1½ miles northeast of Mirror Lake are locally shattered and twisted near their contact with the granodiorite, which forms the divide at the head of Funnel Creek. Near that contact the volcanic beds are cut by countless veins of quartz, most of which are very thin but some of which attain a thickness of a few inches. Some of these quartz veins carry considerable pyrite, but nothing was noted that would justify the hope of finding a workable ore body there. Nearer to the shores of Mirror Lake there is a fissure zone extending for at least half a mile from northwest to southeast. It is crossed by several small streams flowing toward the lake. Pyrite and chalcopyrite are abundant in the quartz veins of this fissure zone. The copper content of this mass is, however, very low, and the total volume of copper-bearing rock is probably small.

Metallic sulphides have been introduced near the contact between the Mesozoic volcanic rocks and the granitic intrusions in the area between Battle Lake and Lake Gibraltar in sufficient quantity to raise the hope that a workable ore body may exist somewhere in this part of the Kamishak Bay district. Careful prospecting in that contact zone seems justified. At the same time, experience with such evidences of mineralization indicates that the chances of rich ores are by no means great.

A somewhat similar introduction of sulphide minerals was noted at several localities where the Paleozoic sediments, now gneiss and schist, are invaded by the same granitic intrusions. The quartzitic schist exposed in the basin of Paint River, for example, contains much pyrite. At only one locality, however, did the mineralization appear extensive enough to justify prospecting. That locality is near the head of Paint River and deserves special consideration. It is described below.

The west margin of the mass of calcareous schist and marble near the mouth of Crevice Creek and extending thence northeastward across the south fork of Paint River is cut by many dikes of basalt and granite or granodiorite. The metamorphosed sediments strike N. 40°–75° E. and dip 70°–80° SE. A number of mining claims were located here in 1911. When the locality was visited in 1923 application for patent on five claims had been filed by C. H. McNeil, E. H. Holly, and others. These claims cover an irregular area along Crevice Creek and Paint River and include most of the showings of mineralized rock along the northwest margin of the calcareous sediments. There are a number of prospect pits and one tunnel about 60 feet long from which some ore has been extracted. Most of the workings are badly caved, and many are mere pits in the gossan. The ore occurs in pockets in the metamorphosed sediments in close proximity to the acidic intrusive rocks. Some of these pockets are filled with an irregular mass of very coarse calcite, many crystals of which are 3 to 5 inches in length. Several of these masses of calcite are surrounded by so-called "garnet rock." Generally a belt of rich chalcopyrite ore, a few inches thick, lies near the "garnet rock," with another belt of coarsely crystallized amphibole, possibly actinolite, also a few inches thick, between. The tunnel follows what appears to have been a bed of limestone, now almost completely replaced and altered to schist and ore. It is not very far from a dike of quartz-feldspar porphyry, the widest dike noted in this locality. The dike is about 20 feet wide and extends in a general north-south direction for at least half a mile. Other intrusives in the vicinity consist of more or less irregular masses of diorite, granodiorite, and granite. A ton of ore from this drift was shipped to the smelter at Tacoma, Wash., where it yielded $6.08 in gold, 10.93 ounces of silver, and 18.19 per cent of copper. Unfortunately the workings are not sufficiently extensive to permit any estimate of the size of this ore body. Where exposed in the tunnel and at the surface it is only a few feet in width. Presumably it continues downward along the almost vertical beds of calcareous schist.

Numerous assays from the many scattered workings on these five claims have yielded varying but in general satisfactory amounts of gold, silver, and copper. About 10½ tons of ore sacked from different openings and representing the best material from each has been shipped to the smelter and gave returns of $2.50 in gold and 15 ounces of silver to the ton and 17.55 per cent of copper.

The expense of transportation is prohibitive, even for ore of the high grade indicated by these samples. Much more prospecting must be done before any adequate knowledge concerning the size of the ore body can be gained. Unless there is a much larger ore body than is now apparent, the large investment necessary to reduce transportation costs would scarcely be justified. These workings are 17 miles from the shore of Kamishak Bay. A wagon road 6 miles long has been constructed from the head of McNeil Cove to the mouth of Kenty Creek. Thence a fairly good horse trail leads to a camp site on Paint River a short distance below the month of Crevice Creek. There are no buildings or cabins, nor is timber available for the mine workings. The nearest sources of supply for mine timber are driftwood on the beach, the cottonwoods along Kamishak River, and the spruce timber on the shore of Lake Kakonak.

PETROLEUM

RELATION TO OTHER OIL FIELDS

Search for petroleum is justified in the area of Jurassic sediments throughout much of the southeastern portion of the Kamishak Bay region. This area is midway between the "oil fields" near Iniskin Bay, 50 miles to the northeast, and the Cold Bay district, 120 miles to the southwest. Several years ago attention was called to the possibilities of this area,[12] and in 1922 a large number of claims were staked along the southwest shore of Kamishak Bay and up the valley of Kamishak River for a distance of about 10 miles. No development has been attempted, however, and, so far as known, no detailed geologic work has been done in the area.

OCCURRENCE OF OIL ON ALASKA PENINSULA

Observations made by numerous geologists at many places along the Alaska Peninsula from Chinitna Bay, on the west shore of Cook Inlet, to Chignik Bay, 300 miles to the southwest, make clear the general conditions surrounding the occurrence of oil throughout that area. The sedimentary formations comprise a great thickness of shale, sandstone, conglomerate, and limestone, ranging from Triassic to Upper Jurassic in age. The sequence of these formations on the land bordering the three principal indentations of this part of the Alaskan coast is indicated in the following table:

[12] Martin, G. C., Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, p. 138, 1905; Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 42, 68, 1921.

Mesozoic sediments on north shore of Shelikof Strait and Cook Inlet

Age	Cold Bay district	Kamishak Bay district	Iniskin Bay district
Upper Jurassic.	Naknek formation; sandy shale overlying conglomerate and arkose; 5,000+ feet.	Naknek formation; sandy shale overlying sandstone and arkose; 4,000–6,000± feet.	Naknek formation; sandstone, arkose, and tuff, 3,000 feet; gray shale with sandstone beds, 1,500 feet.
		Chisik conglomerate, 1,000± feet.	Chisik conglomerate, 290 feet.
	Shelikof formation; black shale with limestone lenses, overlying sandstone, conglomerate, and sandy shale; 5,000–7,000 feet.	Chinitna shale; only uppermost 200 feet exposed. Maximum probably 7,000 feet.	Chinitna shale, 2,300 feet.
Middle Jurassic.	Kialagvik formation; sandstone and sandy shale; 500+ feet.	Tuxedni formation; shale, sandstone, grit, and tuff; 500+ feet.	Tuxedni sandstone; sandstone, shale, arkose, and conglomerate; 7,000 feet.
Lower Jurassic.	Calcareous sandstone and sandy shale; 2,300± feet.	Volcanic rocks, porphyritic lavas and tuffs.	Volcanic rocks, porphyritic lavas and tuffs.
Upper Triassic.	Thin-bedded limestone and calcareous shale; 1,000+ feet.	Kamishak chert; calcareous shale and limestone.	

In the vicinity of Iniskin Bay there are a number of oil seepages and showings of oil in test wells, all of which probably come from beds within the Tuxedni sandstone. That formation displays all the prime requisites of beds suitable to serve as a source of petroleum and includes a number of beds that are eminently adapted for reservoirs of oil and gas. The slight thickness of the beds referred to this formation and exposed on the shores of Kamishak Bay presents no striking indications that they, like the typical Tuxedni, may include both mother beds and reservoir rocks for oil. There is, however, nothing known concerning the Tuxedni in the Kamishak Bay region to show that it or closely associated formations could not include such beds. More than likely the southeastern portion of the Kamishak Bay region is generally underlain by Middle Jurassic strata comparable to those in which oil is known to occur near Iniskin Bay. Where exposed on the east shore of Kamishak Bay such strata are in too intimate contact with intrusive rocks to permit any hope that oil may ever be recovered from them. Elsewhere throughout the Kamishak and Savonoski valleys the Tuxedni formation is almost certainly so deeply buried that it is beyond the reach of ordinary drilling operations. Its top is probably between 4,000 and 6,000 feet below the top of the Chisik conglomerate. Horizons equivalent to those which yield oil in the Iniskin Bay district could therefore be reached by ordinary drilling methods only where the drilling could begin at a horizon close to or below the bottom of the Chisik conglomerate.

In the Cold Bay district the Shelikof formation probably contains both mother beds and reservoir rocks. Numerous seepages indicate the presence of oil in commercial quantities at several horizons within the thick series of clastic sediments constituting that formation. Apparently the most favorable conditions are present in the upper 1,000 to 2,000 feet of those beds. This portion of the Shelikof formation is the equivalent of the Chinitna shale of the Iniskin Bay district and is presumably present throughout that part of the Kamishak Bay region which lies on the southeast side of the major fault plane previously described. It is quite probable that certain beds of shale exposed on the apex of a compressed anticline along the shore of Kamishak Bay between Chenik and Amakdedori represent the uppermost strata of this same formation. There is no reason to doubt that it underlies the Chisik conglomerate throughout the Kamishak and Savonoski valleys.

Reservoir beds from which oil may be obtained in commercial quantities may be expected to occur at several stratigraphic horizons ranging from a few feet to many hundreds of feet below the base of the Chisik conglomerate. Such beds would be within 3,000 feet of the surface under considerable parts of the drainage basins of Kamishak and Savonoski rivers.

Oil may be concentrated in commercial pools within these reservoir beds under at least two conditions. Wherever such beds are flexed into doubly plunging anticlinal folds or domes, oil would be expected at or near the highest points of such folds. Again, where these beds are monoclinal, dipping downward in one direction, suitable traps for petroleum migrating through the reservoir rocks might be provided if the sandstones are lenticular. In that case an oil pool might form at the upper margin of a regularly dipping sandstone lens. Obviously, an oil pool localized in that way could not be foretold from surface indications alone. In the present state of the petroleum industry search for oil in the Kamishak Bay region should be confined to those areas in which the rocks are so flexed as to make structural traps for the upward-migrating hydrocarbons. Any doubly plunging anticlinal fold or dome in which the Chisik conglomerate is either exposed at the surface or is known to be present within a few hundred feet of the surface is worthy of prospecting for oil, unless there are unexpected differences between conditions in the Kamishak Bay region and those near Iniskin Bay, toward the northeast, and Cold Bay, at the southwest.

OIL SEEPAGES

During the progress of the field work on which this report is based no seepages of oil were observed in the Kamishak Bay region, but reliable reports were received concerning an oil seepage near Bruin Bay, within the area mapped.

According to C. H. McNeil, there is a small oil seepage about 50 yards off the point at the south side of the entrance to Bruin Bay. Reefs and a wave-cut flat are exposed here at extremely low tides. Mr. McNeil saw the seepage when there was 4 or 5 feet of perfectly still water over the spot. Bubbles of gas came up from the clean sand and, breaking at the water surface, spread a film of oil over a considerable area. The odor of gas and oil was very distinct, and the film of oil, when broken by an oar, quickly came together again. Reference to the accompanying map indicates that the locality referred to by Mr. McNeil is approximately on the crest of the Chenik anticline, if that anticline extends northeastward from the locality at which it disappears beneath the water of Kamishak Bay.

In an earlier publication [13] there have been references to a seepage of oil near the mouth of Douglas River, which empties into Kamishak Bay near Cape Douglas, 15 miles east of the mouth of Kamishak River. No opportunity was afforded for observations in that locality during the field season of 1923. Mr. McNeil states that he searched for this seepage during the preceding summer but was unable to find it. The reports concerning it, nevertheless, seem to be authentic, and it is extremely likely that oil from the strata beneath the Chisik conglomerate reaches the surface at that point.

GEOLOGIC STRUCTURE

Regional structure.—The greater part of the drainage basins of Kamishak and Savonoski rivers is underlain by comparatively flat-lying sediments, described as belonging to the Chisik conglomerate and the overlying Naknek formation. These Jurassic beds occupy nearly all of that portion of the Kamishak Bay region lying southeast of the great overthrust fault. In close proximity to the fault plane the Jurassic strata are crumpled and display varying strikes and dips. Elsewhere these beds dip 4°–8° SE. The major fault, extending from the north shore of Kamishak Bay southwestward to Lake Alinak, has not been studied throughout its length. Near Bruin Bay it is an overthrust from the northwest, and the fault plane is inclined about 45° NW. South of Amakdedori the fault plane is apparently almost vertical. Near Alinak Lake the only observations which the necessities of travel would permit were made from a considerable distance. They gave the impression, however, that the fault plane was there approximately vertical. The first displacement along this fault plane could not have occurred before

[13] Martin, G. C., Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, p. 138, 1905.

the end of the Jurassic period and probably took place not long thereafter. Possibly there has been recurrence of this movement in later Tertiary time, although no satisfactory data were obtained concerning that matter.

Anticlinal folds.—The most pronounced anticlinal fold that was noted in the southeastern portion of the Kamishak Bay region may be called the Chenik anticline. It extends in a general northeasterly direction parallel to and in close proximity to the major fault plane. The sea cliff 2½ miles north of Chenik crosses the anticlinal fold obliquely and exposes the strata on both limbs. The anticline is tightly compressed, so that the beds are approximately vertical throughout a width of 100 yards on the very summit of the fold at that point. On either side of the crest of this anticline the dip decreases rapidly, and a few hundred yards to the northwest it has been reduced to 40°. A short distance farther northwest the structure is terminated abruptly against the major fault plane. Similarly toward the southeast the dip decreases, and throughout a zone a quarter of a mile in width the beds plunge downward toward the southeast at angles varying from 50° to 75°. About half a mile from the crest of the fold the strata appear practically undisturbed, although in the vicinity of Chenik it was not possible to determine with accuracy their exact attitude, because of the notably irregular bedding of the conglomerates that crop out there.

The summit of the Chenik anticline brings a series of shales to a position which has permitted them to be exposed in the sea cliff. As indicated on page 168, it is probable that these are the uppermost beds of the Chinitna formation. The limbs and in places the summit of the Chenik anticline are composed of the massively bedded Chisik conglomerate. Where steeply inclined these beds are considerably shattered by numerous small displacements. Many bedding planes show slickensides.

The trend of the Chenik anticline at this locality north of Chenik is N. 35° E. The wave-cut flat exposed at low tide displays the fold continuing in the same direction until it disappears beneath the deeper water east of Amakdedori. If the anticlinal trend were extended northward it would pass just offshore from the point separating Bruin Bay and Kamishak Bay. It is at this locality that an active seepage of oil has been reported. In all probability this seepage represents the leakage from the Chinitna shale, which may be exposed by the truncation of the anticlinal fold by wave erosion at that place.

A second anticlinal fold that may be of great economic importance was observed between McNeil Cove and Akumwarvik Bay and may extend for many miles toward the southwest between the valley of McNeil River and that of Strike Creek. The observed strikes and dips in this locality are indicated on the accompanying map. To this uplift the name Kamishak dome may well be applied. Mikfik Creek is overlooked on the east and south by a long hogback ridge with a dip slope rising from the creek bed to the summit, about 600 feet above and 2 miles distant from the stream. In this dip slope the massive resistant beds of Chisik conglomerate strike N. 25° E. and dip 4° NW. This hogback ridge is abruptly terminated by the vertical cliffs forming the wave-cut headland between McNeil and Horseshoe coves. At the farthest point of this headland the strata appear to dip gently downward toward the northeast, but near Horseshoe Cove there is a gentle dip in a direction a few degrees east of south. Farther south, near the head of Pinkidulia Cove and elsewhere along the valley of Strike Creek, the rocks display the normal regional dip toward the southeast. There is, therefore, a well-defined anticlinal axis trending about N. 25° E. through the rugged hills between Mikfik Creek and Pinkidulia Cove. This anticlinal fold plunges slightly at the tip of the headland near the south side of the entrance to McNeil Cove.

As indicated on the accompanying map, there are two fault planes which cut the Chisik conglomerate in this headland. Each makes a conspicuous linear gulch, eroded along the shattered zone. The beds of Chisik conglomerate do not match across the fault planes, but the variations of these beds are so numerous that it is impossible to tell how much vertical displacement is involved. Presumably these faults are only superficial breaks in the competent and brittle Chisik conglomerate where it was stretched on the crest of the anticlinal fold, and probably they do not continue downward more than a short distance into the underlying incompetent shale.

A few scattered observations on the geologic structure of the region drained by Hardscrabble Creek north of Savonoski River were made, for the most part from a considerable distance. These indicate, however, that there is notable departure from the regional dip at that locality. Apparently there must be a broad anticlinal flexure with its apex somewhere near a point about 12 miles north of the confluence of Rainbow and Savonoski rivers. As indicated on the accompanying map, the strata west of that point dip gently toward the southwest, and those east of it dip gently toward the southeast. It is possible that this structure is not closed on the north, but no observations were made in the considerable strip of territory that intervenes before the major fault plane terminates the Jurassic strata.

Mr. McNeil reports the presence of a broad, gently folded anticline near the mouth of Douglas River, but details concerning it are not now available.

RECOMMENDATIONS

From the facts above set forth it is apparent that much of the southeastern portion of the Kamishak Bay region is underlain by beds that may be reasonably expected to contain oil in commercial quantities. In at least two localities the structure is such as to favor the localization of oil in commercial pools, and at each of these localities the horizons at which the oil would be expected to occur are within reasonable drilling distance of the surface. None of the structural features thus far known are so well adapted to serve as a trap for oil as the Pearl Creek dome, in the Cold Bay district. The Chenik anticline is more closely folded, and the Kamishak dome is much more open than the Pearl Creek dome. Nevertheless, each of these two folds is worthy of careful consideration. Further detailed studies may well reveal localities along the summits of these anticlinal folds where conditions are much better than those already observed. Such detailed study, by competent geologists, ought certainly to precede the selection of any drilling sites in the Kamishak Bay district.

The steep inclination of the limbs of the Chenik anticline is not believed to indicate a sufficient intensity of regional stress to have destroyed the hydrocarbon content of the underlying rocks. Rather, the most unfavorable feature of this closely crumpled fold is that the territory from which the oil might migrate to its crest is thereby reduced to a comparatively slight area. On the other hand, the gentle slopes on the flanks of the Kamishak dome permit the gathering of oil in subterranean reservoirs from a considerable area, extending westward nearly or quite to the major fault plane and eastward far beyond the Kamishak Valley. These gentle dips are obviously very much greater than the minimum required for the concentration of oil in many other oil fields, but it is not yet known that they are adequate to cause oil migration in these particular Jurassic rocks. In all probability, experience in and near the Pearl Creek field of the Cold Bay district will ere long provide data from which definite conclusions may be drawn as to the efficiency of the Kamishak dome in this regard.

It would seem advisable at present to delay the drilling of any test wells in the Kamishak Bay region until the practically ideal structure in similar rocks in the Cold Bay district has been adequately tested. Should the drilling operations in that district reveal the presence of considerable quantities of oil, the conditions under which the oil occurs there may soon be deduced. A knowledge of those conditions ought greatly to reduce the chances of failure in the Kamishak Bay region. Should the Cold Bay district prove to contain valuable oil fields, the drilling of test wells in the Kamishak Bay region would certainly be justified and may confidently be expected.

Before drilling sites are finally selected, there should be careful detailed geologic studies to determine with accuracy the limits and conditions of the anticlinal folds to which attention has above been called. From present knowledge it may be expected that favorable drilling sites will be found on the summit of the Chenik anticline north or west of Chenik and on the apex of the Kamishak dome between Mikfik Creek and Horseshoe Cove.

THE COLD BAY-KATMAI DISTRICT

By Walter R. Smith

INTRODUCTION

Location and area.—The following report is a brief account of the general geologic and geographic features of the country extending from the north side of Cold Bay to a point a few miles east of Naknek along Savonoski River, Alaska Peninsula. The district is bounded on the southeast by Shelikof Strait between Cape Kekurnoi and Kashvik Bay; inland toward the west investigation was carried as far as Becharof and Naknek lakes, including the northwest half of the Katmai National Monument. The maximum north-south extent of the district is 60 miles, and the greatest width is about 40 miles. The area mapped during the field season of 1923 is approximately 1,200 square miles and lies between meridians 154° 50′ and 156° west and parallels 57° 40′ and 58° 35′ north, except the Severnson Peninsula in Becharof Lake. The district is in about the same latitude as Juneau, Alaska.

Previous surveys.—Parts of the district as outlined above had been surveyed and were rather well known prior to 1923. However, since Alaska came into the possession of the United States, in 1867, little surveying had been done in this district until 1921. The shore line between Cape Kekurnoi and Kashvik Bay is still uncharted, although some of the bays along the southeast side of the Alaska Peninsula have been charted in recent years by the United States Coast and Geodetic Survey.

General descriptions of the physiography of the Alaska Peninsula with reference to the Katmai district are given by Petrof,[1] Atwood,[2] and others. Geologic observations were made by Spurr[3] in 1898 along the trail from Naknek Lake to Katmai Bay. The report of this trip across Katmai Pass contains the first information regarding the geology of the district. During the summer of 1904

[1] Petrof, Ivan, Report of the population, industries, and resources of Alaska: Tenth Census, vol. 2, 1884.

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

[3] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 59, 1900.

Stanton and Martin[4] made a geologic survey along the southeastern coast of the Alaska Peninsula, from Cook Inlet to Unga Island, with observations along the shore line of the district herein considered.

Renewed interest in the district was caused in 1912 by the great volcanic activity of Mount Katmai and vicinity. However, the volcanic area was not entered until 1915, when a party sent out by the National Geographic Society to study the effect of the ash fall upon vegetation discovered the Valley of Ten Thousand Smokes. Since that time four other expeditions sent out by the National Geographic Society and also investigators from the Geophysical Laboratory have gone into the region. The results of these expeditions, including a topographic map of the Katmai National Monument, have been published in various magazines, scientific papers, and a book, "The Valley of Ten Thousand Smokes," to which reference is made elsewhere in this report.

A stratigraphic section was measured along the north shore of Cold Bay by Capps[5] in 1921, and the following year a United States Geological Survey party[6] extended topographic and geologic mapping farther north into the Kejulik River valley. Independent examinations of possible oil lands have been made during the last four years in the country adjacent to Cold Bay, including the lower Kejulik River valley, by geologists representing western oil companies. Very little was known of the character of the country between the upper part of Kejulik Valley and Naknek Lake prior to 1923.

Present investigation.—The expedition of 1923 in the Cold Bay-Katmai district, in charge of R. K. Lynt, topographic engineer, was one of a series begun by the United States Geological Survey in 1921 to make a topographic map and to investigate the mineral resources of Alaska Peninsula. During the field season of 1922 the work was carried southwest from Wide Bay to Chignik and north from Portage Bay to Kejulik River. In 1923 the investigation began at Cold Bay and was extended north by Mr. Lynt's party until met by a party conducted by R. H. Sargent, topographic engineer, working southwest from Iliamna Lake. The party traveling north consisted of R. K. Lynt, chief of party; C. S. Franklin, recorder; the writer, geologist; and three camp hands. C. N. Fenner, of the Geophysical Laboratory, and Charles Yori accompanied the party as far as Cold Bay and also on the return trip from the Valley of

[4] Stanton, T. W., and Martin, G. C., The Mesozoic section on Cook Inlet and Alaska Peninsula; Geol. Soc. America Bull., vol. 16, pp. 391–410, 1905.

[5] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 90–91, fig. 5, 1923.

[6] Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 151–218, 1924.

Ten Thousand Smokes. Transportation in the field was supplied by 15 pack horses.

The party sailed from Seattle on board the steamer *Admiral Evans* May 24 and arrived at Kanatak, Portage Bay, June 5. The horses were taken overland while the field equipment and provisions were taken by power boat to the head of Cold Bay. From this point Mr. Fenner and the packers set out immediately for the Valley of Ten Thousand Smokes, traveling up the east side of Kejulik Valley. A pass was found across the Kejulik Mountains, and the Katmai district was entered from the west. Upon the return of the packers to Cold Bay, Mr. Lynt's party started north, mapping the country along the route taken by Mr. Fenner as far as Angle Creek. Thence the party traveled west around the mountains near the large lake south of Naknek Lake and entered the Valley of Ten Thousand Smokes from the northwest. A week of unfavorable weather was spent in the valley, and then the party continued to map the country along Savonoski River until Mr. Sargent's party was met August 27. The return trip of both parties to Kanatak, ending September 11, was made most of the way over the same route taken going into the country. After a delay of nearly a week at Kanatak transportation was obtained to Kodiak on the Coast and Geodetic Survey boat *Discoverer*. Both parties sailed from Kodiak September 23 on the *Admiral Evans* and arrived at Seattle October 6.

The writer received valuable assistance from C. N. Fenner in mapping the areal geology in the Katmai district. Especial acknowledgment is due to the officers and men of the *Discoverer*, who supplied a much desired means of transportation from Kanatak to Kodiak and who showed the greatest courtesy in offering the best accommodations the boat could afford.

GEOGRAPHY

TOPOGRAPHY

The coastal mountains between Cold Bay and Katmai Bay reach inland about 18 miles, to the Kejulik and Savanoski valleys, and rise to altitudes of 3,000 to 4,000 feet. These mountains are part of the Aleutian Range, which extends along the south coast of Alaska Peninsula. Near the coast northeast of Cold Bay several sharp peaks, especially on Cape Kubugakli, rise above the neighboring mountains, but farther inland the crests are generally rounded. The range is deeply dissected and is characterized by steep slopes which in places form nearly vertical cliffs. The coast is irregularly indented by many small bays, most of which have broad, low valleys stretching inland a short distance. The Kejulik Valley, about 8 miles wide near the mouth of the river, trends northeast from Becharof Lake and separates the Kejulik Mountains on the northwest from the coastal range. The Kejulik Mountains, a spur of the main Aleutian Range, extend from Mount Mageik to Becharof Lake and are exceedingly rugged, being pinnacled by fantastic spires and castles weathered from volcanic rocks. The contrast between this range, many peaks of which reach altitudes of 5,000 feet, and the coastal mountains is very conspicuous. Another range, separated by Yori Pass from the mountains on the east, rises along the south shore of the lake south of Naknek Lake. These mountains are sharp peaked and are composed almost entirely of coarsely crystalline granite. Within the Katmai National Monument and in the northeastern part of the district visited in 1923 a group of one extinct and five active volcanoes form the most prominent topographic feature in the region. Of these, Knife Peak, situated on the north side of the Valley of Ten Thousand Smokes, is regularly conical in outline and rises to an altitude of nearly 8,000 feet, being thus the highest point in this part of the peninsula. It was considered to be an extinct volcano until 1923, when it was found to be slightly active. Several of the volcanoes constantly send columns of white fumes many hundreds of feet in the air. On a clear day this activity may be observed from any part of the district. The Valley of Ten Thousand Smokes includes an area of about 40 square miles, which is nearly level. In this area there are many hot springs and thousands of active fumaroles. The Valley of Ten Thousand Smokes and the volcanoes of the Katmai region have been described in some detail by Griggs[7] and others, and it is beyond the purpose of this report to discuss them at length.

West of the mountains the country is less than 100 feet above sea level and contains many lakes and marshes which make travel difficult in summer except by small boats. Very little of this broad lowland has been surveyed.

In the latitude of Naknek Lake the Alaska Peninsula is about 90 miles wide, and more than half of it consists of the lowland that borders Bristol Bay. The divide between the Pacific Ocean and Bering Sea drainage lies along the main crest of the coastal range, which is relatively close to the south side of the peninsula. The larger streams of the district between Cold Bay and Naknek Lake have their sources in the vicinity of Mageik Volcano, from which they flow radially. Mageik Creek rises among the glaciers on the east side of the volcano and contributes a large volume of water to Katmai River, the largest stream in the region that flows into the Pacific Ocean. Several tributaries of Kejulik River head in the country southwest of the volcano and flow west into Becharof Lake.

[7] Griggs, R. F., The Valley of Ten Thousand Smokes, Nat. Geographic Soc., 1922.

Kejulik River is the principal stream of the Becharof Lake drainage basin and is rather broad and deep and too swift to be crossed on foot in its lower reaches. Other streams, some of considerable size, flow northwest from the vicinity of Mount Mageik either into Naknek Lake or directly into Bristol Bay. The westward-flowing streams are rather sluggish, except near their heads, and have eroded broad, marshy valleys that are difficult to cross during the summer. In contrast the Pacific drainage is characterized by short, turbulent mountain streams flowing through narrow V-shaped valleys in which there are many beautiful falls.

Savonoski River, flowing into Naknek Lake, drains the central part of the mountainous area northeast of the lake. The lower 15 miles of the Savonoski Valley is swampy and is traversed by several river channels. All the streams are supplied by melting snow and glaciers that persist throughout the summer along the crests of the mountains. However, some of the larger glaciers on the west side of the range, especially in the volcanic area, descend to the heads of broad valleys. The glaciers of Mageik and Katmai volcanoes are from 2 to 4 miles long and reach down to the head of Angle Creek valley and also to the Valley of Ten Thousand Smokes, where the ice water from the glaciers mingles with the hot water from the volcanic ash in the River Lethe and Knife Creek. These two streams unite with Windy Creek at Three Forks, in the lower end of the valley, to form Ukak River, which flows north into Naknek Lake. Knife Peak, although higher than the other volcanoes, has less vigorous glaciers on its flanks.

A series of large lakes occurs along the central part of the peninsula west of the mountains. Two of these lakes, Becharof and Naknek, form the western boundary of the Cold Bay-Katmai district. Becharof Lake has an area of about 450 square miles and is the largest of the series. Lake Alinak and a smaller lake just west of it are situated a few miles north of Naknek Lake. Another lake of considerable size lies south of Naknek Lake. Egegik and Naknek rivers are the respective outlets of Becharof and Naknek lakes. These rivers are navigable by small boats and, together with the lakes, furnish the best routes of travel through the Bering Sea coastal plain.

CLIMATE

In discussing the climate of the country north of Cold Bay only the observations made during the field work in the district are available, as no systematic weather records have been kept. Temperature and rainfall in this region are greatly influenced by local geographic features, so that the meteorologic data for Kodiak, 100 miles southeast, and Ugashik, on Bristol Bay, are of little value for comparison. The summer weather of the Alaska Peninsula is characterized by high winds and wet, driving fogs. This condition is especially true of Cold Bay and the country immediately northwest of it. The prevalent high winds sweep across the relatively narrow strip of land either from the Pacific Ocean or from Bering Sea, their direction depending upon the difference in barometric pressure over these bodies of water. A change in atmospheric conditions either east or west of the land results in a sudden change in the direction of the wind, usually a complete reversal. The heavy moisture content of these sea winds is condensed upon striking the snow fields and glaciers of the mountains, causing dense, driving fogs. As a rule the weather is more favorable when the wind is from the west. Any low passes in the mountains, such as Katmai Pass and the low area between Cold Bay and Becharof Lake, form wind gaps through which the wind blows with velocities so high that at times travel against it is almost impossible. Severe storms that endanger navigation along the coast usually occur about the middle of September but are by no means limited to that time. Heavy rains are not frequent, but the nearly continual drizzle from the oversaturated fogs results in a moderately high annual precipitation that amounts to about 50 inches on Unga Island.

During the summer of 1923, from June 5 to September 12 there were 28 clear or partly clear days in the country between Cold Bay and Naknek Lake. The best weather occurred during the later part of June, the last week in August, and the first week in September. The maximum temperature recorded, August 16, was 90°, which is unusually high for this part of Alaska. The average temperature in the summer is probably about 60°. The amount of snowfall varies from year to year, but it is generally light until the 1st of January. The snow disappears from the lower elevations by the 1st of July. A raincoat and moderately heavy clothing are essential for comfort during the summer on the Alaska Peninsula.

VEGETATION

Although the area under consideration is small, the vegetation of the southwestern part differs greatly from that of the northeastern part. The difference is apparent in the absence of trees near Cold Bay and along the coast between Cape Kekurnoi and Cape Kubugakli, whereas in the vicinity of Naknek Lake the valleys are covered with forests of spruce, birch, and poplar. Two small patches of poplar trees grow in the central part of the Kejulik River valley, and farther east in the valley of Kashvik Creek a few birch and poplar were seen. These localities mark the southwest extent of the forests on the Alaska Peninsula, with the exception of a small isolated area found in 1922 in the vicinity of Mother Goose Lake, 75 miles southwest of Cold Bay. The spruce forest extends southwestward to the upper end of the lake south of Naknek Lake. A single spruce tree was seen on Cape Kubugakli, many miles from its nearest neighbor. The largest trees were found growing in the Savonoski Valley, where spruce trees nearly 3 feet in diameter and 40 to 50 feet in height were frequently seen.

Between the lower end of the Valley of Ten Thousand Smokes and Naknek Lake nearly all the trees, as well as the lower forms of vegetation, were killed by the ash fall and probable acid rains during the Katmai eruption. Farther to the west, in Angle Creek valley, the vegetation was also injured, and for distances of 20 miles or more from the volcano mosses and grasses were destroyed. However, in 1923 several varieties of grass, principally horsetail and redtop, had gained a footing where the covering of ash is not too thick. A few seedlings of poplar were seen, but spruce and birch have not yet started to reforest the devastated area.

The largest forms of plant life in the vicinity of Cold Bay are willow and alder bushes, which are unevenly distributed in nearly all the valleys and at places on the lower slopes of the mountains. In exceptionally protected spots the alders attain a height of 15 feet, but usually they are only a few feet tall and so crooked that they can not be used as tent poles, yet they are a valuable source of fuel for the camper. Camp sites are chosen in the midst of alder thickets for protection against the wind.

The dominant and most conspicuous forms of vegetation in the district are grasses, flowering plants, and mosses, which grow rapidly during the summer and clothe the entire country, except the barren crests and cliffs where soil has not accumulated. Of the grasses the so-called redtop is the most common and grows to a height of over 4 feet. It furnishes excellent grazing during the growing season but is not nutritious after it is killed by frost. Mosses and lichens are abundant, except in the northwestern part of the area, where they were destroyed by volcanic ash. Berries are not plentiful, although occasionally fruitful patches of low-bush cranberries, blueberries, or salmonberries are found. The red, sour berries commonly known as high-bush cranberries grow profusely in the forests of Savonoski Valley.

ANIMAL LIFE

As the greater part of the Cold Bay-Katmai district is not forested, game is not so plentiful there as in many other parts of Alaska. The most numerous of the larger animals is the Kodiak bear, tracks of which are seen nearly every day in all sorts of places.

Usually these bears are very shy, and very few of them have been seen by Geological Survey parties. In the area covered by ashes the food of the bear, consisting principally of grass and fish, has been decreased. However, several trails made by bears cross the region. The timbered area is the westward limit of the range of moose, although a stray one is reported to have been killed recently south of Becharof Lake. Many tracks and a single large moose were seen in the Savonoski Valley by members of the party of 1923. Caribou were fairly plentiful on the Alaska Peninsula 30 or 40 years ago, but during recent years very few have been seen. About 20 were seen in 1922 by members of a United States Geological Survey party southwest of Wide Bay, but only a few tracks were noticed in 1923 in the Katmai region.

Many fur-bearing animals live in the district. The red fox is most abundant, and mink, marten, land otter, wolverine, and lynx are also taken by trappers. Lynx are not found farther south than the upper Kejulik Valley and are rather few there except during certain years, although they are apparently plentiful in the Savonoski Valley. The large Arctic hare is found in the vicinity of Cold Bay; farther northwest it was not seen, but small rabbits are very numerous. Grouse find a suitable environment in the spruce forest, and several varieties of ptarmigan are plentiful on the mountains and tundra. In the forested area around the lakes in the northeastern part of the district small birds are common and include robins, jays, crossbills, and woodpeckers. These birds were not seen near Cold Bay, but golden-crested sparrows, water wrens, magpies, snipe, ravens, and a small yellow-plumed bird belonging to the canary family are numerous. An abundance of waterfowl, including many species of ducks as well as geese and swans, find favorable breeding places in the lakes and swampy areas west of the mountains. Thousands of sea fowl—gulls, shags, and sea parrots—breed in the cliffs and on the rocky islands along the Pacific coast and are often seen flying across the peninsula.

The lakes and streams that drain to Bering Sea are the spawning grounds of the Alaska red salmon. Each year countless thousands of salmon migrate from salt water to the bodies of fresh water in which they were hatched to spawn and die. Along the larger rivers flowing from the lakes into Bristol Bay an extensive canning industry has been established. Several valuable species of salmon occur on the Pacific side, but the red or sockeye salmon is not as plentiful as on the Bristol Bay coast. Large trout are found in nearly every stream in the district, and grayling were caught in a few streams.

POPULATION

The country between Cold Bay and Naknek Lake, a distance of about 60 miles, is not inhabited except by one white man living on Cape Kubugakli. Formerly Katmai village, near the head of Katmai Bay, was one of the largest native villages along the southern coast of the peninsula, but it is now entirely abandoned. Other villages close to Naknek Lake have also been abandoned since the Katmai eruption in 1912. Savonoski, near the mouth of Savonoski River, was the largest of the inland villages.

Several substantial frame buildings were constructed on the west shore of Cold Bay near its entrance in 1902, when the first oil developments were under way. These buildings are still in good condition and formed the principal trading post for many years but were unoccupied in 1923. A trapper's cabin at the head of the bay is the base of several trappers during the winter. The lone white inhabitant of Cape Kubugakli operates several trap lines during the fur season; otherwise the district has not been visited by trappers since the natives were driven out in 1912. Many of the natives have settled on Bristol Bay near the large salmon canneries. The transient population at the canneries during the canning season amounts to several thousand people. A few tourists visit the Katmai National Monument each year, but until the region is made more accessible by roads and roadhouses, few travelers will brave the hardships of the trip.

The nearest white settlement to the district is Kanatak, on Portage Bay, 30 miles south of Cold Bay. This town is the base of supplies and center of activity of the present oil developments on the Alaska Peninsula.

ROUTES OF TRAVEL

Parts of the Cold Bay-Katmai district are rather inaccessible at present. This is especially true of the Valley of Ten Thousand Smokes, which lies about 25 miles inland from the Pacific coast. No provision has yet been made to facilitate the trip over the rough country that lies between the coast and the valley. Formerly Katmai Pass, across the mountains between Katmai Bay and Naknek Lake, afforded an important means of going from the Pacific coast to Bristol Bay. This trail was a tribal highway for centuries before the arrival of white men. Petrof[8] gives the following account of Katmai village and the pass:

> The settlement of Katmai, in this vicinity, was once the central point of transit for travel and traffic across the peninsula. Three different routes converged here and made the station a point of some importance; now

[8] Petrof, Ivan, Report on the population, industries, and resources of Alaska in the Tenth Census, reprinted in Compilations of narratives of explorations in Alaska, 1869-1900, p. 84, Committee on Military Affairs, U. S. Congress, 1900.

Katmai's commercial glory has departed, and its population, consisting of less than 200 Creoles and Innuits, depend upon the sea otter alone for existence.

The people of two villages across the divide, in the vicinity of Lake Walker (Naknek Lake), come down to Katmai to do their shopping and to dispose of their furs, undertaking a very fatiguing tramp over mountains and glaciers and across deep and dangerous streams in preference to the canoe journey to the Bristol Bay stations. On the eastern side of the peninsula the mountains rise abruptly from the sea, a short day's climbing transplanting the traveler from tidewater into the midst of glaciers and eternal snows and scenes of alpine grandeur and solitude.

During the gold excitement at Nome Katmai again became an important point in the long and weary journey to the site of the new discovery. Hundreds of prospectors preferred the rough trail and the fury of the winds in the pass to the long and hazardous ocean trip of 300 miles around the end of the peninsula. A bunk house was constructed at Katmai, and small boats plied Naknek Lake and Naknek River to accommodate the travelers. During the winter the Nome mail was carried over this route by dog sled for many years. A very low divide exists between the head of Cold Bay and Becharof Lake. The route by this divide was never extensively used, however, probably on account of the difficulty of landing and the swampy areas along the way. In the period from 1902 to 1904 a wagon road was constructed from Cold Bay to the headwaters of Becharof Creek. The road is in poor condition at present but was used for several years by the Bristol Bay mail carriers. Although there are many bays along the coast protected harbors are not plentiful, and for this reason the problem of constructing a road into the Valley of Ten Thousand Smokes is more difficult. Three possible routes into the valley could be used. The route that has received the most consideration is by way of Geographic Harbor, the upper part of Katmai Valley and Katmai Pass. Although Geographic Harbor affords good anchorage, it is surrounded by lofty mountains which must be crossed in order to reach the Valley of Ten Thousand Smokes. The construction of a road or even a trail over these mountains would require a considerable expenditure of money. Nevertheless it is the shortest route into the valley, although by no means the easiest. Another possible way of entering the valley is by Cold Bay and the Kejulik River valley. The Kejulik Mountains would have to be crossed near the head of the valley, and this can be accomplished only by pack train. The traveler would enter the valley at its west end by taking this route. A third route is by Kanatak, Becharof Lake, and Yori Pass to the west of the valley. A wagon road has been built from Kanatak to the upper arm of Becharof Lake. Thence a four hours' boat ride would land the traveler on the north side of the lake, west of the Kejulik Mountains. From this point a journey of 35 miles over moderately level country would place him at the west entrance of the valley. This route, although indirect, presents the fewest difficulties and is probably the most feasible of the three ways of entering the valley from the Pacific side of the peninsula. The most serious objection to it is the lack of a safe harbor at Kanatak.

GEOLOGY

GENERAL FEATURES

The investigation of the area between Cold Bay and Naknek Lake was a reconnaissance survey, and only the principal geologic features were noted. (See Pl. IV.) The time spent in any one locality did not permit a detailed study of the geology, and frequently the inclemency of the weather interfered with work. The district is occupied chiefly by sedimentary rocks, which are gently folded, faulted in places, and intruded by igneous rocks. All the sedimentary rocks, except the unconsolidated alluvium and glacial débris, are of Mesozoic age, and the greater part are Upper Jurassic. Therefore, aside from several faulted areas and the problems concerning the volcanoes, the geology of the district is not complicated.

The oldest sedimentary rocks exposed in the district are of Upper Triassic age and occur on Cape Kekurnoi. Above the Upper Triassic beds are several thousand feet of sandstone, shale, and conglomerate, which have been referred to the Lower (?) and Middle Jurassic. Upon these beds a great thickness of Upper Jurassic strata rests unconformably. The Upper Jurassic sequence is divided into the Shelikof and Naknek formations. The Naknek forms the surface rock over the greater part of the district.

Igneous rocks occur in several areas and vary greatly in character. The largest mass extends southwestward from Naknek Lake and consists of coarsely crystalline granite and gabbro. The rugged crest of the Kejulik Mountains is formed by lava flows over the Naknek formation. Andesite intrusions occur in a number of mountains north and south of the Valley of Ten Thousand Smokes, and the valley itself is filled with andesitic volcanic ash and pumice to a depth of 100 feet or more. Thick sills and dikes are exposed on Mount Kubugakli, and older flows and intrusive rocks are interbedded with the Triassic limestone on Cape Kekurnoi.

All the larger valleys, the lowlands at the heads of bays, and the broad area west of the mountains are covered with alluvium or glacial detritus. The most extensive areas covered by glacial moraines are the valley of Angle Creek and adjacent area and the immediate vicinity of Naknek Lake. Active glaciers on the flanks of Mageik and several other volcanoes in the district are depositing considerable amounts of material at their terminals.

The structure of the rocks in the region is rather simple. From the coast to the west side of Kejulik Valley the structure is monoclinal, the beds dipping 4°–30° W. and in general striking N. 60° E. Locally the strata are nearly horizontal, especially along the Kejulik Mountains and in the vicinity of the Valley of Ten Thousand Smokes. An extensive fault probably exists at the contact of the granitic mass and the sedimentary rocks in the western part of the district. Other major faults and several minor faults were noted.

SEDIMENTARY ROCKS

TRIASSIC ROCKS

Little additional information was gained in 1923 regarding the small area of Triassic rocks exposed on Cape Kekurnoi. The rocks are equivalent in age to the Upper Noric of Europe and are the oldest sedimentary beds that crop out in the district. These beds, so far as known, have been described in several publications,[9] although a detailed study of them has not been made. The rather indefinite contact with the overlying Jurassic rocks has not been followed across the cape.

The formation consists chiefly of thin-bedded limestone, interbedded with sills or flows of basalt. However, the lowest beds exposed in the cliffs between Cold Bay and Alinchak Bay consist of very massive buff limestone about 85 feet thick which strike in general N. 75° E. and dip 20°–35° SW., although locally the dip is reversed and the strike is not constant. The cliffs are continuous along the beach between the two bays for nearly 5 miles and average about 80 feet in height. They are nearly vertical for the entire distance; at places they even overhang. About half the rock exposed in the cliffs and in the stream canyons back of the cliffs is basaltic and tuffaceous material containing veinlets of calcite and pyrite. The upper part of this series of rocks, also intercalated with igneous material, is exposed along the southeast shore of Alinchak Bay. Several hundred feet above the lowest bed of sedimentary rocks exposed a widely distributed Upper Triassic fossil, *Pseudomonotis subcircularis* Gabb, occurs abundantly at both Cold Bay and Alinchak Bay. The thickness of the beds of undoubted Triassic age is probably between 600 and 800 feet, but a careful measurement has not been made. The upper part of the limestone yields fossils which are believed by T. W. Stanton to be Jurassic.

[9] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 393–396, 1904. Martin, G. C., Triassic rocks of Alaska: Idem, vol. 27, pp. 685–718, 1916; Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, p. 58, 1921. Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 755, pp. 92–93, 1922. Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 151–218, 1924.

A gradual transition takes place from the limestone to a massive sandstone that is undoubtedly Jurassic, and no evidence of an unconformity has been noted between the limestone and the sandstone.

JURASSIC ROCKS

LOWER (?) AND MIDDLE JURASSIC ROCKS

The oldest Jurassic sedimentary rocks in the district and, so far as known, the oldest in the Alaska Peninsula rest conformably upon the Triassic rocks at Cape Kekurnoi. They are at least 2,000 feet thick and comprise limestone, massive calcareous sandstone, shale, and conglomerate. They extend across the cape from Cold Bay to Alinchak Bay. The beds are cut by several dikes and contain layers of fossiliferous tuff. On the shore at Cold Bay less than 100 feet above the highest zone of *Pseudomonotis* and apparently in the same stratigraphic unit a collection of fossils was made that has been determined by T. W. Stanton as follows:

12076. No. 2. South side of Cape Kekurnoi above Pseudomonotis zone:
- Trigonia? sp.
- Solemya sp.
- Stephanoceras?, crushed fragment.

This lot is believed to be Jurassic.

At Alinchak Bay 200 feet or more above the highest observed *Pseudomonotis* zone a collection of fossils was made from sandy limestone and interbedded layers of tuff that has been identified as follows by Mr. Stanton:

12075. No. 1. Southwest shore of Alinchak Bay:
- Lima sp. related to L. gigantea Sowerby.
- Leda sp.
- Pleuromya? sp.
- Undetermined pelecypods, three species.
- Phylloceras? sp.
- Aegoceras?? sp.
- Other undetermined ammonite fragments.
- Sagenopteris sp. (determined by F. H. Knowlton).

This lot is believed to be Jurassic, as old as the Tuxedni sandstone (Middle Jurassic) or older.

The beds tentatively included in this assemblage were measured by Capps[10] and are approximately as follows:

Section of Lower (?) and Middle Jurassic beds at Cape Kekurnoi

	Feet
Conglomerate (top of section)	75
Mainly black to rusty weathered shale with some thin beds of limestone	800
Prevailingly massive sandstone	800
Prevailingly limy sandstone and limestone	700

[10] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, p. 94, 1922.

The conglomerate was arbitrarily chosen as the top of the section and was thought to mark an unconformity at the base of the Upper Jurassic. The section at Alinchak Bay is very similar in sequence and in lithologic character, except at the top, where the conglomerate is absent. The brown iron-stained shale at the top of the Alinchak Bay section is overlain unconformably by a coarse massive sandstone that is believed to be Upper Jurassic. The total thickness is estimated to be less than at Cold Bay. The unconformity was not traced across the cape.

The beds dip 10°–25° NW. and conform in general to the monoclinal structure of the thick series of overlying Upper Jurassic beds.

UPPER JURASSIC ROCKS

SHELIKOF FORMATION

Probably the thickest section of Upper Jurassic marine sedimentary rocks in North America is found on the Alaska Peninsula. The total thickness of the beds of this series as developed west of Wide Bay is at least 10,000 feet. The lower beds, which are from 5,000 to 7,000 feet thick, consist chiefly of massive sandstone and carbonaceous shale and have been called the Shelikof formation, from their occurrence along the west side of Shelikof Strait. The formation as now known will probably be subdivided into smaller and more distinct lithologic units. The Naknek formation, consisting of thick beds of conglomerate, arkose, and sandy shale with a total thickness of at least 5,000 feet but probably much more, constitutes the upper part of the Jurassic rocks on the Alaska Peninsula. The faunas of the two formations are quite distinct, the Shelikof being characterized by various species of the ammonite *Cadoceras*, whereas the most abundant and characteristic fossil of the Naknek is the widely distributed *Aucella*.

In the area east and northeast of Cold Bay the Shelikof is apparently not so well developed or the exposures are relatively poor except along the northeast shore of Cold Bay. A section made at this locality by Capps shows a thickness of about 5,000 feet. These beds are monoclinal; they strike prevailingly northeast and dip 8°–40° NW. At 10 miles east from the head of the bay the beds flatten, and at Kashvik Bay are concealed by the overlying Naknek. The Shelikof formation is not exposed along the coast, so far as known, north of the upper arm of Alinchak Bay. Although only estimates of the thickness were made, the formation apparently decreases in thickness toward the east from the head of Cold Bay, and some of the massive sandstone beds change laterally into shale.

Section of uppermost beds of the Shelikof formation just north of the head of Cold Bay

	Feet
Thin-bedded bluish shale with thin layers of light-colored fine-grained sandstone	220
Shale and light-colored to dark-brown sandstone	340
Massive sandstone weathering nearly white, light red at base	680
Very massive dark to light brown sandstone	620

The above section and part of the overlying Naknek is duplicated along the northeast side of Cold Bay, having been displaced by two faults, one on each side of and parallel with the lower part of Portage Creek. The relative movement was downward on the southeast side, with a displacement of at least 2,000 feet. In the cliffs at the southwest end of the bay the displacement is greater and the fault is known as the Dry Creek fault. Northeast of the forks of Portage Creek evidence of the faults was not observed, but they probably extend some distance and may account for the apparent thinning of the Shelikof beds.

The base of the Shelikof, as exposed along the north shore of Cold Bay, is composed of a massive conglomerate about 75 feet thick in which some of the boulders are 2 feet in diameter. The conglomerate was not recognized farther east toward Alinchak Bay. A great thickness of massive brown sandstone, some of which is concretionary, with minor amounts of conglomerate and shale, overlies the basal conglomerate at Cold Bay. The sandstone is about 4,000 feet thick and forms the middle and most prominent member of the Shelikof formation. The upper member consists of 500 to 1,000 feet of black shale with some sandstone and limy shale. At places the shale is concretionary, the concretions consisting either of shale or of blue limestone that weathers dark yellow. The amount and thickness of the sandstone beds within the shale vary greatly from place to place, but the shale is always found beneath the conglomerate at the base of the Naknek formation.

Collections of fossils were not made from the Shelikof formation northeast of Cold Bay, but several lots were collected southwest of Cold Bay by Capps in 1921. These fossils, chiefly *Cadoceras*, are also characteristic of the Chinitna shale at its type locality at Chinitna Bay, on Cook Inlet. The thickness and lithology of the two formations differ considerably, but the similarity of the fossils makes the correlation of at least part of the Shelikof with the Chinitna formation rather definite. The upper shale member of the Shelikof yields very few fossils, but its position below the basal conglomerate of the Naknek places it within the Shelikof formation.

NAKNEK FORMATION

The Naknek is the most extensive areal formation in the district north of Cold Bay, as well as in many other parts of the Alaska Peninsula. All the known consolidated sedimentary rocks west of Kashvik and Katmai bays belong to this formation. Lithologically the sequence of beds is rather constant over wide areas, but the individual members vary greatly in thickness from one locality to another. The base of the Naknek is composed of a series of fine to very coarse conglomerate and arkosic sandstone 1,000 feet thick at Cold Bay but attaining a maximum thickness of 2,000 feet or more west of Wide Bay. At most localities a basal conglomerate forms a distinct unit; northeast of Cold Bay, however, the conglomerate is absent or occurs in thin lenses. In this locality coarse pebbly and arkosic sandstone rests upon the upper shale of the Shelikof formation. Above the conglomerate and arkose thick beds of sandy *Aucella*-bearing shale and thin beds of sandstone form the upper part of the Naknek formation southwest and northeast of Cold Bay except in Mount Katolinat, south of Iliuk Arm of Naknek Lake, where about 2,000 feet of sandstone and conglomerate rest upon the fossiliferous shale. This condition could result from a thrust fault, but it more probably represents a near-shore phase of deposition. The higher slopes of Mount Katolinat, which is one of the largest mountain masses in the district, were not visited by the writer. The data are taken from the unpublished notes of C. N. Fenner, who reports many generally horizontal or gently inclined intrusions of hornblende andesite cutting the sedimentary rocks in the mountain. Similar intrusions were noted in neighboring mountains, but the thick beds of conglomerate do not occur.

The westward extent of the Naknek, so far as known, north of Cold Bay is limited by a large granitic mass occurring along the central part of the peninsula southwestward as far as Becharof Lake. The contact of the granitic mass and the Naknek formation was not seen west of Naknek Lake, but a short distance from the granite the sedimentary rocks are broken and discolored, indicating a fault. A fault contact is reported farther northeast near Kamishak Bay. The strata exposed in the Kejulik River valley and the Kejulik Mountains are entirely of Naknek age and consist predominantly of bluish to black sandy shale. Relatively thin beds of sandstone and layers of limy concretions are irregularly interbedded. The thickness of the shale is apparently very great, but it is probable that there are many displacements within the valley that have not been observed. An estimate of the minimum thickness of the upper shaly member of the Naknek in the Kejulik Valley and Kejulik

Mountains is 4,500 feet. However, if there is no great repetition of beds caused by faults parallel to the Kejulik Valley and concealed beneath the alluvium, the thickness is probably twice the amount estimated. A few minor faults of 10 to 20 feet displacement were noted in the Kejulik Valley and Mountains. Considerable faulting has taken place near the base of the south side of the volcano locally known as Mount Martin. The faults apparently do not trend in any general direction, inasmuch as the strata appear to have been broken into large blocks that have been tilted. This faulted area was seen only from a distance, and the extent of the faults and the amount of displacement are not known. It is probable that a fault extends along the east side of the Kejulik Mountains near Becharof Lake, but this is not certainly known and is postulated from observations made on the structure from distant points of view.

The rugged crest of the Kejulik Mountains consists of andesite and very scoriaceous black and red lava that flowed out over the Naknek beds. The vent from which the lava was extruded has not been discovered.

The beds of the Naknek formation strike generally northeast and dip 4°–15° NW. in the Kejulik Valley and in the mountains east of the valley. The rocks in the Kejulik Mountains are nearly horizontal, but along the east side of the range there are slight dips toward the southeast, forming a shallow syncline along the upper northwest side of the valley. The syncline can be seen at the head of the valley east of the mountain locally called Mount Martin. Near the head of Tokayofo Creek, on the west side of the Kejulik Mountains, the beds strike N. 80° E. and dip about 4° SE., forming a broad structural terrace along the Kejulik Mountains that trends somewhat parallel to the crest of the range. The Naknek sandstone and shale exposed in the mountains on both sides of the Valley of Ten Thousand Smokes and also east and southeast of the lower Savonoski Valley are nearly horizontal. Locally, however, the beds dip 2° to 6°, but no well-defined anticlines or synclines were mapped.

Throughout the thickness of sandy shale beds of the Naknek formation *Aucella* is abundant and a few other fossils occur. Several collections were made by the writer and determined by T. W. Stanton, as follows:

12276. No. 3. Head of central and principal tributary of Bear Creek, flowing into north arm of Alinchak Bay, Alaska Peninsula:

Aucella sp. related to A. bronni.
Lima sp.
Artica sp.
Pleuromya sp.

These fossils belong to the Naknek fauna.

12077. No. 4. East side of Kejulik Pass, below Gas Creek:

Rhynchonella sp.
Pleuromya sp.
Turbo? sp.
Belemnites sp.
Phylloceras sp.
Bone fragment.

Jurassic, Naknek.

12078. No. 5. Upper part of Gas Creek. Lowest exposed beds:

Aucella sp.
Eumicrotis? sp.

Jurassic, Naknek.

12079. No. 6. Mountain top east of Yori Pass:

Aucella sp.
Astarte sp.
Pleuromya sp.

Jurassic, Naknek.

12080. No. 8. Baked Mountain, north side of Valley of Ten Thousand Smokes:

Aucella sp.
Lima sp.
Turbo? sp.
Belemnites sp.

Jurassic, Naknek.

12081. No. 9. Float in tributary of Savonoski River:

Aucella sp.
Eumicrotis sp.
Astarte sp.
Tancredia sp.

Jurassic, Naknek.

The rocks exposed on the Severson Peninsula, which projects into Becharof Lake from the east side, consist entirely of thick beds of conglomerate and coarse arkosic sandstone probably belonging to the basal part of the Naknek formation. The total thickness of the beds on the peninsula is probably 400 feet. The general strike is N. 75° E., nearly parallel to the direction of the peninsula. The dip ranges from 6° to 12° N., with local changes to the east and west. No fossils were found on the peninsula.

Fossils have not been found in the basal conglomerate and arkosic member of the Naknek except in some transitional beds near the top. The stratigraphic position of this conglomerate at Cold Bay corresponds rather closely to that of the Chisik conglomerate on the west side of Cook Inlet, where the conglomerate and arkose member rests upon beds yielding *Cadoceras* and is overlain by *Aucella*-bearing shale. At Cold Bay, however, the conglomerate lies about 800 feet above the highest known *Cadoceras* horizon, and the intervening shale may be in part equivalent in age to the Chisik conglomerate. On Cook Inlet and near Kamishak Bay (see pp. 168–169) the conglomerate is considered a distinct unit, but in the Cold Bay-Katmai district it has been included in the Naknek formation on account of the indefinite upper limit of the arkose. However, the conglomerate and arkose of Cold Bay are probably equivalent in part to the Chisik conglomerate of Cook Inlet.

QUATERNARY DEPOSITS

Deposits of alluvium composed chiefly of glacial material transported by streams occur in the lower parts of the valleys and the lowland on the northwest side of the peninsula. Glacial moraines formed by active and ancient glaciers are found in some of the larger valleys and along the margins of the principal lakes. The active glacier on the west side of the volcano at the head of Angle Creek has formed a rather prominent terminal moraine about 200 feet high. Farther down the valley the slopes of the hills adjacent to it are covered by glacial material in the form of irregular moraines roughly parallel to the valley. Many large striated boulders of andesite, probably from the volcano at the head of the valley, are scattered throughout the finer material of the moraines. Ponds and kettle holes are numerous in this area.

A very curious moraine extends unbroken for about 5 miles nearly parallel to the south shore of a lake west of Naknek Lake. The moraine is 2 miles from the shore of the lake; it is not wide but reaches a height of 150 to 200 feet and crosses a ridge several hundred feet above the lake. The area between the moraine and the lake is rather heavily timbered with spruce, but beyond the moraine toward the south there is scarcely a tree. A stream flowing north directly toward the lake is deflected northwestward by the moraine and forms part of the King Salmon River drainage system. A large part of the glacial material consists of hornblende andesite and fragments of shale containing *Aucella*. The mountains immediately south of the moraine, though apparently glaciated, are composed of coarsely crystalline granite, boulders of which could not be found in the débris at the locality examined. Across the lake toward the north andesite and the *Aucella*-bearing beds of the Naknek formation are not known to occur; hence the direction in which the glacier moved and the source of the material it deposited are problematic.

Large mounds of glacial débris were formed at the lower end of the Valley of Ten Thousand Smokes. Huge striated boulders of andesite from the mountains at the upper end of the valley, 12 miles away, are common in the heterogeneous morainal material. The valley is covered to a depth of 100 feet or more with volcanic ash and pumice. A detailed description containing a theory of the origin of the pumice has been published.[11] Detritus from stream and glacial erosion has accumulated in small deltas near the mouths of the larger streams entering Naknek and Becharof lakes. The numerous small islands in the upper part of Becharof Lake are made up entirely of alluvial material. The area of knolls or moraines forming the islands extends over the lowland east of the lake.

The coastal plain west of the mountains is low and contains many lakes, marshes, and areas of tundra. The only rock exposures are along streams and consist of more or less stratified alluvium. Spurr[12] gives the following description of the geology along Naknek River:

> There are no rock outcrops on Naknek River, the shores being always stratified clays and sands, undisturbed and horizontal, containing many boulders, which reach large size. These boulders are often striated and are chiefly mica diorite. At the coast the bluffs are from 40 to 60 feet high, but farther up the river they shrink to 20 feet and then increase again to the same height as those of the coast. At places there are well-marked terraces about halfway up to the top of the bluffs, which are level. At the upper end of the river, where it leaves the lake, there is no rock ridge, but only the same stratified drift as farther down.

IGNEOUS ROCKS

Several areas of igneous rocks, in which both intrusive and effusive types are represented, differing in age and composition, occur in the district under consideration. The largest area extends from the north shore of Becharof Lake, west of the Kejulik Mountains, to Naknek Lake and continues northwestward toward the Alaska Range. The width of the mass is not known; the contact with the Upper Jurassic sedimentary rocks on the east has been mapped, but the western contact is in many places covered with alluvium. The central part of a group of mountains southeast of Naknek Lake is composed of coarsely crystalline granitic and gabbroic rocks. The granites are light gray or pinkish; locally they show weak gneissoid banding. Masses of gabbro occur in close association with the granite but in much smaller amount. The east flank of the mountains is composed of finer-grained acidic and basic rocks, which may be either marginal facies of the coarsely crystalline mass or separate intrusions. The latter mode of origin is indicated by a rather sharp contact at one locality. Several quartz veins and considerable quantities of pyrite were noted on the east side of the range. The rocks containing the pyrite when exposed to the agents of weathering assume a reddish color and can be seen from distant points. Boulders occurring in the basal conglomerate of the Naknek

[11] Fenner, C. N., The origin and mode of emplacement of the great tuff deposit of the Valley of Ten Thousand Smokes: Katmai series No. 1, Nat. Geographic Soc., 1923.

[12] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 145, 1900.

formation are similar in texture and composition to the various kinds of igneous rocks found in place in the mountains southeast of Naknek Lake. No other source of the boulders and pebbles making up this conglomerate is known. Hence it is thought that the age of the coarsely crystalline rocks and probably the finer-textured marginal rocks is pre-Naknek.

Andesite of rather basic composition is found on the sides of the volcanoes and in the lower hills at the head of the Valley of Ten Thousand Smokes, and also near the summits of the mountains northwest of Knife Peak.

Mount Ikagluik, east of Ukak River, is made up of sedimentary rocks to a height of about 3,000 feet, but the upper 1,400 feet of the mountain is composed entirely of extrusive rocks. A depression on the summit of the mountain may be an extinct crater, the source of the igneous material. The rocks exposed in Knife Peak and near the tops of some of the mountains between Knife Peak and Mount Ikagluik are igneous, probably representing various types of andesite and basalt. Several mountains west of the lower part of Windy Creek appear to be composed of light-colored igneous rocks. Small dikes and sills cut the Naknek formation in the high mountains south of Yori Pass. The absence of sedimentary rocks more recent than the Naknek in this area makes the age determination of the andesitic rocks uncertain. However, they are very similar in character to rocks elsewhere on the Alaska Peninsula which are known to be Tertiary. The intrusive rocks of the Katmai district probably do not all belong to a single period of igneous activity, but some of them are undoubtedly of the same age as similar rocks southwest of Wide Bay.

The basaltic dikes and sills and interbedded tuffaceous material of the Triassic limestone of Cape Kekurnoi have already been mentioned (p. 195). Farther northeast along the coast, in the mountains on Cape Kubugakli, massive sills have been intruded into the sedimentary rocks, which are somewhat metamorphosed. Several dikes cut the sills and sedimentary rocks. One of the dikes, about 20 feet wide, exposed on the west side of Kubugakli Mountain, reaches from a point near the base to the summit. In the cliffs along the shore on the cape and in the banks of a small stream flowing from the mountain the country rock is impregnated by many small stringers of calcite and quartz. Some of the quartz stringers carry gold, magnetite, and the common sulphides.

Erratic boulders of igneous rocks—granite, diorite, greenstone, and many other types—are found at many places in the stream beds and scattered over the hills of the Cold Bay-Katmai district. Some of these boulders are angular, but most of them are rounded and are derived chiefly from the basal conglomerate of the Naknek formation.

Besides the pumice in the Valley of Ten Thousand Smokes, a small body of lava came to the surface in the crater of Novarupta during the volcanic activity in 1912. The lava is generally glassy, though slightly porous, and the greater part has the composition of a siliceous soda rhyolite, being much more siliceous than the older lavas in the vicinity. However, there are dark bands both in the lava of Novarupta and in the pumice of the valley which have the composition of a medium andesite. Several analyses [13] of Novarupta lava have been made.

MINERAL RESOURCES

INDICATIONS OF OIL

Oil seepages have been known for many years west of Cold Bay near the head of Oil Creek and to the southwest between Cold Bay and Portage Bay, also southeast of Mount Peulik about 15 miles inland from Portage Bay. Four wells were drilled near the seepages at the head of Oil Creek during the period 1902 to 1904, but the wells were not favorably located in respect to geologic structure, and oil was not found in commercial quantities. From 1920 to 1924 many claims were staked over wide areas from the Kejulik Valley to Chignik, but development did not begin until 1922, when two oil companies began to drill on the Pearl Creek dome, southeast of Mount Peulik. Observations on the geologic structure and the possibility of obtaining oil west and southwest of Cold Bay and in the Kejulik Valley have been recently published.[14] Favorable conditions of stratigraphy and geologic structure for oil accumulation are known to exist in the area termed the Cold Bay district. The expedition of 1923 from Cold Bay to Katmai was made partly for the purpose of finding out whether geologic conditions in this district are similar to those of the adjacent Cold Bay district.

Well-defined large anticlines and domes such as the Bear Creek-Salmon Creek anticline, between Cold and Portage bays, and the Pearl Creek dome, southeast of Mount Peulik, do not occur within at least 60 miles northeast of Cold Bay. In general the structure of the sedimentary rocks in this area is that of a monocline in which the beds dip away from the coast toward the northwest as far as the west side of Kejulik Valley. A few exceptions to this condition occur, especially in the northeastern part of the district, where the beds are nearly horizontal, but even here the slight local dips are

[13] Fenner, C. N., op. cit., p. 59.

[14] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 77–116, 1922. Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 151–218, 1924.

predominantly toward the northwest. On the flank of the monocline between the coast and the west side of Kejulik Valley there are many local changes in degree of dip, so that the beds become less inclined at places and form structural terraces or benches. Conditions similar to these have proved to be favorable for the accumulation of oil in other parts of the world. However, in the area northeast of Cold Bay the structural terraces so far as known are not well defined and do not extend for long distances. Furthermore, in most localities the stratigraphic sequence beneath the benches is not favorable for the discovery of oil at moderate drilling depth. A possible exception to this rule occurs along the east side of Kejulik Valley. At this locality the dip of the beds changes from a maximum of 23° W. in the high mountain east of the valley to 7° and 8° W. along the east side of the valley, becoming steeper farther west. The zone of relatively low dips is about a mile wide. The sandstone of the Shelikof formation, which, to judge from the occurrence of seepages in it west of Cold Bay, may be oil-bearing, should be within moderate drilling depth on the structural terrace extending along the east side of the valley. Whether the change in the degree of dip is sufficient to form a reservoir for oil is not known, but the best possibilities of reaching an oil-bearing bed in the Kejulik Valley are probably in the area of relatively low dips. However, special conditions such as local variations in cementation or porosity of beds and sandstone lenses inclosed in shale or other impervious rocks provide centers of concentration of oil and can not be foretold by surface observation. It is possible that such features exist within the Naknek formation in the Kejulik Valley. A more complete discussion of the occurrence of oil on monoclines is given in a previous paper [15] considering the same area.

A shallow syncline extends along the west side of the upper part of the Kejulik Valley. The dips for short distances on both sides of the syncline average about 4°. The beds on the east side of the Kejulik Mountains dip 4°–8° E. Along the crest of the range in the vicinity of Kejulik Pass (see Pl. IV) the beds are nearly horizontal. On the west side of the mountains the general dip is 2°–4° E., although locally the beds are horizontal or have a very slight dip toward the west. The position of the beds in the Kejulik Mountains forms a broad but not well-defined structural terrace near the pass. Farther northeast, near the volcanoes, the beds are faulted; the lower end of the range, near Becharof Lake, has not been examined. Southwest of the pass the crest of the mountains is very rugged and is composed of lava overlying the Naknek formation. Several minor faults were noted on the east side of Kejulik Pass.

[15] Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 206–209, 1924.

Although numerous gas seepages were found along a fault at Gas Creek, on the east side of the pass, the Kejulik Mountains are not considered at present to be a favorable location for the discovery of oil at moderate depth. The Naknek formation, including the lower arkosic member and the *Aucella*-bearing shale, is at least 6,000 feet thick in the Kejulik Mountains, and there is scarcely any indication of oil occurring within these beds. Aside from the unfavorable lithologic and structural conditions the country is not easily accessible.

Small seepages of petroleum have been reported to occur in the Kejulik Valley, but they have not been seen by members of the Geological Survey. No traces of petroleum are authentically known in the region visited by the writer northwest of Cold Bay. An oil seepage was reported "near Katmai Bay" by Davidson[16] and Dall[17] in 1869, but it is quite probable that they referred to the seepages near Cold Bay. The gas seepages on Gas Creek occur for about 200 yards along the stream and issue from the loose boulders in its bed. The gas has a very faint odor, is colorless, and burns with a bright yellow flame. A small hole was made in the bottom of a lard can and the can inverted over one of the seepages. The gas escaping from the hole burned with a flame about 8 inches in length that was continuously maintained for three days. It furnished sufficient heat to boil water for laundering.

The country west of the Kejulik Mountains is chiefly lowland in which there are very few rock exposures. The observations made in this area show nearly horizontal beds of Naknek shale. A small, low anticlinal fold crosses the north end of the Buttress Range, west of the Valley of Ten Thousand Smokes. The dips on either flank do not exceed 4° and the axis of the fold is apparently very short. The area is almost inaccessible and should not be considered favorable for the discovery of oil until production is obtained at other localities.

The more favorable geologic structural features in the Cold Bay district should be thoroughly tested and the horizon of an oil-bearing bed definitely determined there before drilling is undertaken in any part of the area covered by this report.

CAPE KUBUGAKLI GOLD PLACER

The terrane northeast of Cold Bay is composed chiefly of sedimentary rocks with few large igneous intrusions except in the vicinity of Naknek Lake, and the area is very little mineralized. The only known mineral deposit of economic value occurs on Cape Kubugakli, a bold headland that extends slightly farther than the

[16] Davidson, George, Coast Pilot of Alaska, 1869, p. 36.

[17] Dall, W. H., idem, p. 199.

neighboring capes into Shelikof Strait. In 1915 placer gold was discovered by Fred and Jack Mason in a small stream about 2 miles in length rising in the snow fields of Mount Kubugakli and entering the strait at the point of the cape just west of the southwest boundary of the Katmai National Monument. Four claims were staked, and since 1915 a small amount of gold has been recovered each year. The total amount produced is about 160 ounces.

The valley of the stream is narrow and has steep banks; the floor of the valley is about 100 feet wide. Glacial material, a considerable part of which consists of large boulders, occurs on the banks of the stream, indicating that a small glacier once occupied the valley.

The gold is seemingly confined to one creek, as the area around the mountain has been prospected without success. The source of the gold is evidently the dikes in Mount Kubugakli and the numerous small quartz stringers in the fine-grained igneous rock that forms the bedrock of the stream and the cliffs along the beach. The gold occurs in the creek bed along a sinuous strip 8 to 10 feet wide. The best-paying material is usually found just below quartz stringers, which are a quarter of an inch or less in width. The bedrock is about 2 feet below a covering of gravel and large boulders, and the boulders are so numerous as to make mining unprofitable. Besides gold, small hand specimens of stibnite, molybdenite, galena, and tetrahedrite have been found in some of the stringers. Pieces of magnetite often remain in the sluice boxes.

THE OUTLOOK FOR PETROLEUM NEAR CHIGNIK

By George C. Martin

INTRODUCTION

The Chignik district has attracted considerable attention as a possible oil field ever since the enactment of the oil-leasing law. A large number of oil claims have been staked, some of the township and claim boundaries have been surveyed, and private geologic investigations in behalf of claim holders or oil companies have been made. No wells have yet been drilled, and no active preparations for drilling had been begun in August, 1923. As far as the writer knows, no oil seepages, residues, gas springs, or structural conditions that are especially favorable for the occurrence of petroleum have been found. The causes that led to the staking of most of the oil claims apparently were (1) a general but erroneous popular opinion that much, if not all, of the Alaska Peninsula is probable oil land; (2) the belief that the supposed oil-bearing strata of the Cold Bay and Cook Inlet fields underlie the Chignik district; (3) the presence on a geologic map (U. S. Geol. Survey Bull. 467, Pl. VII) of a symbol indicating "main anticlinal axis of the Aleutian Range"; and (4) the relatively easy accessibility of the Chignik district.

The information and opinions contained in this paper are based in part on a brief examination of the Chignik district which the writer made in August, 1923, and in part on earlier publications. The most comprehensive account of the geology of the Chignik region is that given by Atwood,[1] who described the geology and coal beds in considerable detail but gave no consideration to the possibility of the occurrence of oil near Chignik. Other descriptions, dealing chiefly with the coal, have been written by Dall,[2] Stone,[3] and Smith and Baker.[4]

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

[2] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 801–804, 1896.

[3] Stone, R. W., Coal resources of southwestern Alaska: U. S. Geol. Survey Bull. 259, pp. 163–166, 170, 1905.

[4] Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 151–218, 1924.

The present paper includes a brief and very general account of the stratigraphy and structure, some detailed observations concerning the rocks at the localities which the writer visited, and a statement that in the writer's opinion the geologic conditions in the Chignik district are not favorable for the occurrence of oil.

GEOLOGY

STRATIGRAPHY

The rocks exposed in the Chignik district include the Upper Jurassic shale, sandstone, arkose, and conglomerate of the upper part of the Naknek formation; the Upper Cretaceous sandstone, shale, conglomerate, and coal beds of the Chignik formation; some early Tertiary (Eocene?) sandstone, shale, and conglomerate; some late Tertiary volcanic rocks; and Quaternary alluvial deposits. These rocks have been described in detail by Atwood.[5] A brief summary of their character, sequence, and thickness is given in the following table:

General sequence of rocks in Chignik district

	Feet
Quaternary:	
Alluvial, glacial, and beach deposits	100±
Tertiary:	
Andesitic and basaltic lava, agglomerate, tuff, and breccia	1,000±
Sandstone, shale, and conglomerate, with some thin beds of lignite	1,000
Upper Cretaceous:	
Chignik formation:	
Upper member—conglomerate, sandstone, and shale	300-500
Middle member—shale with many coal beds and some sandstone	300+
Lower member—shale	200±
Upper Jurassic:	
Naknek formation:	
Sandstone, conglomerate, arkose, and shale	1,000+

The base of the Naknek formation has not been recognized in the Chignik district, and it is believed that only the upper part of the formation is exposed. The supposed oil-bearing rocks of the Cold Bay and Cook Inlet fields, which lie in the lower part of the Upper Jurassic or in the Middle Jurassic, are not exposed in the Chignik district. They may not be present there, for they have not been recognized anywhere west of Wide Bay. If they are present beneath the Chignik district, they probably lie at great depths and may not be within the reach of the drill.

[5] Atwood, W. W., op. cit.

STRUCTURE

The structure of the Chignik district is not simple or especially favorable for the occurrence of oil. The rocks in some areas dip at low angles, but the general structure is not that of gentle folds or of flat rocks extending uninterruptedly throughout broad areas, but that of an intensely shattered mass in which the structural constituents consist of relatively small gently tilted blocks separated by faults or zones of shattering. Some of the broader structural features are indicated by the relations along the contacts of the major stratigraphic and structural units. These major rock masses (see Pl. V) include:

1. A large area of Upper Jurassic sedimentary rocks, which trend northeast along the main axis of the Aleutian Range west of Chignik Bay.

2. A belt of Upper Cretaceous sedimentary rocks, which trend northeast along the southeast flank of the Aleutian Range between the area occupied by the Jurassic rocks and the northwest shore of Chignik Bay and dip, in most places, southeast at low angles.

3. A belt of Upper Cretaceous and Tertiary sedimentary rocks, which trend northwest along the south shore of Chignik Bay and dip southwest.

4. A large area of Tertiary volcanic rocks south of the Upper Cretaceous and Tertiary sedimentary rocks south of Chignik Bay.

5. A large area of Tertiary and possibly Quaternary volcanic rocks in the peninsula northeast of Chignik Bay.

6. Broad areas of unconsolidated Quaternary deposits between the Aleutian Range and the shore of Bering Sea.

The southeast boundary of the large area of Upper Jurassic rocks in the mountains west of Chignik Bay is believed to be a fault. The contact between the Upper Jurassic and the Upper Cretaceous rocks on the unnamed creek next north of Whalers Creek is marked by a zone, several hundred feet wide, of brecciated shale cemented with calcite. This shattered zone is believed to lie on the extension of the fault which Atwood[6] represented as bounding the Upper Jurassic rocks south of Chignik Lake.

The writer believes that another fault, parallel to the one just mentioned, lies in the general position of the northwest shores of Chignik Bay and Chignik Lagoon. This fault is believed to form the southeast boundary of the Upper Cretaceous rocks west of Chignik Bay, separating these Upper Cretaceous rocks from the Tertiary rocks at the head of Chignik Lagoon, from the Upper Jurassic rocks near the spit at the entrance to the lagoon, and from the volcanic

[6] Atwood, W. W., op. cit., pl. 7.

rocks west of Hook Bay. It possibly, as Atwood[7] indicates, joins the fault that separates the Naknek formation from the Tertiary volcanic rocks south of Chignik Lake.

The Upper Cretaceous sediments, Tertiary sediments, and Tertiary volcanic rocks on the south shore of Chignik Bay lie in normal stratigraphic sequence, and all have a general northwest strike and southwest dip. There are some abnormal strikes and dips and some indications of faulting in this area, but their exact significance has not been determined.

The chief interest in the structure of the Chignik district is in the supposed oil-bearing Jurassic rocks of the mountains west of Chignik Bay. Such detailed information as is available concerning the structure of that area will therefore be given.

The Upper Jurassic rocks of the Aleutian Range have been described[8] as occurring in "a broad anticlinorium" or on the "main anticlinal axis of the Aleutian Range." The writer believes that the axis of the Aleutian Range in the Chignik district is anticlinal only in the sense that it exposes rocks older than those on the flanks. The range is regarded as a mosaic of uplifted fault blocks rather than an anticlinorium. The rocks may be arched in some places, as they seem to be on Chiaktuak Creek and as they are reported to be at other localities farther east, but such folding is believed to be local rather than typical of the broader structure.

On Chignik Lake the Upper Jurassic rocks dip gently, but their attitude indicates several fault blocks rather than simple folds. The rocks in the cliffs and hills bordering the western two-thirds of the lake strike northwest and dip 5°–25° NE. The rocks on the north shore about 2 miles above the outlet strike east and dip 15° S. The rocks on the southeast shore for 2 miles above the outlet strike northeast and dip 10°–12° SE. The writer believes that a fault crosses the lake at the narrow place about 2½ miles above the outlet and that there probably are one or more other faults between it and the outlet.

About a mile up the large creek that enters Chignik Lake from the west, about a third of the way down the lake, are good exposures of very dense and much shattered sandstone containing poorly preserved fragments of stems, bark, and grasslike leaves. These rocks are cut by a multitude of thin vertical veins of calcite. They are so intensely shattered that they probably could not hold oil. Beds of sandstone and black shale that are much shattered in places, probably on shear or fault zones, are exposed about 2 miles back from the lake. The rocks on this creek strike about N. 20° W. and dip 5°–8° NE.

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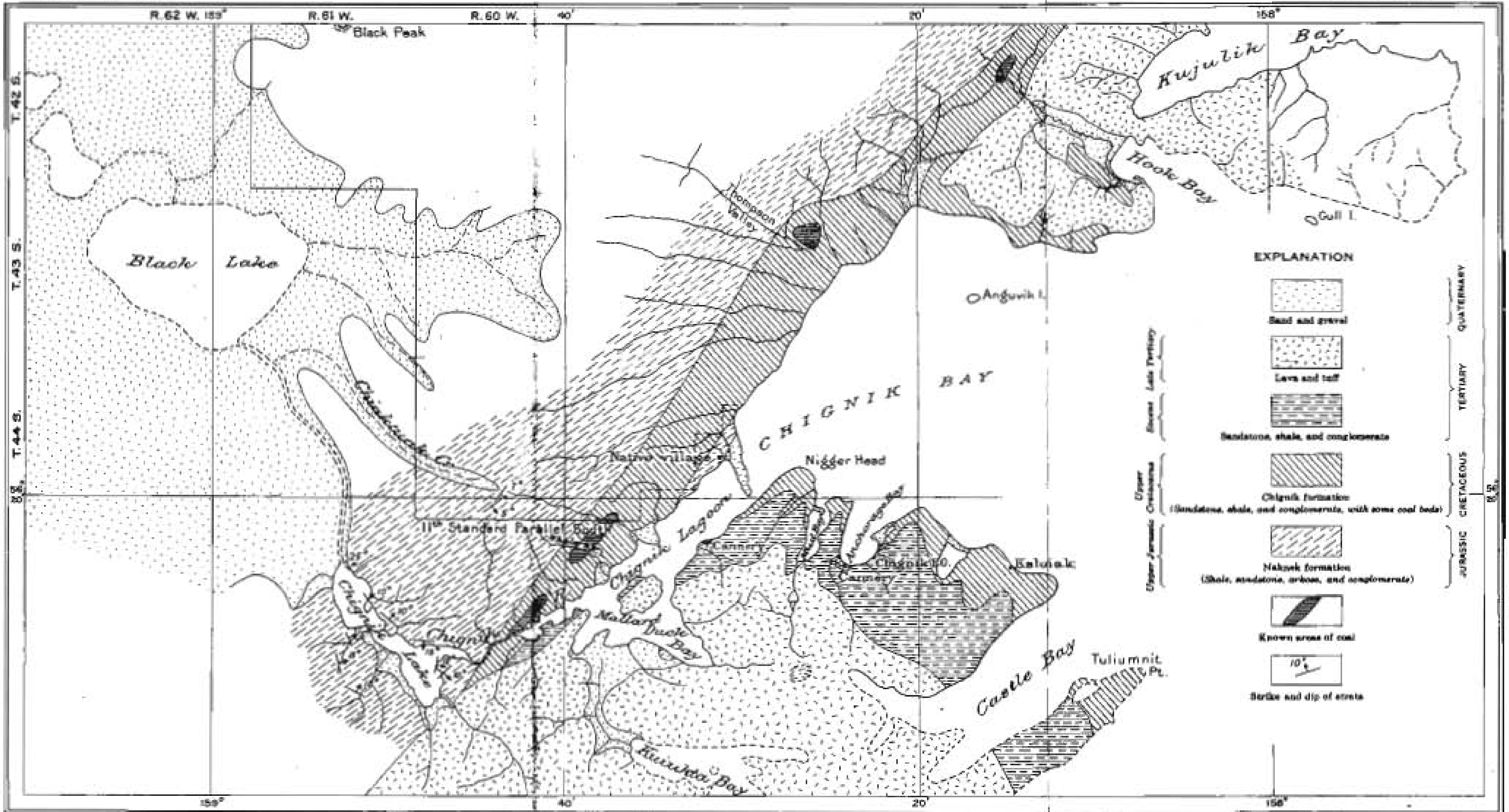
[7] Atwood, W. W., op. cit., pl. 7.

[8] Idem, pp. 28, 38, pl. 7.



Topography by U. S. Geological Survey
Surveyed by H. M. Eakin

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

0 5 10 MILES

Geology by W. W. Atwood and G. C. Martin

GEOLOGIC SKETCH MAP OF CHIGNIK DISTRICT, ALASKA PENINSULA

The exposures on the upper half of the northeast shore of the lake consist of pebbly sandstone and conglomerate that strike N. 33°–53° W. and dip 10°–25° NE. At one locality the conglomerate is cut by sills of basalt. These beds are not as much shattered as those west of the lake.

An exposure on the north shore of the east arm of the lake about 1½ miles above the outlet shows dense "flinty" shale or fine-grained sandstone that strikes about N. 86° W., dips about 15° S., and is cut by a multitude of thin calcite veins.

The Upper Jurassic rocks exposed near the head of Chiaktuak Creek and thence southeast to the contact with the Upper Cretaceous rocks on the creek north of Whalers Creek dip 5°–7° SE. The rocks exposed west of a point about 2 miles below the head of Chiaktuak Creek have a gentle westward dip. The reversal of dip 2 miles below the head of the creek may be on an anticlinal axis, but some of the outcrops near this point apparently show that the rocks have been broken. The reversal of the dip may therefore be due to faulting, possibly along the fault that is believed to cross Chignik Lake.

CONCLUSIONS

No oil seepages, residues, or gas springs have been authentically reported from the Chignik district. The supposed oil-bearing beds of the Cold Bay and Cook Inlet fields apparently do not crop out near Chignik, and if present there probably lie at great depth, perhaps beyond the reach of the drill. The rocks of the Chignik district are cut by many faults and shattered zones, so that in many places they would not be likely to retain oil. No domes are known. It is doubtful if there are any unbroken anticlines. It is possible that oil pools may be found at localities which the writer has not seen or where the oil has been sealed in by variations in the porosity of the beds or by faults, but the available information indicates that the outlook for oil in the Chignik district is not hopeful.

GEOLOGY AND GOLD PLACERS OF THE CHANDALAR DISTRICT

By J. B. Mertie, Jr.

INTRODUCTION

The area here called the Chandalar district lies between meridians 147° and 150° west longitude and mainly between parallels 67° and 68° north latitude, though extending a little north of 68° in the valleys of Dietrich River and the North Fork of Chandalar River. This area includes nearly all of the Chandalar River valley and some of the eastern tributaries of Koyukuk River. Mining operations at present are confined to Little and Big Squaw creeks and to Big Creek, all three of which drain to the North Fork of Chandalar River. The Koyukuk mining district lies to the west of the Chandalar district. (See fig. 8.)

The earliest geologic work in the Chandalar district was done in 1899, when F. C. Schrader[1] and T. G. Gerdine carried a geologic and topographic reconnaissance survey across the Chandalar and Koyukuk valleys. Late in the fall of 1909 A. G. Maddren[2] made a hasty visit to the district, but his work in this area was really only supplementary to more detailed observations in the Koyukuk Valley and added but little to the geologic knowledge of the Chandalar district proper.

The present report is a summary statement of the results of a study of the geology and gold placers of the Chandalar district, made by the writer in 1923. Landing about the middle of June at Beaver, on the Yukon, the party, consisting of a geologist, packer, and cook, proceeded with seven pack horses by the Government road to Caro, on the main Chandalar, thence by trail to the mining district at and around Little Squaw Creek. Leaving a cache at Little Squaw Creek, the party then proceeded northward, visiting the upper valleys of the Middle and North forks of the Chandalar and returning about the first of August to Little Squaw Creek. The second half of the trip consisted of a visit to the lower valley of the

[1] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 441–486, 1900.

[2] Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, 1913.

North Fork of the Chandalar, including Chandalar Lake and Baby Creek, thence westward in Crooked Creek and southward to the divide between Mosquito Fork of the Koyukuk and West Fork of the Chandalar, thence along the divide between Chandalar and Hodzana and Orenzik rivers to Caro, and returning about the last of August to Beaver. The remainder of the season was devoted to a boat traverse on the Yukon from Beaver to Tanana.

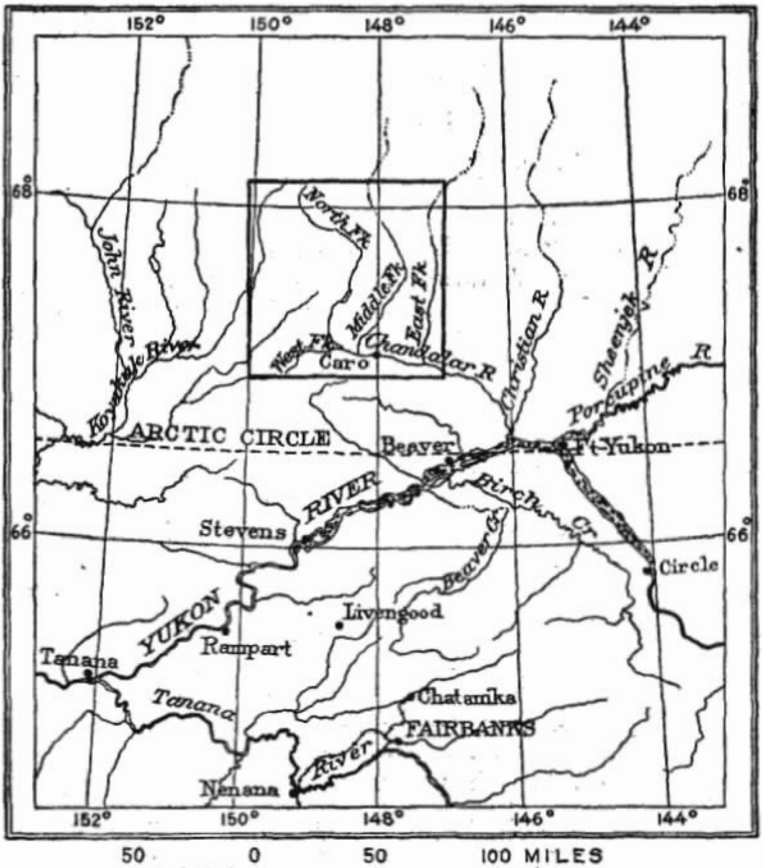


FIGURE 8.—Index map showing location of Chandalar district. Rectangle shows area covered by Plate VI

About 75 days was spent in the Chandalar district, and geologic observations were made in an area of about 4,000 square miles. The topographic map, made in 1899 by Gerdine, was used as a base for plotting geologic notes in part of the area. The writer, however, carried a foot traverse from Beaver to Little Squaw Creek and thence northward on the Middle Fork of the Chandalar, joining with Gerdine's topographic mapping at the forks of the North Fork of the Chandalar. The mapping on Plate VI of the drainage in that part of the area, therefore, is based on this foot traverse, and the same is true of the drainage of the headwaters of the West Fork of the Chandalar. Additional data on the drainage were taken from the topographic and geologic map prepared by Maddren.

The writer takes this opportunity to thank the white people in the Chandalar district for their interest in the work and for their unfailing cordiality and assistance. In particular, thanks are due to Messrs. Frank Yasuda and Charles Schultz, at Beaver, and to Messrs. Harry Patterson and Fred Smith, at Little Squaw Creek, for assistance rendered. The writer also acknowledges with thanks the faithful services rendered by Messrs. Earl Hunter and Clark Abel, the other two members of the party.

GEOGRAPHIC AND ECONOMIC FEATURES

RELIEF AND DRAINAGE

The northern and central parts of the Chandalar district constitute the south flank of the Endicott Range, a part of the Arctic Mountain system, which extends from the international boundary westward to Kotzebue Sound. This portion of the district is a region of rugged mountains, which have been intensely glaciated. The ridges are much dissected, and the crest lines, particularly in the areas of limestone, are irregular, thus making it difficult to follow the divides. The geologic structure of the rocks has played an important part in determining the trend of the ridges and the valleys.

Toward the south end of the district the hills are less sharply dissected, and the crest lines are lower and less rugged. This is particularly true south of Chandalar River, along the divide between the Chandalar and the Hodzana and Orenzik. Here the country begins to show rounded and rolling hills, which resemble those of the Yukon-Tanana region, though here, as in the Yukon-Tanana region, great granitic batholiths form isolated mountains of exceeding roughness. The mountains at the head of the West Fork of the Chandalar exemplify very well this phase of the topography.

The highest mountains, though not the most rugged, occur in the northern part of the district, toward the crest of the Endicott Range. Table Mountain, at the headwaters of the North Fork of the Chandalar, has an altitude of more than 7,000 feet and is about the highest point within the area here mapped. The lowest point is at the southeast corner of the district, in the valley of Chandalar River, where the valley begins to open up into the flats. The altitude here is about 750 feet, so that the maximum relief for the district is about 6,300 feet.

The Chandalar district is drained by Chandalar and Koyukuk rivers, both of which flow southward to the Yukon. Hodzana and Orenzik rivers head against the Chandalar at the south edge of the area mapped but can scarcely be included in the Chandalar district.

Most of the Chandalar district is drained by the West, North, Middle, and East forks of Chandalar River. Dietrich and Bettles rivers, joining to form the Middle Fork of Koyukuk River, together with South Fork and Mosquito Fork of Koyukuk River, drain the western third of the district. Observation during the season of 1923 was confined largely to the North, Middle, and West forks of Chandalar River. North, Middle, and East forks are three streams which are very similar in size and direction of flow and whose valleys are similar in physiographic character. West Fork, which joins North Fork to form the main Chandalar, differs in all three respects from the other forks.

North, Middle, and East forks of Chandalar River are large streams that drain in a general southerly direction from the Endicott Mountains. North Fork is better known than the other two. Heading in the crest of the mountains, against Dietrich River on the west and Middle Fork of the Chandalar on the east, it flows S. 60° E. for about 50 miles and then changes its course abruptly to S. 20° W., in which direction it flows for about 40 miles to the main Chandalar. This abrupt change in direction is undoubtedly controlled by the geologic structure of the country rock. In the upper 30 miles of its course North Fork is a swift mountain stream, flowing over a sand and gravel bed with numerous riffles and fordable almost anywhere on foot at ordinary stages of water. Then, rather abruptly, it enters a silt-filled and lake-dotted valley, through which it meanders tortuously for 35 miles to Chandalar Lake. In this stretch the river is sluggish, deep, and fordable with difficulty. Chandalar Lake is a body of water about 8 miles long and perhaps 1½ miles in average width, which lies in this same silt-filled valley. Below Chandalar Lake, however, the grade increases again and sand and gravel banks appear, and 8 miles below the lake the gradient of the river becomes very steep, forming the Chandalar Rapids, which extend downstream for a quarter of a mile. Below the rapids to the main Chandalar the North Fork is a swift mountain stream of considerable size, flowing over sand and gravel bars.

Middle Fork is much like the North Fork, except that no lake as large as Chandalar Lake is known in its course. It flows more or less parallel to the North Fork, at a distance ranging from 10 to 20 miles, and has a similar bend and a similar silt-filled valley in its middle course. East Fork is reported to have the same general character but was not explored in 1923. Viewed from a distance, however, the topography along the East Fork is less rugged and suggests more the rounded hills of the Yukon-Tanana region, to the south.

Another striking drainage feature is a wide cross valley which, starting from the North Fork of Chandalar River a few miles above Chandalar Lake, extends S. 70° E. to the East Fork. This depression is now occupied by small streams and evidently marks an earlier drainage channel of a larger stream. In common with the North, Middle, and East forks of the Chandalar, however, it has been grooved and deepened by later glacial action.

West Fork of the Chandalar is a smaller, swift-flowing stream from source to mouth. It is fordable almost anywhere at ordinary stages of water. About 10 miles above its mouth it splits into two forks, the smaller of which heads against Mosquito Fork of the Koyukuk and the larger heads against Hodzana River. Neither the West Fork nor the main Chandalar shows the features of glacial erosion that are seen in the valleys of North, Middle, and East forks.

Dietrich and Bettles rivers, the headwater tributaries of the Middle Fork of Koyukuk River, are both swift mountain streams, similar to the upper courses of North and Middle forks of the Chandalar. Their gradient, however, is more or less uniform, neither of them having silt-filled valleys along their middle courses like those of the North and Middle forks. Bettles River flows around the south end of the massive Silurian limestone and shows particularly well the control exercised by geologic structure on the courses of the streams in this district.

The main Chandalar is a swift stream down to the point where it flows out onto the Yukon Flats. It has been navigated by small river steamboats up to a point 7 miles above the mouth of the East Fork.

SETTLEMENTS AND POPULATION

Very few people are now living within the Chandalar district. A few white men and a number of Indians live at the settlement of Caro, on the north side of Chandalar River at the mouth of Flat Creek. The only other white men in the country are at the Little Squaw Creek mining camp, where perhaps 25 or 30 men live during the winter mining season. In addition, several small Indian settlements are scattered throughout the area.

TRAILS AND TRANSPORTATION

Caro is connected with Beaver, on the Yukon, by a wagon road 74 miles long, though in the early part of the summer this road is too wet for wagon transportation, being more suited to pack horses.

(See fig. 9.) Caro is connected with the Little Squaw Creek mining district by two trails. One of these goes up Flat Creek, thence across to Middle Fork, up Middle Fork to Grave Creek, and up Grave Creek to Little Squaw Creek. The other goes northwestward from Caro to Middle Fork and on to Big Creek, thence up

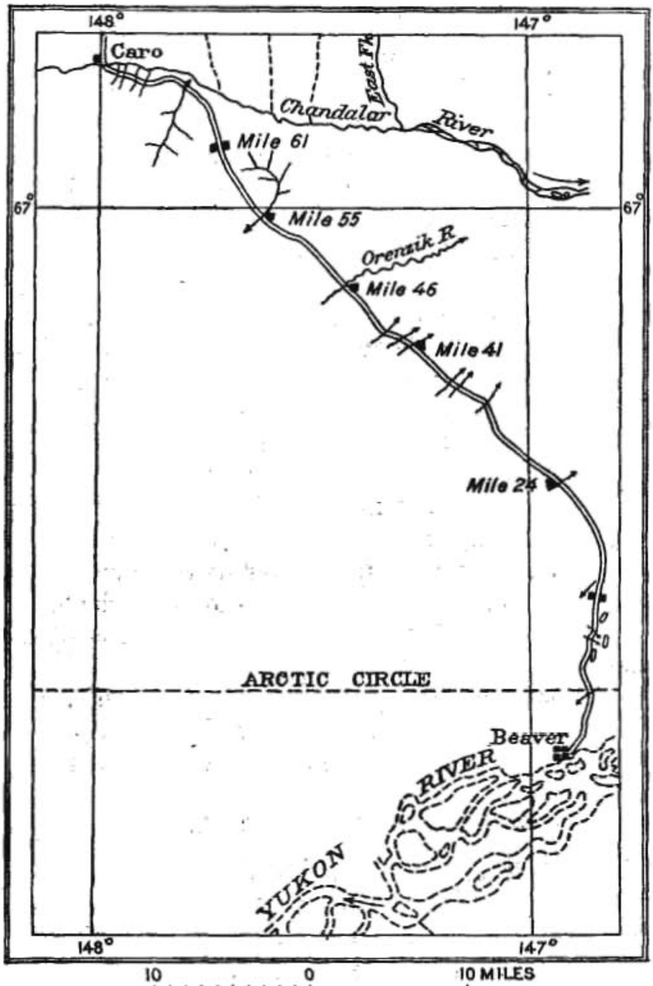


FIGURE 9.—Sketch map showing wagon road and drainage from Beaver to Cairo

Big Creek to its head, and over the divide into Little Squaw Creek. During the summer of 1923 a tram was constructed across Chandalar River at Caro by the Alaska Road Commission.

Supplies for the mining district at Little Squaw Creek are freighted from Beaver to Caro by wagon during the late summer and by dog sleds in winter. Freighting from Caro to the mining camp has so far been done by dog sleds in winter, but a tractor is now at Caro, and winter tractor transportation may soon be attempted.

Beaver receives its supplies largely from Skagway by the White Pass & Yukon Route but in part from Nenana.

CLIMATE

No records of temperature or precipitation have been kept for the Chandalar district, but it is believed that the climatic conditions do not differ very greatly from those in the Koyukuk Valley. According to Maddren,[3] temperatures as low as 70° below zero have been recorded, the average temperature for the three coldest months of winter is 15° below zero, and the average temperature for the three summer months is 55°. Brief records indicate that the annual precipitation in the Koyukuk Valley is between 11 and 12 inches, but it is believed by the writer that the precipitation in the Chandalar district is even less than this.

The summer of 1922 was cold and rainy, and the freeze-up came early, but the summer of 1923 was exceedingly warm and dry, the thermometer registering 90° several times during June, and the autumn was very late. Neither of these two summers really typifies the average summer weather. In general the summers are short and warm, the winters are long and cold, and neither in summer nor in winter is the precipitation heavy. Owing to the absence of any thawing weather in winter, however, all the snow remains, and it often accumulates to a depth of 3 or 4 feet before spring.

VEGETATION AND FORAGE

The lowlands of Chandalar and Koyukuk rivers and their tributaries are timbered with spruce, cottonwood, and birch, together with brushy growths of willow and alder. On the lower courses of the larger streams spruce grows as large as 2 feet in diameter at the base, but over much of the area timber is scarce and small. Timber line ranges from 2,000 to 2,500 feet above sea level, but in some of the main valleys small timber continues upstream to altitudes of 3,000 feet or even higher. Thus timber is found for some distance above the forks of the North Fork of Chandalar River, up to an altitude of perhaps 3,200 feet. The general distribution of timber is shown on the accompanying sketch map (fig. 10).

In this district, as elsewhere in interior Alaska, moss forms the main covering of the ground, and moss and lichens together extend up 1,000 feet or more above timber line. Grass for stock is not plentiful but is sufficient to support pack horses during the sum-

[3] Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, p. 27, 1913.

mer. A horsetail rush grows in great profusion in many places and seems to be greatly relished by horses. Many kinds of small plants grow during the summer, but none of these have been collected. Blueberries and low-bush cranberries are usually plentiful, and some high-bush cranberries and red currants are also found.

GAME AND FISH

Caribou, moose, mountain sheep, and bear, both brown and black are found in the district. Caribou in small bands were seen in 192

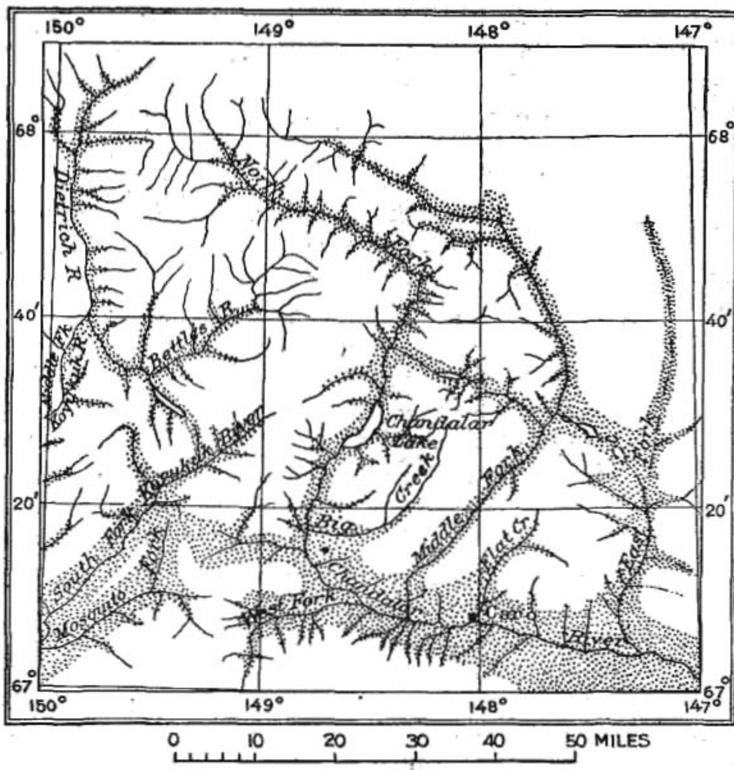


FIGURE 10.—Sketch map showing distribution of timber in Chandalar district

but no great herds like those of the Yukon-Tanana region are present. Mountain sheep appear to be scarce. In the middle courses of the North and Middle forks of Chandalar River, where these streams meander over silt-filled flood plains dotted with lakes, many moose were seen, but not elsewhere. Bear, particularly the great brown bear, are very common, especially in the high mountain groups, such as the granite area at the head of the West Fork of Chandalar River. Ptarmigan and grouse appear to vary greatly in number from year to year, the ptarmigan being fairly abundant in 1923. Ducks and geese also abound on the lakes and rivers, particularly in the fall. Salmon are found in the larger streams, and grayling (Arctic trout), pickerel, lake trout, and whitefish are found in the streams and lakes. Grayling in particular are abundant.

GEOLOGY

OUTLINE

The exact distribution and age of the several geologic formations and the geologic history of the region are as yet imperfectly known, but the major geologic features are now fairly well recognized. The geologic data here given include not only the results of the work of 1923 but also the earlier observations of Schrader and Maddren.

The oldest sedimentary rocks occur at the south end of the district, and, with certain exceptions to be mentioned later, younger rocks appear successively toward the north. Seven sedimentary formations and four igneous formations are shown on the accompanying geologic map (Pl. VI), but some of these are known to be composite groups that will be subdivided by later work.

The oldest sedimentary rocks are a group of quartzite and quartzite schist which crop out along the ridge south of the main Chandalar River. These resemble some of the rocks of the Birch Creek schist of the Yukon-Tanana region, of pre-Ordovician and possibly of pre-Cambrian age, and are referred with certain reservations to that formation.

North of the Birch Creek schist (?) occurs a great thickness of rocks, principally schist and phyllite, which on the basis of their lithology and fossils are referred to the early Paleozoic. These rocks were included by earlier writers as a part of the Birch Creek schist.

The early Paleozoic rocks are adjoined on the north, in the valleys of North and Middle forks of Chandalar River and also in the valleys of Bettles and Dietrich rivers, by a great body of massive crystalline limestone and dolomite, of middle or upper Silurian age.

Still farther north Middle Devonian slates occur, apparently lying unconformably upon the Silurian limestone. The crest of the Endicott Range at this longitude, to judge from the gravels in the stream, is made up of still later rocks, probably of Mississippian age, but these lie beyond the area included in the geologic map.

In the southwestern part of the Chandalar district Upper Devonian or Mississippian rocks occur, lying unconformably upon the older rocks. This occurrence forms one of the exceptions to the general rule that the rock formations are successively younger toward the north.

In the lower Koyukuk Valley, southwest of the Chandalar district, great areas are covered by Upper Cretaceous sandstone and related rocks, and one small lobe of these rocks reaches up into the southwest corner of the Chandalar district. These rocks lie unconformably above all the older rocks of the district. The Quaternary deposits form the seventh geologic unit distinguished on the map. They include, as mapped, both Recent stream deposits and older (Pleistocene) deposits of glacial and glacio-fluviatile origin. They cover large areas in the lower courses of the river valleys, particularly in the valleys of Mosquito Fork and South Fork of the Koyukuk. The Recent stream deposits will eventually be differentiated from the older alluvial deposits, when a more detailed topographic map of the district is made.

Four formations of igneous rocks are shown on the geologic map. The oldest are ancient granitic rocks of gneissoid character, which are exposed typically in the valley of North Fork of Chandalar River at the big bend, though they are also known elsewhere. They intrude the Birch Creek schist (?), the early Paleozoic schist, and possibly the Silurian limestone but are unknown in the Devonian and later rocks. These rocks are believed to be of late Silurian or early Devonian age.

Another formation composed of basic intrusive and perhaps extrusive rocks of greenstone habit is believed to be in part of Mississippian age but in part of early Paleozoic age, possibly Devonian or Silurian, but the necessary data for separating the rocks into two formations are lacking, and they are grouped together as one unit.

In the southwestern part of the district occurs a great massif of Mesozoic granodioritic rocks, which are separately mapped, and in the valleys of Chandalar River and its West Fork are basic lavas and intrusive rocks of Tertiary age.

The Birch Creek schist (?) shows the greatest deformation, but the early Paleozoic schist and the Silurian limestone are also greatly deformed. The most prominent trend line is somewhat east of north, but these three older formations also show the effects of an earlier deformation in which the major axes apparently trended more nearly north. The Devonian and Mississippian rocks are less disturbed than older rocks of a similar degree of competence and do not appear to have partaken of the earlier deformation. The Upper Cretaceous rocks are even less deformed, though they are really not well known in this district.

BIRCH CREEK SCHIST (?)

Distribution, lithology, and structure.—The only rocks in the Chandalar district that are believed to be the possible equivalent in age of the Birch Creek schist are those south of the main Chandalar, along the divide between Chandalar and Orenzik rivers. Little study has been given to these rocks, however, the available data consisting of a few observations made by Schrader in 1899 and by the writer in 1923.

These rocks crop out in places along the Beaver-Caro trail, from mile 61 to Schilling Creek, and along the ridge extending to the east and west. In that vicinity they consist chiefly of quartzite schist and quartzite, cut by many veins of massive white quartz. No indication of mineralization was noticed in this quartz. Observations by Schrader on the ridge farther east seem to show that this schist is invaded by the gneissoid granitic rocks of early Paleozoic age.

Few data on the structure of these rocks are available, but what little is known indicates that they dip northward under the younger rocks. They have been much changed by dynamic metamorphism, but the harder members do not seem to be closely folded, though intense crenulation was observed in some of the rocks. Minor folds along the ridge between Chandalar and Orenzik rivers were observed to pitch northeastward, but this is probably a composite structure, resulting from crustal movements during more than one period.

Age and correlation.—No fossils have been found in these rocks, and therefore no absolute evidence is available regarding their age. They underlie a group of younger schists and phyllite in which Silurian fossils have been found and are therefore probably pre-Silurian. Lithologically, however, they resemble some of the rocks of the Yukon-Tanana region that are designated Birch Creek schist and are of pre-Ordovician and possibly of pre-Cambrian age. Solely on lithologic grounds, therefore, these rocks are correlated tentatively with the Birch Creek schist.

EARLY PALEOZOIC ROCKS

Distribution.—The early Paleozoic rocks have a greater areal distribution than any of the other formations mapped in the Chandalar district, owing probably to the fact that under this designation are grouped a great variety and thickness of undifferentiated metamorphic rocks. Beginning at Chandalar River, these rocks extend about 40 miles northward, adjoining to the north the Silurian limestone. The east-west continuity of this vast area is broken at the mouth of the West Fork of Chandalar River, where rocks of Upper Devonian or Mississippian age begin and extend westward in an expanding wedge.

Lithology.—The early Paleozoic rocks consist mainly of mica schist and phyllite, both of which are in places graphitic. In addition, they include quartzose varieties, such as quartz-mica schist and arenaceous phyllite, and some narrow bands of crystalline limestone, from one of which fossils were collected. Locally, in the vicinity of intrusive rocks, particularly near the borders of the Paleozoic granitic intrusives, biotite schist is developed, some of it with garnet and other minerals due to contact metamorphism. Associated with the early Paleozoic schist are bodies of granite gneiss, granitic schist, greenstone, and greenstone schist, all of Paleozoic age. The more conspicuous bodies of these ancient intrusive and extrusive rocks have been mapped as separate formations, but the area here mapped as early Paleozoic doubtless contains numerous bodies of such rocks that have not been seen by the writer.

Structural relations.—Relatively few observations on the geologic structure of these rocks have been made, owing chiefly to the reconnaissance character of the work so far done in this region. These rocks are shown as covering an area of over 2,000 square miles, in which only about twenty observations of strike and dip are recorded. The general trend of the contact of the early Paleozoic rocks with the adjoining rocks, particularly with the Silurian limestone, gives in reality a better idea of the formational trend than these few isolated observations of structural relations; and this contact indicates that the regional trend is about due east, or perhaps a little north of east. (See structure section, Pl. VI.) Similarly, the presence of older rocks to the south and of younger rocks to the north and the absence of data pointing to overthrusting indicate that the general dip is northward.

The scattered observations of strike and dip, however, show plainly that much irregularity exists in the attitude of these rocks. One noteworthy feature is the presence at many localities, particularly along the North Fork of Chandalar River, of an apparent structural trend of about N. 20° E. The significance of this trend is considered later. In addition, the dip observations show reversals which are interpreted as indicating minor anticlines and synclines that modify the larger structural trends. Schrader has noted such a reversal of dip at the rapids of the North Fork of Chandalar River, where the rocks below the rapids dip south and those above the rapids dip north. West of Chandalar Lake and elsewhere similar reversals of dip are common.

The early Paleozoic rocks are in general highly deformed, showing crenulation, close folding, and shearing. In fact, these rocks appear from cursory examination to be more metamorphosed and structurally deformed than the Birch Creek schist (?) to the south, but they are of more argillaceous composition, and their higher degree of deformation is interpreted as due in the main to inferior competency. The great massif of gneissoid granite in their midst, however, may have exerted a supplementary deformational influence.

Other structural features of interest occur, such as faulting and jointing, but few details are available. Faults, or more properly fault zones, are indicated by zones of sheared rock at some places but were not studied carefully. These zones are apparently due to movements when the rocks were deeply buried under a heavy load. On the other hand, fissures filled with quartz, many of them following the cleavage but perhaps quite as many cutting across it, were noted at many places, particularly in the valleys of Grave and Lake creeks and their tributaries. On the ridge south of Grave Creek, a few miles west of the Middle Fork of Chandalar River, the phyllite country rock is greatly jointed, breaking at the surface into elongated slabs about 1 by 3 by 24 inches and larger.

The structural relation of the early Paleozoic rocks to the older rocks to the south is obscure—in fact, practically unknown. By reasoning from analogy an unconformity might be postulated between the two groups of rocks, because that relation appears to exist south of the Yukon, in the Yukon-Tanana region. Too little is known of the stratigraphy and structure of either group in this district, however, to make such a hypothesis very convincing. It is suggested, therefore, as a reasonable possibility rather than a definite conclusion.

On the north, however, the structural relation of the early Paleozoic rocks to the Silurian limestone is better understood. The field evidence points strongly to a conformable relation between the two groups of rocks. This is indicated by the absence of any structural discordance between them, by the similar degree of metamorphism in both groups, and by an apparent lithologic gradation between the two. In approaching the main body of limestone from the south, small bodies of limestone become more common in the early Paleozoic schist. One such body of fairly large size northeast of Bend Mountain is shown on the geologic map. Similarity in the fossils also points to the same conclusion.

Age and correlation.—The rocks here grouped as early Paleozoic schist and phyllite include the rocks named by Schrader the "Rapids" schist and the "Lake" quartzite schist. No lithologic differences, however, were observed that are considered adequate for separating the early Paleozoic schist into two formations, and the distinction has therefore not been made. Schrader considered that the "Rapids" schist underlies the "Lake" quartzite schist, and as the former occurs to the south of the latter and both in a general way dip northward, this conclusion is doubtless true. It is believed, however, that the differences on which this separation was originally made are due largely to local variations in the lithology and degree of metamorphism that will not hold over large areas.

West of the Chandalar district, in the valley of John River, Schrader[4] found a group of rocks consisting mainly of mica schist and quartz-mica schist to which he applied the name Totsen "series." These rocks lie south of the Silurian limestone belt of John River, having the same geographic position relative to the limestone that the early Paleozoic rocks have to the Silurian limestone in the Chandalar district. Nevertheless, he believed that the Totsen "series" or group was younger than the Silurian limestone. The writer disagrees with this interpretation and is strongly inclined to correlate the Totsen group with the early Paleozoic rocks that lie below the Silurian limestone in the Chandalar district.

Schrader considered the "Rapids" schist and the "Lake" quartzite schist, which are included in the rocks here designated early Paleozoic, to be correlative with the Birch Creek schist, and in the absence of any additional data Maddren later accepted this interpretation. In 1923, however, a collection of fossils was made in the very center from north to south of the area occupied by these rocks and necessitated a revision of the earlier ideas regarding their age. These fossils were found in a lens of black yet crystalline limestone, not more than 50 feet thick, interbedded in the phyllitic rocks and separated by only a few feet from a body of the intrusive gneissoid rock. The exact location is about 6 miles N. 30° W. of the junction of Grave Creek with the Middle Fork of Chandalar River, on the summit of the ridge, at an altitude of about 4,000 feet. This location is indicated on the geologic map. The fossils were examined by Edwin Kirk, of the United States Geological Survey, who reports the following forms, which he assigns to the Silurian:

Cladopora sp.

Clorinda? sp. Pentameroid brachiopod. May be same as the species referred to Clorinda in the White Mountains district (Yukon-Tanana region).

One fossil collection in so great a thickness of rocks does not of course determine the age of the entire sequence. The massive limestone to the north, however, is now known to be of Silurian age, though somewhat younger than these rocks, and it is only reasonable to infer that the rocks for an equal distance south of this fossil locality, as far as the Chandalar, are at least not older than Paleozoic, though they may well be older than Silurian. The entire sequence of rocks, therefore, lying between Chandalar River and the massive Silurian limestone is mapped as early Paleozoic.

[4] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 58–60, 1904.

SILURIAN LIMESTONE

Distribution.—The Silurian limestone crosses the Chandalar district in a general east-west direction just south of the sixty-eighth parallel, forming a belt from 2 to 8 miles wide. The narrowest place in this belt occurs where it crosses the North Fork of Chandalar River. To the east, toward the Middle Fork, the belt becomes much wider; and to the west, very much wider. From the head of Quartz Creek one great lobe of the limestone extends southward for nearly 20 miles to the bend of Bettles River, and some outlying bodies of limestone occur even south of Bettles River. West of Quartz Creek, where the limestone crosses Dietrich River, it appears to have a width comparable with its width at the Middle Fork of Chandalar River. These variations in the areal distribution are considered elsewhere (pp. 230–231).

Lithology.—In general, this formation consists of crystalline and semicrystalline limestone, probably dolomitic at many localities. The usual color, both from a distance and close at hand, is white or light gray, though this grades into darker colors. In some places much red and brown iron staining occurs. At the fossil locality on the upper part of the North Fork of Chandalar River the limestone is almost black and has a strong odor of decomposed organic matter. This condition, however, is exceptional.

The massive limestone is much jointed, and the less massive varieties, particularly near the contact with the older rocks, are in places sheared to the condition of a calcareous schist. The rock is also much fractured in places and veined with calcite and less commonly with quartz.

On the southern border of the limestone belt, where it crosses the North Fork of Chandalar River, a band of sheared greenstone adjoins the limestone, and smaller lenses of this same material are found within the main body of the limestone, indicating a constant association of rocks of these two types. The gneissoid granite to the south is believed to have been intruded after the limestone was deposited, but the two rocks have not been observed anywhere in contact.

Structure and thickness.—The Silurian limestone, because of its easily recognizable contacts and also on account of its conformable relation with the older rocks to the south, is an excellent index of the regional structure of the early Paleozoic rocks. Accurate mapping of this southern contact, together with numerous observations of the bedding of the limestone and a careful evaluation of possible faulting, should yield much information about the orogenic history of the early Paleozoic. Such work, of course, is not accomplished in reconnaissance surveys, but the general trend of this southern contact is sufficiently well known to warrant certain broad generalizations.

The most prominent and universal structure in the rocks of the Chandalar district trends about due east. The youngest of the Paleozoic formations, as well as the oldest, partake of this structure, and it is therefore believed to represent a regional crustal disturbance that occurred after Paleozoic time. Notwithstanding this unmistakable trend, the early Paleozoic rocks on both sides of the North Fork of Chandalar River, both above and below Bend Mountain, show a distinct structure, the average trend of which is about N. 20° E., and the same is true of the Silurian limestone at certain localities. This structure is interpreted as evidence of an older period of folding, which affected the Silurian and pre-Silurian rocks but not the later Devonian rocks.

The hypothesis is therefore suggested that the Silurian and pre-Silurian rocks were folded in early Devonian or late Silurian time, and that all the Paleozoic rocks were again folded in post-Paleozoic time, possibly in more than one stage. The axes of these two sets of folds are believed to make an angle of about 70° with each other. It has been shown that the trend of the later structure is about east and that the regional dip is north. It remains to interpret the areal distribution of the Silurian limestone in terms of an older folding modified by a later folding. Now, while it is true that the later structure is in general monoclinal, with a prevailing northward dip, it is also true that reversals of dip are present, which must be accounted for in any interpretation. Moreover, it is known that faulting has played an important part in determining the areal and topographic form of the limestone. Nevertheless, if a series of anticlines and synclines striking about N. 20° E. are folded in an east-west direction and are welded into an east-west monocline dipping north, the net effect will be an irregular contact line, the old synclines projecting and the old anticlines forming reentrants on the south side. On the north side the reverse will be true, the anticlines forming the projecting lobes and the synclines the reentrants. In the case of the Silurian limestone this effect may be further complicated on the north side by the presence of the adjoining Middle Devonian rocks, which lie unconformably above the limestone. Reversals of dip in the east-west structure will reverse these relations, but probably on a smaller scale, producing secondary lobes and reentrants of minor magnitude. The observed irregularity of the contact lines of the Silurian limestone is interpreted as a result of two such periods of folding, modified of course by faulting. Under this hypothesis the great lobe of Silurian limestone that projects southward from Quartz Creek to the bend of Bettles River may be interpreted broadly as a manifestation of such a composite structure, although it is fully recognized that faulting, particularly on the south edge of this lobe, has also played an important part in the process.

It has been stated that the general trend of the early Paleozoic rocks is east. This is true in the Chandalar district, but observations over a larger area indicate that the easterly trend of the limestone is tangential to the structure of a larger orogenic feature, a crescentic arc that is parallel in a general way to the Alaska Range and to the big bend of Yukon River at Fort Yukon. The evidence for this conclusion consists in the fact that the Silurian limestone of John and Alatna rivers is southwest of the same limestone in Chandalar River, whereas the Silurian limestone of Porcupine River, below the mouth of the Coleen, is southeast of the limestone of the Chandalar district. It is further inferred by a study of the symmetry of this arc that the Chandalar district lies a little west of a line normal to the tangent to the arc at its northern extremity. This fact accounts for the apparent tendency of the later structure to trend somewhat north of east, rather than east, in the Chandalar district.

If this interpretation of the structure of the limestone is accepted, it is manifestly difficult without detailed work to make a trustworthy computation of the thickness of the beds. Obviously the place to measure a section will be at some point where the trends of the older and younger structural features coincide, and such points of course will be found at the noses or ends of the old anticlinal and synclinal folds. The effects of faulting being neglected, such localities will show a minimum north-south distance across the limestone belt. Just east of the North Fork of Chandalar River such a minimum distance between contacts occurs. The average dip at this locality is about 35° N., and with this attitude of the beds the limestone appears to have a thickness of perhaps 6,000 feet.

Age and correlation.—The Silurian limestone was first described by Schrader[5] under the name Bettles "series," but no definite age was assigned to it, although he recognized that this limestone was probably younger than the schists to the south. Later Schrader[6] described under the name Skajit formation another wide belt of limestone and mica schist which crosses John River, about 70 miles to the west of the Chandalar district. Some obscure fossil remains were found in the limestone of the Skajit formation, which indicated that it could not be older than Silurian nor younger than Carboniferous. Schrader inferred from this and certain other evidence that the Skajit formation might be upper Silurian and so designated

[5] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, p. 475, 1900.

[6] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 56–58, 1904.

it in the text of his report. Maddren, however, suggested that both the Bettles "series" and the Skajit formation might be of Carboniferous age.

In 1923 a fossil collection was made by the writer from the limestone in the upper part of the North Fork of Chandalar River. The exact location is on a southern tributary of the North Fork entering about 6 miles from the confluence of the West and North forks of the North Fork, about three-quarters of a mile upstream from the mouth of the tributary. These fossils were identified as *Conchidium?* sp. by Edwin Kirk, of the United States Geological Survey, who reports as follows:

> This may be the same as the *Conchidium?* sp. from the White Mountains of the Yukon-Tanana region. The latter seems to have a relatively thin shell, while this species has one of extraordinary thickness. This may, however, be due to differences in preservation. What appears to be the same genus is found in the upper Silurian of southeastern Alaska.

The fossils collected from the limestone in the White Mountains of the Yukon-Tanana region are regarded by Mr. Kirk as highest middle Silurian. The limestone formation of the Chandalar district is therefore either highest middle Silurian or upper Silurian.

This limestone, as previously stated, is the Bettles "series" of Schrader and is believed to be correlatable with the Skajit formation, to the west, on John River. The Skajit formation also continues westward into the valley of Alatna River, where it was observed by Smith.[7] Smith correlated the Skajit tentatively with the Lisburne limestone, of Mississippian age, but it now seems certain that the Skajit formation and its westward continuation in the Alatna Valley are of Silurian age.

The Silurian limestone of the Chandalar district is correlated in a general way with the buff-colored magnesian limestone that crops out in the Lower Ramparts of Porcupine River, below the mouth of Coleen River, although this limestone was determined by Kindle[8] as middle rather than upper Silurian. It is also correlated with the upper middle Silurian limestone of the White Mountains, south of the Yukon. A part of the Port Clarence limestone of Seward Peninsula, particularly in the Don River valley,[9] is now believed to be middle or upper Silurian, though the main part of the Port Clarence limestone is of Ordovician age. The Silurian limestone may therefore be correlated with the Silurian limestone of Don River, and last of all it may be correlated also in a general way with

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[7] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, pp. 61–67, 1913.

[8] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 324–325, 1908.

[9] Steidtmann, Edward, and Cathcart, S. H., Geology of the York tin deposits, Alaska: U. S. Geol. Survey Bull. 733, p. 23, 1922.

the Silurian limestone of southeastern Alaska, in particular with the upper Silurian limestone of Glacier Bay.

MIDDLE DEVONIAN ROCKS

Distribution.—Middle Devonian rocks begin a short distance south of the 68th parallel, at the northern limit of the Silurian limestone, and continue northward to the limit of the area mapped—that is, for about 10 to 15 miles. These rocks, however, do not extend to the crest of the Endicott Range, for it is known both from the gravel seen at the headwaters of the North Fork of Chandalar River and from data acquired in other ways that younger rocks, probably of Upper Devonian or Mississippian age, crop out at the very crest of the range at this longitude. The Middle Devonian rocks, then, form a belt more or less parallel to the belt of Silurian limestone, extending across the northern limit of the Chandalar district in a general east-west direction.

Two lobes of Middle Devonian rocks, however, project southwestward from the main belt, extending up both sides of Quartz Creek for a distance of 8 or 9 miles. A third area, apparently completely detached from the main belt, lies still farther southwest, forming the divide between Quartz and Limestone creeks. This third area was mapped from a distance, and the boundaries shown on the map are likely to be more or less inaccurate.

Lithology.—The Middle Devonian rocks consist dominantly of slate, with a minor proportion of sandstone and some thin beds of limestone. These rocks form rounded hills up to an altitude of 4,000 feet, and even in the higher mountains up to 6,000 feet they do not produce the ragged seriate crest line characteristic of the Silurian limestone. The slate hills, particularly below an altitude of 5,000 feet, have a mottled yellow and brown appearance, due to the yellow weathering of the slate; above 5,000 feet the hills are black, owing to the presence of relatively unweathered black talus.

The slate in the hills on the northeast side of the Middle Fork of Chandalar River, in the vicinity of the forks of this stream, is literally permeated with vein quartz. Much of this quartz shows the oxidized pyrite cubes that are characteristic of the vein quartz in the vicinity of Little Squaw Creek, and such quartz is probably gold-bearing. Quartz veining, in fact, seems to be a distinctive feature of the Middle Devonian slate, though the quartz is not everywhere so plentiful as at the locality above mentioned, nor is it everywhere mineralized.

In the vicinity of the forks of the North Fork of Chandalar River several small bodies or lenses of dark-gray limestone, not of mappable size, are interbedded with the slate. Two such lenses were observed on the spur between the North and West forks of the North Fork of the Chandalar, one of which is cleaved almost to a calcareous slate. Somewhat higher on this spur but stratigraphically below the limestone beds a fossil collection was obtained from the slate. From the forks of the North Fork of the Chandalar down the valley to Quartz Creek the slate seems more than ordinarily metamorphosed and shows phyllitic and schistose phases.

Small bodies of sheared diabasic or basaltic rock of greenstone habit are associated with the Middle Devonian slate at numerous localities. These greenstones occur usually in small bodies, none of mappable size being observed. From their form and general character they are judged to be small intrusive bodies, and most are believed to be of late Paleozoic age.

Structure and thickness.—The Middle Devonian rocks are believed to lie unconformably above the Silurian limestone. This conclusion is borne out by numerous observations on the structure of the two formations along their contact and by the evidence furnished by the fossil collections.

In the vicinity of the fossil locality in the Silurian limestone, previously mentioned, this unconformable relation is particularly well shown. The unconformity is believed to represent one of the major periods of deformation and erosion in the Paleozoic sequence of rocks in this region.

The Middle Devonian slate is intricately folded and crumpled and has evidently presented little resistance to deformational forces. The folds are sharp and many of them are of small magnitude, and in this respect they stand in marked contrast to the more open type of folding that is characteristic of the more competent Silurian limestone. Necessarily, therefore, many reversals of dip occur, indicating numerous folds, only a few of the larger of which have probably been recognized. In general, however, these rocks are believed to dip northward, plunging under younger rocks that form the crest of the Endicott Range. The general strike is east.

The upper stratigraphic limit of the Middle Devonian slate was not reached by the writer, but it is believed to end a very short distance beyond the northern limit shown on the map. Partly on this account, but more particularly on account of the intricate folding and numerous reversals of dip in these rocks, no very trustworthy estimate of the thickness can be made. It is believed, however, that the Middle Devonian slate is between 5,000 and 10,000 feet thick.

Age and correlation.—One fossil collection was made from the Middle Devonian slate. The exact locality is about 2½ miles N. 50° W. from the confluence of the West and North forks of the

North Fork of Chandalar River, on the spur between the two streams at an altitude of about 3,600 feet. These fossils have been examined by Edwin Kirk, of the United States Geological Survey, who pronounces them unquestionably of Middle Devonian age. The forms recognized are as follows:

Striatopora sp.
Diphyphyllum sp.
Cyathophyllum cf. C. caespitosum Goldfuss.
Alveolites sp.
Atrypa reticularis Linné.
Spirifer sp. (type of S. mucronatus Conrad).
Cyrtina cf. C. hamiltonensis Hall.

This fauna is the same as that found by Kindle[10] in the limestone on Porcupine River at the mouth of Salmontrout River. The difference in lithology at these two fossil localities serves to show the possible variation in the character of the Devonian rocks along the strike. It is interesting to note that Kindle also believed that the Middle Devonian rocks of the Porcupine lie unconformably above the Silurian rocks, though his conclusion was based entirely on faunal differences in the two groups of rocks.

The Chandalar and Porcupine valleys are the only two districts in which Middle Devonian rocks have been definitely recognized north of the Yukon. On Yukon River, however, below Woodchopper Creek,[11] is a series of limestone and shale which are unquestionably of Middle Devonian age.

South of the Yukon, in the Yukon-Tanana region, and also south of the Tanana, Middle Devonian rocks are known at numerous localities. The Tonzona group of the Yukon and Tanana valleys is probably in part of Middle Devonian age. The Tonzona group resembles the Middle Devonian slate of the Chandalar district, in that it is dominantly argillaceous and arenaceous, with only a subordinate amount of included limestone. In the valley of Jack River, however, just above its confluence with the Nenana, there is a Middle Devonian limestone which resembles more nearly the Salmon Trout limestone of the Porcupine Valley.

UPPER DEVONIAN OR MISSISSIPPIAN ROCKS

Distribution.—Rocks that are believed to be of Upper Devonian or Mississippian age crop out at the junction of the West Fork and North Fork of Chandalar River and continue westward into the valleys of the South Fork and Mosquito Fork of Koyukuk River.

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[10] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 327–329, 1908.

[11] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, pp. 279–284, 1908.

Schrader found much chert in the gravel at the mouth of the East Fork of Chandalar River, and it is likely that rocks of the same age are present between Flat Creek and the East Fork and perhaps east of the East Fork, but this district was not visited, and such rocks, if present, have not been mapped.

North of the Middle Devonian rocks at the northern limit of the Chandalar district younger rocks are also probably present, but this region lies beyond the area mapped in 1923. They differ lithologically from the Devonian rocks and so are easily recognized in stream gravel. Gravel of these rocks, including chert and chert conglomerate, was found in 1923 in the headwaters of the North and Middle forks of Chandalar River, and two men who have crossed the Arctic divide have told the writer that the crest at the longitude of the North Fork is formed of a chert conglomerate. It is therefore concluded that younger rocks, possibly in part equivalent to the rocks north of the West Fork of Chandalar River, adjoin the Middle Devonian rocks on the north.

Lithology.—These rocks were first noticed by Schrader west of the junction of the West Fork and North Fork of Chandalar River, and he called them the West Fork "series." According to his description,[12] they consist of fine-grained dark-gray quartzite, black flint, calcareous black shale, and impure limestone, which are cut by greenish dioritic or diabasic dikes that trend northeast, with the structure of the rocks. Later in the same season he recognized the same rocks on Jim Creek, in the valley of the South Fork of Koyukuk River. He also found these rocks just below Rose Creek, the next eastern tributary of the Middle Fork of Koyukuk River below Slate Creek. Maddren,[13] in 1910, made some further observations on these rocks and mapped them as far northeast as Boiler Creek.

Schrader's published description is accurate and carries all the information that is likely to be obtained regarding these rocks in this district, for they occur on low ridges and are recognized mainly from their weathered débris. Few or no structural data are available. The writer examined the base of these rocks on the ridge north of the West Fork and west of the North Fork of Chandalar River, and the only additional information obtained is that the base here consists of a cherty grit, which in the field was mistaken for a tuff. This grit consists of subangular grains of quartz and chert in an iron-stained kaolinic cement. Additional data concerning the intrusive greenstone are given on pages 244–246.

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[12] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 475–476, 1900.

[13] Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, pp. 50–51, 1913.

Structure and thickness.—The structure of these rocks, as stated above, is largely unknown. They appear to trend northeast, to judge from the elongation of the sills and dikes within them, but this trend may be more apparent than real. Without doubt, however, they rest unconformably upon the early Paleozoic rocks, but their stratigraphic and structural relations to the Middle Devonian rocks to the north are unknown.

Age and correlation.—No determinable fossils have been found in place in these rocks. Some fossils were found by Schrader, however, in gravel along the main Chandalar River that are likely to have come from this group of rocks. The localities of these fossils and the report on them by G. H. Girty, made in 1899, are given herewith:

No. 2. Chandalar River 20 miles above mouth: *Syringopora* sp. 2.

No. 5. Chandalar River 48 miles above mouth (17½ miles below East Fork): Cyathophylloid coral.

No. 22. Chandalar River 57 miles above mouth (8½ miles below East Fork): *Syringopora* sp. 1.

No. 47. Chandalar River 98 miles above mouth (1 mile above Middle Fork): *Spirifer, disjunctus* type.

Syringopora is, so far as known, not found above the Carboniferous; therefore specimens 2 and 22 may be referred with little doubt to the Paleozoic.

The *Spirifer* of specimen 47 is of a type not found below and in a measure restricted to the Devonian. If, as I suspect, the form is *Spirifer disjunctus* itself or one of its close allies, specimen 47 may pretty safely be referred to the Devonian, probably to the Upper Devonian.

The coral found in specimen 5 probably belongs to the genus *Acervularia*. The age indicated is certainly Paleozoic and probably Devonian.

These determinations should be checked in the light of additional paleontologic data gathered in Alaska in the last 25 years, but the fossils have been lost and are no longer available. With the exception of specimen 47 all these collections might as well be referred to the Mississippian as the Devonian, particularly when it is remembered that the type Mississippian fauna of Alaska, that of the Lisburne limestone, was originally referred to the Devonian. *Spirifer disjunctus*, however, is a form which is said by paleontologists to be characteristic of the Upper Devonian. Moreover, this is not the only collection of *Spirifer disjunctus* made in this region, for Schrader, in 1901, collected it from the Fickett "series" of rocks at two places on John River. It is not likely, therefore, that the determination of specimen 47 is erroneous.

It is necessary to consider the geologic section north of the Skajit formation on John River, in order to arrive at any satisfactory conclusion regarding this West Fork "series." Adjoining the Skajit formation on the north is a great thickness of sediments, of very diverse character, mapped by Schrader under the name Fickett "series." To the north of these beds lies the Lisburne limestone, within which was found a chert conglomerate formation, which he called the Stuver "series." The Fickett "series" was interpreted as Mississippian, the Lisburne as Devonian, and the Stuver as pre-Devonian. It is now known, from later determinations of these fossil collections, that the Lisburne is Mississippian. The Stuver was believed to underlie the Lisburne but is probably either a part of the Mississippian or the base of it. The Fickett "series" probably includes rocks of several ages, from Middle Devonian at the base to Upper Devonian or Mississippian at the top. This would account for the diversity of faunas found within it.

With this section in mind, it seems reasonable to regard the West Fork "series" as equivalent to a part of the Fickett "series." Lithologically the West Fork "series" differs from the Middle Devonian rocks of the Chandalar district in containing chert. On the other hand, it does not appear to have the chert conglomerate of the Stuver "series." It seems best, therefore, to correlate it with the upper part of the Fickett "series," stratigraphically below the chert conglomerate of the Stuver "series." This horizon may be either Upper Devonian or Mississippian.

The chert conglomerate cobbles that are found in the headwaters of the North and Middle forks of Chandalar River are probably derived from the chert conglomerate, or Stuver "series," probably at the base of the Lisburne formation. These cobbles, however, are very hard and resistant to weathering and may have traveled far. It is therefore possible that a formation equivalent to the West Fork "series" may intervene between the northern limit of the Middle Devonian rocks in the Chandalar district and this chert conglomerate formation on the north.

UPPER CRETACEOUS ROCKS

Only one small area of Upper Cretaceous rocks is known in the Chandalar district. This area, which lies at the southwest corner of the district, was not visited by the writer, and the character of the rocks is not known. In general the Upper Cretaceous rocks of the Koyukuk region consist of sandstone, shale, and conglomerate. They have been greatly folded and to some extent faulted, but their structure is relatively simple compared with that of the older Paleozoic rocks. The Upper Cretaceous rocks lie unconformably above all the Paleozoic rocks and probably also above the Mesozoic granodiorite of this region.

QUATERNARY DEPOSITS

The Quaternary deposits consist of unconsolidated silt, sand, and gravel, which now fill the bottoms of the stream valleys and in places extend up onto benches along the sides of the valleys. These deposits are conventionally divided into two types, the division being made primarily on the basis of age and secondarily on the character of the deposits. The older or Pleistocene deposits originated for the most part from glacial erosion during the last period of glaciation in this district, but as found to-day they show that they have in general been reworked by subsequent stream action. The Pleistocene deposits therefore consist in part of true glacial débris, or till, and in part of reworked glacial débris, commonly known as outwash deposits. The latest or Recent deposits consist of sand, gravel, and silt, which have been derived in part from the hard-rock formations by weathering and stream transportation and in part by the reworking and transportation of the older or Pleistocene deposits. On the accompanying map these two types of deposits have been grouped together as a single map unit, designated Quaternary deposits.

PLEISTOCENE GLACIATION AND DEPOSITS

The term Pleistocene epoch is used as more or less synonymous with the term glacial age, though it is well known that the period of glaciation in Alaska began earlier and continued later than in the northern United States. Glaciation requires an annual snowfall greater than the present annual dissipation of snow and ice. Most of the interior of Alaska, notwithstanding its low mean annual temperature, has not been glaciated, because of its relatively light snowfall. Even the Arctic Mountains and Arctic slope, with a somewhat heavier precipitation and lower mean annual temperature than interior Alaska, are not glaciated to any extent at the present time. But a marked increment in one or both of these factors during Pleistocene time caused a severe glaciation of the Arctic Mountains, the effects of which are still clearly visible.

With a glacial climate established, snow accumulates from year to year, and the lower parts of the snow banks gradually congeal to ice. When the weight of superincumbent snow and ice becomes too great the ice begins to flow and creeps slowly down into the valleys, often extending miles beyond the main site of accumulation. This ice movement, which measures usually but a few feet a year, produces a type of erosion quite different from stream erosion. It is primarily a scouring action, accompanied by a sapping action on the main crest lines. The valleys and ridges are scoured smooth, while the main divides just above the flowing ice are converted into ragged crest lines. The ice-borne débris is carried down into the lower valleys and there deposited, where it is picked up again by glacial streams issuing from the ends of the glaciers and redistributed to a greater or less extent farther down the valleys. The original glacial débris is characterized by a complete lack of assortment, boulders and rock fragments of all sizes being mingled indiscriminately with finer débris and clay. The rock débris is unrounded, and many of the cobbles are scoured on one or more sides to produce flat or faceted surfaces. Such material is called till. The partly reworked material, or outwash deposit, preserves to some extent its original form and character, but by prolonged stream action it gradually develops into normal stream sand and gravel.

At the time of maximum glaciation the crest of the Arctic Mountains was probably covered by a continuous ice cap, which probably extended some distance down the Arctic slope before separating into individual valley glaciers. On the south slope, however—for example, in the Chandalar district—the glaciation was mainly of the valley or alpine type, although the glaciers extended high up onto the valley walls. On the divide between the North and Middle forks of Chandalar River, northeast of Bend Mountain, at about latitude 67° 50′, erratic boulders of chert conglomerate were seen by the writer at an altitude of 3,500 feet, showing that the glacial ice at one time extended at least that high at that latitude. Farther south glacial deposits were seen at an altitude of about 2,900 feet on the north side of the valley of Grave Creek. Apparently, then, only the main ridges were quite free from moving ice. The ice tongues of the North, Middle, and East forks of Chandalar River coalesced in the main valley and probably extended to a much lower altitude, almost if not quite to the southeast corner of the district. Other ice streams flowed southwestward into the Koyukuk Valley, forming a great valley glacier that was joined farther down the valley by tributary ice tongues from the north. The ridge south of Chandalar River is not believed to have been extensively glaciated, though the high granitic massif at the head of the West Fork may have generated some small alpine glaciers that flowed off both to the north and south.

The North, Middle, and East forks of Chandalar River, as well as Dietrich and Bettles rivers, show the characteristic U-shaped valleys that are produced by glacial action. The spurs that extend down from the main ridges into the valleys have been truncated at their bases, resulting in oversteepened valley spurs. In keeping with their condition, some of the smaller tributary valleys, particularly those which headed on lower divides and contributed little ice, were unable to cut down their valleys as fast as the glaciers in the main valleys and were therefore left as hanging valleys when the ice retreated. Subsequent stream erosion has cut narrow V-shaped gorges at the lower ends of such valleys, where they join the main valleys. Woodland Creek, which enters the North Fork of the Chandalar from the west, below Chandalar Lake, is an example of such a hanging valley. The valley now occupied by Lake and Grave creeks was apparently a nearly stagnant body of ice in the later stages of the glacial epoch, a kind of back flow from the active glacier of the North and Middle forks of the Chandalar. Little and Big Squaw creeks, on the south side of this valley, therefore, contain glacial deposits, which, as shown later, have had an important influence in determining the position and character of the gold placer deposits in these valleys. Big Creek, which heads against Little Squaw Creek and flows southward, apparently has not been glaciated, as the ridge to its north did not accumulate enough snow to produce independent ice tongues.

Deposits of glacial origin are therefore found in all the main valleys that extend southward from the Arctic Mountains and also in the main Chandalar Valley. Most of these deposits, however, appear to have been reworked to a considerable degree by contemporaneous and later stream action, so that they belong mainly to the class designated outwash deposits. The remnants of such outwash deposits form benches at many places in the valleys, and profiles of them may be seen to advantage where the streams have cut down through them in recent time. Chandalar Lake and the silt and sand filled valley that extends 35 miles upstream above Chandalar Lake are physiographic features that are due to glacial action. A number of older beach lines are preserved as benches along the walls of the valley at Chandalar Lake and continue upstream, indicating that the lake was formerly of larger size and has shrunk progressively since the retreat of the ice. North Fork, however, flows on bedrock in the rapids just below the lake, and it is hard to explain the silt-filled depression above the rapids except as a basin excavated by ice erosion. The reason for this depression may probably be that North Fork originally flowed out to the east through the present valley of Lake and Grave creeks, forming a tributary of the Middle Fork. In that case the present course of the North Fork from Chandalar Lake southward is a postglacial feature, and the site of the rapids was once the head of a northward-flowing tributary of the North Fork that joined it at the present mouth of Lake Creek. This explanation will account for the apparent northward slope of bedrock from the rapids to Lake Creek.

The glacial deposits consist of silt, sand, and gravel and attain a considerable thickness in some of the larger valleys. Even as far north as the valley occupied by Lake and Grave creeks these deposits seem to be more or less sorted, and the gravel is fairly well rounded. Some of the deposits appear to be a true till. The material that forms the false bedrock on Little Squaw Creek seems to be of this character. Schrader has described deposits of till along

Chandalar River which form bluffs 100 to 200 feet high, and he also found similar material on the south side of Chandalar Valley at an altitude of 2,200 feet. In a strict sense, however, this material would be more properly designated outwash deposits, for the gravel and cobbles within it are fairly well rounded. Similar deposits crop out on the north side of the West Fork about 10 miles above its mouth, forming high bluffs along the river.

Another type of deposits formed in the glacial epoch consists of silt and clay. These deposits have been formed in some places by the damming up of unglaciated valleys by glaciers in the trunk valleys, thus causing lakes in which fine sediments were deposited. The silt and clay deposits in the lower parts of Tobin and Big creeks are cited by Maddren [14] as good examples of this type of deposit.

RECENT DEPOSITS

The Recent deposits consist mainly of sand, gravel, and silt and form the flood plains of the present streams. In a mountainous region like the Chandalar district such deposits should normally be mainly sand and gravel, and in fact the material that has been derived directly from the rocks in postglacial time by weathering and stream transportation is chiefly of these kinds. In addition, however, the streams are handling a great deal of the glacial outwash deposits and till, which contain silt and clay as well as the coarser materials. In places, therefore, the Recent alluvium consists of more or less silt. The silt-filled basin in the valley of the North Fork may be cited as an example of silt reworked to some extent by the present streams. Many such deposits on the valley floors are thick.

To the southwest of the Chandalar district, on the South Fork of the Koyukuk, and also to the southeast, on the lower Chandalar, are extensive deposits of silts of Recent age. These are darker in color than the Pleistocene silts, owing to an admixture of vegetal matter, and those that are very dark are often referred to as "muck." Such silt deposits form bluffs 20 feet or more high along the banks of the streams at some localities. Locally in these silts are found lenses of clear ice.

The Recent deposits include also residual deposits formed by the disintegration of rock in place and weathered material in process of migration down the hill slopes. At the mouths of steep gulches such weathered material may form alluvial fans that project onto the main valley floors.

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[14] Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, pp. 64–65, 1913.

IGNEOUS ROCKS

PALEOZOIC GNEISS

Distribution.—The main body of granitic gneiss extends from the Middle Fork of the Chandalar, east of Bend Mountain, southwestward to the head of the South Fork of the Koyukuk, including practically all the valley of Baby Creek and the heads of Sheep and Phoebe creeks. The mapping of the southwestern limit of this formation is not accurate and is likely to be considerably in error. The formation may also continue northeastward beyond the Middle Fork of the Chandalar, but that area was not visited. It is known to have a length of at least 35 miles and a width of 5 to 15 miles. A smaller body is shown northeast of Grave Creek, and another in the upper valley of Robert Creek.

Petrographic character.—In hand specimens the rocks of this formation range from massive granitic rocks through gneiss to a contorted granitic schist. The common type is a speckled gray granitic gneiss, much of which shows a greenish tinge, due to alteration of the dark-colored minerals it contains.

Under the microscope the gneiss is seen to be composed essentially of quartz, albite, and chloritic products and sericite derived from original hornblende, biotite, and feldspar. Calcite and epidote are also common secondary products. The accessory minerals include apatite, titanite, and some iron hydroxides. The albite is fresh in appearance and is believed to be a secondary feldspar. In one of the least altered specimens, collected on Baby Creek, orthoclase and albite occur together in such a relation as to suggest that orthoclase is the original feldspar and that albite is secondary. Another specimen from Baby Creek shows no albite, the feldspar consisting of a mixture of orthoclase and microcline, with little or no plagioclase. In this specimen some original biotite is preserved, thus showing the original rock to be a biotite granite. Other specimens also indicate that the dark minerals of the original rock may have been mainly biotitic. Garnet is present is some specimens.

Another variety of the gneiss is seen at Bend Mountain, on the North Fork of Chandalar River. This phase is likewise composed of quartz and albite but contains a larger proportion of dark minerals, among which both biotite and green hornblende have been identified, though both are more or less altered. Chlorite, epidote, and calcite are the common alteration products. These rocks are interpreted as a dioritic or perhaps kersantitic variety of the biotite granite.

A third variety is a contact phase, perhaps of the country rock rather than the intrusive rock. This was seen at the forks of

Baby Creek. The rock consists of phenocrysts of garnet set in a matrix of sericite, chlorite, calcite, quartz, epidote, and biotite. The garnet shows the consanguinity of this contact rock with the main intrusive mass.

Structure, age, and correlation.—The granitic gneiss and granitic schist have a structure simulating bedding, which apparently is conformable in trend and pitch with the early Paleozoic schist that it intrudes. The state of deformation of both formations is about of the same order, due allowance being made for the superior competency of the granitic rocks. It was fully recognized by Schrader[15] that this granitic gneiss or gneissoid granite was an ancient intrusive body. In fact, he considered it the oldest rock in the district, regarding it as a basal granite. The gneiss was found in 1923, however, intruding Silurian phyllite and limestone, and the fossils listed on page 228 were found only a few feet from the contact of the gneiss with these rocks. The gneiss is therefore not older than Silurian. It has not been observed to intrude the Middle Devonian rocks, nor even the main mass of middle or upper Silurian limestone. This limestone, however, was probably not buried deeply enough at the time of the granitic injection to be intruded. The absence of the gneiss in the Middle Devonian rocks, together with its general ancient aspect, leads to the conclusion that it was injected before the Middle Devonian rocks were laid down. It is believed, therefore, that this granitic gneiss is of late Silurian or early Devonian age.

Areas of granitic gneiss have been found at numerous other localities in Alaska, particularly in the Yukon-Tanana region and in Seward Peninsula, but the geologic section is not sufficiently well known to permit the assignment of a definite age to these areas. It is likely that some of these older granitic rocks may later be found to be contemporaneous with the granitic gneiss of the Chandalar district.

PALEOZOIC GREENSTONE

Distribution.—Greenstone, comprising altered rocks of basic and intermediate composition, occurs as dikes, sills, and possibly flows associated with all the Paleozoic and pre-Paleozoic rocks. At the south side of the Chandalar district such rocks are very intimately associated with the formation mapped as Upper Devonian or Mississippian; and in the northern part of the area similar greenstone, though perhaps more altered, is found as dikes and flows (?) at many localities in the early Paleozoic rocks and the Silurian limestone. It occurs as dikes in the Middle Devonian rocks.

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[15] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 471–472, 1900.

Only the larger areas of these rocks are shown on the geologic map. One prominent greenstone, which probably represents an original flow, flanks the Silurian limestone on its south side, on the North Fork of Chandalar River, and also crops out to the west in the center of an anticline surrounded by the Silurian limestone; another large mass, intrusive in character, is seen between Flat and Funchion creeks; and still other small intrusive bodies occur in the Upper Devonian or Mississippian rocks to the west.

An outcrop of granular greenstone, similar to that east of Flat Creek, also crops out at about mile 16 on the Beaver-Caro road, and a considerable body of such rock apparently continues to the west.

Petrographic character.—The band of greenstone that adjoins the Silurian limestone on the south, along the North Fork of Chandalar River, differs from the other greenstone of the district. It is in reality a greenstone schist and shows no trace of its original fabric. It is best described as a chlorite schist. It is light green in color but varies in appearance in the field, according to whether it is wet or dry. In wet weather the hills composed of this rock are decidedly green, but in dry weather it looks not greatly unlike the Silurian limestone from a distance, except for a slight greenish tone. This rock contains much quartz, in lenses and veinlets, all of which, however, appears to have been crumpled and sheared along with the rock itself. An assay of this quartz, which Schrader had made in 1899, showed 0.42 ounce in gold and 0.14 ounce in silver to the ton.

A second variety of greenstone consists of altered fine-grained basic rocks, which occur as dikes or sills in all the Paleozoic rocks but particularly in the formation described as Upper Devonian or Mississippian. These rocks are usually much altered and commonly schistose, but in a number of specimens collected the original fabric is still preserved. They appear originally to have been chiefly diabase and subordinately basalt, consisting essentially of plagioclase feldspar, augite, and iron oxides. In their present condition they consist largely of chlorite, calcite, sericitic and kaolinic products, and iron hydroxides, accompanied by more or less epidote and secondary quartz. The plagioclase feldspar is altered to these secondary products beyond a chance of determination of its original character, and only in one specimen was some unaltered augite seen.

A third variety of greenstone comprises massive greenish granular rocks of dioritic or gabbroic character. Two areas of these were noted. One of them is outside the Chandalar district, on the Beaver-Caro wagon road at about mile 16. The rock here is at least half plagioclase feldspar, apparently andesine, together with hornblende, a little augite, and quartz. Apatite, magnetite, and ilmenite occur as accessory minerals. The plagioclase feldspar is greatly altered to kaolin and chloritic and sericitic material, and the hornblende is partly altered to biotite and chlorite. This rock is a quartz diorite of greenstone habit. The other occurrence is a large mass of dark-green massive intrusive rock that crops out east of Flat Creek. This rock consists of labradorite, augite, and magnetite and is not greatly altered. The augite is titaniferous. The rock is a gabbro of greenstone habit.

Age and correlation.—The greenstone schist or chlorite schist along the south flank of the Silurian limestone crops out also in the center of an anticline to the west of the North Fork of Chandalar River. It seems, therefore, to follow the lower contact of the limestone and for this reason may be interpreted tentatively as an ancient lava flow. It could, however, be an old intrusive body that runs parallel to the bedding of the limestone. This formation is the same as that described by Schrader[16] under the name "amphibolite schist" and correlated by him with the older rocks of the region.

The altered diabasic and basaltic dikes and sills described as the second variety of greenstones probably include rocks of more than one age, but data are not available for their separation on the basis of age. Some of them are old and may be correlated in a general way with the greenstone schist on the North Fork of Chandalar River. Others, however, particularly those found in the Upper Devonian or Mississippian rocks, are probably of late Paleozoic age and may be correlated in a general way with the basic extrusive and intrusive rocks of the Rampart group, now believed to be of Mississippian age. The quartz diorite and gabbro of greenstone habit above described are also believed to have been intruded at about this same time.

MESOZOIC GRANODIORITE

Distribution.—A large area of granitic rocks occurs south of Chandalar River, extending from a point about opposite the Middle Fork westward to the Mosquito Fork of the Koyukuk. This intrusive mass is about 40 miles long and from 5 to 10 miles wide.

Petrographic character.—A variety of igneous rocks are found within this massif, but the main type is determined as a granodiorite. This rock is dark gray and granular. Much of it is porphyritic, showing phenocrysts of plagioclase and orthoclase. Under the microscope it is seen to consist essentially of quartz, andesine, ortho-

[16] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 472–473, 1900.

clase, biotite, and hornblende. Augite, apatite, and titanite are the accessory minerals. The rock is not altered either by chemical or by dynamic metamorphism and does not at all resemble the Paleozoic granitic rocks, either in petrographic character or in state of preservation. The ratio of andesine to orthoclase is about 3 to 1, so that the rock is designated a granodiorite rather than a quartz diorite or a quartz monzonite.

The granodiorite is cut by aplitic and lamprophyric dikes and larger intrusive bodies, which show a considerable range in petrographic character. One of the typically aplitic intrusives is a light-colored granular rock consisting of quartz and feldspar, the latter predominantly orthoclase and microcline, with some plagioclase. The potash feldspar is graphically intergrown with quartz. Another light-colored product of differentiation consists almost exclusively of feldspar, chiefly microcline with a little plagioclase, quartz, and biotite. This rock closely approaches a syenite. A typical basic differentiate is a granular rock which consists of about two-thirds hornblende and about one-third plagioclase and quartz, with some iron oxides and a little orthoclase. This may be described as a kersantitic variety of the granodiorite.

Observations along the mountain tops south of the West Fork of Chandalar River indicate that the main intrusive rock is granodiorite, but some fairly large bodies of a more granitic type of rock, corresponding chemically to the aplite above described, appear also to be present. These more acidic and also more basic rocks appear to have been injected into the main granodiorite at a late stage in the general process of intrusion.

Age and correlation.—No direct evidence is available regarding the age of these rocks, except that they intrude the latest Paleozoic rocks of the district. They might be either Mesozoic or Tertiary. They resemble the Mesozoic granitic intrusive rocks of the Yukon-Tanana region, however, more than they resemble the Tertiary granitic intrusives of the lower Yukon and Kuskokwim valleys, and for this reason alone they are referred to the Mesozoic.

TERTIARY BASALT

Distribution.—The Tertiary igneous rocks consist of basaltic intrusives and extrusives that crop out in the valleys of the West Fork and the main Chandalar. Beginning at the forks of the West Fork, an elongated dikelike intrusive body extends for 10 miles a little south of west, forming a characteristic trap ridge. In the lower valley of the West Fork lavas occur, and these extend intermittently down Chandalar Valley to the beginning of the flats.

Petrographic character.—The intrusive trap rock is a fine-grained greenish microporphyritic rock, with an intersertal fabric. The microphenocrysts are plagioclase feldspar. The rock was composed originally of plagioclase feldspar, augite, and iron oxides but is now much altered, the plagioclase and pyroxene being changed in large part to chlorite, sericite, and some epidote, while the iron oxides have been converted to iron hydroxides. The rock is determined to be an altered basalt.

The lavas farther east are altered fine-grained trap rocks, many of which are amygdaloidal. One very fine-grained amygdaloidal specimen was seen under the microscope to be composed in large part of a dark-colored volcanic glass, which has been much chloritized. The vesicles are filled with calcite. This is probably a basaltic glass. Other specimens are fine grained but only partly glassy.

Age and correlation.—The exact age of these basaltic intrusive and extrusive rocks is not known. The intrusives cut the Mesozoic granodiorite, however, and the extrusives appear to overlie it. They are therefore believed to be of Tertiary age. Similar Tertiary trap rocks have a wide distribution in interior Alaska but are perhaps best developed in the lower Yukon and Kuskokwim basins.

REGIONAL STRUCTURE

The geologic structure in the Chandalar district is not simple, nor yet as complex as the structure in some other parts of Alaska, as for instance in Seward Peninsula. The rocks have been deposited during a number of different epochs and have been deformed, elevated, and eroded in a number of different cycles, of which, however, the principal ones are believed to have been recognized. The intrusion of granitic rocks on a large scale has taken place in at least two periods during the geologic history, adding further complexity to the structure; and basic intrusions also have played a part in the tectonic history. A complete analysis of the structure of this region can not of course be given, for the small amount of work so far done does not justify a final statement on the many problems involved. A few structural generalizations, however, may serve as a guide for future work in the region.

In many regions structural features are indicated by marked parallelism of the stream valleys. Thus in the Yukon-Tanana region the marked change in the course of Yukon River above and below Fort Yukon is reflected in the stream valleys to the south of the Yukon, and these two directions have always been considered to have a structural meaning. Similarly, in the Silurian and pre-Silurian rocks of the Chandalar district, two well-marked structural directions are indicated by the valley trends, one of which is about N. 20°

E., while the other is about at right angles, or S. 70° E. On the other hand, the strike of the formational contacts does not appear to follow either of these trends, except in minor features, but is about east or perhaps a little north of east. The most prominent of these contacts is the one between the early Paleozoic rocks and the Silurian limestone, and as has been shown this is probably a contact between two conformable formations and must therefore represent on a large scale the general trend of the bedding of the Silurian limestone and the early Paleozoic rocks. Now if a series of rocks are folded and refolded, and the axes of the two systems of folds are inclined to one another, it is to be expected that the later folding will be more prominent, and that the main trend of the depositional contacts will follow the later axial trends. It has been shown also that the Middle Devonian rocks lie unconformably above the Silurian and pre-Silurian rocks and that these Middle Devonian rocks also trend east. It may also be pointed out that the N. 20° E. and S. 70° E. trends of the stream valleys do not appear to continue northward into these Middle Devonian rocks. It is therefore concluded that in post-Devonian time there was a period of deformation which folded the Middle Devonian rocks for the first time and established the east-west trend of the formational contacts as they now appear. But the Silurian and pre-Silurian rocks, which lie unconformably below the Middle Devonian rocks, must have been folded before the latter were deposited and must therefore have suffered deformation during at least two periods. This earlier folding must have taken place in late Silurian or early Devonian time, and the structural trends of the valleys above noted are believed to reflect some of the structural features then produced. It has already been suggested that the N. 20° E. trend in the older rocks represents the axial trend of an older system of folding, and that the southward extension of the Silurian limestone into the bend of Bettles River represents a synclinal fold of this older system that plunges northward, owing to the northward-dipping monocline of post-Devonian age. The S. 70° E. trend in the older rocks is harder to explain. It appears to control the direction of the valley of the North Fork of Chandalar River above Bend Mountain, as well as of the Lake-Grave Creek valley and the main Chandalar Valley. In this connection, however, it should be pointed out that this direction continues to Porcupine River and affects the post-Silurian rocks in that valley. Moreover, a complementary structure trending about S. 70° W. commences in the Chandalar district and continues into the Koyukuk Valley, affecting younger rocks also in that region. Both these structural trends conform in a general way with the trend of Yukon Valley above and below Fort Yukon. The east-west structure of the Silurian limestone is confined to the Chandalar district, for the limestone bends southeastward to the Porcupine Valley and southwestward to the valleys of John and Alatna rivers. From a consideration of these facts it is believed that the east-west axial trend in the Chandalar district is a tangential structure to a great arc, and that the S. 70° E. and S. 70° W. directions indicate the trend of this arc and are a measure of its curvature. These two directions, therefore, are interpreted as elements in the post-Devonian folding, and the east-west trend of the rocks in the Chandalar district is interpreted as the combined result of these two structural trends.

In considering the Birch Creek schist (?), it was suggested that an unconformity might separate these rocks from the early Paleozoic rocks. This hypothesis, however, is proposed only because this relation appears to exist in the Yukon-Tanana region, and it is therefore entirely inferential. No structural data have been collected in the Chandalar district either to prove or disprove the hypothesis.

It remains to suggest some more definite period for the post-Middle Devonian folding. The Upper Devonian or Mississippian rocks in the southwestern part of the Chandalar district appear to have been affected by this same system of deformation and to a similar degree. It seems best, on the whole, to believe that this folding took place at some time in the Mesozoic era, and if so, it was probably more or less synchronous with the intrusion of the Mesozoic granitic rocks. This event is generally believed to have taken place in Jurassic time, and in the absence of any further evidence it is assumed that the post-Middle Devonian folding is of Jurassic age.

Still later deformational movements have affected the rocks of the Chandalar district, for the Tertiary lavas are no longer horizontal, but little is known of these later movements. It is likely, however, that they have not been the source of any new large-scale regional structural features but have acted rather to accentuate the preexisting Mesozoic deformation.

GEOLOGIC HISTORY

The oldest rocks in the Chandalar district are the quartzite schist and quartzite south of Chandalar River. After the deposition of the sediments from which these rocks are derived they were probably folded, elevated, and eroded before the early Paleozoic rocks were deposited. This break in the stratigraphic sequence, however, is inferred and not proved. Then followed the deposition of a great thickness of marine sediments, but the geologic period in which this sedimentation began is not known, though it is known to have continued into Silurian time. If the deposition of these early Paleozoic rocks began in Cambrian or in Ordovician time, it would be surprising if the sequence as mapped does not contain one or more unconformities representing discontinuities in the deposition of the rocks. Such stratigraphic breaks will be recognized only by more detailed studies.

The Silurian or upper part of this sequence of early Paleozoic rocks appears to have graded without a stratigraphic break from deposits of a dominantly marine argillaceous type into marine calcareous deposits, so that in middle or upper Silurian time a great thickness of limestone was laid down. A greenstone schist, which is shown on the geologic map as lying at the base of this Silurian greenstone, may be either an altered flow or an intrusive body, of basic composition. If it is a flow, it shows that a certain amount of volcanic action occurred at the time of the deposition of the Silurian limestone. If it is a dike or sill, the volcanism was of later date.

After the Silurian limestone was deposited the rocks of the district, both Silurian and pre-Silurian, were folded, elevated, and eroded, the first well-recognized break in the sequence of sedimentation being thus produced. It was during this period of deformation and terrestrial conditions that the Paleozoic gneiss is believed to have been intruded into the preexisting rocks. This gneiss, however, has not been observed invading the main belt of Silurian limestone. Its absence may be either a fortuitous circumstance in the localization of the granitic intrusives, or it may be due to the fact that the intrusions took place at too great a depth to reach the limestone. In any event, the age of the gneiss is believed to be either late Silurian or early Devonian.

Subsequently, in Middle Devonian time, the district was again invaded and covered by the sea, and a great thickness of marine argillaceous sediments were laid down, which now form a thick mass of slate. Marine fossils of Upper Devonian age are also found in this district, but the Upper and Middle Devonian rocks have not been observed in contact with one another, so that it is not known whether or not sedimentation continued without interruption from Middle into Upper Devonian time. The Upper Devonian rocks, however, appear to contain slate, chert, and some limestone, indicating that at least there was a difference in the type of sedimentation.

Paleozoic rocks of post-Devonian age were not recognized in the Chandalar district, but in the valley of John River, to the west, there is a series of marine Mississippian rocks, known as the Lisburne limestone, with a chert conglomerate, known as the Stuver "series," at its base. These facts are interpreted as evidence that a break in sedimentation occurred after the latest Devonian rocks were deposited, accompanied by reelevation and possibly erosion. It is not known whether this break in sedimentation was also accompanied by deformation of the Devonian and pre-Devonian rocks.

Pennsylvanian, Permian, Triassic, and Jurassic rocks have not yet been found between the Arctic Mountains and Yukon River, but such rocks are present between the Arctic Mountains and the Arctic Ocean. No evidence is available at present to indicate whether such rocks were deposited and subsequently eroded in the region south of the Arctic Mountains, or whether that region was a land surface during these geologic periods.

Along the Yukon, to the south, great outpourings of basic lava, accompanied by intrusions of basic igneous rocks, took place in Mississippian and possibly in later Carboniferous time. Most of the intrusive greenstones of the Chandalar district are correlated with this period of volcanic activity. Also in Jurassic time a great intrusion of granitic rocks is believed to have taken place, which is now represented by the granodiorite massif south of Chandalar River.

The next recorded period of marine sedimentation south of the Arctic Mountains began in Lower Cretaceous time. The rocks deposited at this time are found in the lower Koyukuk Valley but do not occur in the Chandalar district. More sediments, partly marine and partly estuarine or terrestrial, were laid down in Upper Cretaceous time, but it is not definitely known whether a break in sedimentation occurred between the Lower and Upper Cretaceous. A small area of these Upper Cretaceous rocks is found in the southwestern part of the Chandalar district.

Tertiary sediments are unknown in the Chandalar district, but they may have been deposited and subsequently eroded. If such sediments were deposited, however, it is very likely that they were of estuarine or terrestrial character, similar to the Tertiary conglomerate, sandstone, and shale found elsewhere in interior Alaska. Volcanic action took place in Tertiary time, resulting in lava flows in the Chandalar district and in great intrusions of acidic and basic rocks in southwestern Alaska. The basic lavas of the Chandalar Valley are believed to have been poured out in Tertiary time.

Pleistocene time witnessed the advent of a glacial epoch, as a result of which the high mountains in the Chandalar district were covered with ice caps and the valleys were filled with ice tongues extending outward from these ice caps. The melting of the ice caps and the retreat and final disappearance of the valley glaciers initiated Recent time, which has been characterized by terrestrial conditions and normal stream erosion.

MINERAL RESOURCES

Gold is the only metal that has yet been mined in the Chandalar district and the only one that is likely to be mined in the near future. Gold placer mining is now being done on Little Squaw, Big, and

Big Squaw creeks, but the camp in all is a small one. Both summer and winter placer mining is being carried on. In addition to the placer mining, a crew of four men was engaged during most of the summer of 1923 in prospecting a gold quartz lode on Little Squaw Creek. The character and distribution of mining operations in the Chandalar district in 1923 is shown in the subjoined table:

Mining operations in Chandalar district, 1923

	Drifting		Open-cut work	Prospecting	
	Winter	Summer		Drift	Lode
Little Squaw Creek	1	1		1	1
Big Creek		1	1		
Big Squaw Creek			1		
	1	2	2	1	1

About 30 men in all were engaged in mining work in the district in 1923.

ECONOMIC CONDITIONS

Supplies for this camp are transported from Beaver, on the Yukon, a distance of about 120 miles by trail. A wagon road extends from Beaver to Caro, about 75 miles, but this road can not be traveled by a loaded wagon until about the middle of July, after the high water of spring has subsided and the ground has dried out to some extent. From Caro one trail goes up Flat Creek, then over the Middle Fork of the Chandalar, up the Middle Fork to Grave Creek, and up Grave Creek to Little Squaw and Big creeks. The Big Creek trail goes northwestward to Big Creek and thence up the creek to its head.

The winter rate for freighting supplies from Beaver to Little Squaw Creek is said to be about 15 cents a pound. In reality, a good part of the supplies used at Little Squaw Creek are freighted from Beaver to Caro by wagon late in the summer and by sled from Caro to Little Squaw Creek in winter.

Timber of good size and quality is available in the valleys of Grave, Lake, and Big creeks, but the Little Squaw-Big Creek camp is well above timber line, and the essential firewood and mining timber must be transported a considerable distance, thus being very expensive. On Big Creek cordwood and timber has to be freighted 12 miles upstream in winter by dog teams, and the wood is estimated to cost $50 a cord landed at the mouth of St. Mary's Gulch. This figure is the actual cost of the labor and freighting, the work being done by the placer miners themselves. The length of the summer mining season on Big Creek is determined by the amount of cordwood that can be hauled in winter, rather than by the length of the open season.

Water in sufficient quantity for summer sluicing is available on Little Squaw, Big, and Big Squaw creeks. Winter dumps are taken out on Little Squaw Creek and sluiced in June, when the water is high.

The wages paid to placer miners are $6 a day and board, but men doing work of special kinds, such as winchmen and cooks, receive $7 a day and board.

LITTLE SQUAW CREEK

PHYSIOGRAPHIC HISTORY

Little Squaw Creek is between 3 and 4 miles in length, heads against Big Creek, and flows somewhat east of north, joining the head of Lake Creek above Ogburn Lake. The divide at the head of Little Squaw Creek has an altitude of about 4,800 feet, while the junction of Little Squaw and Lake creeks is at an altitude of about 2,300 feet. The creek therefore has a gradient of 2,500 feet in less than 4 miles, but most of this fall is in the upper part of the creek, above the placer mines. The principal placer-mining operations are about 1½ or 2 miles from the mouth of Little Squaw Creek, and the altitude here is estimated at 3,000 feet.

The physiographic history of Little Squaw Creek can be inferred with considerable assurance. Prior to the advent of the glacial epoch Little Squaw Creek had much the same course as at present and emptied into a large stream that flowed eastward through the present Lake-Grave Creek valley. The valley floor of this trunk stream, however, was higher than the present floor of the Lake-Grave Creek valley, whose lower altitude is due chiefly to subsequent glacial erosion. In the early stages of glaciation the ice in the present Lake-Grave Creek valley probably formed an active glacier, moving slowly downstream. In the later stages, as the ice overflowed the divide south of Chandalar Lake and cut a channel out to the south, the movement of the ice in the Lake-Grave Creek valley probably gradually decreased, and the ice finally became more or less stagnant. As the glaciers retreated and the ice melted, a new trunk stream was established at the lower end of the glacier, in the present North Fork valley, and this stream has been able to retain the upper drainage thus captured by cutting a bedrock channel below Chandalar Lake. In this process the new stream was aided by deposits of glacial material from the melting ice, which were dumped in the Lake-Grave Creek depression.

In the process above sketched the lower part of the preglacial channel of Little Squaw Creek was obliterated by the large glacier scouring along the Lake-Grave Creek or old North Fork valley. The hills to the south; however, including the divide between Little Squaw and Big creeks, did not carry active glaciers, although they probably supported an ice cap of considerable proportions. The preglacial channel of the upper part of Little Squaw Creek was therefore preserved as far downstream as the upper part of the main North Fork glacier. When the glacier retreated it left behind a great mass of morainal deposits, which extended up Little Squaw Creek almost to the upper limit of the glacier. In the postglacial reestablishment of the Little Squaw Creek drainage system these glacial deposits acted at first as a new base-level, over which Little Squaw Creek flowed into the present Lake-Grave Creek valley. Subsequently, as the glacial material was partly removed from the Lake-Grave Creek valley, Little Squaw Creek cut a new postglacial channel down through these glacial deposits in its lower course.

The various stages in this physiographic history are now shown by the character and distribution of the alluvial deposits in the valley of Little Squaw Creek. The creek contains both creek and bench deposits, though these two types of deposits are not everywhere separable, because at places the postglacial channel has cut across the old preglacial channel. In other words, the stream and bench deposits are not distinct and separable by a bedrock rim, as they are, for instance, on Livengood Creek in the Tolovana district. Glacial deposits begin at the upper end of claim No. 3 above Discovery, about 1½ or 2 miles upstream from the mouth of Little Squaw Creek, and continue downstream into the valley of Lake Creek. The old preglacial channel appears to continue downstream under these glacial deposits but probably does not extend very far, because it was doubtless eroded in its lower reaches by glacial action. An early postglacial channel also extends downstream above the glacial deposits, which form a false bedrock for this later gravel. The preglacial alluvial deposits that lie upstream from the glacial deposits and the postglacial deposits that extend out over the glacial deposits have both been mined, but the downstream extent of the preglacial channel under the glacial deposits has not yet been explored by mining operations, though some prospecting has been done for this purpose. On the other hand, the early postglacial channel that lies above the glacial deposits probably also extends for no great distance downstream, because Little Squaw Creek rapidly cut into the glacial gravel and established a later and different channel. These events in the physiographic history of Little Squaw Creek have been the dominating influences in the localization of the gold placer deposits.

GOLD PLACERS

Placer mining and prospecting have been in progress on Little Squaw Creek for a number of years. Figure 11 shows the location of the placer mines on Little Squaw, Big Squaw, and Big creeks. Until a few years ago placer mining on Little Squaw Creek had been confined to the old preglacial channel upstream from the glacial deposits in the valley. This gravel, however, as before stated, is not

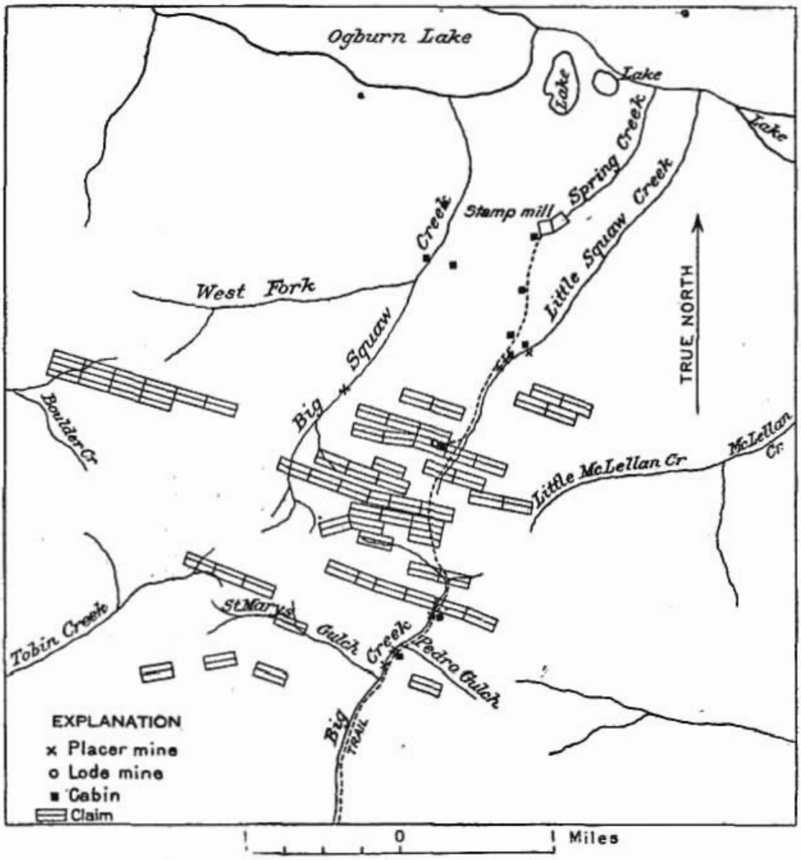

FIGURE 11.—Sketch map showing approximate location of placer mines and lode claims on Little Squaw, Big Squaw, and Big creeks

everywhere sharply separable from the later postglacial deposits. The upper preglacial gravel is now pretty well mined out, but a few years ago, in working the lower end of this gravel, just upstream from the glacial deposits, very rich gold-bearing gravel was struck. In following this rich gravel downstream, the pay streak was found to leave bedrock and continue out over the glacial deposits, which act as a false bedrock. The chief mining operations in Little Squaw Creek are now confined to this early postglacial channel, though some mining is still being done in the old preglacial channel upstream from the glacial deposits.

The bedrock in Little Squaw Creek is a mica schist containing numerous veins of gold-bearing quartz. The schist itself is also mineralized, as shown by the weathered pyrite crystals found in the country rock. The schist is also cut by numerous dikes and perhaps sills of greenstone. The quartz veins and mineralized schist are the proximate source of the gold in the gold placers.

The most extensive placer-mining operations at present on Little Squaw Creek are on claim No. 3 above Discovery, where a gold placer is being mined by drifting in the early postglacial channel, which lies above the glacial till. This deposit is on the west side of the valley at a distance of perhaps 200 feet from the creek. The depth from the surface to the glacial deposits or false bedrock ranges from 55 to 100 feet. The shallow holes are at the upper end of the claim, where the glacial deposits begin, but the variation in depth is due in part to variation in surface configuration and in part to the unevenness of the upper surface of the glacial deposits. Holes have also been sunk through the glacial débris to true bedrock, showing a thickness of 25 to 50 feet of glacial deposits at the upper end of this claim.

The glacial material consists of worn or unworn angular débris, cemented by clay. The large proportion of clay is one of the distinguishing characteristics of this material. Faceted pebbles, some of which show distinct striae due to glacial scouring, are numerous. This material may be classed as a true till. Above the true glacial material comes 10 feet of partly rounded gravel, which is evidently glacial débris that has been reworked to a greater or less extent by stream action. The gold occurs in the upper 6 or 8 feet of this material. Above this zone, and continuing to the surface, is partly rounded material of the same general character, but this is barren of gold from top to bottom. The chief kinds of rock found, both in the till and in the overlying gravel, are schist and greenstone, though the greenstone appears to be more prevalent in the later stream gravel than in the glacial débris. These greenstone cobbles and boulders come from the greenstone intrusions above mentioned, and because of their superior hardness and resistance to erosion they are more numerous than the bedrock distribution appears to justify. Much quartz is also present, both in the gravel and in the till.

Gold, both from this mine and from the preglacial channel upstream, was seen by the writer. Both varieties are said to have the same value, but the gold from the preglacial channel upstream is somewhat darker, coarser, and more waterworn. Nuggets as large as $180 have been found in the preglacial deposits, but none worth over $10 in the early postglacial deposits that lie above the till. A number of assays of gold from the Chandalar district, including the gold from Little Squaw, Big, and Big Squaw creeks, were given to the writer by Mr. Frank Yasuda, of Beaver. These are presented below.

Value of gold from Chandalar district

Sample	Fineness		Value per ounce		Value of silver per ounce at time of assay
	Gold	Silver	Before melting	After melting	
1	0.84975	0.147	$17.30	$17.70	$0.90
2	.84875	.149	17.32	17.65	.69
3	.848	.147	17.05	17.65	.80
4	.84925	.147	17.31	17.65	.61
5	.84925	.148	17.31	17.65	.63
6	.848	.149	17.25	17.62	.63
7	.84875	.148	17.33	17.65	.70
8	.8535	.143	17.34	17.74	.71
9	.849	.148	17.27	17.65	.69
10	.850	.146	17.34	17.71	.95
11	.83575	.159	17.04	17.37	.58
12	.84875	.147	17.27	17.65	.69
Mean	.84823	.1482	17.26	17.64	

The average value of the gold as recovered by the mines is seen to be $17.26 an ounce. This gold passes commercially at Beaver at $17 an ounce, which is a very fair return to the miner, when it is remembered that only 26 cents an ounce is required to cover the express and insurance charges on the gold from Beaver to the mint, as well as the assay charges.

The concentrates recovered in the sluice boxes with the gold on Little Squaw Creek consist chiefly of pyrite, together with smaller amounts of hematite, arsenopyrite, and scheelite (calcium tungstate). A piece of galena was also picked up by one operator in Little Squaw Creek. The hematite occurs in well-banded black tabular crystals, and the scheelite in amber-brown individuals, many of which show crystal outlines. Practically no magnetite occurs in the heavy sands.

Farther upstream, in the old preglacial channel, drift mining on a small scale is being done on claim No. 4 above Discovery, on the west side, about 50 feet from the creek. The depth to bedrock here is 35 feet, of which the lower 5 feet is composed of rounded but lenticular gravel. The shape is due to the preponderance in the gravel of mica schist, which weathers out of bedrock in slablike pieces and becomes disklike rather than spheroidal by stream transportation. The upper 30 feet of gravel is as well or better rounded, owing apparently to a greater admixture of greenstone with the schist. The lower 5 feet is believed to be of preglacial origin. The gold is found almost entirely in 2 or 3 feet of decayed schist bedrock, practically none occurring in the gravel above bedrock. The ground is solidly frozen from the surface to bedrock but is probably unfrozen nearer the creek.

Only drift mining is done on Little Squaw Creek, but the mining on claim No. 3 above Discovery is being done in winter, and that on claim No. 4 above Discovery is being done in summer. The determining factor is the presence or absence of frozen ground. On claim No. 3 the main shaft passes through frozen ground, but the working drifts lead off into unfrozen ground. The bottom of the shaft is therefore filled with water 20 feet deep in summer, but curiously enough this water all drains out in winter, leaving the workings dry. A block of ground 400 by 28 feet, or nearly 11,000 square feet, was mined from a shaft 100 feet deep in claim No. 3 during the winter of 1922–23. All the pay gravel is removed, no pillars being left. Caps and posts are used to support the roof. Where the ground is frozen 7-foot steam points are used for thawing. The plant consists essentially of a boiler and hoist. The gravel is conveyed from the face to the shaft by wheelbarrows, elevated to the surface in an iron bucket, and conveyed by an overhead cable to the gin pole outside and there dumped. This winter dump is sluiced in the spring. Probably a dozen men were employed at this property during the winter of 1922–23.

The work being done on claim No. 4 at the time of the writer's visit was more in the nature of prospecting. The gravel was being elevated to the surface in a bucket by means of a wooden windlass worked by one man. One other man was at work underground.

Still another shaft was sunk by two men during the summer of 1923 on the east side of Little Squaw Creek, about half a mile below the shaft on claim No. 3 above Discovery. This work was being done primarily to discover, if possible, whether the old preglacial channel below the glacial till extends that far downstream. The shaft was sunk 70 feet, apparently to bedrock, and some fine colors of gold were found. More work was expected to be done here during the winter of 1923–24.

BIG SQUAW CREEK

Big Squaw Creek lies about a mile west of Little Squaw Creek and drains into Lake Ogburn. Its physiographic history and general character are similar to those of Little Squaw Creek. Near the head of Big Squaw Creek one man has been mining in a small way for a number of years. During the summer of 1923 a narrow cut, about 6 feet wide, was opened up and from 3 to 4 feet of coarse gravel was shoveled into small sluice boxes. The bedrock here is schist, the cleavage of which strikes N. 55° W. and dips 20° N. The gravel is subangular and includes many large boulders of greenstone and slabs of schist. The surface of the bedrock is very irregular, and the gold occurs both in the gravel and on the bedrock. The gold is coarse and little worn. The heavy minerals of the concentrates include pyrite and arsenopyrite, and one piece of stibnite also was observed. As bearing on the source of the gold, one oxidized crystal of pyrite was seen at this locality, which was about half gold, the gold apparently having been intergrown originally with the pyrite.

BIG CREEK

Big Creek, unlike Little Squaw and Big Squaw creeks, has not been glaciated, and the deposits in its valley belong to the normal type of stream gravel. Clay and silt occur at the lower end of Big Creek, but the gold placers now being mined are at the extreme head of Big Creek. Figure 11 shows the location of the gold placers on Big Creek. Two placer-mining plants were operated on this creek during the summer of 1923.

The upper plant, on claim No. 1 above Discovery, consisted of an open cut with an automatic splash dam and shear boards in the cut to direct the water. The pay streak is about 40 feet wide and consists of a body of fairly coarse gravel averaging about 15 feet thick. Mining operations are being conducted directly in the present stream beds, evidently in gravel of recent age. The country rock of Big Creek above this plant is schist cut by dikes of greenstone. One such dike crosses the creek in the cut and gives rise to numerous large boulders. Just above the open cut some gold quartz veins cut across the creek in a direction about N. 70° W., and numerous other quartz veins are found in the hills near by. These seem to be the main source of the gold on Big Creek. The relation of the gold in the open cut to the quartz veins upstream is particularly evident, as the good placer ground begins downstream from these veins. The concentrates, recovered with the gold, consist mainly of pyrite but include hematite, limonite, monazite (cerium phosphate), scheelite (calcium tungstate), rutile, and arsenopyrite. The monazite is particularly interesting, because it is the first recorded occurrence of this mineral in Alaska. It occurs as small amber-colored grains, the largest of which measure 2 millimeters in diameter. This mineral, though primarily a cerium phosphate, contains also the elements lanthanum, yttrium, erbium, and thorium and is the source of the cerium and thorium compounds that are used in the manufacture of incandescent gas mantles. The occurrence on Big Creek has no economic significance, because the monazite is not sufficiently plentiful nor sufficiently concentrated to be recovered.

On claim No. 5 below Discovery summer drift mining was in progress in 1923. The gravel here is 22 feet thick, and the gold is concentrated in the lower 3 to 5 feet, with very little gold on bedrock. The bedrock is schist, with a very irregular surface. None of the gravel is well rounded, but the lowest 3 to 5 feet is more rounded than the overlying gravel. Many large boulders of greenstone, as much as 3 feet in diameter, occur in the pay gravel and cause trouble in mining. The gold seems to be most plentiful in the lower foot of gravel, which has a sandy matrix and is stained reddish by iron. The gold is fairly coarse and rather ragged. The largest nugget found in 1923 was worth about $5. The concentrates or heavy sands recovered in the sluice boxes with the gold are the same as those found on claim No. 3, upstream, including also the monazite. A block of ground 85 by 125 feet was worked during the summer of 1923. The gravel is wheeled in a barrow to the shaft, hoisted, and dumped in the regular way. The plant consists of a 14-horsepower boiler, hoist, and self-dumping bucket. In thawing 8-foot steam points are used, and pillars are left to support the roof. Only frozen ground is worked. Eight men were at work at this plant.

GOLD LODES AND MINERALIZATION

Numerous gold quartz veins are found at the heads of Little Squaw, Big Squaw, Boulder, Tobin, Big, and McLellan creeks. A sketch map showing the location of the principal lode claims that have been staked was loaned to the writer by Mr. Harry Patterson, of the Chandalar Mining Co., and used in preparing Figure 11.

These quartz veins have been known and staked for 15 years or more, and considerable prospecting and sampling of them has been done. Many open cuts and a few shafts and tunnels have been made in prospecting these veins, but most of these have now caved so that little may be seen except at the surface. A small stamp mill was erected near Little Squaw Creek in 1910.

The principal work in progress at the present time is being done by the Chandalar Mining Co., on the Little Squaw group of claims, in the upper basin of Little Squaw Creek. On the west side of Little Squaw Creek, at an altitude of about 3,800 feet, a tunnel has been driven 150 feet along one of these quartz veins, and at the end of the tunnel a winze has been sunk about 60 feet on the vein. The cleavage of the schist country rock at the mouth of this tunnel strikes N. 5° W. and dips about 15° E., and the vein cuts across the cleavage, striking N. 75° E. and dipping 80° S. The quartz is about 4 feet thick at the portal of the tunnel but varies considerably in thickness. At the 60-foot level in the winze the dip of the vein changes to about 60° and the vein itself consists of several quartz stringers, with much arsenopyrite; but some later work in this winze, after the writer's visit, is said to have shown the vein widening out again. In the tunnel it is apparent that movement has taken place along the footwall, after the quartz was deposited. It is likely that these quartz veins are variable in thickness, and they may also be faulted off at places by later movements.

The gold occurs free in the quartz, locally with arsenopyrite and its green alteration product, scorodite. Some of the gold quartz is of very high grade, but it should not be expected that all the vein will be of this character. The gold probably occurs in rich ore shoots, and in the exploitation of such a mine due allowance must be made for much unprofitable mining and for deadwork in prospecting the vein for new ore shoots. The ore shoots may average $40 to $50 in gold to the ton, but the quartz veins as a whole are much leaner.

A number of the quartz veins in this district were visited, including those on the Overlook, Eneveloe, Woodchuck, Golden Eagle, Summit, Little Mikado, Tonopah, Eclipse, and Crystal claims. Little can be seen at most of these properties, except the direction of the veins and, at some of them, the thickness. On the Little Mikado claim, at the head of Tobin Creek, a shaft was sunk 100 feet deep some years ago but is now caved in. Some distance down the hillside a crosscut was run 160 feet but apparently failed to intersect the main vein.

In general the gold quartz of these veins is white, in places iron-stained, and much of it shows cavities into which crystals of quartz project. Much of the quartz is crushed, and some of it is apparently recrystallized. One of the effects of later movement in the veins is the development of a sort of sheeting in the quartz, which runs parallel to the walls of the veins. Thin seams of altered arsenopyrite lie along many of these sheared fractures, emphasizing to the eye this parallel shearing. It appears that much of the movement within and parallel to these veins has taken place after the mineralization. The commonest sulphide in the quartz is arsenopyrite, but some stibnite, galena, and sphalerite also are found. The quartz on the Little Mikado claim is more massive and closer textured and contains more pyrite than arsenopyrite. Siderite also was observed in some of the vein quartz. The country rock in the neighborhood of the quartz veins also shows the effects of mineralization in numerous oxidized pyrite crystals.

The general trend of the stronger quartz veins ranges from N. 75° E. to N. 60° W., but no general system of veining was discovered. Some of the veins dip to the north and some to the south. Many of the veins intersect the cleavage of the schist, but some appear to follow the cleavage.

It is evident that the gold in the placers on Little Squaw, Big Squaw, and Big creeks has been derived in large measure from the gold quartz veins in the basins of these creeks. The source of the quartz veins, however, is a more involved though not less important problem. The discovery of minerals like monazite and rutile in the concentrates on Big Creek may have some bearing on the question. As Big Creek and the mountains at the head of it have not been overridden by glaciers, these minerals are certainly derived from a bedrock source within the drainage basin of Big Creek; and from the known occurrence of these minerals, particularly monazite, it is believed that this bedrock source is some highly acidic granitic rock, possibly of pegmatitic character. Gold quartz veins, too, are commonly believed to be connected genetically with the intrusion of granitic rocks, but it does not follow that these veins and the monazite are both derived from the same granitic rocks. This genetic relationship is suggested, however, and the suggestion may serve as a basis for further studies in this district.

Granitic rocks of Paleozoic and Mesozoic age are found in the Chandalar district, but only the Paleozoic type, a granitic gneiss, occurs in the vicinity of the Little Squaw-Big Creek mining district. The nearest known Mesozoic granitic rocks (granodiorite) are 30 miles to the southwest, whereas granitic gneiss, though not in bodies of mappable size, is known on the north side of the valley of Lake Creek, about 4 or 5 miles distant. It is possible that some small bodies of the gneiss may also be present in the upper basin of Big Creek, but none are known at present. It remains to be determined, therefore, first whether the quartz veins and the monazite are related genetically, and second, what was the age or ages of the mineralization that produced them. These questions will be answered only by more detailed studies.

METAL PRODUCTION

The production of gold and silver in the Chandalar district, from 1906 to the present time, is shown in the accompanying table.

Placer gold and silver produced in the Chandalar district, 1906–1923

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	1922	4,015.12	83,000	574	574
1917	725.63	15,000	104	86	1923	2,031.75	42,000	288	236

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 certain number of copies are delivered to the Director of the Survey, from whom they can be obtained for a limited period free of charge (except certain maps) on application.

2. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at the prices indicated. No copies are available of those marked with an asterisk (*); they may be consulted at many public libraries.

3. 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 for maps 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.

Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin 259, 1905, pp. 18-3. 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.

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Iniskin-Chinitna Peninsula, Cook Inlet region; scale, 1:62,500; by C. P. McKinley, D. C. Witherspoon, and Gerald Fitz Gerald (preliminary edition). Free on application.

The Alaska Railroad route: Seward to Matanuska coal field; scale, 1:250,000; by J. W. Bagley, T. G. Gerdine, R. H. Sargent, and others. 50 cents retail or 30 cents wholesale.

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Lake Clark-central Kuskokwim region; scale, 1:250,000; by R. H. Sargent, D. C. Witherspoon, and C. E. Giffin. In Bulletin 655, 30 cents. Not issued separately.

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REPORTS.

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The Fortymile quadrangle, Yukon-Tanana region, Alaska, by L. M. Prindle. Bulletin 375, 1909, 52 pp. 30 cents.

Water-supply investigations in Yukon-Tanana region, Alaska, 1907–8 (Fairbanks, Circle, and Rampart districts), by C. C. Covert and C. E. Ellsworth. Water-Supply Paper 228, 1909, 108 pp. 20 cents.

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A geologic reconnaissance of a part of the Rampart quadrangle, Alaska, by H. M. Eakin. Bulletin 535, 1913, 38 pp. 20 cents.

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*The gold and platinum placers of the Tolstoi district, by G. L. Harrington. In Bulletin 692, 1919, pp. 338–351.

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

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Geology of Fairbanks and Rampart quadrangles, by J. B. Mertie, jr.

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Circle quadrangle (No. 641); scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, and others. 50 cents retail or 30 cents wholesale. Also in Bulletin 538, 20 cents.

Fairbanks quadrangle (No. 642); scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, R. B. Oliver, and J. W. Bagley. 50 cents retail or 30 cents wholesale. Also in Bulletin 337, 25 cents, and Bulletin 525, 55 cents.

Fortymile quadrangle (No. 640); scale, 1:250,000; by E. C. Barnard. 10 cents retail or 6 cents wholesale. Also in Bulletin 375, 30 cents.

Rampart quadrangle (No. 643); scale, 1:250,000; by D. C. Witherspoon and R. B. Oliver. 20 cents retail or 12 cents wholesale. Also in Bulletin 337, 25 cents, and part in Bulletin 535, 20 cents.

Fairbanks special (No. 642A); scale, 1:62,500; by T. G. Gerdine and R. H. Sargent, 20 cents retail or 12 cents wholesale. Also in Bulletin 525, 55 cents.

Bonnifield region; scale, 1:250,000; by J. W. Bagley, D. C. Witherspoon, and C. E. Giffin. In Bulletin 501, 20 cents. Not issued separately.

Iditarod-Ruby region; scale, 1:250,000; by C. G. Anderson, W. S. Post, and others. In Bulletin 578, 35 cents. Not issued separately.

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Surface water supply of Seward Peninsula, Alaska, by F. F. Henshaw and G. L. Parker, with a sketch of the geography and geology by P. S. Smith and a description of methods of placer mining by A. H. Brooks; including topographic reconnaissance map. Water-Supply Paper 314, 1913, 317 pp. 45 cents.

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TOPOGRAPHIC MAPS.

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Seward Peninsula, northeastern portion, reconnaissance map (No. 655); scale, 1:250,000; by D. C. Witherspoon and C. E. Hill. 50 cents retail or 30 cents wholesale. Also in Bulletin 247, 40 cents.

Seward Peninsula, northwestern portion, reconnaissance map (No. 657); scale, 1:250,000; by T. G. Gerdine and D. C. Witherspoon. 50 cents retail or 30 cents wholesale. Also in Bulletin 328, 70 cents.

Seward Peninsula, southern portion, reconnaissance map (No. 656); scale, 1:250,000; by E. C. Barnard, T. G. Gerdine, and others. 50 cents retail or 30 cents wholesale. Also in Bulletin 328, 70 cents.

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Nulato-Norton Bay region; scale, 1:500,000; by P. S. Smith, H. M. Eakin, and others. In Bulletin 449, 30 cents. Not issued separately.

Grand Central quadrangle (No. 646A); scale, 1:62,500; by T. G. Gerdine, R. B. Oliver, and W. R. Hill. 10 cents retail or 6 cents wholesale. Also in Bulletin 533, 60 cents.

Nome quadrangle (No. 646B); scale, 1:62,500; by T. G. Gerdine, R. B. Oliver, and W. R. Hill. 10 cents retail or 6 cents wholesale. Also in Bulletin 533, 60 cents.

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NORTHERN ALASKA.

REPORTS.

A reconnaissance in northern Alaska across the Rocky Mountains, along Koyukuk, John, Anaktuvuk, and Colville rivers and the Arctic coast to Cape Lisburne in 1901, by F. C. Schrader, with notes by W. J. Peters. Professional Paper 20, 1904, 139 pp. 40 cents.

Geology and coal resources of the Cape Lisburne region, Alaska, by A. J. Collier. Bulletin 278, 1906, 54 pp. 15 cents.

Geologic investigations along the Canada-Alaska boundary, by A. G. Maddren. In Bulletin 520, 1912, pp. 297–314. 50 cents.

The Noatak-Kobuk region, Alaska, by P. S. Smith. Bulletin 536, 1913, 16 pp. 40 cents.

The Koyukuk-Chandalar region, Alaska, by A. G. Maddren. Bulletin 532, 1913, 119 pp. 25 cents.

The Canning River region of northern Alaska, by E. de K. Leffingwell. Professional Paper 109, 1919, 251 pp. 75 cents.

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Koyukuk River to mouth of Colville River, including John River; scale, 1:1,250,000; by W. J. Peters. In Professional Paper 20, 40 cents. Not issued separately.

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Noatak-Kobuk region; scale, 1:500,000; by C. E. Giffin, D. L. Reaburn, H. M. Eakin, and others. In Bulletin 536, 40 cents. Not issued separately.

Canning River region; scale, 1:250,000; by E. de K. Leffingwell. In Professional Paper 109, 75 cents. Not issued separately.

North Arctic coast; scale, 1:1,000,000; by E. de K. Leffingwell. In Professional Paper 109, 75 cents. Not issued separately.

Martin Point to Thetis Island; scale, 1:125,000; by E. de K. Leffingwell. In Professional Paper 109, 75 cents. Not issued separately.

Northwestern part of Naval Petroleum Reserve No. 4, Alaska; scale, 1:500,000; by E. C. Guerin, Gerald Fitz Gerald, and J. E. Whitaker (preliminary edition). Free on application. Surveyed for Department of the Navy.

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