DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 692

MINERAL RESOURCES OF ALASKA

REPORT ON PROGRESS OF INVESTIGATIONS IN

1917

BY

G. C. MARTIN AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1919

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MINERAL RESOURCES OF ALASKA, 1917.

By G. C. MARTIN and others.

PREFACE.

By G. C. MARTIN.

This volume is the fourteenth of a series of annual bulletins[1] treating of the mining industry of Alaska and summarizing the results achieved during the year in the investigation of the mineral resources of the Territory. These reports are intended to give prompt publication of the more valuable economic results of the year. The time available for their preparation does not permit full office study of the field notes and specimens, and some of the statements made here may be subject to modification when the study has been completed. Those interested in any particular district should therefore procure a copy of the complete report on that district as soon as it is available.

This volume, like the others of the series, contains an account of the mining industry, including statistics of mineral production, and also preliminary statements on investigations made by the Geological Survey. It is intended that this series of reports shall serve as convenient reference works on the mining industry for the years which they cover. It is not possible for a member of the Survey to visit every mining district each year, and therefore the information used in preparing the summary on mining development is in part obtained from other reliable sources.

Again, as for many years in the past, the Geological Survey is under great obligation to residents of the Territory for statistical data. Those who have thus aided include the many mine operators who have made reports on production as well as developments. There are still some Alaskan mineral producers who fail to respond to requests for information, but many prospectors, Federal officials,

[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, and 662.

engineers, and officers of transportation and commercial companies have contributed valuable data. It is impracticable to enumerate all who have aided in this work, but it should be stated that without the assistance of these public-spirited citizens it would be impossible to prepare this report. Special acknowledgments should be made to the Director and other officers of the Mint; the officers of the Alaska customs service; Wells, Fargo & Co.; the members and officers of the Alaskan Engineering Commission; the Alaska Mexican Gold Mining Co., Alaska United Gold Mining Co., and Alaska Treadwell Gold Mining Co., of Treadwell; B. L. Thane, of Juneau; G. H. Miller, of Skagway; George M. Esterly, of Nizina; James J. Godfrey, of McCarthy; Stephen Birch, of Kennicott; John E. Hughes, of Valdez; John Ronan, of Seward; William K. McLennan, of Chisana; J. A. Kemp, of Steel Creek; Jos. Danker, of Chicken; U. G. Myers, of Eagle; Frank A. Reynolds, of Circle; First National Bank, American Bank of Alaska, Tanana Valley Railroad, A. Bruning, J. A. Fairborn, George Hutchinson, Falcon Joslin, Alex Mitchell, and R. C. Wood, of Fairbanks; Frank Hagel, of Berry; J. C. Felix, of Nenana; George L. Morrison and S. S. Rowell, of Hot Springs; A. Bock and Joseph Heller, of Tofty; George W. Ledger, of Rampart; W. H. Carney, of Tanana; Frank Cook, of Ruby; C. P. Wood and Miners & Merchants Bank, of Iditarod; Harry Fothergill, of Ophir; Harry Maclison, of Tolstoi; George W. Pilcher, of Fortuna Ledge; Henry Howard, of Aniak; W. F. Green, of Tokotna; William Loisell and A. Stecker, of Quinhagak; R. W. J. Reed, of Nome; John D. Flannigan, of Council; Lars Gunderson, of Haycock; and Lewis Lloyd, of Shungnak.

ADMINISTRATIVE REPORT.

By G. C. Martin.

INTRODUCTION.

Eleven parties were engaged during 1917 in Alaska surveys and investigations. The length of the field season ranged from 2½ to 12 months, being determined by the character of the work and by the climatic conditions prevailing in different parts of the Territory. The parties included 9 geologists, 1 topographer, 1 engineer, and 18 packers, cooks, and other auxiliaries. Nine of the parties were engaged in geologic surveys, one in topographic surveys, and one in stream gaging. The areas covered by reconnaissance geologic surveys on a scale of 1:250,000 (4 miles to an inch) amount to 1,750 square miles; by detailed geologic surveys on a scale of 1:62,500 (1 mile to an inch), 275 square miles. Much of the time of the geologists was devoted to the investigation of special problems relating to the occurrence of minerals, the results of which can not be expressed in terms of area. About 1,050 square miles was covered by reconnaissance topographic surveys on a scale of 1:250,000 (4 miles to an inch). In cooperation with the Forest Service, stream gaging was continued in southeastern Alaska.

In 1917 the entrance of the United States into the war and the beginning of the construction of the Government railroad in Alaska gave more than ordinary importance to the collection of reliable statistics of mineral occurrence and production. Many governmental agencies connected more or less directly with the prosecution of the war were seeking information concerning available supplies and reserves of raw material. Therefore, the greater number of the geologists assigned to Alaskan work were charged with investigations of the occurrence and production of minerals of economic value, among which were tin, tungsten, platinum, copper, chrome iron ore, nickel, and sulphur.

Of the five parties whose work may be classified geographically, two parties worked in southeastern Alaska, two on Prince William Sound, and one in the region tributary to the Government railroad.

The following tables show the allotments, including both field and office work, of the total appropriation of $100,000 for the fiscal year 1917, classified by regions, by kinds of surveys, and by kinds of expenditures. In addition to these funds a balance of about $6,000 from last year's appropriation was expended in equipping parties for the season's field work. In the first table, the general office expenses are apportioned to the several allotments, account being taken of variations in character of work. The results are expressed in round numbers. Salaries of the permanent staff are included up to the end of the fiscal year 1918, but expenses other than these include only the cost of field and office work during 1917. The "general investigations" include, among other things, the cost of collecting mineral statistics, of office work relating to the field investigations of previous seasons, and of investigations under the direct administration of the geologic branch. A balance of about $37,300 is available for equipping the field parties in 1918.

Approximate general distribution of appropriations for Alaska investigations, 1917.

Southeastern Alaska	$20,300
Prince William Sound, Copper River, and Controller Bay	10,300
Cook Inlet and Susitna Basin	7,600
Southwestern Alaska	3,900
Yukon Basin	5,500
Seward Peninsula	1,900
General investigations	13,200
To be allotted to field work, 1918	37,300
	100,000

Approximate allotments to different kinds of surveys and investigations, 1917.

Reconnaissance geologic surveys	$9,100
Detailed geologic surveys	3,400
Special geologic investigations	17,500
Reconnaissance topographic surveys	4,000
Investigations of water resources	5,400
Collection of mineral statistics	1,600
Miscellaneous, including administration, inspection, clerical salaries, office supplies and equipment, and map compilation	21,700
To be allotted to field work, 1918	37,300
	100,000

Allotments for salaries and field expenses, 1917.

Scientific and technical salaries	$24,964
Field expenses	18,536
Clerical and administrative salaries and miscellaneous expenses	19,200
To be allotted to field work, 1918	37,300
	100,000

The following table exhibits the progress of investigations in Alaska and the annual grant of funds since systematic surveys were begun in 1898. It should be noted that a varying amount is spent each year on special investigations that yield results which can not be expressed in terms of area.

Progress of surveys in Alaska, 1898–1917.

Year.	Appropriation.	Areas covered by geologic surveys.			Areas covered by topographic surveys.[a]					Water resources investigations.	
		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.	Stream volume measurements.
		Sq. m.	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Miles.*			
1898	$46,189	9,500	......	......	12,840	2,070	......	......	...	......	......
1899	25,000	6,000	......	......	8,690	......	......	......	...	......	......
1900	60,000	3,300	6,700	......	630	11,150	......	......	...	......	......
1901	60,000	6,200	5,800	......	10,200	5,450	......	......	...	......	......
1902	60,000	6,950	10,050	......	8,330	11,970	96	......	...	......	......
1903	60,000	5,000	8,000	96	......	15,000	......	......	...	......	......
1904	60,000	4,050	3,500	......	800	6,480	480	86	19	......	......
1905	80,000	4,000	4,100	536	......	4,880	787	202	28	......	......
1906	80,000	5,000	4,000	421	......	13,500	40	......	...	14	286
1907	80,000	2,600	1,400	442	......	6,120	501	95	16	48	457
1908	80,000	2,000	2,850	604	......	3,980	427	76	9	53	556
1909	90,000	6,100	5,500	450	6,190	5,170	444	......	...	81	703
1910	90,000	......	8,635	321	......	13,815	36	......	...	69	429
1911	100,000	8,000	10,550	496	......	14,460	246	......	...	68	309
1912	90,000	......	2,000	525	......	......	298	......	...	69	881
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	......
	1,561,189	73,200	101,285	5,507	51,680	148,030	3,731	453	74	......	......
Percentage of total area of Alaska	......	12.48	1.727	0.94	8.81	25.24	0.64	......	...	......	......

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

GEOGRAPHIC DISTRIBUTION OF INVESTIGATIONS.

GENERAL WORK.

Alfred H. Brooks, geologist in charge of the division of Alaskan mineral resources, was engaged in office and administrative work until May 17, when he entered the military service as captain of the Corps of Engineers, United States Army, and was assigned to active duty in France, where he is now serving as lieutenant colonel. His time in office in the early part of 1917 was divided as follows: Fifty days to routine and administrative work, 23½ days to the preparation of the progress report, 3½ days to writing a pamphlet on mineral supplies of Alaska, 6½ days to a memorial of Dr. C. Willard Hayes, 5 days to compilation of mineral statistics of Alaska, 2½ days to the critical reading of manuscript, 5½ days to field plans, 2 days to scientific meetings, 2½ days to study of the physiography of Alaska, and 11 days to matters connected with military service.

The writer has been acting geologist in charge of the Alaska division since May 17. He was engaged in office work till August 1, when he started for Alaska. Two days were spent in Juneau, collecting data on mining developments. The time from August 15 to 21 was spent in the Katalla oil field. The time from August 26 to September 6 was devoted to a field conference with the engineer in charge of the Government coal mines in the Matanuska Valley. A brief visit was then made to the Nenana coal field. He returned to Washington on October 11.

In the office the writer devoted his time to the following work: Forty-seven days to study of notes and preparation of report on the Nenana coal field, 22 days to report on upper Matanuska region, 43 days to compilation of data for use in establishing leasing units in the Nenana coal field, 5 days to preparation of memorandum for the Secretary of the Interior on the Nenana coal field, 13 days to preparation of memorandum for the Secretary of the Interior on the Matanuska coal field, 5 days to proof reading, 2 days to study of Alaska stratigraphy, and 9 days to the Alaska press bulletin.

During the writer's absence in Alaska F. H. Moffit was acting geologist in charge and devoted considerable time to executive work. Since June 11, 1917, most of Mr. Moffit's time has been given to assisting Maj. Bagley in his investigations of airplane mapping, and since November he has devoted himself exclusively to that work.

R. H. Sargent continued the general supervision of the Alaska topographic surveys and map compilation until May 26, when he was furloughed to accept a scientific position abroad. He has since returned to the Survey and is doing topographic work in the Northwestern States.

E. M. Aten continued as office assistant to the acting geologist in charge and assisted in the collection of statistics of production of precious metals in Alaska until July 13, when he went into the military service as captain in the Quartermaster Corps, United States Army. After that date Miss L. M. Graves took up Mr. Aten's administrative duties and T. R. Burch assisted in the collection and compilation of the mineral statistics.

J. W. Bagley's investigations of photo-topographic methods were early recognized as of potential military value. Both he and F. H. Moffit devoted considerable time to this work early in the year and on

June 22 Mr. Bagley received a commission as captain (now major) of engineers. Since that date he has devoted all his time to airplane mapping work. He has been assisted by Mr. Moffit, Capt. C. E. Giffin, and J. B. Mertie.

A systematic investigation of the heavy placer minerals of Alaska was begun by G. L. Harrington and J. B. Mertie, jr., during the year. This work has already yielded results of considerable value. Platinum was found in concentrate from Aloric River in the Kuskokwim Delta and also from Marshall. Tin ore (cassiterite) was found in concentrates from Yentna River in such amount as to indicate that it possibly occurs in commercial quantities. Cassiterite was also found in small quantities in concentrates from Boob Creek in the Tolstoi district, from Willow Creek near Nome, and from Riglagalik River in the Kuskokwim Delta. Scheelite was determined in a number of concentrates from the vicinity of Nome and from Bonanza Creek at the base of Seward Peninsula. These localities are not new but are important as indicating that the mineral may occur in sufficient amount to be a valuable by-product of placer mining. Scheelite was also found at a new locality on Jack Wade Creek.

SOUTHEASTERN ALASKA.

Field work in southeastern Alaska included special investigations of Paleozoic stratigraphy and paleontology by Edwin Kirk, a continuation of the geologic reconnaissance of the Ketchikan district by Theodore Chapin, a reconnaissance of parts of Chichagof Island with special investigations of the nickel deposits by R. M. Overbeck, a reconnaissance of Lituya Bay and special investigations of the iron ores of the Ketchikan district and of mining conditions in the Juneau district by J. B. Mertie, jr., and a continuation of the investigation of water resources by G. H. Canfield.

Studies of the ore deposits and mining developments in the Ketchikan district were continued by Theodore Chapin, who devoted the time from July 10 to 20 and from September 25 to November 4 to this work. Especial attention was given to the copper deposits.

An investigation of the reported occurrence of platinum at Lituya Bay was made by J. B. Mertie, jr., in July. Mr. Mertie also investigated the iron ores of southeastern Alaska in October.

A reconnaissance of the geology and mineral deposits of the Sitka district, with especial reference to the nickel-bearing copper ore on the west side of Chichagof Island, was made by R. M. Overbeck.

The investigation of the water resources of southeastern Alaska, begun in 1915 under a cooperative agreement with the Forest Service, was continued throughout 1917. G. H. Canfield, who had charge of this work, maintained 17 automatic gages throughout the year. In addition to these gages 3 others were installed in cooperation with individuals and corporations. The results are briefly summarized in another section of this report. This work could not have been carried on without the cordial cooperation of the Forest Service, many members of which have given substantial aid; particular acknowledgment should be made to W. G. Weigle, special agent at Ketchikan, and to Leonard Lundgren, district engineer at Portland, Oreg.

A study of the Paleozoic rocks of southeastern Alaska was assigned to Edwin Kirk in the summer of 1917. He left Washington July 1 and remained in the field until the later part of September studying the stratigraphy and making large collections of fossils from localities in southeastern Alaska.

PRINCE WILLIAM SOUND AND COPPER RIVER REGION.

Mr. B. L. Johnson in 1917 continued his investigations of mining developments in the Prince William Sound region and the eastern part of Kenai Peninsula. He also made a detailed survey of part of the Jack Bay district. Mr. Johnson devoted the time from July 14 to October 19 to this work.

The reconnaissance topographic survey of the Prince William Sound region, which was begun several years ago, was extended eastward by D. C. Witherspoon in 1917. The season's work comprised 1,000 square miles, including the eastern shore line of Prince William Sound from Fidalgo Bay to the entrance of Orca Inlet, which was mapped on a scale of 1:250,000. In addition, Mr. Witherspoon surveyed the eastern end of Hawkins Island.

A brief investigation of the reported nickel ore in the Copper River valley was made by R. M. Overbeck, who devoted a few days in August to this work.

COOK INLET, SUSITNA REGION, AND SOUTHWESTERN ALASKA.

The progress of construction of the Government railroad in Alaska created a demand for information on the geology and mineral resources of the region tributary thereto. S. R. Capps was charged with the investigation of an area tributary to the railroad in the upper Susitna Valley. Between July 1 and September 7 he made geologic reconnaissance surveys covering an area of more than 1,500 miles on a scale of 1:250,000, and also investigated the copper and gold lodes of the western Talkeetna Mountains and of the Willow Creek district.

Investigations of the platinum deposits of the Yentna district and of the chromite deposits of lower Cook Inlet were made by Mr. Mertie.

The sulphur deposits of Makushin and Akun islands and near Stepovak Bay were investigated by A. G. Maddren. Mr. Maddren also made a brief visit to the beach placers on the west side of Kodiak Island. His field work extended from July 21 to September 22.

YUKON REGION.

The work in the Yukon region included special investigations of the tungsten, tin, and platinum deposits of the Fairbanks, Hot Springs, and Ruby districts by Theodore Chapin; a special investigation of platinum deposits in the Tolstoi district by G. L. Harrington; and an examination of the coal along the main line of the railroad west of Nenana River by G. C. Martin. No areal surveys were undertaken.

SEWARD PENINSULA.

Work on the Seward Peninsula included investigations by G. L. Harrington of the gold and platinum placers of the Candle and Koyuk districts, of the placer and lode tin and the graphite of the York district and Imuruk basin, and of the general mining developments. No areal surveys were made.

COLLECTION OF STATISTICS.

The collection of statistics of production of metals in Alaska, begun by the Alaska division in 1905, was continued as usual. Preliminary estimates of mineral production for 1917 were published on January 1, 1918.

PUBLICATIONS.

During 1917 the Survey published 1 bulletin and 1 water-supply paper relating to Alaska. In addition, 2 professional papers and 5 bulletins were in press, and 21 reports, including this volume, were in preparation at the end of the year. Five topographic maps were in press at the end of the year.

REPORTS ISSUED.

BULLETIN 657. The use of the panoramic camera in topographic surveying, with notes on the application of photogrammetry to aerial surveys, by J. W. Bagley.

WATER-SUPPLY PAPER 418. Mineral springs of Alaska, by G. A. Waring.

REPORTS IN PRESS.

PROFESSIONAL PAPER 109. The Canning River region, northern Alaska, by E. DeK. Leffingwell.

PROFESSIONAL PAPER 120–D. The structure and stratigraphy of Gravina and Revillagigedo islands, Alaska, by Theodore Chapin. (Published Aug. 22, 1918.)

BULLETIN 655. The Lake Clark-Central Kuskokwim region, Alaska, by P. S. Smith. (Published Apr. 17, 1918.)

Bulletin 662. Mineral resources of Alaska, 1916, by Alfred H. Brooks and others. (Published Aug. 1, 1918.)

Bulletin 667. The Cosna-Nowitna region, Alaska, by H. M. Eakin. (Published Apr. 12, 1918.)

Bulletin 668. The Nelchina-Susitna region, Alaska, by Theodore Chapin.

Bulletin 675. The upper Chitina Valley, Alaska, by F. H. Moffit, with a description of the igneous rocks, by R. M. Overbeck. (Published June 26, 1918.)

REPORTS IN PREPARATION.

Bulletin 664. The Nenana coal field, Alaska, by G. C. Martin.

Bulletin 682. The marble resources of southeastern Alaska, by E. F. Burchard.

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

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

The lower Kuskokwim region, by A. G. Maddren.

The Kotsina-Kuskulana district, by F. H. Moffit.

The upper Matanuska basin, by G. C. Martin.

Geology of the Glacier Bay and Lituya region, Alaska, by F. E. Wright and C. W. Wright.

Geology of the region along the international boundary from Porcupine River to the Arctic Ocean, by A. G. Maddren.

The Porcupine district, Alaska, by H. M. Eakin.

The Yakataga district, Alaska, by A. G. Maddren.

The Mesozoic stratigraphy of Alaska, by G. C. Martin.

The Port Valdez and Jack Bay district, Alaska, by B. L. Johnson.

The Ruby-Kuskokwim region, Alaska, by J. B. Mertie, jr., and G. L. Harrington.

The Cretaceous and Tertiary flora of Alaska, by Arthur Hollick.

The Ketchikan district, Alaska, by Theodore Chapin.

The geology and mineral resources of Latouche and Knight Island districts, Alaska, by B. L. Johnson.

A geologic reconnaissance in the northern part of the Yukon-Tanana region, Alaska, by Eliot Blackwelder.

The western Talkeetna Mountains, Alaska, by S. R. Capps.

The Juneau district, Alaska, by A. C. Spencer and H. M. Eakin.

TOPOGRAPHIC MAPS IN PRESS.

Lower Matanuska Valley, by R. H. Sargent; scale, 1:62,500; contour interval, 50 feet. Sale edition. (Issued Feb. 28, 1918.)

Reconnaissance map of Cosna-Nowitna region, Alaska, by H. M. Eakin, C. E. Giffin, and R. B. Oliver; Yukon River from Fort Gibbon to Nowitna River from Alaska Road Commission; scale, 1:250,000; contour interval, 200 feet. (Issued April 12, 1918, as Plate I, Bulletin 667.)

Reconnaissance map of Lake Clark-Central Kuskokwim region, Alaska, by R. H. Sargent, D. C. Witherspoon, and C. E. Giffin; scale, 1:250,000; contour interval, 200 feet. (Published Apr. 17, 1918, as Plate I, Bulletin 655.)

Reconnaissance map of Upper Chitina Valley, Alaska, by International Boundary Commission, F. H. Moffit, D. C. Witherspoon, and T. G. Gerdine; scale, 1:250,000; contour interval, 200 feet. (Issued June 26, 1918, as Plate I, Bulletin 675.)

Juneau and vicinity Alaska, by D. C. Witherspoon, control by U. S. Coast and Geodetic Survey, D. C. Witherspoon, and Alaska Gastineau Mining Co.; scale, 1:24,000; contour interval, 50 feet. Sale edition. Issued July 27, 1918.)

THE ALASKAN MINING INDUSTRY IN 1917.

By G. C. Martin.

GENERAL FEATURES.

The mineral production of Alaska in 1917 is valued at $40,700,212. This output is less than that for 1916, which was $48,632,138, but is greater than that of any other year. The decrease is chiefly in copper, production of which fell from 119,602,028 pounds, valued at $29,484,291, in 1916, to 88,783,400 pounds, valued at $24,240,598, in 1917. The reduction in the output of copper was due largely to labor troubles, which included a strike at the Kennecott mine and shortage of labor at other mines. The production of gold fell off about $2,500,000 and is the smallest since 1904. The reduction in the output of gold is due chiefly to curtailment of operations because of the scarcity of labor and the high cost of materials but is also due in part to the disaster at the Treadwell mine and the depletion of some of the richer placers. There was a reduction in the output of silver, which was due to the decrease in production of gold and copper. The value of silver produced in Alaska in 1917 was, however, the greatest in the history of mining in the Territory. The production of lead increased somewhat. The production of tin showed a considerable decrease, although the value of tin produced was greater than ever before. The production of antimony fell to very small proportions, owing to the inability of the producers in the interior of Alaska to compete with the cheaper foreign product. The production of coal was the largest in the history of mining in Alaska, owing to the beginning of commercial mining in the Matanuska field. Tungsten mining continued in the Fairbanks district and the Seward Peninsula on about the same scale as in the preceding year. Petroleum continued to be produced from the single patented claim near Katalla, and the local refinery was operated on about the customary scale. The production of marble and gypsum in southeastern Alaska was somewhat less than in 1916. The year 1917 marks the beginning of the production of chromite in Alaska. The production of platinum, which was begun in 1916, continued on an increased scale. The production of platinum was chiefly from the Chistochina district and from Seward Peninsula, but small amounts this industry, as now presented, are therefore a close approximation to the actual output.

Estimated sources of gold and silver produced in Alaska, 1880–1917.

	Gold.		Silver.	
	Quantity.	Value.	Quantity.	Value
	Fine ounces.		*Fine ounces.*	
Siliceous ores [a]	4,066,033	$84,052,353	1,229,825	$841,332
Copper ores	75,593	1,562,664	4,608,461	2,947,429
Placers	10,020,543	207,142,992	1,703,323	961,764
	14,162,169	292,758,009	7,541,609	4,750,525

[a] Including small amounts of lead ore.

The above table shows that about 28½ per cent of the total gold production of Alaska has been obtained from the auriferous lode mines (siliceous ores). In 1917 the lode-gold production was 31 per cent; in 1916, 38 per cent; in 1915, 37 per cent; in 1914, 32 per cent; in 1913, 31.6 per cent; and in 1912, 29 per cent. In the following table the production of precious metals in 1917 has been distributed as to sources:

Sources of gold and silver produced in Alaska, 1917.

	Total quantity.	Gold.		Silver.	
		Quantity.	Value.	Quantity.	Value
	Tons.	*Fine ounces.*		*Fine ounces.*	
Siliceous ores	3,414,660	221,507	$4,578,930	131,503	$108,358
Copper ores	659,951	12,829	265,223	1,040,185	857,113
Placers		474,559	9,810,000	64,410	53,074
Lead and lead-copper ores	46	155	3,200	3,052	2,515
	4,074,657	709,050	14,657,353	1,239,150	1,021,060

Thirty-one gold-lode mines were operated in 1917. There was also a production from nine prospects or small mines that were not in regular operation. Twenty-nine mines were operated in 1916. The value of the lode gold output decreased from $5,912,736 in 1916 to $4,581,453 in 1917. Southeastern Alaska, especially the Juneau district, is still the only center of large quartz-mining developments in the Territory. Next in importance is the Willow Creek lode district. There was also considerable gold lode mining on Prince William Sound. The production in the Fairbanks district increased slightly, but lode mine owners of Fairbanks are still awaiting the cheapening of operating costs, especially of fuel, which will be brought about by the Government railroad. Of the producing mines 10 were in southeastern Alaska, 3 on Prince William Sound, 4 on Kenai Peninsula, 5 in the Willow Creek district, and 9 in the Fairbanks district. In 1917 the average value of the gold and silver contents for all siliceous ores mined was $1.37 a ton; the average for 1916 was $1.70 a ton. These averages reflect the dominance in the total lode production of the large tonnage produced from the low-grade ores of the Juneau district.

The production by districts of gold and silver in 1917 from gold lode mines, including small amounts from lead-silver mines which can not be given separately without disclosing individual productions, is given in the following table:

Production of gold and silver from gold lode mines by districts, 1917.

District.	Mines operated.	Ore mined (short tons).	Gold.		Silver.		Average value of ore in gold and silver.
			Fine ounces.	Value.	Fine ounces.	Value.	
Southeastern Alaska	10	3,400,120	205,107	$4,239,914	129,691	$106,865	$1.28
Prince William Sound	[a] 3	5,350	4,509	93,208	697	575	17.53
Kenai Peninsula	4	140	223	4,614	124	102	33.68
Willow Creek	5	7,885	9,466	195,662	713	588	24.89
Fairbanks district [b]	[c] 9	1,200	2,311	47,781	2,217	1,827	41.34
Seward Peninsula [d]	([e])	5	13	274	145	119	78.60
	13	3,414,700	221,629	4,581,453	133,587	110,076	1.37

[a] Also 5 prospects.
[b] Includes some lead ore.
[c] Also 2 prospects.
[d] Lead ore.
[e] One prospect on Seward Peninsula; also 1 shipment from an unknown locality.

The value of the output of placer gold in Alaska in 1917 was about $9,810,000; in 1916 it was $11,140,000. The decrease was due chiefly to restriction of operations because of the high cost of supplies and the scarcity of labor. These adverse conditions were felt in all parts of Alaska and everywhere tended to reduce the output of gold. Production was increased only where local conditions permitted an expansion of the industry in spite of increased costs. Such conditions existed in some of the newly discovered camps, and consequently there was an increase in the output of placer gold in the Tolovana, Marshall, Tolstoi, and Koyuk or Dime Creek districts. The production of the Ruby district increased slightly, owing to the very successful operation of the Greenstone dredge. There was also an apparent increase in the output of the Kuskokwim region, but this may be due to underestimates of the production of the previous year.

It is estimated that about 610 placer mines were operated in the summer of 1917 and 200 during the previous winter, but many for only a part of the season. About 3,550 men were engaged in productive placer mining in the summer and 950 in the winter. In addition, several hundred men were engaged in prospecting or other nonproductive work relating to placer mining. The only new placer-bearing areas discovered during 1917 were in the Kuskokwim region, and these have not as yet made any large production.

The following table shows approximately the total bulk of gravel mined annually and the value of the gold recovered per cubic yard. The table is based in part on returns made by placer mine operators and in part on certain other information which is not available this year. The figures for 1917 are based on an assumption that the ratio of the recovery per cubic yard for the mines which supplied complete information to the recovery per cubic yard for all mines is the same as in 1916. Although the table is thus only approximately correct, the amounts given are probably near the true figures.

Estimated amount of gravel sluiced in Alaskan placer mines and value of gold recovered, 1908–1917.

Year.	Total quantity of gravel.	Value of gold recovered per cubic yard.	Year.	Total quantity of gravel.	Value of gold recovered per cubic yard.
	Cubic yards.			*Cubic yards.*	
1908	4,275,000	$3.74	1913	6,800,000	$1.57
1909	4,418,000	3.66	1914	8,500,000	1.26
1910	4,036,000	2.97	1915	8,100,000	1.29
1911	5,790,000	2.17	1916	7,100,000	1.57
1912	7,050,000	1.70	1917	5,900,000	1.68

The above table shows that from 1908 to 1914 there was a decline in the average gold content of the gravels mined. This decline reflects the improved methods of placer mining that have been introduced, especially in the use of dredges. If data were available on the average recovery of gold previous to 1908 a far greater decline would be noted. The rise of the average recovery from 1914 to 1917 is due largely to the fact that the Alaskan dredges were for the most part working on far richer placers. This change is also influenced by the fact that in 1916 and 1917 a larger percentage of the placer gold came from the rich deposits of the newer districts, where recoveries of $7 to $20 a cubic yard are not uncommon. In the final analysis the movement of the miners away from the lower-grade placers, made evident by the average recoveries for 1915 to 1917, is the result of the present economic conditions, which affect gold mining more adversely than most other industries.

Thirty-six gold dredges were operated in Alaska in 1917, two more than in 1916. Twenty-eight dredges were in Seward Peninsula, three in the Iditarod, and one each in the Ruby, Fairbanks, Circle, Fortymile, and Yentna districts. These dredges produced about $2,500,000 worth of gold and handled about 3,700,000 cubic yards of gravel. In 1916 the 34 dredges handled about 3,900,000 cubic yards of gravel and recovered gold worth $2,679,000. The average recovery of gold per cubic yard was about 67½ cents in 1917 and 69 cents in 1916. The gold dredges of Seward Peninsula made an average recovery of 49 cents a cubic yard in 1917 and 53 cents in 1916. The dredges of the Alaska Yukon districts are working on placers of relatively high gold tenor. The value of gold recovered per cubic yard in 1917 was about 94 cents; in 1916, about 85 cents.

Though dredges were built for use in the Alaska Yukon as early as 1898 and at Nome in 1900, this method of placer mining did not reach a profitable stage until 1903, when two small dredges were successfully operated in Seward Peninsula. Dredging began in the Fortymile district in 1907; in the Iditarod, Birch Creek, and Fairbanks districts in 1912; and in the Yentna district in 1916. Up to the end of 1917 gold to the value of $17,610,000 has been mined by dredges. The distribution of this output by years is shown in the following table:

Estimate of gold produced from dredge mining in Alaska, 1903–1917.

Year.	Number of dredges operated.	Value of gold output.	Year.	Number of dredges operated.	Value of gold output.
1903	2	$20,000	1912	38	$2,200,000
1904	3	25,000	1913	36	2,200,000
1905	3	40,000	1914	42	2,350,000
1906	3	120,000	1915	35	2,330,000
1907	4	250,000	1916	34	2,679,000
1908	4	171,000	1917	36	2,500,000
1909	14	425,000			
1910	18	800,000			17,610,000
1911	27	1,500,000			

COPPER.

The copper production of Alaska in 1917 was about 88,793,400 pounds, valued at about $24,240,598. This is less than the production in 1916, which was 119,854,839 pounds, valued at $29,484,291, but is greater than the production of any other year. The reduction in total output for the year was due largely to scarcity of labor and to a strike at the Kennecott-Bonanza mine. During the year 17 copper mines were operated, compared with 18 in 1916. Of these mines seven are in Ketchikan district, seven in the Prince William Sound district, and three in the Chitina district. Small shipments of copper were also made from nine prospects or mines not in regular operation. The output of the Alaska copper mines by districts is shown in the following table:

Output of Alaska copper mines by districts in 1917.

	Mines.	Ore (tons).	Copper.		Gold.		Silver.	
			Pounds.	Value.	Fine ounces.	Value.	Fine ounces.	Value.
Ketchikan district	[a] 7	41,060	2,646,553	$722,509	2,338	$48,337	20,500	$16,891
Chitina district	[b] 3	267,541	70,587,110	19,270,281	....	6	887,880	731,614
Prince William Sound [c]	[d] 7	351,356	15,559,737	4,247,808	10,524	217,557	132,773	109,405
	......	659,957	88,793,400	24,240,598	12,862	265,900	1,041,153	857,910

[a] Also small shipments from two prospects.
[b] Also a small amount of placer copper and small shipments from four prospects.
[c] Including a small amount from Cook Inlet.
[d] Also small shipments from three prospects.

The average copper content of the ores mined in 1917 was 6.4 per cent. The ores also yielded an average of $0.382 in gold and $1.233 in silver. The average yield for 1916 was 9.7 per cent of copper and $1.60 to the ton in gold and silver. The decrease in the content of copper for 1917 was due to the smaller proportion of high-grade Kennecott ores in the total production. The following table shows the total production of copper in Alaska by years:

Copper produced in Alaska, 1880–1917.

Year.	Ore mined.	Copper produced.	
		Quantity.	Value.
	Tons.	*Pounds.*	
1880	a 40,000 (1880–1904)	3,933	$826
1881–1900		....	....
1901		250,000	40,000
1902		360,000	41,400
1903		1,200,000	156,000
1904		2,043,586	275,676
1905	52,199	4,805,236	749,617
1906	105,729	5,871,811	1,133,260
1907	98,927	6,308,786	1,261,757
1908	51,509	4,585,362	605,267
1909	34,669	4,124,705	536,211
1910	39,365	4,241,689	538,695
1911	68,975	27,267,878	3,408,485
1912	93,452	29,230,491	4,823,031
1913	135,756	21,659,958	3,357,293
1914	153,605	21,450,628	2,852,934
1915	369,600	86,509,312	15,139,129
1916	617,264	119,654,839	29,484,291
1917	659,957	88,793,400	24,240,598
	2,521,007	428,561,614	88,644,470

a Estimated.

Among the noteworthy features of copper mining in Alaska in 1917 was the continued enormous output of the Kennecott-Bonanza mine in the Chitina district, which, as in previous years, overshadowed all other operations. The total output of the coastal mines increased in 1917, largely owing to the increased production of the Beatson mine, but the aggregate production of the so-called independent mines was also larger than in 1916 in spite of the shortage of labor and ships. The heavy production from the smaller low-grade mines is, of course, due to the high price of copper and will not be maintained by all of them. However, some of the mines which are now being placed on a productive basis or on an enlarged capacity under the stimulus of high prices will probably be able to maintain their output with copper at a lower price, and the copper industry of Alaska will in general continue to advance, although there will doubtless be temporary setbacks. Work preparatory to the production of copper was continued energetically on several of the nonproducing mines and prospects in all three of the Alaska copper districts. No important new discoveries were reported.

LEAD.

The production of lead in Alaska in 1917 is estimated at 852 tons, valued at $146,584. This is the largest production in the history of mining in Alaska. The production of 1916, which was larger than that of any previous year, was 820 tons, valued at $113,160. Lead in Alaska is still, as in past years, derived chiefly from the concentrates of the gold mines at Juneau. The production of lead in 1917 includes small amounts derived from the galena ores of the Fairbanks district and Seward Peninsula and from copper-lead ores of southeastern Alaska. Though silver-lead ores are found in many parts of Alaska, most of the deposits have not yet been opened on a commercial basis. The following table shows the production of lead in Alaska, so far as it can be determined from available data:

Estimate of lead produced in Alaska, 1892–1917.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Tons.			*Tons.*	
1892	30	$2,400	1906	30	$3,420
1893	40	3,040	1907	30	3,180
1894	35	2,310	1908	40	3,360
1895	20	1,320	1909	69	5,934
1896	30	1,800	1910	75	6,600
1897	30	2,160	1911	51	4,590
1898	30	2,240	1912	45	4,050
1899	35	3,150	1913	6	588
1900	40	3,440	1914	28	1,344
1901	40	3,440	1915	437	41,118
1902	30	2,460	1916	820	113,160
1903	30	2,520	1917	852	146,584
1904	30	2,580			
1905	30	2,620		2,933	369,348

TIN.

The Alaskan mines produced about 100 tons of metallic tin, valued at $123,300, in 1917, compared with 139 tons, valued at $121,000, in 1916. The decrease was due in part to unusually heavy rains, which interfered with the work of the Seward Peninsula dredges, and in part to the cessation of large gold-mining operations in the Hot Springs district on account of the high cost and scarcity of supplies and labor. Not all of the tin ore mined in 1917 was shipped, for Knopf[1] estimates that the ore mined and shipped in 1917 yielded about 80 tons of metallic tin. This amount is considerably smaller than that given by the collector of customs, who states that 219 long tons of tin ore, containing 219,894 pounds (about 110 short tons) of

[1] Knopf, Adolph, U. S. Geol. Survey Mineral Resources, 1917, pt. 1, p. 63, 1919.

metallic tin, was shipped during 1917. The difference is probably due to the fact that a large amount of ore mined in 1916 was not shipped till 1917. The following table shows the production of tin in Alaska since 1902:

Tin produced in Alaska, 1902–1917.

Year	Quantity.	Value	Year.	Quantity.	Value.
	Tons.			*Tons.*	
1902	15	$8,000	1911	61	$52,798
1903	25	14,000	1912	130	96,000
1904	14	8,000	1913	69	44,103
1905	6	4,000	1914	104	66,560
1906	34	38,640	1915	102	78,846
1907	22	16,752	1916	139	121,000
1908	25	15,180	1917	100	123,300
1909	11	7,638			
1910	10	8,335		867	703,152

Most of the tin ore mined in 1917 came from the placers of the York district, Seward Peninsula, where two dredges and some sluicing yielded about 146 tons of tin ore. The gold placer mines of the Hot Springs district yielded about 25 tons of stream tin.

Some development work was done on the tin lode claims of the York district, but no ore was milled or shipped. In the Hot Springs district there appears to be a considerable amount of stream tin in the old tailings and in the unworked ground. Prospecting in 1917 showed that both gold and stream tin occur in the basin of Sullivan Creek, considerably below the area which has been mined. Prospecting on Midnight Creek in the Ruby district has shown the presence of tin at several places.

The systematic examination of placer concentrates by the United States Geological Survey has shown that tin ore (cassiterite) exists in considerable amounts and possibly in commercial quantities in the placers of the Yentna district. This locality is a new one for tin ore and is the first at which tin ore has been authentically reported south of the Alaska Range. Cassiterite was also found in concentrates from Boob Creek in the Tolstoi district, from Willow Creek near Nome, and from Riglagalik River in the Kuskokwim Delta. The occurrence on Boob Creek possibly indicates an extension of the previously known area that contains tin in the Ruby-Poorman district.

TUNGSTEN.

The production of tungsten in Alaska in 1917 is estimated at about 28 tons of scheelite concentrates valued at about $45,000. The Fairbanks district and Seward Peninsula were the principal producers of tungsten in Alaska in 1917. In the Fairbanks district two tungsten mines are in course of development. At one of these mines one unit of a 75-ton mill is in operation and late in the summer was turning out several hundred pounds of scheelite concentrates daily. At the other mine a similar mill was in course of construction. Underground work was in progress at both mines. The present indications give promise of a large increase in the production of tungsten in the Fairbanks district. In Seward Peninsula tungsten was produced principally by sluicing the residual scheelite-bearing lode material in Sophie Gulch. Smaller quantities were recovered as the result of placer mining at other localities.

As a result of the examination of placer concentrates by the United States Geological Survey, scheelite was determined in a number of concentrates from the vicinity of Nome and from Bonanza Creek at the base of Seward Peninsula. These localities are not new but are nevertheless of importance, as there appears to be a possibility of the production of scheelite as a valuable by-product of placer gold mining. A new locality, on Jack Wade Creek, in the Fortymile district, was found for this mineral.

ANTIMONY.

The Alaska output of antimony in 1917 was about 165 tons of crude ore worth about $28,000. The entire output came from the Fairbanks district and part of it was derived from reworking of old tailings.

Production of antimony in Alaska, 1915–1917.

Year	Quantity of crude ore.	Value.
	Tons.	
1915	833	$74,000
1916	1,458	134,000
1917	165	28,000
	2,456	236,000

PLATINUM.

It is estimated that the output of platinum in Alaska in 1917 was about 81 ounces of crude platinum valued at about $5,500. The largest productions were from Dime Creek on Seward Peninsula, from Boob Creek in the Tolstoi district, and from Slate Creek in the Chistochina district. Small amounts were produced from Sweepstakes Creek in Seward Peninsula and from the beach placers of Kodiak Island.

Platinum is proving to be very widely distributed in Alaska. In addition to the localities at which it has been previously recorded,[1] it has been found as a result of the systematic investigation of placer concentrates by the Geological Survey in concentrates from Aloric

[1] U. S. Geol. Survey Bull. 662, pp. 21–25, 1918; U. S. Geol. Survey Bull. 666–P, p. 8, 1917.

River in the Kuskokwim Delta and from the Marshall district. It has also been reported from the placers of Anvik River and of Valdez Creek, but these reports have not been confirmed.

CHROMITE.

The first production of chromite in Alaska was in 1917, when shipments were made from Port Chatham near the lower end of Cook Inlet. The Cook Inlet deposits have been known[1] for a number of years, but were reexamined in 1917 by J. B. Mertie, jr.,[2] who has written a paper on the subject which appears elsewhere in this volume.

NICKEL.

Nickel ore has been reported at three localities in Alaska—on the west coast of Chichagof Island, near Copper River, and on Knight Island, Prince William Sound. The deposits on Chichagof Island and near Copper River were examined in the summer of 1917 by R. M. Overbeck,[3] who has written an account which appears elsewhere in this volume. A brief statement of the results of that examination follows:

The nickel deposits of Chichagof Island are situated on the west coast of the island about 3 miles northwest of Pinta Bay, or about 65 miles northwest of Sitka. The developments consisted in 1917 of a 180-foot shaft, with 155 feet of drifts at the 80 and 180 foot levels, and of several prospect holes.

The ore occurs in and near the margin of a mass of hornblende gabbro or norite which is intrusive into quartz-mica schist. This contact is parallel to the shore. The ore is exposed in two outcrops about half a mile apart. A shaft was sunk at the more northerly of these outcrops. There is a third outcrop about half a mile farther north, where a mass of limonite is believed to be the weathered capping of the ore. These outcrops form irregular areas, about 70 feet in maximum diameter, projecting somewhat above the surrounding surface. At several other places the ore minerals were seen to be disseminated in small amounts through the country rock.

The ore contains copper and nickel, the most abundant sulphide minerals being pyrrhotite, chalcopyrite, and pentlandite. Pentlandite is an iron-nickel sulphide, (FeNi)S, containing 22 per cent of nickel. The minerals in the ore include also a small amount of niccolite, which is an arsenide of nickel containing about 43.9 per cent of nickel. Two selected samples of ore from the 80-foot level contain 4.68 and 3.93 per cent of nickel and a trace of cobalt.

The number, size, and shape of the ore bodies have not been determined. The only opportunity for underground observation in 1917 was in the 80-foot level at the center outcrop. The shaft is in igneous rock that is free from ore

[1] Grant, U. S., The southeastern coast of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 237–238, 1915.

[2] Mertie, J. B., jr., Chromite deposits in Alaska: U. S. Geol. Survey Press Bull. 361, p. 1, April, 1918.

[3] Overbeck, R. M., Nickel in Alaska: U. S. Geol. Survey Press Bull. 376, p. 2, August, 1918.

minerals. The drift for about 30 feet from the shaft is also in barren hornblende gabbro, but the last 30 feet of the drift is in massive ore. At the face of the drift there are some masses of barren rock, but the drill holes in the face are apparently in sulphides. There has been some faulting at this level, but its extent is not known. The drift at the 180-foot level could not be reached, but it is said to be about 80 feet long and to reveal ore which has apparently been somewhat broken up by faulting.

The three outcrops described above apparently have no surface connection and may have no connection underground. They may possibly be the exposures of a single continuous ore body, but they are more likely to be outcrops of separate ore bodies that lie in a mineralized zone along the intrusive contact. This zone probably contains other ore bodies that do not show at the surface.

Neither the outcrops nor the underground workings are of sufficient extent to permit any reliable estimate of the amount of ore that may be present at this locality. Ore bodies of this kind are generally very irregular. The amount of ore shown in the present workings therefore does not justify large investments in facilities for mining, ore treatment, or shipping. The amount of ore in sight and the geologic conditions at the locality do, however, encourage the hope that workable ore bodies will be developed, and justify the expenditure of a moderate amount of money in blocking out the known ore body and in the search for other ore bodies. This search should include the thorough prospecting of the entire area along the contact of the intrusive rock with the schist. It is believed that diamond drilling near the known outcrops, and at the localities where disseminated ore is seen, may reveal additional ore bodies that do not reach the surface.

The Copper River nickel locality is situated near the headwaters of Canyon Creek about 13 miles east of Copper River opposite Mile 121 on the Copper River & Northwestern Railroad at an altitude of more than 4,000 feet. Mining claims have been located on the outcrops of basic dikes which cut the schists, but only a little underground work has been done. Pyrrhotite and chalcopyrite are localized at a few places, but there is no evidence of extensive mineralization. The amount of ore can not be estimated on account of the small amount of underground work and the fact that at one locality, at least, the ore body has been faulted. A selected specimen of ore contains 7.23 per cent nickel and a trace of cobalt, but most of the known ore is believed to be of much lower grade.

A nickel deposit is said to have been discovered on Knight Island, Prince William Sound. It is reported that this deposit was being prospected with a diamond drill in the summer of 1917, but the locality has not been visited by any member of the Geological Survey and no authentic information is available.

MOLYBDENUM.

No molybdenum has yet been produced from Alaska, but operations preparatory to mining were undertaken in 1917 at a molybdenite-bearing lode near Shakan on the west coast of Prince of Wales Island, at the molybdenite prospect 9 miles north of Skagway, and at a molybdenite deposit on Reid Creek, a tributary to Little Susitna River in the Willow Creek district. A molybdenite deposit is reported on Ptarmigan Creek, a tributary to the Dry Delta about 50 miles above the Tanana. An occurrence of molybdenite on Healy River is described by Theodore Chapin elsewhere in this volume.

COAL MINING.

The production of coal in Alaska in 1917 was 53,955 tons, valued at about $265,317. This production was by far the largest in the history of coal mining in Alaska, and it probably marks the beginning of coal mining on a moderate but permanent commercial scale. The major part of the production was derived from the Matanuska coal field, especially from the Eska Creek mines, which were opened under private auspices in 1916 but were taken over and operated by the Alaskan Engineering Commission in 1917. The Matanuska branch of the Government railroad was completed late in the fall of 1917, which rendered the coal on Chickaloon River available for exploitation. The coal on Chickaloon River is being opened by the Alaskan Engineering Commission. A large amount of underground work must be done before mining can be attempted on a large scale, but small shipments of coal obtained in the course of development of the mines were made late in 1917. A small mine on Moose Creek was operated under a mining permit throughout the year, and work preparatory to mining was undertaken by private lessees on Moose Creek and near Chickaloon River. A more extended account of mining in the Matanuska field is given elsewhere in this volume.

The lignite fields on Cook Inlet rank next to the Matanuska coal fields in point of production for 1917. A considerable quantity of lignite that was mined near Bluff Point was shipped to towns on Cook Inlet for local consumption. A lignite mine on Cache Creek in the Yentna district was operated during part of the year in order to supply fuel for a gold dredge.

Steps preparatory to opening the Nenana coal field were in progress throughout the year. The Government railroad was being extended south toward this field from Nenana on Tanana River. The more accessible coal lands in the Nenana field were offered for leasing early in 1918.

There was apparently no coal mining in the Bering River field during 1917. A railroad under construction from the east shore of Controller Bay to a patented coal claim in the eastern part of Bering River field is reported to be nearing completion. No leases had been granted in the Bering River field up to the close of 1917, but two claims have been patented, and it is said that one application for patent is still pending.

The following table gives the estimated production of coal in Alaska since 1888. The production for 1888 to 1896 is estimated from the best data available but is only approximate. The figures for 1897 to 1917 are based for the most part on data supplied by operators. Most of the coal mined before 1916 was lignite. There was a small production of bituminous coal from the west end of the

Bering River field in 1906. The table does not include 855 tons of coal mined in the Bering River field in 1912 and 1,100 tons mined in the Matanuska field in 1913 for test by the United States Navy.

Production of coal in Alaska, 1888 to 1917.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Short tons.			*Short tons.*	
1888–1896	6,000	$84,000	1908	3,107	$14,810
1897	2,000	28,000	1909	2,800	12,300
1898	1,000	14,000	1910	1,000	15,000
1899	1,200	16,800	1911	900	9,300
1900	1,200	16,800	1912	355	2,840
1901	1,300	15,600	1913	2,300	13,800
1902	2,212	19,048	1914	....	....
1903	1,447	9,782	1915	1,400	3,300
1904	1,694	7,225	1916	13,073	52,317
1905	3,774	13,250	1917	53,955	265,317
1906	5,541	17,974			
1907	10,139	53,600		116,397	685,063

The following table shows the coal consumption of Alaska, including both local production and imports since 1899. Most of the coal shipped to Alaska was bituminous, but a little was anthracite:

Coal consumed in Alaska, 1899–1917, in short tons.

Year.	Produced in Alaska, chiefly subbituminous and lignite.	Imported from States, chiefly bituminous from Washington.	Total foreign coal, chiefly bituminous from British Columbia.	Total coal consumed.
1899	1,200	10,000	[a] 50,120	61,320
1900	1,200	15,048	[a] 56,623	72,871
1901	1,300	24,000	[a] 77,674	102,974
1902	2,212	40,000	[a] 68,363	110,575
1903	1,447	64,626	[a] 60,605	126,678
1904	1,694	36,689	[a] 76,815	115,198
1905	3,774	67,713	[a] 72,567	144,054
1906	5,541	69,493	[a] 47,590	122,624
1907	10,139	46,246	[a] 88,596	144,981
1908	3,107	23,893	[a] 72,831	99,831
1909	2,800	33,112	[a] 74,316	110,228
1910	1,000	32,138	[a] 73,904	107,042
1911	900	32,255	[a] 88,573	121,728
1912	355	27,767	[a] 59,804	87,926
1913	2,300	61,666	[a] 60,600	124,566
1914	....	41,509	46,153	87,662
1915	1,400	46,329	29,457	77,186
1916	13,073	44,934	53,672	111,679
1917	53,955	58,116	56,589	168,660
	107,397	775,534	1,214,852	2,097,783

[a] By fiscal years ending June 30.

It is too early to forecast the future of coal mining in Alaska, especially in the Bering River and Matanuska fields. If future discoveries in the Matanuska field reveal any considerable extension of the known coal lands, especially the lands containing high-grade coal, the areas of which as now known are very small; if it be found that the greatly disturbed bituminous coals of the Bering River and Matanuska fields can be mined at a moderate cost; if the Matanuska or Bering River coal proves to be suitable for the manufacture of coke; or if it is found that there is a supply of coal suitable for the

Navy in the Matanuska or Bering River fields and if the Navy requires coal rather than oil—then there will probably be a rapid expansion of coal mining in one or both of these fields. The facts now known indicate, however, that there may be considerable difficulty in producing and in selling any large amount of coal at a profit, and that mining in both these fields will probably proceed at a moderate rate. If the general public still retains the extravagant and entirely false impression that was created by sensational magazines a few years ago as to the amount and value of Alaska coal it should be prepared for disappointment.

The future of the Nenana coal field is more definite. This field contains a large amount of lignite of fair grade that can be mined at a moderate cost. The market is reasonably certain. Although this coal is not suitable for export, it will furnish a valuable and much-needed fuel in portions of interior Alaska that are now dependent on a scanty and expensive supply of wood. The coal of the Nenana field will probably be used as locomotive fuel on the Government railroad, for power and thawing at the mines in the Tanana Valley, as domestic fuel in the Tanana Valley, and as fuel on local Tanana River boats and possibly on some of the Yukon steamers. The coal of the Nenana field should, if possible, be used on the greater part of the railroad, rather than the higher-grade Matanuska coal, because the heavy freight traffic will be northbound, leaving southbound empties available for hauling coal. The Nenana coal field is nearer the summit of the Alaska Range than any known coal south of the divide. It seems reasonable to expect that a coal-mining industry of moderate size will begin in this field in the near future. The growth of coal mining in this field will be dependent on the growth of other industries. Gold mining, coal mining, and agriculture in the Tanana Valley should be mutually interdependent, and each industry, through the stimulating effect of the others, should expand at a gradually accelerating rate.

The possibility of the growth of an important coal-mining industry on Cook Inlet should not be overlooked. There is a large amount of lignite on Cook Inlet, and it is of fair quality, being of about the same grade as the lignite of the Nenana field. Much of it is situated on waters that are navigable throughout the year, and it lies in beds that are but slightly folded. Its mining and shipment should, therefore, be relatively cheap. The possibility of coal mining on Cook Inlet on a large scale depends, however, on the success of experiments in the treatment of lignite in order to render it available for purposes for which the higher-grade coals are now required. If lignites can, at a moderate cost, be rendered suitable for such purposes the lignites of Cook Inlet must be regarded as one of the most important factors in the Alaska coal situation.

PETROLEUM.

The production of petroleum from the only oil claim patented in Alaska, in the Katalla district, was increased somewhat in 1917 by cleaning out the old wells. The Katalla refinery was operated as usual. Two new wells were drilled, and drilling was continued at a well started in a previous year, but no new productive wells were obtained. Some of the oil claims in the Katalla field were surveyed preparatory to application for patent.

The consumption of petroleum in Alaska is indicated approximately by the imports, which are shown in the following table:

Petroleum products shipped to Alaska from other parts of the United States, 1905–1917, in gallons.[a]

Year.	Oil used for fuel, 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
	194,785,913	21,511,481	7,909,276	2,260,417

[a] Compiled from Monthly Summary of Foreign Commerce of the United States, 1905 to 1917, Bureau of Foreign and Domestic Commerce.

STRUCTURAL MATERIAL, ETC.

One marble quarry and one gypsum mine were operated in southeastern Alaska in 1917. No barite was shipped. Work was continued on two graphite deposits in Seward Peninsula, and considerable graphite was mined and shipped. A brickyard was operated at Anchorage, and it is reported that one is being operated at Seward. A small limestone quarry and kiln and a deposit of marl near Anchorage were worked and made small productions of lime.

REVIEW BY DISTRICTS.

The following review summarizes briefly the principal developments in all the districts. Many of the districts were not visited by members of the Geological Survey in 1917 and some operators failed to make reports, so that the information at hand about mining in some of the districts is incomplete and scanty. The space here devoted to any district is therefore not necessarily an indication of its relative importance. The arrangement is geographic, from south to north.

SOUTHEASTERN ALASKA.

The mineral production of southeastern Alaska in 1917 was derived from 10 gold lode mines, 8 copper mines, 3 placer mines, 1 gypsum mine, and 1 marble quarry. The value of the mineral production fell from $7,032,010 in 1916 to $5,407,902 in 1917. The value of the different products is shown in the following table:

Mineral production of southeastern Alaska, 1917.

	Gold lode mines.		Copper mines.		Placer mines.		Value of products of all mines and quarries.
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.	
Gold	205,107	$4,239,914	2,338	$48,337	1,790	$37,000	$4,325,251
Silver	129,691	106,825	20,500	16,891	133	109	123,825
			Pounds.				
Copper			2,646,553	722,509			721,686
Lead, marble, gypsum, etc							236,317
							5,407,902

The largest mining operations, as in previous years, were at the gold mines in the Juneau district. All the productive copper mining of southeastern Alaska was in the Ketchikan district. Placer mining was limited to the Porcupine district and to small beach operations at Yakataga and Lituya Bay.

The principal copper producers in the Ketchikan district were the Rush & Brown, It, Jumbo, and Mount Andrew mines. The Mamie mine was closed down in the spring, and an increased output was made at the It. The Rich Hill copper property, on Kasaan Peninsula, is being developed and made a small production. A 60-ton flotation mill was constructed on the Salt Chuck mine (formerly the Goodro mine). A molybdenite-bearing lode in the vicinity of Shakan, on the west coast of Prince of Wales Island, is being developed. Marble quarrying at Tokeen was continued about as usual. The Dunton mine was the only gold mine in operation. It is reported that a small plant for treating ore is under construction at the Complex mine on Moira Sound.

Development of the copper lodes of the Ketchikan district, particularly on Kasaan Peninsula, has led to the uncovering of large bodies of magnetic iron ore at a number of places. This magnetite, which contains in general about 0.5 per cent of copper, has hitherto been regarded only as a low-grade copper ore. Attention has recently been redirected to these ores as a source of iron. Magnetic separation should yield a high-grade iron ore and a valuable byproduct of chalcopyrite to pay for the cost of separation. Plans for utilizing these iron ores are now being considered.

Gold lode mining continued on a large scale at the mines near Juneau.

As a result of a cave-in at the Treadwell, 700-foot, and Mexican mines, which occurred on April 21, these mines are now flooded with sea water and are not in operation. The surface equipment of these three mines is being dismantled and sold. The Ready Bullion mine, though connected at the 1,350-foot level with the Mexican mine, was saved by a concrete bulkhead, which after the cave-in was made permanent and greatly strengthened. At the end of June the drawing of all broken and caved ore above the 2,000-foot level was discontinued, in order to render the mine entirely safe, and all open stopes are now being filled with waste. Development of the mine continued in the lower levels. The 2,400-foot level is now completed, and rapid progress is being made in the 2,600-foot level. The present plans contemplate the ultimate extension of the new No. 2 shaft to the 3,000-foot level. If the ore is of satisfactory grade at that depth a prospect drift will be run along the ore body underneath the flooded workings of the other mines. The production of gold at the Ready Bullion mine was decreased to one-third the normal quantity when work above the 2,000-foot level was discontinued but will gradually be increased as the lower levels are opened up.

The Alaska-Gastineau (Perseverance) mine and mill operated throughout the year. Operations were restricted by the scarcity of labor; there were only 712 men employed in 1917 against 940 in 1916. The supply of broken ore in the stopes overcame the deficiency caused by the shortage of labor, and the mine and mill were operated on a somewhat larger scale than in 1916. Development and prospecting for ore bodies was prosecuted as energetically as conditions permitted. A total of 15,472 feet of drifts, crosscuts, and raises and 12,754 feet of diamond drilling was completed. The principal object of this work was to find new and richer ore bodies in order to maintain the average grade of the ore sent to the mill and, if possible, to increase the average value. The mine is said to be in condition to furnish a maximum tonnage of ore whenever the necessary labor is available. The milling plant has shown a capacity of not less than 10,000 tons a day, and the transportation system, both underground and from the mine to the mill, is in a position to supply this tonnage.

The Alaska Juneau mine was operated throughout the year. The new mill at this mine was started in April but has been running at less than half its capacity.

Development work was continued at the Alaska-Ebner mine. The Jualin mine, at Berners Bay, was operated during most of the year but shut down in October on account of the scarcity and high price of supplies and labor. Other properties in the Juneau gold belt were also developed or operated in a small way, and prospecting for new lodes was continued.

Development work continued at the molybdenite prospect 9 miles north of Skagway.

On Chichagof Island both the Chichagoff gold mine and the gypsum mine of the Pacific Coast Gypsum Co. were operated on about the same scale as last year. The main tunnel of the Chichagoff mine is now over 4,400 feet long. At the gypsum mine work was started on the new 300-foot level. This mine has been a steady producer since 1906.

Development work was continued on the group of copper claims near the head of Pinta Bay, about 15 miles northwest of Chichagof. A little prospecting but no underground development work was done on the copper-nickel deposit at Nickel, about 22 miles northwest of Chichagof.

COPPER RIVER REGION.

The largest mining operations of the Copper River region in 1917, as in several years preceding, were at the Jumbo and Kennecott-Bonanza copper mines. Considerable copper was also shipped from the Mother Lode mine and small shipments were also made from several other properties. Other mineral production included placer gold mining in the Nizina and Chistochina districts.

The Jumbo and Kennecott-Bonanza mines and the mill at Kennecott were operated on a large scale throughout the year, although production was considerably smaller than in 1916. This reduction in the output was due to a strike in the middle of summer and to shortage of labor throughout much of the year. The mill was operated at practically its full capacity throughout the winter, and this was the first time that it had not been necessary to shut down during the winter on account of the shortage of water. The ammonia leaching plant continued in successful operation, and it is reported that its capacity will be increased.

Automobile roads for hauling ore from the Mother Lode and Nugget creek mines were constructed. Much development work was done at these mines and also at several other mines in the region.

Hydraulic placer mining continued on a large scale in the Nizina district, where 2 mines employing 4 miners were operated in the winter of 1916–17, and 6 mines employing 91 miners in the summer of 1917. These mines produced about $120,000 in placer gold and also a little placer copper. No important developments or discoveries are reported.

Placer mining on Slate Creek in the Chistochina district was continued on a large scale. The production of this district is estimated at about $100,000 worth of gold and 15 or 20 ounces of platinum.

Platinum is said to occur in about the proportion of one part by bulk of platinum to 100 parts of gold, but not all of the platinum is saved.

Some underground work was done on the American Eagle lode near Tiekel, and a small production of gold was made. It is said that a small mill will be installed in 1918.

PRINCE WILLIAM SOUND.

The value of mineral production on Prince William Sound was $4,667,929 in 1917 compared with about $3,000,000 in 1916. This amount is the value of the product at seven copper mines and three gold mines which can be classed as regular producers and of additional small shipments from eight other small mines or prospects.

Mineral production of Prince William Sound, 1917.

	Ore (tons).	Gold (fine ounces).	Value.	Silver (fine ounces).	Value.	Copper (pounds).	Value.
Copper mines [a]	351,356	10,524	$217,557	132,773	$109,406	15,559,737	$4,247,808
Gold mines	5,350	4,509	93,208	697	575		
	356,706	15,033	310,765	133,470	109,981	15,559,737	4,247,808

[a] Including one small shipment from Cook Inlet.

The productive copper mines in 1917 included the Beatson, Blackbird, Schlosser property, Midas, Mackintosh property, and Ellamar. The Blackbird group, on Latouche Island, began shipping after lying dormant for several years. At the Beatson-Bonanza large operations were continued, the capacity of the milling plant was increased, and 350 men were employed. On the Blackbird 25 men were employed and a new ore body was opened up. On the Schlosser property 27 men were employed and considerable underground work was done. The Mackintosh property employed 13 men stoping an old lead and extending the adit tunnels on it and crosscutting to a new lead. The Ellamar mine, which employed 100 men, continued operations throughout the year on about the usual scale. At the Midas 50 men were employed during the year, underground operations were continued, the tram was operated, and large shipments were made. On the Rua property 600 feet of tunnel and crosscuts were driven. A large low-grade copper property was discovered on Long Bay. Some diamond drilling on a nickeliferous deposit on Knight Island is reported.

A detailed statement regarding the mining on Prince William Sound is given in another chapter of this volume.

KENAI PENINSULA.

The mineral production of Kenai Peninsula includes about $30,000 of placer gold, $4,600 of lode gold, a small amount of silver obtained incidentally to the mining of the gold, a considerable amount of chromite, which was mined at Port Chatham on Cook Inlet, and some lignite mined at Bluff Point on Cook Inlet. There was very little activity in lode gold mining and no extensive developments are reported. A mill and tram are being installed at the Ronan & James mine in the Moose Pass district. The largest placer mining operations were on Resurrection and Crow creeks. Preliminary steps were taken toward the inauguration of large-scale operations at Canyon Creek. Very heavy rains in the fall caused serious damage at the placer mines throughout the district.

WILLOW CREEK DISTRICT.

The mineral production of the Willow Creek district in 1917 included $195,662 worth of gold and $586 worth of silver, all derived from quartz mines. The Alaska Free Gold, Gold Bullion, Gold Cord, Mabel, and Talkeetna (formerly Matanuska) mines were operated. The amount of ore milled was 7,883 tons. A promising new quartz vein which was opened at the Gold Cord mine at the head of Fishhook Creek has already been traced for several claim lengths.

YENTNA DISTRICT.

The Cache Creek district continues to be the principal source of placer gold in the Yentna basin. The inaccessibility of the placers on Cache Creek has made mining expensive, but a new wagon road, which is now under construction, from Talkeetna, on the Government railroad, to Cache Creek, will soon afford a quick and easy approach to the district. A dredge that burned local coal was operated on Cache Creek, and 15 hydraulic plants were working on Cache and Peters creeks during the summer. More than 100 men were employed, producing placer gold valued at $125,000 to $150,000. Operations at the end of the season were hampered by protracted rains and serious floods, which caused considerable damage to several mining plants. Late in the fall a Hudson dry dredge was installed on ground along the north side of Kichatna River, at the mouth of Nakochna River, to begin mining in the spring of 1918. Some prospecting and mining were done in the Camp Creek and Lake Creek basins.

Along the lower Kahiltna River prospecting for platinum was carried on by one company at two localities—one about 3 miles below the mouth of Peters Creek and the other a short distance upstream from the mouth of the river. A hand drill and two power drills were used in prospecting the river bars, about 12 men having been employed in this work. The prospecting is to be continued next season. Platinum occurs at many other places in the Susitna basin, including Cache, Peters, Camp, and Lake creeks, as well as on Kichatna and Chulitna rivers, and placers that contain platinum in commercial quantities may ultimately be found.

An examination of placer concentrates from Yentna River by the United States Geological Survey has revealed the presence of tin ore (cassiterite) in considerable amount and possibly in commercial quantities.

UPPER SUSITNA REGION.

The mineral production of the upper Susitna valley is still restricted to the placer gold of the Valdez Creek district. The lodes of the Broad Pass and Talkeetna districts are being prospected.

In 1916 and 1917 about 20 groups of claims were staked on gold and copper bearing lodes in the basin of Iron Creek, a tributary of Talkeetna River from the southeast, but practically no underground work has yet been done. The discovery of a large dike that carries gold is reported from upper Talkeetna River. Some massive bornite that carried visible free gold and that was reported to have been found in the basin of Kashwitna River was brought in by a party of prospectors.

The prescribed amount of annual assessment work was performed on about a dozen groups of lode claims in the upper basin of Chulitna River, which is often referred to as the Broad Pass district. No mines in this district are yet productive, but more vigorous exploitation of the gold, copper, and antimony deposits awaits the better transportation that will be furnished by the Government railroad.

A new discovery of copper is said to have been made near the head of MacLaren River. The vein is reported to be chalcopyrite from 2 to 10 inches wide in amygdaloidal greenstone.

SOUTHWESTERN ALASKA.

The known mineral production in southwestern Alaska in 1917 comprised a test shipment of copper ore from a locality near Kamishak Bay and some placer gold from the Kodiak beaches, from a creek near Katmai Bay, and from Portage Creek in the Clark Lake district.

YUKON BASIN.

GENERAL FEATURES.

The value of the gold produced by the placer mines of the Alaska Yukon districts in 1917 is estimated to have been $6,583,000, compared with $7,550,000 in 1916. About 380 placer mines were operated in the summer of 1917, giving employment to about 2,550 men, and about 165 placer mines were operated in the winter, employing about 790 men. Nine small lode mines, all in the Fairbanks district, were productive in 1917. The following table gives the estimated gold output of the principal Yukon placer camps:

Estimated value of gold produced from placers of Yukon basin, 1917.

Iditarod	$1, 500, 000	Koyukuk	$250, 000
Fairbanks	1, 310, 000	Circle	200, 000
Tolovana	1, 150, 000	All others	413, 000
Ruby	885, 000		6, 583, 000
Hot Springs	450, 000		
Marshall	425, 000		

The Yukon placer mines also produced about $39,000 worth of silver in 1917. The above figures do not include the output of the lode mines, which in 1917 produced gold and silver to the value of $49,607. There was also a small output of tin from the Hot Springs district, and considerable tungsten and some antimony ore was mined in the Fairbanks district. (See pp. 20–21.) The total value of the entire mineral production from the Alaska Yukon in 1917 was $6,747,835; that in 1916 was $7,839,757. Since mining began in 1886 the Alaska Yukon has produced minerals to the value of $123,180,000, of which $121,625,000 has been derived from the gold placers.

The most noteworthy feature of the placer mining of the year was the increased output of the Tolovana placers. There was also an increased production in the Marshall, Tolstoi, and Ruby districts. The other districts show a decreased output, owing chiefly to a general retrenchment by operators because of the high cost of supplies and scarcity of labor.

FAIRBANKS DISTRICT.

The mineral production of the Fairbanks district in 1917 included placer gold worth $1,310,000, lode gold worth $47,781, placer silver worth $6,904, lode silver worth $1,826, and lead, tungsten, and antimony worth $58,257. The total value of the mineral output for 1917 was $1,424,768. The aggregate value of the entire mineral output of the district up to the close of 1917 is $70,417,000. Much the larger part of this amount represents the value of the placer gold, the production of which is shown by years in the subjoined table. In addition to the actual production of the district about $1,000,000 worth of gold mined in tributary areas passes through Fairbanks each year.

Placer gold and silver produced in the Fairbanks district, 1903–1917.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1903	1,935.00	$40,000	348	$188
1904	29,025.00	600,000	5,225	2,821
1905	290,250.00	6,000,000	52,245	28,212
1906	435,375.00	9,000,000	78,367	42,318
1907	387,000.00	8,000,000	69,660	37,616
1908	445,050.00	9,200,000	79,900	43,151
1909	466,818.75	9,650,000	84,027	45,375
1910	295,087.50	6,100,000	53,116	28,683
1911	217,687.50	4,500,000	52,245	27,690
1912	200,756.25	4,150,000	48,182	29,632
1913	159,637.50	3,300,000	20,274	12,245
1914	120,937.50	2,500,000	29,024	16,050
1915	118,518.75	2,450,000	28,444	14,421
1916	87,075.00	1,800,000	11,058	7,276
1917	63,371.25	1,310,000	8,379	6,904
	3,318,525.00	68,600,000	620,503	342,582

The available information as to the source of the gold by creeks is not very accurate. An attempt has been made in the following table, however, to distribute the total placer gold production of the Fairbanks district by the creeks on which the mines are located:

Approximate distribution of gold produced in Fairbanks district, 1903–1917.

Cleary Creek and tributaries	$22,860,000
Goldstream Creek and tributaries	13,800,000
Ester Creek and tributaries	11,230,000
Dome Creek and tributaries	7,910,000
Fairbanks Creek and tributaries	7,400,000
Vault Creek and tributaries	2,640,000
Little Eldorado Creek	2,100,000
All other creeks	660,000
	68,600,000

No new discoveries or important developments in placer mining were made in 1917. A large dredge will be installed on upper Fairbanks Creek to begin operations in 1918.

Gold lode mining in the Fairbanks district declined from 1913 to 1916 but showed a slight increase in production in 1917. The cost of supplies and fuel has become so high that many operators will wait for more favorable conditions rather than work at a low profit and run the risk of actual loss. Eight gold lode mines were worked in a small way, and five of these operated their own mills. One silver-lead deposit is being worked and made an output. One antimony mine was in operation and some ore was hand-picked from old tailings and shipped. Two tungsten mines are in process of development. One is in operation and during the fall produced 500 pounds of scheelite concentrates a day. On the other the mill was in course of construction, and surface and underground development work was in progress.

Details regarding lode mining are presented by Mr. Chapin in another chapter of this report. The following table shows the production of gold and silver from the Fairbanks lode mines since this form of mining began in 1910:

Lode gold and silver produced in the Fairbanks district, 1910–1917.

Year.	Crude ore (tons).	Gold.		Silver.	
		Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1910	148	841.19	$17,339	106	$57
1911	875	3,103.02	64,145	582	308
1912	4,708	9,416.54	194,657	1,578	971
1913	12,237	16,904.98	349,457	4,124	2,491
1914	6,528	10,904.75	225,421	2,209	1,222
1915	5,845	10,534.91	217,776	1,796	910
1916	1,111	1,904.81	39,376	140	92
1917	1,200	2,211.38	47,731	2,217	1,826
	32,650	55,921.58	1,155,952	12,752	7,877

CHISANA DISTRICT.

Placer mines were operated on Bonanza, Big Eldorado, Gold Run, and Little Eldorado creeks in the Chisana district. A total of 11 mines employed 44 men and produced gold to the value of about $40,000. This camp is growing smaller year by year in spite of the fact that there is considerable prospecting on the neighboring creeks during winter. Only two mines were operated last winter. Prospecting is still going on in Notch Creek, but the ground is deep and thawed, and water consequently has to be pumped. Gold has been found in the gravel, but bedrock has not thus far been reached.

FORTYMILE DISTRICT.

The mineral production of the Fortymile district in 1917 consisted of placer gold worth about $80,000 that was derived from 25 mines employing 68 miners, which operated in the winter of 1916–17, and 35 mines employing 93 miners, which operated in the summer of 1917. In addition to this mining a small dredge was operated at Franklin. It is reported that the benches on Fortymile River are proving very good. Preparations are being made for mining the bench claims at several localities additional to those at which mining has already been carried on. The discovery of stibnite is reported on the Middle Fork of Fortymile River, 12 miles south of Josephs village.

EAGLE DISTRICT.

Twelve placer mines employing 25 men were operated in the Eagle district in 1917 and yielded a gold production of about $13,000. The largest number of mines and miners and the largest production was on American Creek. Preparations were being made for the installation of a hydraulic outfit on Seventymile River in 1918. The hydraulic plant on Alder Creek tributary to Seventymile River had to close down early in the season for lack of water. A 6-mile ditch was being completed on Long Creek preparatory to hydraulic mining in 1918.

CIRCLE DISTRICT.

Owing to unfavorable conditions, chiefly lack of rain during the later part of August and during September, the gold production for nearly all creeks in the Circle district was greatly curtailed. The production was about $200,000, which is about $100,000 less than in 1916. About the same number of mines were operated and the same number of men employed as last year. The chief developments for 1917 included the installation of a hydraulic plant on Independence Creek, and the survey of placer mining ground for patent on Mammoth, Mastodon, Independence, and Miller creeks. Material for the construction of a hydraulic plant on Deadwood Creek has been landed at Circle.

RAMPART DISTRICT.

The value of the gold produced in the Rampart district in 1917 was about $33,000. This gold was obtained from the operation of 2 mines employing 5 men in the winter of 1916–17 and 10 mines employing 26 men in the summer of 1917. The largest production was on Hunter and Little Minook creeks.

TOLOVANA DISTRICT.

The output of the placer mines of the Tolovana district for 1917 was about $1,150,000, which is a 50 per cent increase over the production for 1916. About 50 mines were operated. Considerable prospecting has been reported, but authentic information as to the results is not at hand.

HOT SPRINGS DISTRICT.

The gold production of the Hot Springs district in 1917 is estimated to be $450,000. Placer mines employing 190 men were operated on 30 claims situated on Eureka, Sullivan, American, and Boulder creeks. The tin production is estimated at 25 tons. The decrease in the production of both gold and tin is due in part to the cessation of large operations on Woodchopper Creek and in part to the high cost of food and of mining supplies, which has prevented the working of any except high-grade ground. Although the tin output was small, there appears to be a considerable amount of stream tin in the old tailings and in the unworked ground. Prospecting in 1917 showed that both gold and stream tin occur in the basin of Sullivan Creek, considerably below the area which has been mined, and that large bodies of low-grade gravels occur on Boulder Creek. It is reported that several prospectors are at work in Gold Basin, where they are finding considerable tin but only little gold.

RUBY DISTRICT.

Mining operations in the Ruby district in 1917 were conducted on about the same scale as in 1916, and placer gold worth $885,000 was produced, which is a little more than the production of 1916. It is reported that 19 mines, employing 310 men, were at work in the summer of 1917 and 19 mines, employing 520 men in the winter of 1917–18. The largest productions were on Greenstone, Poorman, Long, Spruce, and Tamarack creeks. The dredge on Greenstone Creek had a successful season, but the dredging ground has been worked out and the dredge will be moved. Good ground was discovered by winter prospecting on Ketchum Creek, but the ground is too deep for easy exploitation. Prospecting on Midnight Creek has shown the presence of placer tin at several places.

INNOKO DISTRICT.

The gold production of the Innoko district in 1917 is estimated at $125,000. About 7 mines employing 46 men operated in the winter of 1916–17 and 20 mines employing 78 men in the summer of 1917. The chief activity was on Yankee, Gaines, Little Spruce, and Ophir creeks. There were no new developments during the year.

TOLSTOI DISTRICT.

In the winter of 1916–17 a stampede to Tolstoi occurred, and there were at times as many as 400 men at that camp. There was much prospecting during the winter and spring, but not over 50 men were there in July. About $50,000 was taken out during the winter and summer in the Tolstoi district, the result of the operations of about 25 men on 5 plants, most of the production being made by one outfit on Boob Creek. Boob Creek is the only creek from which there was any production of platinum. It was not separated from the gold but was sold with it to a bank in Iditarod. The platinum in the gold was said to amount to about 1 per cent, which would make approximately 30 ounces of platinum produced.

IDITAROD DISTRICT.

The placer gold production of the Iditarod district in 1917 was about $1,500,000, about $450,000 less than the production of 1916. The decrease was due largely to continued breakdowns of the Otter Creek dredge. Detailed information concerning mining in this district is not at hand, but it is believed that in addition to the 3 dredges there were about 15 mines employing nearly 400 men at work in the summer of 1917 and 2 mines employing about 10 men in the winter of 1916–17.

KOYUKUK DISTRICT.

Very little authentic information has been received concerning mining in the Koyukuk district except as a small proportion of the operators have supplied data on the output of their own properties. It is estimated that the total value of the gold produced in the Koyukuk district was about $250,000, which is considerably less than the production for 1916. In the Indian River district 8 men were at work in the summer of 1917 on Indian Creek, Felix Fork, and Black Creek, and they produced about $4,000 in placer gold.

MARSHALL DISTRICT.

The production at Marshall was about $425,000, as compared with $270,000 in 1916. Most of this gold was produced by 5 mines on Willow Creek, employing about 200 men, but some smaller plants were at work on Willow, Disappointment, and Elephant creeks. A small amount of platinum occurs with the gold on some of the creeks at Marshall, but none has yet been saved.

SMALLER YUKON DISTRICTS.

About 4 placer mines employing 9 men are known to have been operated in the Chandalar district. It is estimated that the total production of the district was about $15,000. No information concerning lode mining has been received.

The Richardson district, in the Tanana region, apparently produced about $25,000, which is considerably smaller than in 1916. The discovery of a promising gold lode on Democrat Creek has been reported. No production has been reported from the Goodpaster region, though it is known that considerable prospecting was done.

There were no large mining operations in either the Bonnifield or the Kantishna district during 1917. The value of the output of the Bonnifield district is estimated at $12,000 and of the Kantishna district at $15,000, both of which are somewhat less than in 1916. There was also some lode development in both districts.

There was no gold production in the Gold Mountain district, but considerable dead work is said to have been done preparatory to mining next year. Open cuts were made at Lancaster Creek, American Gulch, and Grant Creek, and a hydraulic plant was installed on Mason Creek. The ground is said to average 12 to 20 feet deep. The benches consist of wash gravel and are not frozen. Very little prospecting has been done on them.

A strike is said to have been made on Anvik River by two men. Platinum is reported in association with the gold.

KUSKOKWIM REGION.

The gold production of the Kuskokwim region in 1917, according to the best information at hand, was about $135,000. The largest production was on Candle and Moore creeks. The dredge that was shipped in last year will be placed on the upper end of Candle Creek to work downstream. It is reported that a new strike was made on the left limit of Nixon Fork, between Nixon Fork and the North Fork of the Kuskokwim, a little below the mouth of South Fork.

Another new discovery of placer gold was said to have been made on Wahmus or Watermouse Creek, in the Goodnews Bay district, where it is said that 4 men took out between $12,000 and $20,000 in 3 weeks. The gravels are said to be about 4 feet thick and to yield from $2 to $4 to the square foot. It is also reported that prospecting on Holitna River is yielding encouraging results. The Kuskokwim region is still without adequate means of transportation, so both prospecting and mining are done under great difficulties.

SEWARD PENINSULA.

The mines of Seward Peninsula produced gold to the value of about $2,600,000 in 1917 as against $2,950,000 in 1916. The value of tin, tungsten, silver, and graphite produced in 1917 was about $147,600; in 1916 it was $170,000. The value of the total gold production since mining began in 1897 is about $76,892,000. Nearly all this gold was taken from placers; up to the present time little has been produced from lodes. Silver, tin, and other substances have been produced to the value of about $1,027,600. This amount makes the value of the total mineral output of Seward Peninsula to the end of 1917 about $77,900,000.

Approximately 750 men were employed in placer mining in Seward Peninsula, exclusive of those employed on dredges. They worked with 170 plants. About half the men were employed in the Nome and Council precincts.

In 1917 twenty-eight gold dredges were operated on the peninsula—7 in the Nome district, 5 in the Solomon River district, 10 in the Council district, 2 in the Port Clarence district, 2 in the Fairhaven district, and 2 in the Kougarok district.

Gold production on Dime Creek was greater than in the preceding year, 6 plants making a very large part of the $150,000 produced by deep mining during late winter and early spring. An additional $20,000 will about cover the summer production, mostly from three open cuts. Platinum occurs with the gold in the ratio of about 1 ounce of platinum to $5,000 worth of gold on the lower claims of the creek and on bench claims. The proportion of platinum is somewhat larger on claims near the head of the creek. The platinum production in 1917 amounted to about 35 ounces. In all 17 plants worked during the winter and summer, employing about 85 men. This mining was done on 4 claims, but on other claims there was prospecting or setting up of plants for winter work. A number of men were engaged in this work for short periods during the summer, as well as in constructing ditches and in sluicing winter dumps.

About $10,000 was produced on Sweepstakes Creek, between Bear Creek and Dime Creek, by 4 plants employing 11 men. This gold also contains a small amount of platinum, about an ounce having been separated from the gold.

The gold production from Bear Creek is not known. Four outfits, employing 14 men, worked during the season. Some prospecting also was done on this creek. A few pennyweights of platinum were produced.

Exclusive of dredge production, the gold produced from the Port Clarence precinct is estimated at $27,000. That from the Kougarok precinct, likewise exclusive of dredge production, is estimated at $55,000.

Lode mining developments for the year consisted for the most part of little more than the necessary assessment work. The high prices of lead and silver gave an impetus to the search for those metals in the vicinity of Lost River and on the Kugruk, considerable work having been done on some properties in both localities. A mill was set up on a gold lode property near Bluff.

During the summer two tin dredges were in operation in the York region—one on Buck Creek, the other on Grouse Creek below the mouth of Buck. In addition to the tin won by the dredges, a small amount of placer tin was sluiced by two men working on Iron Creek, which flows into Sutter Creek, a tributary of Buck Creek. One of the dredges was prospecting for future dredging ground, as the next season will finish up their present ground. Unusually heavy rains during the last week in August delayed the work of both dredges. About 25 men were engaged in the placer mining of tin.

Some development work was done on tin lode claims at the head of Buck Creek, Tin City, Lost River, and Ear Mountain. No ore was milled or shipped from any of these properties.

Most of the tungsten ore (scheelite) produced in 1917, as in 1916, came from Sophie Gulch. A few pounds was saved as the result of smaller placer operations on one of the small tributaries of Snake River, below Glacier Creek, and a small production was made on Sunset Creek, in the Port Clarence district.

Work was done on two graphite properties during the summer of 1917. On one of these properties it consisted only of assessment work. On the other property about 4 miles of road were constructed from the property to Graphite Bay, an arm of Imuruk Basin. Some graphite was mined and was hauled to Graphite Bay by a gasoline tractor.

KOBUK RIVER.

During the year about 20 men were mining on Kobuk River, but they took out grubstakes only. The production of the district was probably about $25,000. The ground is worked by open cut in summer, the deeper spots being worked in winter. Most of the mining is done on Klery Creek. One outfit was prospecting on Ambler River and another on the Noatak. It is reported that a strike was made at Walker Lake during the summer and that 4 or 5 men were rocking out $10 to $15 a day. About 9 mines employing 16 men were operated on Lynx, Riley, and Dahl creeks and Shungnak River making an estimated production of about $5,000.

WATER-POWER INVESTIGATIONS IN SOUTHEASTERN ALASKA.[1]

By GEORGE H. CANFIELD.

INTRODUCTION.

The streams of Alaska have been important factors in its industrial growth. The success of placer mining in northern and central Alaska has depended primarily on the water available for hydraulicking and dredging, and in southeastern Alaska water power has long been used by mines, canneries, sawmills, and other industries, although until recently most of the plants have been small.

Since 1906 the United States Geological Survey has made systematic studies of the water resources of Alaska. Investigations with special reference to placer mining have been made in Seward Peninsula [2] and the Yukon-Tanana region,[3] and reconnaissance surveys for water power have been made about Prince William Sound, Copper River, Kenai Peninsula, and in other parts of southeastern Alaska.

In the summer of 1914 Leonard Lundgren, district engineer of the Forest Service, made a reconnaissance of water-power sites to determine the possibility of establishing the pulp industry in the Tongass National Forest, which covers a large part of southeastern Alaska. In connection with this reconnaissance a census of water powers was taken (see following table), which has been revised by Mr. Lundgren to January 1, 1917, and is here published by courtesy of the Forester.

Developed water powers in southeastern Alaska Jan. 1, 1917, in horsepower.

[Prepared by Leonard Lundgren, district engineer, U. S. Forest Service.]

Ketchikan region:		
Citizens Light, Power & Water Co.	2,000	
New England Fish Co.	2,200	
Miscellaneous plants	1,000	
		5,200
Wrangell region		0

[1] In cooperation with the United States Forest Service.

[2] Henshaw, F. F., and Parker, G. L., Surface water supply of Seward Peninsula, with a sketch of the geography and geology by P. S. Smith and a description of methods of placer mining by A. H. Brooks: U. S. Geol. Survey Water-Supply Paper 314, 1913.

[3] Ellsworth, C. E., and Davenport, R. W., Surface water supply of the Yukon-Tanana region, Alaska: U. S. Geol. Survey Water-Supply Paper 342, 1915; A water-power reconnaissance in south-central Alaska, with a section on southeastern Alaska by J. C. Hoyt: U. S. Geol. Survey Water-Supply Paper 372, 1915.

Sitka region:			
Sitka Wharf & Power Co.		350	
Chichagoff Mining Co.		750	
Miscellaneous plants		150	1,250
Juneau region:			
Alaska-Treadwell Mining Co.:			
Douglas Island plant	4,000		
Sheep Creek plant	4,100		
Nugget Creek plant	5,700	13,800	
Alaska-Gastineau Mining Co.:			
Salmon Creek plant, No. 1	5,000		
Salmon Creek plant, No. 2	5,000		
Annex Creek plant	5,000	15,000	
Alaska Electric Light & Power Co.		1,000	
Miscellaneous plants		1,000	30,800
Skagway region			100
			37,350

During the last few years some large water-power plants have been installed near Juneau to supply power for mining, and attention has been called to the feasibility of improving other power sites in that region and elsewhere in southeastern Alaska, to meet the increasing demand for power to be used in mining, lumbering, and fisheries, and the possible future demand for its use in the manufacture of wood pulp and electrochemical products. The streams on which it is possible to develop power and the bays or other water bodies into which these streams discharge are listed in the following table and shown on the map (Pl. I):

Streams affording power sites in southeastern Alaska, with position or water bodies into which they flow.

Mainland.

Porcupine River, near Porcupine.[1]
Endicott River, west coast of Lynn Canal.
Sherman Creek.[2]
Cowee and Davies creeks, Berners Bay.
Lemon Creek, near Juneau.[3]
Gold Creek, at Juneau.[4]
Sheep Creek, near Juneau.[4]
Carlson Creek, Taku Inlet.[4]
Turner Lake outlet, Taku Inlet.[5]
Speel River, Speel River project, Port Snettisham.[4]
Grindstone Creek, north shore of Stephens Passage.[4]
Rhein Creek, north shore of Stephens Passage.

[1] Gaging station maintained in 1909 by Porcupine Gold Mining Co.
[2] Gaging station maintained for short period by mining company of Juneau.
[3] Gaging station maintained by Kensington Mining Co., Aug. 17, 1914, to Dec. 31, 1916. See U. S. Geol. Survey Bull. 662, p. 102, 1918.
[4] See list of gaging stations, p. 46.
[5] Gaging station maintained in 1908 and 1909 by Alaska-Treadwell Gold Mining Co.

Long Lake outlet, Speel River project, Port Snettisham.[1]
Crater Lake outlet, Speel River project, Port Snettisham.[1]
Tease Lake outlet, Speel River project, Port Snettisham.
Sweetheart Falls Creek, south arm of Port Snettisham.[1]
Port Houghton, Stephens Passage.
Farragut Bay, Frederick Sound.
Cascade Creek, Thomas Bay.[1]
Mill Creek, near Wrangell.[1]
Bradfield Canal, upper end of Cleveland Peninsula.
Smugglers Cove, southeast shore of Cleveland Peninsula.
Helm Bay, southeast shore of Cleveland Peninsula.
Shelockum Lake outlet, Bailey Bay.[1]
Chickamin River, east shore of Behm Canal.
Rudyerd Bay, east shore of Behm Canal.

Baranof Island.

Port Conclusion, southeast coast.
Port Walter.[2]
Patterson Bay, east coast.[2]
Red Bluff Bay, east coast.
Cascade Bay, east coast.[2]
Baranof Lake outlet, Warm Spring Bay, east coast.[1]
Kasnyku Bay, east coast.
Green Lake outlet, Silver Bay, west coast.[1]
Necker Bay, west coast.
Deep or Redoubt Lake, west coast.

Chichagof Island.

Slocum Arm, west coast.
Suloia Bay, Peril Strait.[2]
Khaz Bay, west coast.
Freshwater Bay, east coast.
Sitkoh Bay, southeast coast.
Basket Bay, southeast coast.
Penta Bay, west coast.

Admiralty Island.

Kootznahoo Inlet, west coast.
Hood Bay, west coast.

Kosciusko Island.

Davidson Inlet.[2]

Prince of Wales Island.

Karta River, Karta Bay.[1]
Whale Passage, behind Thorne Island, northeast coast.
Myrtle Lake outlet, near Niblack post office.[1]
Reynolds Creek, near Coppermount.

Revillagigedo Island.

Orchard Lake outlet, at Shrimp Bay.[1]
Beaver Falls, George Inlet.[1]
White River, George Inlet.
Swan Lake outlet, east shore near head of Carroll Inlet.[1]
Fish Creek, Thorne Arm.[1]
Gokatchin Creek, Thorne Arm.
Ketchikan Creek, at Ketchikan.[1]

Annette Island.

Tamgas Harbor.

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[1] See list of gaging stations, p. 46.
[2] See list of miscellaneous measurements at end of report.

Lack of definite information in regard to the quantity of water available and other physical factors that determine the feasibility of a power site has been one of the principal impediments to development. For this reason a systematic investigation, designed to determine the location and the feasibility of water-power sites in southeastern Alaska, was begun by the Geological Survey, in cooperation with the Forest Service, in the spring of 1915.

The practicability of a water-power site depends on the quantity of water available, the fall, and the possibility of storing water. Information in regard to fall and storage can be obtained by surveys at any time, but the volume and distribution of flow can be determined only by observations extending over several years, as future flow must be predicted from that of the past. In beginning the investigations, therefore, the collection of stream-flow data was given precedence and constituted the principal work. Some general information, however, has been obtained, and in the fall of 1915 a few rainfall stations were established at higher elevations to supplement observations at mean sea level by the United States Weather Bureau. As a result of the investigations records of flow are now available for 20 gaging stations, as shown by the following list and indicated by corresponding numbers on Plate I. The date of establishment is indicated in parentheses.

1. Myrtle Lake outlet at Niblack, Prince of Wales Island (July 30, 1917).
2. Ketchikan Creek at Ketchikan (established November 1, 1909; discontinued June 30, 1912; reestablished July 1, 1915).
3. Beaver Falls Creek at George Inlet, Revillagigedo Island (Aug. 3, 1917).
4. Fish Creek near Sea Level, Revillagigedo Island (May 19, 1915).
5. Swan Lake outlet at Carroll Inlet, Revillagigedo Island (Aug. 24, 1916).
6. Orchard Lake outlet at Shrimp Bay, Revillagigedo Island (May 28, 1915).
7. Shelockum Lake outlet at Bailey Bay (June 4, 1915).
8. Karta River at Karta Bay, Prince of Wales Island (July 16, 1915).
9. Mill Creek on mainland, near Wrangell (June 17, 1915).
10. Cascade Creek at Thomas Bay, near Petersburg (Oct. 27, 1917).
11. Green Lake outlet at Silver Bay, near Sitka (August 22, 1915).
12. Baranof Lake outlet at Baranof, Baranof Island (June 28, 1915).
13. Sweetheart Falls Creek near Snettisham (July 31, 1915).
14. Crater Lake outlet at Speel River, Port Snettisham (Jan. 23, 1913).
15. Long River below Second Lake, at Port Snettisham (Nov. 11, 1915).
16. Speel River at Port Snettisham (July 15, 1916).
17. Grindstone Creek at Stephens Passage (May 6, 1916).
18. Carlson Creek at Sunny Cove, Taku Inlet (July 18, 1916).
19. Sheep Creek near Thane (July 26, 1916).
20. Gold Creek at Juneau (July 20, 1916).

In addition to the stations in this list, records for Long Lake outlet (Jan. 23, 1913, to Nov. 10, 1915) and for Sherman Creek at Kensington mine, Lynn Canal (Aug. 17, 1914, to Dec. 31, 1916) are contained in the report for 1916.[1]

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[1] U. S. Geol. Survey Bull. 662, pp. 136-139, 150-153, 1918.

The available power sites in each area were carefully considered, and gaging stations were established at those which apparently afforded the greatest opportunities for development.

The records have been collected in accordance with the standard methods used elsewhere in the United States by the Geological Survey. Owing to the inaccessibility of the stations, water-stage recorders were used at all the stations except that on Ketchikan Creek, and cables have been installed from which discharge measurements are made. Special arrangements were made for observations through the winter to obtain a record of the low-water flow which occurs at that season.

The data collected at the gaging stations are presented in the following pages and include a general description of each station and tables showing the results of discharge measurements and the computed daily discharge.

Much of the work has been made possible by the use of the Forest Service launches, on which transportation has been furnished to the engineers and others engaged in installing and maintaining the stations. The local knowledge of the Forest Service employees has also been of great assistance in carrying on the work, and special acknowledgment is due to W. G. Weigle, forest supervisor at Ketchikan, who has represented the Forest Service in the cooperation; to Leonard Lundgren, district engineer; and to George L. Drake, J. W. Wyckoff, C. T. Gardner, George H. Peterson, James Allen, W. H. Babbitt, Lyle Blodgett, and Milo Caughrean, who have assisted in various ways.

During the winter of 1916–17 the field work was carried on by C. O. Brown, assistant engineer, United States Geological Survey.

The following individuals and organizations assisted in maintaining gaging stations as indicated:

T. J. Jones, Seattle, Wash., furnished a Stevens water-stage recorder, materials, and labor for installing a gage on Swan Lake outlet.

The Alaska Gastineau Mining Co. installed gages and furnished gage-height records for Gold Creek near Juneau, Sheep Creek near Thane, and Carlson Creek at Sunny Cove.

The Alaska Taku Mining Co. furnished a Lietz gage, labor, material, and transportation for the installation of a gage on Grindstone Creek at Taku Inlet.

The Speel River Project (Inc.), of Juneau, installed and maintained gages and furnished gage readings for Crater Lake outlet at Speel River, Long Lake outlet at Port Snettisham, Long River below Second Lake, and Speel River at Port Snettisham.

The Kensington Mining Co., of Comet, furnished gage readings for Sherman Creek at Kensington mine.

The Citizens Light, Power & Water Co., of Ketchikan, furnished gage readings for Ketchikan Creek at Ketchikan.

The G. M. Wakefield Mineral Lands Co. furnished gage, materials, and part of labor for the installation of a gaging station on Myrtle Lake outlet at Niblack; maintained gage, and furnished gage record.

Mr. C. W. Bloodgood furnished gage and part of materials for installation of gaging station on Cascade Creek at Thomas Bay.

GAGING-STATION RECORDS.

MYRTLE CREEK AT NIBLACK, PRINCE OF WALES ISLAND.

LOCATION.—Halfway between beach and Myrtle Lake outlet which is one-third mile from tidewater, 1 mile from Niblack in north arm of Moira Sound, Prince of Wales Island, and 35 miles by water from Ketchikan.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—July 30 to December 31, 1917.

GAGE.—Stevens continuous water-stage recorder on right bank; reached by a trail which leaves beach near mouth of creek.

DISCHARGE MEASUREMENTS.—At medium and high stages from a cable across creek at outlet of lake; at low stages made by wading.

CHANNEL AND CONTROL.—The gage is in a pool 10 feet upstream from a contracted portion of channel at a rocky riffle which forms a well-defined and permanent control. At the cable section the bed is smooth, the water deep, and the current uniform and sluggish.

EXTREMES OF STAGE.—Maximum stage during the period 4.40 feet at 5 p. m. November 18; minimum stage, 1.27 feet at 7 a. m. August 10.

ICE.—Stage-discharge relation not affected by ice. Data inadequate for determination of discharge.

Myrtle Lake, the outlet of which is 800 feet from tidewater, is at an elevation of 95 feet above sea level and is 122 acres in area. Niblack Lake, the outlet of which is 5,700 feet from tidewater, is at an elevation of 450 feet above sea level and is 383 acres in area. Mary Lake, which is unsurveyed, is about 6,000 feet from tidewater and 650 feet above sea level.

Discharge measurements of Myrtle Creek at Niblack in 1917.

Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
July 30	G. H. Canfield	1.39	42
Nov. 26	do	2.81	164

Daily gage height, in feet, of Myrtle Creek at Niblack for 1917.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		1.46	1.87	2.17	3.8	2.15	16		1.82	2.00	1.96	3.55	1.80
2		1.49	1.78	2.40	3.6	1.95	17		1.85	1.88	2.10	4.05	1.77
3		1.41	1.72	2.49	3.25	1.90	18		2.13	1.90	2.55	4.3	1.73
4		1.37	1.66	2.47	3.25	1.85	19		2.6	2.03	2.42	4.1	1.70
5		1,35	1.61	2.7	3.5	1.82	20		2.39	1.95	2.55	3.7	1.68
6		1.34	1.56	2.42	4.05	1.78	21		2.16	1.95	2.42	3.35	1.66
7		1.32	1.52	2.28	4.1	1.75	22		2.31	1.98	2.55	3.05	1.64
8		1.29	1.49	2.22	3.75	2.05	23		2.18	1.93	2.50	2.9	1.62
9		1.29	1.45	2.16	3.4	2.35	24		2.06	1.88	2.43	2.9	1.59
10		1.31	1.42	2.14	3.5	2.40	25		1.94	1.93	2.36	2.85	1.58
							26		2.00	1.97	2.25	2.9	1.56
11		1.43	1.42	2.20	3.25	2.30	27		2.27	2.10	2.16	3.1	1.54
12		1.40	1.73	2.13	3.15	2.15	28		2.43	2.42	2.65	2.85	1.53
13		1.38	1.82	2.15	3.75	2.00	29		2.20	2.35	2.7	2.6	2.05
14		1.40	1.87	2.08	4.3	1.92	30	1.39	2.06	2.23	2.85	2.35	2.6
15		1.67	2.01	2.02	3.95	1.80	31	1.38	1.96		3.1		3.1

NOTE.—Gage heights Nov. 29 to Dec. 15 and Dec. 21-31 estimated from maximum and minimum stages indicated by recorder and comparison with gage-height graph for Karta River.

KETCHIKAN CREEK AT KETCHIKAN.

LOCATION.—One-fourth mile below power house of Citizens Light, Power & Water Co., one-third mile northeast of Ketchikan post office, downstream 200 feet from mouth of Schoenbar Creek (entering from right), 1¼ miles from mouth of Granite Basin Creek (entering from left), and 1½ miles from outlet of Ketchikan Lake.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—November 1, 1909, to June 30, 1912; June 9, 1915, to December 31, 1917.

GAGE.—Vertical staff fastened to a telephone pole near board walk on left bank at bend of creek 200 feet downstream from mouth of Schoenbar Creek; read by employee of the Citizens Light, Power & Water Co. The gage used since June 9, 1915, consists of the standard United States Geological Survey enameled gage section graduated in hundredths, half-tenths, and tenths from zero to 10 feet. The original gage, established November, 1909, and read until June 30, 1912, is at same location and same datum. It is a staff with graduations painted every tenth.

DISCHARGE MEASUREMENTS.—At medium and high stages from footbridge about 500 feet upstream from gage; measuring section poor, as the bridge makes an angle of 20° with the current, and at high stages the flow is broken by large stumps near left bank and at middle of bridge. Low-stage measurements made by wading 50 feet below bridge or at another section 100 feet above gage. The flow of Schoenbar Creek has been added to obtain total flow past gage.

CHANNEL AND CONTROL.—Gage is located in a large deep pool of still water at a bend in creek. The bed of the stream at the outlet of this pool is a solid rock ledge, but changes in a gravel bar at lower right side of pool cause occasional changes in stage-discharge relation.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 8.3 feet, November 18 (discharge not determined); minimum stage recorded, 0.08 foot December 27 (discharge not determined).

1909–1912 and 1915–1917: Maximum stage recorded 8.3 feet November 18, 1917; minimum stage recorded 0.28 foot September 24, 1915 (discharge, 34 second-feet). A stage of 0.08 foot recorded December 27, 1917, but rating curve is not sufficiently well defined to determine discharge at that stage.

ICE.—Ice forms along banks but control remains open.

DIVERSIONS.—A small quantity of water is diverted above the station for the use of the town of Ketchikan, the New England Fish Co., and the Standard Oil Co.

REGULATION.—Small timber dam and headgates are located at outlet of Ketchikan Lake. Water diverted through power house is returned to creek above gage but causes very little diurnal fluctuation. During low water the flow is increased by water from the reservoir.

ACCURACY.—Stage-discharge relation changed during high water August 19. Rating curve used January 1 to August 18 well defined below and poorly defined above 2,000 second-feet. Gage read to hundredths once daily. Daily discharge ascertained by applying gage height to rating table. Sufficient discharge measurements have not been made to define rating curve applicable August 19 to December 31. Records fair.

Discharge measurements of Ketchikan Creek at Ketchikan in 1917.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Jan. 24	C. O. Brown	1.13	151	Oct. 18	G. H. Canfield	0.94	172
Aug. 24	G. H. Canfield	1.23	218	Nov. 27	.....do	2.20	615
26	.....do	1.10	191				

Daily discharge, in second-feet, of Ketchikan Creek at Ketchikan for period Jan. 1 to Aug. 18, 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
1	118	61	54	42	125	228	720	180
2	69	54	54	42	93	196	382	200
3	71	54	61	245	90	196	493	160
4	66	108	66	241	74	196	720	180
5	64	176	69	125	76	220	616	160
6	74	249	66	99	160	308	357	160
7	142	232	61	82	160	216	382	160
8	262	285	54	79	523	436	285	160
9	87	212	50	76	285	262	180	142
10	262	216	50	76	220	196	160	241
11	267	168	52	71	216	200	160	142
12	115	125	54	76	220	204	142	125
13	82	523	52	76	212	204	142	108
14	79	450	48	64	200	204	142	160
15	74	740	44	64	180	204	142	285
16	64	377	44	64	180	196	139	241
17	66	180	66	66	180	204	139	332
18	66	118	61	90	285	553	142	1,290
19	85	108	54	142	220	493	142	....
20	74	69	61	176	200	332	125	....
21	61	66	54	142	180	382	125	....
22	64	66	71	139	172	357	125	....
23	102	64	69	142	160	220	125	....
24	142	64	56	142	176	220	285	....
25	204	61	54	142	180	180	155	....
26	125	61	54	142	176	180	125	....
27	122	64	44	142	180	180	180	....
28	90	54	44	139	180	160	142	....
29	66	....	46	142	216	160	142	....
30	64	....	44	139	220	180	142	....
31	61	....	42	....	220	....	180	....

Daily gage height, in feet, of Ketchikan Creek at Ketchikan for period Aug. 19 to Dec. 31, 1917.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1	....	0.60	1.00	5.4	0.50	16	....	1.18	1.00	1.9	0.20
2	....	.60	1.80	4.4	.42	17	....	.90	1.00	3.5	.20
3	....	.50	1.84	1.8	.34	18	....	1.00	1.00	8.3	.20
4	....	.50	1.40	1.4	.20	19	6.0	.80	.90	5.3	.18
5	....	.50	3.30	1.2	.30	20	4.0	.60	1.40	2.9	.18
6	....	.50	1.70	4.0	.40	21	2.0	.60	1.50	2.0	.16
7	....	.46	1.20	7.7	.90	22	4.5	.60	2.5	1.2	.10
8	....	.40	.90	3.4	2.1	23	1.8	.58	2.4	1.2	.10
9	....	.40	.82	1.8	.90	24	1.3	.58	1.3	1.8	.10
10	....	.40	.70	2.4	.50	25	1.1	1.10	1.2	1.9	.10
11	....	.50	1.40	1.9	.30	26	1.0	.66	1.3	1.6	.10
12	....	.56	1.20	1.6	.20	27	1.4	1.10	1.2	2.5	.08
13	....	.60	1.00	6.3	.20	28	2.0	1.40	1.7	1.4	.10
14	....	.80	.90	7.8	.20	29	1.2	1.62	1.3	.9	1.12
15	....	1.10	1.00	3.7	.20	30	1.1	1.56	2.8	.64	1.30
						31	1.06	....	....	....	1.20

Monthly discharge of Ketchikan Creek at Ketchikan for 1917.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	267	61	106	6,520
February	740	54	179	9,940
March	71	42	54.8	3,370
April	245	42	114	6,780
May	523	74	192	11,800
June	553	160	249	14,800
July	720	125	240	14,800
August 1-18	1,290	108	246	8,780
The period	....	....	....	76,800

BEAVER FALLS CREEK AT GEORGE INLET, REVILLAGIGEDO ISLAND.

LOCATION.—Two hundred feet above diversion dam and flume for shingle mill and salmon cannery; 800 feet from beach on west shore of George Inlet; 10 miles by water from Ketchikan.

DRAINAGE AREA.—5.9 square miles (United States Forest Service survey made in 1917).

RECORDS AVAILABLE.—August 3 to October 10, 1917.

GAGE.—Stevens continuous water-stage recorder on left bank, a quarter of a mile from tidewater; reached by a corduroy trail which leaves beach back of cannery buildings. The gage was washed out by high water in November.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from log-gaging bridge across stream a quarter of a mile upstream from gage; at low stages made by wading under bridge.

CHANNEL AND CONTROL.—The gage is in a partly sheltered pool in a narrow, deep, rocky canyon, 15 feet upstream from a small rocky fall, which forms a well-defined and permanent control.

DIVERSIONS.—A small quantity of water is diverted about 200 yards below station into a flume for use of shingle mill and cannery.

Lower Silvis Lake, whose elevation is 790 feet above sea level, is 1½ miles from the beach, and its area is 62 acres. The elevation of upper Silvis Lake, whose outlet is only 1,100 feet from the upper end of the lower lake, is 1,100 feet above sea level, and its area is 234 acres. Drainage area above outlet of lower lake is 4.9 square miles; above outlet of upper lake, 3.6 square miles.

Data inadequate for determination of discharge.

Discharge measurements of Beaver Falls Creek at George Inlet in 1917.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
July 26	......	88	Oct. 13	1.71	149
Aug. 3	1.30	83	Oct. 18	1.32	98

Daily gage height, in feet, of Beaver Falls Creek at George Inlet for 1917.

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1	......	0.68	1.66	11	1.13	0.35	......	21	2.53	1.93	......
2	......	.60	2.80	12	1.08	.79	......	22	3.42	1.58	......
3	1.35	.57	2.31	13	1.00	1.28	......	23	2.34	1.18	......
4	1.17	.48	3.29	14	1.08	2.09	......	24	......	1.85	......
5	1.07	.43	2.01	15	2.16	2.42	......	25	......	2.50	......
6	.98	.39	1.28	16	3.05	1.85	......	26	......	1.68	......
7	.95	.36	1.03	17	3.10	1.28	......	27	2.63	3.08	......
8	.90	.33	.87	18	4.03	1.75	......	28	2.75	2.96	......
9	.86	.30	1.07	19	4.40	1.22	......	29	1.80	2.24	......
10	.90	.29	1.76	20	3.54	1.28	......	30	1.11	1.37	......
								31	.82	......	......

FISH CREEK NEAR SEA LEVEL, REVILLAGIGEDO ISLAND.

LOCATION.—In latitude 55° 24′ N., longitude 131° 12′ W., near outlet of Lower Lake on Fish Creek, 600 feet from tidewater at head of Thorne Arm, 2 miles northwest of mine at Sea Level, and 25 miles by water from Ketchikan.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—May 19, 1915, to December 31, 1917.

GAGE.—Stevens continuous water-stage recorder on right shore of Lower Lake, 200 feet above outlet.

DISCHARGE MEASUREMENTS.—At medium and high stages made from cable across creek, 1 mile upstream from gage and 500 feet above head of Lower Lake; at low stages made by wading at cable. Only one small creek enters Lower Lake, at point opposite gage, between the cable site and control.

CHANNEL AND CONTROL.—The lake is about 500 feet wide opposite the gage. Outlet consists of two channels, each about 60 feet wide, separated by an island 40 feet wide. From the lake to tidewater, 200 feet, the creek falls 20 feet. Bedrock exposed at the outlet of the lake forms a well-defined and permanent control.

EXTREMES OF DISCHARGE.—Maximum stage during year, 5.33 feet at 6 p. m. November 1 (discharge, computed from an extension of rating curve, 4,600 second-feet); minimum stage 0.81 foot, March 16 (discharge, 57 second-feet).

1915–1917: Maximum stage 5.33 feet November 1, 1917 (discharge, 4,600 second-feet); minimum stage, 0.50 foot, February 11, 1916 (discharge, 22 second-feet).

ICE.—Lower Lake freezes over, but as gage is set back in the bank ice does not form in well, and the relatively warm water from the lake and the swift current keep the control open.

ACCURACY.—Stage-discharge relation affected by brush lodged at control January 1 to August 17; most of brush removed April 10 and remainder washed out on August 17. Rating curve used January 1 to April 10 well defined below and poorly defined above 400 second-feet; curve used April 11 to August 17 well defined; curve used August 18 to December 31 is open-water curve used May 19, 1915, to August 23, 1916, and is well defined below and extended above 1,500 second-feet. Operation of water-stage recorder satisfactory except for periods indicated by breaks in record shown in the footnote to daily-discharge table. Daily discharge ascertained by applying to rating table daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean daily gage heights for regular intervals of day. Records excellent, except for short periods of break in record and for period when control was obstructed by brush, for which they are fair.

There are three large lakes in the upper drainage basin: Big Lake, 2 miles from beach at elevation 275 feet, covers 1,700 acres; Third Lake, 250 acres; and Mirror Lake, at elevation 1,000 feet, 800 acres. Two-thirds of the drainage basin is covered with a thick growth of timber and brush interspersed with occasional patches of beaver swamp and muskeg. Only the tops of the highest mountains are bare. This large area of lake surface and vegetation, notwithstanding the steep slopes and shallow soil, affords a little ground storage and after a heavy precipitation maintains a good run-off. During a dry, hot period in summer, however, after the snow has melted, the flow becomes very low because of lack of ice or glaciers in the drainage basin.

Discharge measurements of Fish Creek near Sea Level in 1917.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Jan. 25	C. O. Brown	a1.48	243	June 23	G. H. Canfield	c1.89	557
Mar. 2	.....do	a.86	65	Oct. 12	.....do	d1.82	550
Apr. 16	G. H. Canfield	b1.16	164				

a Control obstructed by brush and logs.
b Part of obstruction on control removed Apr. 10.
c Obstruction on control.
d Control clear.

Daily discharge, in second-feet, of Fish Creek near Sea Level for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	137	130	76	70	394	710	482	256	254	857	4,240	302
2	135	119	67	69	382	616	623	354	208	686	3,680	~~245~~
3	127	107	69	70	370	547	670	370	168	830	~~3,040~~	192
4	119	96	83	127	342	495	870	315	142	766	1,200	161
5	109	87	83	159	337	502	978	265	126	1,060	1,300	142
6	107	93	76	176	354	766	906	234	108	1,030	1,620	123
7	156	169	72	190	382	879	734	212	96	694	2,500	126
8	284	278	72	162	595	1,150	630	188	87	539	2,620	200
9	408	290	70	137	897	1,150	528	170	82	428	1,780	302
10	499	284	67	132	897	822	436	152	76	368	1,400	351
11	492	284	65	130	670	609	382	148	73	395	974	296
12	408	284	64	130	540	502	354	152	91	525	750	243
13	316	300	64	130	560	450	320	162	197	588	1,380	192
14	244	420	62	130	567	456	290	168	384	553	3,000	161
15	202	788	58	136	521	456	270	265	870	486	2,680	139
16	166	874	57	162	469	436	265	581	1,730	440	1,730	123
17	143	748	69	180	436	406	275	1,150	1,250	440	1,820	116
18	127	541	98	194	443	514	275	1,960	814	486	3,220	108
19	127	338	91	242	495	942	275	2,380	618	454	3,900	101
20	132	227	89	270	514	1,050	265	2,260	480	532	3,060	96
21	137	179	87	256	495	942	252	1,510	384	588	1,840	89
22	198	162	91	242	443	806	242	1,040	368	806	1,160	84
23	198	143	107	229	394	616	229	857	525	947	830	80
24	198	127	102	224	370	502	275	618	460	947	702	76
25	249	114	98	251	400	436	388	447	473	848	602	73
26	263	102	107	275	482	406	388	351	694	655	602	69
27	244	91	100	305	581	376	337	318	726	512	774	61
28	198	83	93	337	670	354	295	492	1,190	574	734	61
29	169	......	87	365	742	342	260	525	1,680	744	574	180
30	153	......	82	388	766	337	234	414	1,300	1,080	414	606
31	140	......	76	......	726	......	220	324	......	2,690	......	1,730

NOTE.—Discharge Jan. 21–24, Jan. 29 to Mar. 1, Apr. 5–16, Oct. 3–11 estimated, because of stopping gage clock, from maximum and minimum stages indicated by the recording pencil, from weather records, and from comparison of the hydrograph for this stream with hydrographs of other streams in near-by drainage basins.

Monthly discharge of Fish Creek near Sea Level for 1917.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	499	107	212	13,000
February	874	83	266	14,800
March	107	57	80.2	4,930
April	388	69	196	11,700
May	897	337	524	32,200
June	1,150	337	619	36,800
July	978	220	418	25,700
August	2,380	148	601	37,000
September	1,730	73	524	31,300
October	2,690	368	727	44,700
November	4,240	414	~~1,830~~	~~109,000~~
December	1,730	61	220	13,500
The year	4,240	57	~~518~~	~~375,000~~

SWAN LAKE OUTLET AT CARROLL INLET, REVILLAGIGEDO ISLAND.

LOCATION.—Halfway between Swan Lake and tidewater; on east shore of Carroll Inlet, 1 mile from its head; 30 miles by water from Ketchikan.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—August 24, 1916, to October 13, 1917.

GAGE.—Stevens continuous water-stage recorder on left bank, half a mile from tidewater; reached by a trail which leaves beach back of old cabin one-fourth mile south of mouth of creek. Gage was washed out by extreme high water in November, 1917.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from a cable across stream 100 feet downstream from gage; at low stages made by wading.

CHANNEL AND CONTROL.—The gage well is in a deep pool 25 feet upstream from a contracted portion of channel, where a fall of a foot over bedrock forms a permanent control. The effect of the violent fluctuation of the water surface outside of gage well is decreased in the inner float well because the intake holes at the bottom are very small. At the cable section the bed is rough, the water shallow, and the current very swift. Point of zero flow is at gage height 0.0±0.2 foot.

EXTREMES OF DISCHARGE.—Maximum stage during period, 6.35 feet at 7 p. m. August 19, 1917 (discharge, computed from extension of rating curve, 1,900 second-feet); minimum stage, 1.01 feet at 10 p. m. April 2, 1917 (discharge, 39 second-feet).

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve fairly well defined between 50 and 900 second-feet. Operation of water-stage recorder satisfactory except January 1–25 and September 16–30. Daily discharge ascertained by applying to rating table daily gage height determined by inspecting gage-height graph. Records fair.

Swan Lake, whose area is about 350 acres, is 1½ miles from tidewater, at an elevation of 225 feet above sea level.

Discharge measurements of Swan Lake outlet at Carroll Inlet in 1917.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Jan. 26	C. O. Brown	1.72	205	Apr. 7	G. H. Canfield	1.52	141
Feb. 2	.....do	1.27	78	June 23	.....do	3.14	645

Daily discharge, in second-feet, of Swan Lake outlet at Carroll Inlet for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	104	92	82	44	452	799	816	388	319	
2	99	80	78	42	423	716	850	452	272	
3	96	76	71	40	407	633	918	426	238	
4	84	89	71	58	398	584	1,060	378	213	
5	78	145	67	102	404	633	1,020	344	173	
6	74	251	65	136	468	816	952	325	170	
7	169	356	62	148	534	850	782	294	154	
8	263	468	60	142	833	969	683	285	139	
9	340	468	58	133	969	969	600	260	127	
10	404	436	54	130	833	799	551	254	118	
11	388	391	52	133	650	666	518	254	115	
12	340	344	53	130	584	584	485	269	124	
13	272	414	52	130	666	567	452	282	288	683
14	216	518	49	133	650	633	423	306	468	
15	163	891	46	148	584	633	436	551	1,010	
16	136	901	44	172	551	617	430	910		
17	109	683	45	200	534	584	452	1,300		
18	96	502	53	229	568	666	452	1,600		
19	96	375	62	260	584	864	449	1,700		
20	99	294	60	278	584	884	426	1,600		
21	104	235	59	269	534	833	433	1,160		
22	124	191	59	263	485	765	388	986		
23	127	169	69	260	446	666	372	833		
24	127	145	65	282	452	584	468	650		
25	191	127	62	334	534	567	534	502		
26	206	112	62	375	650	551	502	430		
27	184	102	62	398	749	518	426	468		
28	154	89	58	433	816	502	394	600		
29	133		54	452	867	502	356	518		
30	115		53	485	850	502	337	420		
31	102		48		833		340	388		

NOTE.—Discharge Jan. 1–25 estimated from maximum and minimum stages indicated by recording pencil and comparison with gage-height graphs for Fish Creek near Sea Level; discharge Sept. 16–30 estimated at 1,100 second-feet by comparison with records of flow for Fish Creek.

Monthly discharge of Swan Lake outlet at Carroll Inlet for 1917.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	404	74	168	10,300
February	901	76	319	17,700
March	82	48	59.2	3,600
April	485	40	211	15,600
May	969	398	609	37,400
June	969	502	682	40,600
July	1,060	337	558	34,300
August	1,700	254	618	38,000
September			681	40,500
The period				238,000

ORCHARD LAKE OUTLET AT SHRIMP BAY, REVILLAGIGEDO ISLAND.

Location.—In latitude 55° 50′ N., longitude 131° 27′ W., at outlet of Orchard Lake, one-third mile from tidewater at head of Shrimp Bay, an arm of Behm Canal, 46 miles by water from Ketchikan.

Drainage area.—Not measured.

Records available.—May 28, 1915, to October 10, 1917.

Gage.—Stevens continuous water-stage recorder on right bank 300 feet below Orchard Lake and 100 feet above site of timber-crib dam, which was built in 1914 for proposed pulp mill and washed out by high water August 10, 1915. Datum of gage lowered 2 feet September 15, 1915. Gage heights May 29 to August 10, 1915, referred to first datum; August 11, 1915, to August 17, 1916, to second datum. Datum of gage lowered 1 foot August 17, 1916. Gage heights August 18, 1916, to October 10, 1917, referred to this datum. Gage washed out in November, 1917.

Discharge measurements.—At medium and high stages made from cable 50 feet downstream from gage; at low stages by wading near cable.

Channel and control.—From Orchard Lake, at elevation 134 feet above high tide, the stream descends in a series of rapids for 1,000 feet through a narrow gorge, then divides into two channels and enters the bay in two cascades of 100-foot vertical fall. Opposite the gage the water is deep and the current sluggish. At the site of the old dam bedrock is exposed, but for 30 feet upstream the channel is filled in with loose rock and brush placed during construction of dam. This material forms a riffle which acts as a control for water surface at gage at low and medium stages and is scoured down when ice goes out of lake; the rock outcrop at site of old dam acts as a control at high stages and is permanent.

Extremes of discharge.—Maximum stage during period, 8.4 feet at 2 a. m. October 16, 1915 (discharge 6,230 second-feet); minimum discharge estimated, 20 second-feet February 11, 1916.

Ice.—Ice forms on Orchard Lake, but because of swift current and relatively warm water from lake the outlet and control remain open.

Accuracy.—Stage-discharge relation changed January 12 when logs lodged on control; also on August 16, when logs were washed out and old gravel cofferdam under cable was scoured down farther. Rating curve used January 1–11 same as curve used April 13 to December 31, 1916, and is fairly well defined. Seven discharge measurements were made and six points for platting were computed by comparison with record of Fish Creek during the period January 1 to October 10 by means of which rating curves have been constructed which are applicable as follows: January 12 to August 16, well defined below and poorly defined above 500 second-feet; August 17 to October 10, poorly defined. Operation of water-stage recorder satisfactory, except January 15–29, when it stopped. Daily discharge ascertained by applying to rating tables daily gage height, determined by inspecting gage-height graph, or for days of considerable fluctuation by averaging the discharge for equal intervals of the day. Records fair.

The highest mountains on this drainage basin are only 3,500 feet above sea level and are covered to an elevation of 2,500 feet by a heavy stand of timber and a thick undergrowth of brush, ferns, alders, and devil's club. The topography is not so rugged as that of the area surrounding Shelockum Lake, and the proportion of vegetation, soil cover, and lake area is greater, so that more water is stored and the flow in the Orchard Lake drainage basin is better sustained.

Discharge measurements of Orchard Lake outlet at Springs Bay in 1917.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Jan. 30	Brown and Gardner	1.04	101	Aug. 1	Drake and Blodget	2.38	460
Mar. 6	do	.74	67	26	C. T. Gardner	2.09	358
Apr. 14	G. H. Canfield	1.39	180	Oct. 11	G. H. Canfield	3.26	880
June 21	do	4.22	1,070				

Daily discharge, in second-feet, of Orchard Lake outlet at Shrimp Bay for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	93	82	79	54	690	1,400	935	380	270	840
2	91	72	74	50	595	1,140	1,020	495	225	807
3	89	65	70	49	578	970	1,100	465	193	1,380
4	84	67	70	62	542	858	1,430	380	165	1,170
5	76	95	70	123	560	948	1,340	342	150	2,080
6	77	165	67	172	630	1,280	1,170	318	136	1,220
7	133	282	66	184	770	1,370	690	280	128	710
8	262	435	66	182	1,170	1,400	730	262	116	560
9	357	495	65	170	1,490	1,250	630	230	110	455
10	398	465	62	161	1,170	995	560	218	105	410
11	440	420	61	170	835	860	525	216	102	
12	322	355	61	170	690	790	510	235	112	
13	248	368	60	170	970	770	465	239	249	
14	196	495	56	174	1,020	880	420	300	450	
15	163	1,000	54	214	880	880	420	606	1,500	
16	125	1,400	51	264	835	790	405	1,150	2,370	
17	98	880	52	330	792	750	450	2,560	1,700	
18	78	578	60	380	880	790	435	2,860	1,180	
19	79	392	72	380	835	995	435	2,880	915	
20	83	290	75	405	835	1,020	435	2,420	630	
21	83	222	72	380	730	1,070	495	1,520	508	
22	83	183	74	368	650	1,070	420	1,300	840	
23	83	154	78	368	595	860	380	1,060	890	
24	85	130	75	432	630	750	510	730	690	
25	132	117	68	510	835	750	730	525	730	
26	216	106	70	578	1,070	750	710	410	890	
27	188	95	67	612	1,370	670	525	410	790	
28	154	86	65	670	1,520	612	435	508	2,000	
29	128		62	710	1,640	595	372	508	2,240	
30	112		56	770	1,550	595	318	410	1,480	
31	95		54		1,430		318	328		

NOTE.—Discharge Jan. 1–14 estimated, because of stopping of clock, from maximum and minimum stages indicated by the recorder, from weather records, and from records of flow for Karta River.

Monthly discharge of Orchard Lake outlet at Shrimp Bay for 1917.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	440	76	157	9,650
February	1,400	65	339	18,800
March	79	51	65.6	4,030
April	770	49	309	18,400
May	1,640	542	928	57,100
June	1,400	595	929	55,300
July	1,430	318	623	38,300
August	2,880	215	791	48,600
September	2,370	102	729	43,400
October 1–10	2,080	410	963	19,100
The period				313,000

SHELOCKUM LAKE OUTLET AT BAILEY BAY.

LOCATION.—In latitude 56° 00′ N., longitude 131° 36′ W., on mainland near outlet of Shelockum Lake, three-fourths mile by Forest Service trail from tidewater at north end of Bailey Bay, and 52 miles by water north of Ketchikan.

DRAINAGE AREA.—18 square miles (measured on sheets Nos. 5 and 8 of the Alaska Boundary Tribunal, edition of 1895).

RECORDS AVAILABLE.—June 1, 1915, to December 31, 1917.

GAGE.—Stevens continuous water-stage recorder on right shore of lake, 250 feet above outlet. Gage house was pushed off the well by a snowslide January 4, 1917. Gage not put into operation again until May 23.

DISCHARGE MEASUREMENTS.—Made from cable across outlet of lake, 200 feet below gage and 50 feet upstream from crest of falls.

CHANNEL AND CONTROL.—Opposite the gage the lake is 600 feet wide; at the outlet bedrock is exposed and the water makes a nearly perpendicular fall of 150 feet. This fall forms an excellent and permanent control for the gage. At extremely high stages the lake has another outlet about 200 feet to left of main outlet. Point of zero flow is at gage height 0.6 foot.

EXTREMES OF DISCHARGE.—1915–1917: Maximum stage during year, 6.84 feet, at 8 a. m. November 1 (discharge, 2,780 second-feet); minimum discharge, estimated from climatic records, 2.5 second-feet, January 31.

ICE.—Ice forms on Shelockum Lake and at gage, but because of the swift current and relatively warm water from lake, the control remains open and stage-discharge relation is not affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined. Gage not in operation January 4 to May 22. Operation of water-stage recorder for rest of year satisfactory except for periods of break in record shown in the footnote to daily-discharge table. Daily discharge ascertained by applying to the rating table daily gage height determined by inspection of gage-height graph, or, for days of considerable fluctuation, by averaging the discharge for equal intervals of the day. Records January 4 to May 22 and June 2–20 poor; excellent for rest of year except those for October 1–10 and December 1–27, which are fair.

Shelockum Lake, at elevation 344 feet, is only 350 acres in area. The drainage basin above the lake is rough and precipitous and is covered with little soil or vegetation. There are no glaciers or ice fields at the source of the tributary streams. Therefore, as there is little natural storage, the run-off after a heavy rainfall is rapid and not well sustained, and during a hot, dry summer the flow becomes very low. The large amount of snow that accumulates during the winter months maintains a good flow.

Discharge measurements of Shelockum Lake outlet at Bailey Bay in 1917.

Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
Jan. 31	C. O. Brown	(a)	[b]2.5
Apr. 13	G. H. Canfield	(a)	42
June 21	....do	3.30	420

a Gage buried in snow and was not read. b Discharge estimated.

later decided to be 25 sf (est) Field

Daily discharge, in second-feet, of Shelockum Lake outlet at Bailey Bay for 1917.

Day.	Jan.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	47			379	510	259	104	204	2,300	107
2	45				510	338	72	222	1,540	91
3	44				620	252	59	366	500	84
4					788	185	58	525	305	77
5					600	150	45	835	407	71
6					480	125	39	742	518	65
7					352	110	34	366	1,160	71
8					325	100	31	238	674	91
9					288	91	27	179	435	107
10					260	88	25	225	640	123
11					250	106	31	435	495	107
12					243	110	94	366	495	91
13		42			227	109	187	352	1,250	78
14					202	170	450	308	2,400	68
15					204	366	480	255	1,270	60
16					229	792	379	218	525	58
17					282	858	480	189	685	48
18					275	950	480	229	1,670	44
19					275	1,010	308	220	1,670	41
20					243	820	248	308	1,630	39
21				435	227	480	366	450	640	37
22				435	296	525	379	560	465	35
23			236	366	189	407	288	600	421	33
24			258	341	318	280	300	560	318	31
25			330	341	347	202	407	393	252	30
26			393	320	305	191	352	288	258	28
27			421	288	232	312	548	211	366	27
28			435	262	194	495	720	223	282	25
29			450	262	160	344	480	393	198	41
30			435	280	136	225	298	465	134	88
31	25		407		142	154		1,190		740

NOTE.—Discharge estimated, because of no gage-height record after Jan. 3, from flow Jan. 1-3, two discharge measurements, weather records, and comparison with records of flow for Orchard Lake outlet, as follows: Jan. 1-31, 16 second-feet; Feb. 1-28, 40 second-feet; Mar. 1-31, 16 second-feet; Apr. 1-30, 80 second-feet; May 1-22, 235 second-feet; June 2-20, 350 second-feet; estimates only roughly approximate and should be used with caution. Discharge Oct. 1-10 and Dec. 1-27 estimated from maximum and minimum stages indicated by the recorder and comparison of the hydrograph of this station with the hydrograph for Orchard Lake outlet.

Monthly discharge of Shelockum Lake outlet at Bailey Bay for 1917.

[Drainage area, 18 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
January			16	0.889	1.02	984
February			40	2.22	2.31	2,220
March			16	.889	1.02	984
April			80	4.44	4.95	4,760
May			200	11.1	12.80	12,300
June			345	19.2	21.42	20,500
July	788	136	310	17.2	19.83	19,100
August	1,010	88	342	19.0	21.90	21,000
September	720	25	259	14.4	16.07	15,400
October	1,190	179	384	21.3	24.56	23,600
November	2,400	134	780	43.3	48.31	46,400
December	740	25	84.9	4.72	5.44	5,220
The year	2,400		238	13.2	179.63	172,000

KARTA RIVER AT KARTA BAY, PRINCE OF WALES ISLAND.

Location.—In latitude 55° 34′ N., longitude 132° 37′ W., at head of Karta Bay, an arm of Kasaan Bay, on east coast of Prince of Wales Island, 42 miles by water across Clarence Strait from Ketchikan.

Drainage area.—49.5 square miles (U. S. Forest Service reconnaissance map of Prince of Wales Island, 1914).

Records available.—July 1, 1915, to December 31, 1917.

Gage.—Stevens continuous water-stage recorder on left bank, half a mile above tidewater, at head of Karta Bay and 1¼ miles below outlet of Little Salmon Lake. Two per cent of total drainage of Karta River enters between outlet of lake and gage.

Discharge measurements.—At medium and high stages made from cable across river 50 feet upstream from gage; at low stages by wading at cable section.

Channel and control.—From Little Salmon Lake, 1¼ miles from tidewater, the river descends 105 feet in a series of rapids in a wide, shallow channel, the banks of which are low but do not overflow. The bed is of coarse gravel and boulders; rock crops out only at outlet of lake. Gage and cable are at a pool of still water formed by a riffle of coarse gravel that makes a well-defined and permanent control.

Extremes of discharge.—Maximum stage during year, 5.5 feet at 11 p. m. November 1 (discharge determined from extension of rating curve, 5,070 second-feet); minimum flow, estimated by a comparison with the record for Fish Creek, 80 second-feet on March 16.

1915–1917: Maximum stage, 5.5 feet November 1, 1917 (discharge, 5,070 second-feet); minimum flow, 21 second-feet, February 11, 1915.

Accuracy.—Stage-discharge relation permanent. Rating curve well defined between 80 and 1,500 second-feet; extended below 80 second-feet to the point of zero flow and above 1,500 second-feet by estimation. Operation of water-stage recorded satisfactory except for periods indicated by breaks in record as shown in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graphs, or for days of considerable fluctuation by averaging results obtained by applying to rating table mean gage height for regular intervals of day. Records excellent except for periods of break in record and for discharge above 1,500 second-feet, for which they are fair.

The combined area of Little Salmon Lake at elevation 105 feet, and Salmon Lake at elevation 110 feet, is 1,600 acres. The slopes along the right shore of lakes and at head of Salmon Lake are gentle, and the area included by the 250-foot contour above lake outlet is 5,500 acres. The drainage area to elevation, 2,000 feet, is heavily covered with timber and dense undergrowth of ferns, brush, and alders. The upper parts of the mountains are covered with thin soil and brush. Only a few peaks at an elevation of 3,500 feet are bare. This large lake and flat area and thick vegetal cover affords considerable natural storage, which, after heavy precipitation, maintains a good run-off. The snow usually melts by the end of June, and the run-off becomes very low during a dry, hot summer.

The Forest Service in the summer of 1916 constructed a pack trail from tidewater to outlet of Little Salmon Lake.

Discharge measurements of Karta River at Karta Bay in 1917.

Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
Feb. 6	C. O. Brown	1.48	289
June 25	G. H. Canfield	1.85	524

Daily discharge, in second-feet, of Karta River at Karta Bay for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	156	229	100	......	633	722	402	184	280	943	4,440	480
2	152	192	88	......	595	641	415	184	228	898	3,770	382
3	145	206	83	......	550	558	467	176	197	1,070	1,880	308
4	149	210	86	......	515	515	565	164	172	1,050	1,270	259
5	121	238	83	......	515	501	748	156	149	1,480	1,700	229
6	118	290	86	......	543	558	773	145	153	1,070	2,020	206
7	377	389	118	......	610	595	625	135	121	748	2,360	201
8	697	501	125	......	952	665	543	121	112	588	1,820	338
9	790	515	118	......	1,030	633	501	118	100	467	1,270	730
10	824	536	106	......	862	565	434	121	94	408	2,120	756
11	764	508	103	......	645	501	376	118	83	460	1,940	625
12	588	460	103	......	572	448	332	112	91	474	1,880	494
13	460	536	......	......	558	422	296	112	168	508	2,540	396
14	370	756	......	......	565	448	264	121	202	494	3,860	282
15	302	1,170	......	......	558	494	248	192	1,020	448	3,500	285
16	254	1,040	......	......	580	494	254	370	1,070	428	1,700	248
17	220	739	......	......	565	487	274	665	907	448	1,820	220
18	210	550	......	......	588	487	259	808	1,120	641	3,100	197
19	215	408	......	......	565	487	243	1,420	1,070	565	3,520	180
20	224	308	......	370	588	494	229	1,370	817	782	2,820	168
21	233	248	......	363	565	543	220	990	756	880	1,880	260
22	332	201	......	350	501	673	206	1,170	1,040	1,220	1,220	142
23	332	180	......	338	467	649	197	1,070	990	1,540	1,060	132
24	332	152	......	350	467	610	224	799	817	2,060	1,070	128
25	370	132	......	396	536	515	228	588	739	1,590	990	118
26	434	121	......	454	649	448	220	467	765	1,070	934	109
27	402	112	......	501	730	383	220	494	799	764	1,480	103
28	363	103	......	588	799	350	248	543	1,710	925	1,220	97
29	320	......	......	625	862	320	228	494	2,120	1,640	860	396
30	290	......	......	665	853	308	206	415	1,440	1,760	625	1,270
31	259	......	......	......	625	......	192	338	......	3,100	......	2,430

NOTE.—Discharge Jan. 28 to Feb. 5 estimated, because of stopping of clock, from maximum and minimum stages indicated by recorder and from a comparison of hydrograph for this station with that for Fish Creek.
No gage-height record, owing to stick caught in float wheel; discharge estimated from a comparison of hydrograph for this station with that for Fish Creek: Mar. 13–31, 120 second-feet; Apr. 1–20, 140 second-feet. Discharge Dec. 27 interpolated.

Monthly discharge of Karta River at Karta Bay for 1917.

[Drainage area, 49.5 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
January	824	118	348	7.03	8.10	21,400
February	1,170	103	358	7.23	7.53	19,900
March	....	....	112	2.26	2.61	6,890
April	....	....	255	5.15	5.75	15,200
May	1,030	467	634	12.8	14.76	39,000
June	722	308	517	10.4	11.60	30,800
July	773	192	343	6.93	7.99	21,100
August	1,420	112	457	9.23	10.64	28,100
September	2,120	83	644	13.0	14.50	38,300
October	2,960	408	977	19.7	22.71	60,100
November	4,440	625	2,020	40.8	45.53	120,000
December	2,430	97	393	7.94	9.15	24,200
The year	4,440	....	587	11.9	160.87	425,000

MILL CREEK NEAR WRANGELL.

LOCATION.—In latitude 56° 28′ N., longitude 132° 12′ W., near outlet of Lake Virginia on east shore of Eastern Passage, a narrow channel between Wrangell Island and mainland, 6 miles by water from Wrangell.

DRAINAGE AREA.—50 square miles (measured on U. S. Coast and Geodetic Survey chart 8200).

RECORDS AVAILABLE.—June 17, 1915, to September 30, 1917.

GAGE.—Stevens water-stage recorder on left bank one-fourth mile below Lake Virginia and three-fourths mile above tidewater. Gage washed out by extreme high water November 14, 1917; record August 8 to November 14 lost with gage.

DISCHARGE MEASUREMENTS.—Made from cable across creek, 10 feet upstream from gage.

Channel and control.—From the outlet of the lake, at an elevation of 100 feet above sea level and at a distance of 1 mile from tidewater, the creek descends in a series of rapids and falls. The bed is glacial drift and boulders at the rapids and rock outcrop at points of concentrated fall. The gage is in a pool of still water created by a small fall at a contracted point of channel. This fall makes a well-defined, permanent, and sensitive control.

Extremes of discharge.—1915–1917: Maximum stage, 8 feet October 16, 1915 (discharge, computed from extension of rating curve, about 3,310 second-feet, differs from that published in Bulletin 642 because of revision of rating curve); minimum stage, 0.02 foot February 11, 1916 (discharge, 15 second-feet).

Ice.—Ice forms on the lake, at gage, and along the banks, but the swift current and flow of relatively warm water from the lake keeps the control open.

Accuracy.—Stage-discharge relation permanent; not affected by ice. Rating curve well defined below 1,200 second-feet; extended above 1,200 second-feet. Operation of water-stage recorder not satisfactory January 1 to May 18 and July 15 to August 1. Daily discharge, except for periods shown in footnote to daily-discharge table ascertained by applying to the rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by averaging discharge for equal intervals of the day. Results good except for periods when water-stage recorder was not operating satisfactorily.

The drainage basin is covered with a heavy stand of timber to an elevation of 2,500 feet and a dense undergrowth of ferns, brush, alders, and devil's-club, but because of the steep slopes and thin soil the run-off after heavy rains is rapid and the ground storage is small. During a dry, hot period in summer the flow is augmented by melting ice from glaciers at the headwaters of two of the tributary streams.

No discharge measurements were made at this station during the year.

Daily discharge, in second-feet, of Mill Creek near Wrangell for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
1	60	60	70	38	380	965	909	590
2	57	55	65	36	350	715	1,030	1,030
3	55	48	60	34	330	540	1,150	680
4	53	55	60	38	310	492	1,660	510
5	51	70	58	45	330	760	1,250	430
6	51	110	58	62	460	1,340	965	388
7	70	120	56	85	580	1,030	715	409
8	100	190	54	85	700	965	742	....
9	130	260	52	78	820	875	645	....
10	160	188	50	78	580	645	558	....
11	180	170	47	78	350	540	540	....
12	160	155	46	78	280	510	525	....
13	140	200	45	78	540	525	575	....
14	120	300	43	80	600	680	525	....
15	100	700	40	85	520	662	....	....
16	85	1,230	40	87	490	575	....	....
17	72	700	40	92	465	575	....	....
18	62	400	40	108	525	662	....	....
19	55	280	50	125	492	750	....	....
20	57	220	55	149	489	750	....	....
21	59	190	55	170	397	715	....	....
22	60	160	55	160	331	698	....	....
23	60	140	55	160	302	592	....	....
24	65	120	55	190	361	558	....	....
25	85	105	55	230	525	525	....	....
26	150	95	52	270	645	510	....	....
27	130	85	51	300	732	475	....	....
28	110	75	50	340	770	439	....	....
29	95	....	46	365	830	454	....	....
30	80	....	43	400	790	492	....	....
31	70	....	40	....	965	....	....	....

Note.—Water-stage recorder not working properly for the following periods: Jan. 1 to May 18; daily discharge estimated from discharge measurement Jan. 21, staff gage, readings Jan. 21, Feb. 10, Mar. 10, Apr. 20, May 11, maximum and minimum stages indicated by the recorder for each of periods Jan. 1–20, Jan. 22 to Feb. 9, Feb. 11 to Mar. 9, Mar. 13 to Apr. 19, Apr. 21 to May 10, and May 12–18, and from a comparison of hydrograph for this station with that for Orchard Lake outlet; discharge July 15–31 (625 second-feet) estimated from maximum and minimum stages indicated by recorder and by comparison with records for Baranof Lake outlet; discharge, Aug. 7–30, estimated at 850 second-feet and Sept. 1–30, 725 second-feet, by comparison with records of flow for Baranof Lake outlet.

Monthly discharge of Mill Creek near Wrangell for 1917.

[Drainage area, 50 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
January	180	51	89.7	1.79	2.06	5,520
February	1,230	48	231	4.62	4.81	12,800
March	70	40	51.2	1.02	1.18	3,150
April	400	34	137	2.74	3.06	8,150
May	965	280	524	10.5	12.11	32,200
June	1,340	439	667	13.3	14.84	39,700
July			723	14.5	16.72	44,500
August			[a] 788	15.8	18.22	48,500
September			[a] 725	14.5	16.18	43,100
The period						238,000

[a] Estimated.

CASCADE CREEK AT THOMAS BAY, NEAR PETERSBURG.

LOCATION.—One-fourth mile above tidewater on each shore of south arm of Thomas Bay; 22 miles by water from Petersburg. One small tributary enters the river from the left one-half mile above gage and 2 miles below lake outlet.

DRAINAGE AREA.—21 square miles (measured on the United States Geological Survey geologic reconnaissance map of the Wrangell mining district, edition of 1907).

RECORDS AVAILABLE.—October 27 to December 31, 1917.

GAGE.—Stevens continuous water-stage recorder on left bank, one-fourth mile from tidewater; reached by trail which leaves beach back of old cabin at mouth of creek.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from log footbridge across stream one-fourth mile upstream from gage; at low stages, made by wading.

CHANNEL AND CONTROL.—From the outlet of a lake at an elevation of 1,200 feet above sea level and 3 miles from tidewater the river descends in a continuous series of rapids and falls through a narrow, deep canyon. Gage is in a protected eddy above a natural rock weir, which forms a well-defined and permanent control. The bed of river under the footbridge is rough and the current swift and irregular, but this section is the only place on whole river where even at low and medium stages there are no boils and eddies.

EXTREMES OF STAGE.—Maximum stage during period, 7.65 feet at 11 p. m., November 18; minimum stage, 1.95 feet about December 31.

ICE.—Stage-discharge relation not affected by ice.

Data inadequate for determination of discharge.

The first site on this stream for a storage reservoir is at a small lake 3 miles from tidewater and at elevation of 1,200 feet above sea level. The drainage area above the gaging station is 21 square miles and above the lake outlet, 17 square miles. Flow during summer is augmented by melting ice from glaciers on upper portion of drainage area.

The following discharge measurement was made by G. H. Canfield:

October 29, 1917: Gage height, 3.24 feet; discharge, 181 second-feet.

Daily gage height, in feet, of Cascade Creek at Thomas Bay, near Petersburg, for 1917.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1	......	5.65	2.79	11	......	4.65	2.33	21	......	5.6	......
2	......	6.6	2.67	12	......	4.55	2.25	22	......	5.05	......
3	......	4.95	2.55	13	......	5.2	2.20	23	......	4.55	......
4	......	4.25	2.43	14	......	6.8	2.15	24	......	4.0	......
5	......	4.05	2.37	15	......	5.85	......	25	......	3.7	......
6	......	4.2	2.33	16	......	4.9	......	26	......	3.6	......
7	......	4.75	2.32	17	......	5.2	......	27	2.9	3.65	......
8	......	4.2	2.5	18	......	7.2	......	28	3.4	3.35	......
9	......	3.8	2.47	19	......	7.25	......	29	3.2	3.15	......
10	......	4.6	2.38	20	......	6.6	......	30	3.7	2.93	......
								31	4.55	......	......

GREEN LAKE OUTLET AT SILVER BAY, NEAR SITKA.

Location.—In latitude 56° 59′ N., longitude 135° 5′ W., at outlet of Green Lake, at head of Silver Bay, 10½ miles by water south of Sitka.

Drainage area.—Not measured.

Records available.—August 22, 1915, to December 31, 1917.

Gage.—Stevens water-stage recorder on right bank at outlet of lake, reached by trail which leaves the beach one-fourth mile north of mouth of stream, ascends a 600-foot ridge, and then drops down to the outlet of the lake. Gage datum lowered 1.0 foot December 27, 1916.

Discharge measurements.—Made from cable across outlet 30 feet below gage.

Channel and control.—From Green Lake, 240 feet above sea level and 1,800 feet from tidewater, the stream descends in a series of falls and rapids through a narrow canyon whose exposed rock walls rise perpendicularly more than a hundred feet.

Extremes of discharge.—Maximum stage during year, 10.74 feet at 12.30 a. m. November 20 (discharge, 2,220 second-feet); minimum stage, 0.12 foot April 2 (discharge, 15 second-feet).

1915–1917: Maximum stage, 11.22 feet (referred to datum used after December 27, 1916) on September 19, 1916 (discharge, 2,400 second-feet); minimum stage, 0.12 foot April 2, 1917 (discharge, 15 second-feet).

Ice—Ice forms on lake and at gage, but because of current and flow of relatively warm water from the lake the control remains open.

Accuracy.—Stage-discharge relation permanent. Rating curve well defined between 10 and 1,300 second-feet. Operation of water-stage recorder satisfactory except for periods indicated by breaks in record, as shown in the footnote to the daily-discharge table. Daily discharge ascertained by applying to the rating table mean daily gage height, determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table gage heights for regular intervals of day. Records good, except those for periods when gage was not operating satisfactorily, which are only roughly approximate.

In the fall and winter the flow is low because there is little ground storage, and on most of the drainage area the precipitation is in the form of snow. This accumulated snow produces a large run-off during the spring, and the melting ice from the glacier and the ice-capped mountains augment the run-off from precipitation during the summer. The area of Green Lake is estimated to be only 100 acres.

The following discharge measurement was made by G. H. Canfield:

August 12, 1917: Gage height, 3.82 feet; discharge, 377 second-feet.

Daily discharge, in second-feet, of Green Lake outlet at Silver Bay for 1917.

Day.	Jan.	Feb.	Apr.	May.	June.	July.	Aug.	Oct.	Nov.	Dec.
1	27	....	18	233	599	866	....	....	712	121
2	23	....	15	177	490	728	....	....	800	108
3	20	....	15	156	397	728	....	....	406	99
4	14	....	16	152	388	662	....	....	262	94
5	12	....	18	161	442	599	....	912	262	87
6	13	....	22	172	424	620	....	471	391	85
7	....	....	23	258	406	557	....	1,160	835	92
8	....	....	22	480	415	641	....	866	458	138
9	....	....	21	442	452	480	....	1,130	247	177
10	....	136	26	294	362	433	....	774	830	134
11	....	120	32	206	294	433	....	797	816	96
12	....	101	34	188	286	424	380	568	537	79
13	....	101	35	194	397	424	337	499	631	68
14	....	156	39	212	537	406	317	508	1,470	65
15	....	470	58	226	547	....	....	406	943	62
16	....	346	71	270	480	....	....	278	438	59
17	....	212	70	262	490	....	....	206	400	55
18	....	138	67	286	480	....	....	200	1,010	53
19	....	97	68	312	547	....	....	226	1,280	52
20	....	....	67	246	620	....	....	490	1,800	55
21	....	....	65	212	662	....	....	607	1,140	54
22	....	....	73	200	599	....	....	741	684	53
23	....	....	85	188	557	....	....	985	470	52
24	....	....	107	206	528	....	....	751	371	50
25	....	....	142	286	480	....	....	480	346	49
26	....	....	161	371	470	....	....	371	380	48
27	....	....	156	512	480	....	....	240	480	46
28	....	....	177	751	442	....	....	362	336	45
29	....	....	247	684	461	....	....	548	200	44
30	....	....	278	641	530	....	....	799	145	56
31	....	....	....	620	....	....	....	1,130	....	145

NOTE.—Water-stage recorder not working properly for the following periods: Jan. 1 to Feb. 9 and Feb. 20 to Apr. 1; discharge estimates from climatic records and comparison of hydrograph for this station with that for Baranoff Lake outlet, as follows: Jan. 7–31, 90 second-feet; Feb. 1–9, 110 second-feet; Feb. 20–28, 45 second-feet; Mar. 1–31, 50 second-feet; May 19–20, daily discharge estimated from maximum and minimum stages indicated by the recorder. Discharge estimated by comparison with records of flow for Baranoff Lake outlet as follows: July 15–31, 425 second-feet; Aug. 1–11, 400 second-feet; Aug. 15–31, 640 second-feet; Sept. 1–30, 620 second-feet; Oct. 1–4, 930 second-feet. Gage well frozen Dec. 22–28; discharge interpolated.

Monthly discharge of Green Lake outlet at Silver Bay for 1917.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	....	....	76.1	4,680
February	470	....	120	6,660
March	....	....	50	3,070
April	278	15	74.3	4,420
May	751	152	310	19,100
June	662	286	475	28,300
July	....	....	491	30,200
August	....	....	526	32,300
September	....	....	620	36,900
October	....	200	652	40,100
November	1,800	145	636	37,800
December	177	44	78.1	4,800
The year	....	....	343	248,000

BARANOF LAKE OUTLET AT BARANOF, BARANOF ISLAND.

LOCATION.—In latitude 57° 5′ N., longitude 134° 54′ W., at townsite of Baranof, at head of Warm Spring Bay, east coast of Baranof Island, 18 miles east of Sitka across island, but 96 miles from Sitka by water through Peril Strait.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—June 28, 1915, to December 31, 1917.

GAGE.—Stevens continuous water-stage recorder on right bank 700 feet below Baranof Lake and 800 feet above tidewater at head of Warm Spring Bay.

DISCHARGE MEASUREMENTS.—Made from cable across stream 100 feet below lake and 600 feet above gage.

CHANNEL AND CONTROL.—From Baranof Lake, at elevation 130 feet above sea level and 1,500 feet from tidewater, the stream descends in a series of rapids and small falls and enters the bay in a cascade of about 100 feet concentrated fall. The bed is of glacial drift, boulders, and rock outcrop. The gage is in an eddy 50 feet downstream from the foot of a small fall and 100 feet upstream from a riffle which forms a well-defined control.

EXTREMES OF DISCHARGE.—Maximum stage during year, 4.90 feet at 6 p. m. November 19 (discharge, 2,780 second-feet); minimum stage, 0.40 foot April 3 (discharge, 31 second-feet).

1915–1917: Maximum stage, 5.3 feet August 10, 1915 (discharge, computed from extension of rating curve, 3,350 second-feet); minimum flow estimated by discharge measurement and climatic data, 28 second-feet on February 13, 1916.

ICE.—Because of the swift current and flow of relatively warm water from the lake, the stream remains open.

DIVERSIONS.—The flume to Olsen's sawmill diverts from the stream 200 feet below gage only sufficient water to operate a 25-horsepower Pelton water wheel.

ACCURACY.—Stage-discharge relation permanent; not affected by ice. Rating curve well defined below 2,000 second-feet. Operation of water-stage recorder satisfactory except for short periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging discharge for equal intervals of day. Records good except for periods when recorder did not operate satisfactorily and for periods when water was frozen in well, for which they are fair.

The drainage area is rough and precipitous, and the vegetable and soil cover is thin, even on the foothills of the mountains. The run-off is rapid, and the ground storage is small. During a dry, hot period, however, the flow is greatly augmented by melting ice from several small glaciers and ice-capped mountains.

No discharge measurements were made at this station during the year.

Daily discharge, in second-feet, of Baranof Lake outlet at Baranof for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	64		45	36	352	930	1,280	590	420	668	590	208
2	61		43	33	321	788	1,100	668	392	695	448	177
3	59		45	31	294	651	1,050	640	384	1,280	345	153
4			46	34	288	615	930	568	370	1,280	294	137
5			42	36	279	615	855	545	342	1,140	291	122
6			44	37	288	615	820	545	327	695	291	116
7			48	37	330	615	788	545	309	1,380	376	110
8			46	37	590	615	788	545	300	1,100	384	112
9			44	36	695	615	695	545	276	1,100	339	108
10			42	37	545	545	668	545	264	855	464	104
11			40	42	432	496	695	590	261	820	755	96
12			39	51	366	480	695	545	545	668	695	91
13			37	57	352	568	725	492	678	568	725	86
14			35	59	388	725	668	460	640	500	1,330	81
15			34	69	440	788	640	500	855	448	1,050	76
16			37	80	460	755	668	725	668	380	615	71
17			52	86	460	725	725	1,050	980	336	500	67
18			57	92	468	725	695	1,100	1,650	309	890	63
19			57	108	500	788	788	1,540	1,380	306	1,840	59
20			56	114	480	890	820	1,170	1,230	400	2,000	69
21			54	110	412	930	755	820	1,100	532	1,230	70
22		78	55	108	380	890	668	1,010	1,180	695	820	65
23		72	60	113	376	855	640	1,230	930	890	590	63
24		66	50	129	388	820	615	930	640	788	620	61
25		60	57	175	452	820	615	668	480	590	480	59
26		55	62	183	568	755	590	590	444	460	464	57
27		52	57	201	725	725	545	930	934	362	545	55
28		48	51	222	930	725	522	1,050	2,000	330	388	53
29			46	285	1,010	725	492	855	1,430	380	303	50
30			50	352	1,050	788	444	615	930	432	245	65
31			37		1,010		464	488		800		90

NOTE.—Discharge estimated for following periods, because of unsatisfactory operation of water-stage recorder: Jan. 4–31 (80 second-feet) and Feb. 1–28 (100 second-feet) from weather records and by comparison with records of flow for streams in near-by drainage basins. Discharge Dec. 12–18 interpolated and Dec. 23–31 estimated by comparison with records of flow for Green Lake outlet.

Monthly discharge of Baranof Lake outlet at Baranof for 1917.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January			78.2	4,810
February			90.4	5,020
March	62	34	47.4	2,910
April	352	31	99.7	5,930
May	1,050	279	504	31,000
June	930	480	719	42,800
July	1,280	444	724	44,500
August	1,540	460	745	45,800
September	2,000	261	745	44,300
October	1,380	306	683	42,000
November	2,000	245	664	39,500
December	208	50	90.1	5,540
The year	2,000	31	434	314,000

SWEETHEART FALLS CREEK NEAR SNETTISHAM.

LOCATION.—In latitude 57° 56½′ N., longitude 133° 41′ W., on east shore 1 mile from head of south arm of Port Snettisham, 3 miles south of mouth of Whiting River, 7 miles by water from Snettisham, and 42 miles by water from Juneau. No large tributaries enter river between gaging station and outlet of large lake, 2½ miles upstream.

Drainage area.—27 square miles (measured on the United States Geological Survey topographic map of the Juneau gold belt, edition of 1905).

Records available.—July 31, 1915, to March 31, 1917.

Gage.—Stevens water-stage recorder on right bank 300 feet upstream from tidewater on east shore of Port Snettisham. Gage washed out by high water in November, 1917, and record from April 20 last with the gage.

Discharge measurements.—Made from cable across river one-fourth mile upstream from gage.

Channel and control.—From the outlet of lake at an elevation of 520 feet above sea level and 2½ miles from tidewater the river descends in a series of rapids and falls through a narrow, deep canyon. Gage is in a pool at foot of two falls, each 25 feet high, which are known as Sweetheart Falls; outlet of pool is a natural rock weir which forms a well-defined and permanent control for gage.

Extremes of discharge.—Maximum stage during period, 4.2 feet August 14, 1915 (discharge, computed from an extension of the rating curve, 1,420 second-feet); minimum flow, estimated from discharge measurement and climatic data, 15 second-feet February 11, 1916.

Ice.—Stage-discharge relation not seriously affected by ice.

Accuracy.—Stage-discharge relation practically permanent; affected by ice January 29 to February 16. Rating curve well defined between 40 and 1,300 second-feet, extended beyond these limits by estimation. Operation of water-stage recorder satisfactory except for periods indicated by breaks in record, as shown in footnote to daily discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph. Records excellent except for periods of break in record, for which they are fair.

In the fall and winter the run-off is small because the precipitation is in the form of snow and because of the small amount of ground storage; during a hot, dry period the low run-off from the ground and lake storage is augmented by melting ice from one glacier.

Discharge measurements of Sweetheart Falls Creek near Snettisham in 1917.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Mar. 9	C. O. Brown	0.32	48	May 25	G. H. Canfield	1.71	412
Apr. 24	.....do	.66	94	Sept. 14	.....do	1.71	410

Daily discharge, in second-feet, of Sweetheart Falls Creek near Snettisham for 1917.

Day.	Jan.	Feb.	Mar.	Day.	Jan.	Feb.	Mar.	Day.	Jan.	Feb.	Mar.
1	26	51	80	11	70	77	42	21	57	141	48
2	28	48	80	12	68	67	40	22	59	110	45
3	31	54	59	13	68	150	37	23	56	99	55
4	19	64	51	14	67	296	36	24	67	91	65
5	18	77	57	15	64	224	35	25	84	83	77
6	18	98	55	16	57	258	32	26	82	82	65
7	57	127	51	17	56	242	36	27	70	82	55
8	70	150	47	18	63	195	46	28	63	82	45
9	70	127	45	19	67	178	51	29	57	......	40
10	70	94	43	20	61	148	50	30	56	......	35
								31	54	......	30

Note.—Because of clock stopping or backwater from ice, discharge estimated from weather records at Juneau and from comparison of hydrograph for this station with hydrographs for Crater and Carlson creeks, Jan. 7–13, Jan. 29 to Feb. 16, and Mar. 23–31.

Monthly discharge of Sweetheart Falls Creek near Snettisham for 1917.

[Drainage area, 27 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
January	84	18	56.5	2.09	2.41	3,480
February	242	48	127	4.70	4.89	7,0[illegible]0
March	80	30	49.5	1.83	2.11	3,010
The period						13,500

CRATER LAKE OUTLET AT SPEEL RIVER, PORT SNETTISHAM.

LOCATION.—At outlet of Crater Lake, 1 mile upstream from the edge of tide flats at head of north arm of Port Snettisham, 2 miles by trail from cabins of Speel River Project (Inc.), which are 42 miles by water from Juneau.

DRAINAGE AREA.—11.9 square miles at outlet of Crater Lake and 13 square miles at mouth of stream at beach (measured on topographic maps of the Alaska Boundary Tribunal, edition of 1895).

RECORDS AVAILABLE.—January 23, 1913, to December 31, 1917.

GAGE.—Stevens water-stage recorder on left shore of lake, 100 feet upstream from outlet. A locally made water-stage recorder having a natural vertical scale and a time scale of 1 inch to 24 hours was used until replaced by Stevens gage June 29, 1916. The gage datum remained the same during the period. During the winter months, because of inaccessible location and deep snow, the operation of the gage at the lake was discontinued, and the stage read at staff gage in channel exposed at low tide at beach. The first gage at beach was set at an unknown datum and washed out in winter of 1915–16. Another staff gage was set at about the same location and used after November 24, 1916.

DISCHARGE MEASUREMENTS.—Made from cable across outlet of lake, 100 feet downstream from gage and 10 feet upstream from crest of first falls. The rope sling from which discharge measurements were first made was replaced in fall of 1915 by a standard United States Geological Survey gaging car, making more accurate measurements possible.

CHANNEL AND CONTROL.—The gage is on left shore of lake, 100 feet upstream from outlet where the stream becomes constricted into a narrow channel, the bed of which is composed of large boulders and rock outcrop, which form a well-defined and permanent control.

EXTREMES OF DISCHARGE.—Maximum stage during the year, 5.0 feet August 19 (discharge, 1,270 second-feet); minimum flow, 12 second-feet March 15–16 and April 13–15.

1913–1917: Maximum stage during the period, 5.9 feet August 13, 1915 (discharge, estimated from extension of rating curve, 1,680 second-feet); minimum flow, 5 second-feet February 1–13, 1916, estimated from one discharge measurement and weather records.

ACCURACY.—Stage-discharge relation permanent. Rating curve defined by 19 discharge measurements, 13 of which were made by employees of the Speel River Project (Inc.) and 6 by an engineer of the United States Geological Survey, and is well defined below and extended above 1,000 second-feet. Rating curve used January 1 to May 25 for staff gage at beach, fairly well defined. Operation of water-stage recorder satisfactory except June 30 to July 3, when gage clock was run down, September 13–16, 19–30, and November 1 to December 31. Discharge record January 1 to May 25 computed from gage-height records for staff gage at beach. Daily discharge May 26 to October 31 ascertained by applying to rating table daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of the day. Discharge September 13–16, 19–30, and November 1 to December 31 estimated by comparison with records of flow for Long River. Records obtained from gage at lake, good; those from gage at beach, fair; those obtained by comparison with records for Long River only roughly approximate.

Crater Lake is at an elevation of 1,010 feet above sea level and covers 1.1 square miles. The sides of the mountains surrounding the lake are steep and barren, and the tops are covered by glaciers.

Discharge measurements of Crater Lake outlet at Speel River, Port Snettisham, in 1917.

Date.	Made by—	Gage height.	Dis-charge.	Date.	Made by—	Gage height.	Dis-charge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Jan. 1	Grosseth and Hayes	1.12	33.6	Mar. 29	C. N. Hayes	0.98	27.3
9	.....do	1.43	44.8	31	.....do	.87	19.7
10	Gust Grosseth	.10	37.4	Apr. 5	.....do	.75	14.5
10	Brown and Hayes	1.36	44.6	10	.....do	.69	13.1
12	.....do	1.16	32.2	12	.....do	.69	12.9
17	Grosseth and Hayes	.96	20.9	18	.....do	.80	17.1
29	Gust Grosseth	.05	22.5	22	Brown and Hayes	.89	22.3
31	Grosseth and Hayes	.97	19.7	23	C. O. Brown	.88	21.2
Feb. 7	.....do	1.38	48.6	24	.....do	1.06	34.5
24	C. N. Hayes	1.22	39.0	25	C. N. Hayes	1.00	32.4
26	.....do	1.10	30.8	27	.....do	1.11	42.2
Mar. 2	.....do	.93	19.9	29	.....do	1.28	70
10	.....do	a.84	14.8	May 10	.....do	1.68	211
14	.....do	a.75	13.9	12	.....do	1.50	128
17	Brown and Hayes	a.69	13.4	16	.....do	1.54	136
24	.....do	1.17	44.4	24	G. H. Canfield	1.45	105
27	.....do	1.09	38.0	Dec. 7	.....do	b1.08	39

a Stage-discharge relation changed owing to blasting rocks out of channel.
b New gage and datum at same location as old gage at beach.

NOTE.—All discharge measurements except those made by Gust Grosseth Jan. 10 and 29 were made at the beach; gage heights referred to gage at beach.

Daily discharge, in second-feet, of Crater Lake outlet at Speel River, Port Snettisham, for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	37	21	20	19	65	304	402	697	223	186
2	30	18	20	17	60	280	487	642	198	231
3	27	22	20	15	60	245	642	416	184	408
4	25	28	19	15	60	241	547	316	183	443
5	24	32	19	15	65	304	472	272	184	338
6	46	39	18	15	100	350	388	265	191	282
7	69	46	17	14	150	306	472	272	194	517
8	58	53	16	14	200	253	443	282	191	502
9	50	47	16	14	270	223	327	282	189	710
10	46	41	15	13	211	200	293	293	192	517
11	39	36	16	13	150	183	304	362	221	675
12	33	37	17	13	125	193	375	362	414	416
13	30	38	14	12	129	229	388	316	....	429
14	26	60	14	12	132	269	350	293	....	293
15	25	82	12	12	136	362	402	429	....	212
16	23	78	12	13	140	338	429	648	....	143
17	21	74	13	14	130	304	472	955	402	105
18	25	71	15	17	140	327	723	885	780	90
19	28	68	16	28	145	443	692	1,050	....	90
20	32	60	24	26	150	416	562	1,070	....	86
21	41	54	25	24	120	362	429	724	....	90
22	39	48	32	22	100	388	338	728	....	87
23	37	43	39	28	105	362	338	815	....	103
24	36	36	45	29	108	338	532	594	....	101
25	45	33	43	30	118	350	610	375	....	90
26	40	30	40	36	127	338	594	293	....	84
27	36	26	37	42	167	316	444	709	....	70
28	32	24	32	54	200	316	327	955	....	70
29	30	....	28	67	221	304	267	698	....	94
30	27	....	24	70	241	316	229	416	....	106
31	24	....	20	....	280	....	381	280	....	203

NOTE.—Daily discharge for days when staff gage was not read during period Jan. 1 to May 25 estimated from weather records and records of flow for Long River. Daily discharge June 30 to July 3 estimated from maximum and minimum stages indicated by the recorder and records of flow for Long River. Records Jan. 1 to May 26 show discharge at beach; May 26 to Dec. 31 discharge at outlet of Crater Lake. Discharge estimated, because gage was not operating, by comparison with records of flow for Long River, as follows: Sept. 13-16, 330 second-feet; Sept. 19-30, 480 second-feet; Nov. 1-30, 250 second-feet; Dec. 1-31, 35 second-feet. Records for these periods only roughly approximate.

Monthly discharge of Crater Lake outlet at Speel River, Port Snettisham, for 1917.

[Drainage area 13.0 square miles at tidewater; 11.9 square miles at outlet of Crater Lake.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
January	69	21	34.9	2.68	3.09	2,150
February	82	18	44.5	3.42	3.56	2,470
March	45	12	22.5	1.73	1.99	1,380
April	70	12	23.8	1.83	2.04	1,420
May	280	60	142	10.9	12.57	8,730
June	443	183	305	25.6	28.56	18,100
July	723	229	441	37.1	42.77	27,100
August	265	265	539	45.3	52.23	33,100
September	....	183	361	30.3	33.81	21,500
October	710	70	251	21.1	24.33	15,400
November	....	....	250	21.0	23.43	14,900
December	....	....	35	2.94	3.39	2,150

NOTE.—Records Jan. 1 to May 25 show discharge at beach. Records May 26 to Dec. 31 show discharge at outlet of Crater Lake. See footnote to daily-discharge table.

LONG RIVER BELOW SECOND LAKE, AT PORT SNETTISHAM.

LOCATION.—One-half mile downstream from outlet of Second Lake, 1 mile downstream from outlet of Long Lake, one-half mile upstream from head of Indian Lake; 2½ miles by trail and boat across Second Lake from cabins of the Speel River project at head of the North Arm of Port Snettisham, 42 miles by water from Juneau.

DRAINAGE AREA.—33.2 square miles (measured on sheet No. 12 of the Alaska Boundary Tribunal maps, edition of 1895).

RECORDS AVAILABLE.—November 11, 1915, to December 31, 1917.

GAGE.—Stevens continuous water-stage recorder on right bank one-half mile below outlet of Second Lake.

DISCHARGE MEASUREMENTS.—At medium and high stages made from cable across river at gage; at low stages made by wading one-fourth mile downstream.

CHANNEL AND CONTROL.—At the gage the channel is deep and the current sluggish; banks are low and are overflowed at extremely high stages; bed smooth except for one large boulder. A rapid, 500 feet downstream, forms a well-defined and permanent control.

EXTREMES OF DISCHARGE.—Maximum stage during year, 7.35 feet at 1 a. m. August 20 (discharge, 2,900 second-feet); minimum stage, 0.28 foot March 26 (discharge, 37 second-feet).

1916–17: Maximum stage, 7.35 feet August 20, 1917 (discharge, 2,900 second-feet); minimum flow, 23 second-feet, February 13, 1916.

ICE.—Stage-discharge relation affected by ice during January, February, and March.

ACCURACY.—Stage-discharge relation permanent; affected by ice or poor connection between well and river January 3–6, 21, 22, January 27 to February 7, February 19–28, and April 15 to May 5. Rating curve fairly well defined between 50 and 400 second-feet and well defined between 400 and 2,000 second-feet. Operation of water-stage recorder satisfactory throughout year except January 18–19, February 22–27, June 23–28, July 28 to August 3, November 21–25, and November 30 to December 31. Daily discharge ascertained by applying to the rating table daily gage height determined by inspecting the gage-height graph. Records good except for stages below 400 second-feet, for which they are fair.

The area draining to Long River between Long Lake outlet and this station comprises only 1.3 square miles, including First Lake and Second Lake. Because this area is at a low altitude and has no glaciers the run-off per square mile from it is greater early in the spring but much less in summer than that from the area above Long Lake, which is partly covered by glaciers.

Discharge measurements of Long River below Second Lake, at Port Snettisham, in 1917.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Jan. 11	C. O. Brown	1.10	95	May 23	Charles Hayes	2.10	271
20	Grosseth and Hayes	.77	57	24	G. H. Canfield	2.10	277
Mar. 22	Brown and Hayes	.40	47.1	July 5	......do	4.56	1,190
Apr. 20	......do	.62	57				

Daily discharge, in second-feet, of Long River below Second Lake, at Port Snettisham, for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	81	77	85	57	......	680	908	1,580	660	506	470	154
2	73	73	77	67	......	680	1,090	1,550	582	408	377	130
3	69	68	72	57	......	600	1,280	1,110	530	885	276	120
4	56	64	70	49	......	620	1,330	908	502	998	216	118
5	53	60	61	51	......	720	1,180	780	495	863	222	114
6	63	130	57	52	263	720	1,040	740	492	660	227	112
7	133	198	54	52	303	680	1,090	740	498	1,180	488	109
8	183	222	51	51	380	620	1,020	760	492	1,260	399	105
9	119	129	50	49	464	565	840	760	478	1,600	298	103
10	102	103	49	49	412	502	760	760	478	1,330	318	100
11	92	91	48	48	318	467	760	862	478	1,600	530	99
12	82	82	45	48	295	488	840	908	495	1,720	526	98
13	75	106	45	48	303	548	840	840	660	1,040	620	96
14	69	179	43	48	332	620	800	800	840	780	1,410	95
15	66	263	42	......	326	720	862	1,020	1,100	600	1,520	93
16	59	196	40	......	315	700	908	1,380	1,180	422	930	91
17	73	179	40	......	309	680	1,020	908	1,230	306	620	88
18	96	164	41	......	326	720	1,360	1,960	1,630	276	975	86
19	118	157	42	......	350	862	1,410	2,360	2,370	276	1,460	83
20	77	150	43	......	362	862	1,260	2,580	2,110	306	1,960	82
21	74	143	44	......	318	840	1,040	1,750	2,370	234	1,300	81
22	71	136	45	......	290	885	885	1,810	1,900	232	1,000	81
23	68	130	41	......	268	840	840	1,990	1,340	309	800	80
24	75	123	49	......	268	780	1,020	1,630	908	303	670	79
25	130	116	53	......	309	760	1,130	1,160	640	276	550	78
26	104	109	37	......	362	760	1,160	1,410	640	271	460	77
27	99	103	48	......	428	740	1,040	1,460	565	182	408	77
28	95	97	46	......	488	740	885	1,990	582	182	332	76
29	91	......	54	......	530	720	760	1,630	760	284	250	76
30	86	......	73	......	582	730	660	1,130	680	335	192	76
31	82	......	62	......	680	......	840	820	......	582	......	76

NOTE.—Water-stage recorder not working properly or stage-discharge relation affected by ice or poor connection between well and river for following periods: Jan. 3–6, 18–19, 21–22, Jan. 27 to Feb. 7, Feb. 19–28; daily discharge estimated from weather records and comparison with records of flow for Crater Creek. Discharge estimated from weather records and by comparison with records of flow for Crater Lake outlet as follows: Apr. 15–31, 80 second-feet; May 1–5, 160 second-feet. Discharge June 23–28, July 28 to Aug. 3, and Nov. 21–25 estimated from maximum and minimum stages indicated by the recorder and comparison with records of flow for Crater Lake outlet and Speed River. Discharge Nov. 29 to Dec. 31 estimated from readings of staff gage Dec. 10, 19, and 28 and from weather records.

Monthly discharge of Long River below Second Lake, at Port Snettisham, for 1917.

[Drainage area, 33.2 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
January	183	53	87.6	2.64	3.04	5,390
February	263	60	130	3.92	4.08	7,220
March	85	37	51.9	1.56	1.80	3,190
April	....	....	66.5	2.00	2.23	3,960
May	680	....	335	10.1	11.64	20,600
June	885	467	695	19.4	21.64	41,400
July	1,410	660	995	30.0	34.59	61,200
August	2,580	740	1,290	38.9	44.85	79,300
September	2,370	478	923	27.8	31.02	54,900
October	1,720	182	652	19.6	22.60	40,100
November	1,960	192	660	19.9	22.20	39,300
December	154	76	94.6	2.85	3.29	5,820
The year	2,580	37	501	15.1	204.66	362,000

SPEEL RIVER AT PORT SNETTISHAM.

LOCATION.—At entrance of canyon one-fourth mile downstream from mouth of Long River, and 8 miles upstream from tide flats and the cabins of the Speel River Project (Inc.), which are at head of north arm of Port Snettisham and 42 miles by water from Juneau.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—July 1, 1916, to December 31, 1917.

GAGE.—Stevens continuous water-stage recorder 150 feet to the left of the constriction of the river at the entrance of the canyon. The gage is reached from cabins of the Speel River Project by trail to head of Second Lake, boat across Second Lake, trail to head of Indian Lake, boat across Indian Lake, trail down Long River and Indian River to canyon, and cable across river near entrance of the canyon—a total distance of about 7 miles.

DISCHARGE MEASUREMENTS.—At all stages made from cable having a clear span of 400 feet across river, one-half mile below gage and one-fourth mile below lower end of canyon.

CHANNEL AND CONTROL.—For several miles above the canyon the river flows in several channels through a wide, flat, sandy valley in which the channels are continually shifting. The river is constricted from a width of 500 feet to 75 feet at entrance of canyon. This constriction of channel and rock outcrop at entrance of canyon form a very sensitive and permanent control. The extreme range in stage is 28 feet. Above a stage of 22 feet part of the flow passes through a secondary channel (the bed of which is rock overgrown with brush) which begins near gage and rejoins main channel at lower end of canyon. Below a stage of about 4 feet (discharge, 920 second-feet) water from stream does not reach the well except by seepage through gravel and water in well does not assume the level of the water in river. At the gaging cable the bed of the river is gravel, with one large rock outcrop near middle of stream. The current is very swift and carries a large quantity of sand in suspension.

EXTREMES OF DISCHARGE.—Maximum stage during period of record, 21.5 feet, September 19, 1917 (discharge determined from an extension of the rating curve, 18,000 second-feet); minimum flow, 150 second-feet April 14, 1917, estimated by aid of discharge measurement March 25 and by comparison with record of flow of Long River.

ICE.—Ice does not form at control, but so much frost forms in gage shelter and on metal parts of gage that the gage does not operate satisfactorily during the winter.

ACCURACY.—Stage-discharge relation permanent, but for stages below 4 feet (920 second-feet) water from river does not reach gage well except by seepage through gravel. For low stages, therefore, water in the well does not assume the level of the water in the river and frequent measurements are necessary to estimate the flow. Rating curve fairly well defined between 1,200 and 10,000 second-feet; extended above 10,000 second-feet. Operation of water-stage recorder not satisfactory for periods indicated in footnote to daily-discharge table because of the frequent stopping of clock, due to the binding of paper-supply roll or to running down at times when ice on lakes was unsafe for crossing. Daily discharge ascertained by applying to rating table daily gage height determined by inspecting gage-height graph. Records fair for periods when gage was operating satisfactorily; poor for periods when clock was not running.

Discharge measurements of Speel River at Port Snettisham in 1917.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Jan. 13	C. O. Brown	1.82	302	Apr. 21	C. O. Brown	2.25	334
Mar. 25	do	.94	185	Sept. 15	G. H. Canfield	13.9	5,910

Daily discharge, in second-feet, of Speel River at Port Snettisham for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	410	500	165	180	1,040	3,530	6,100		3,800	5,500	2,720	500
2	410	500	165	180	980	3,330	6,100		3,800	5,500	2,470	500
3	410	500	165	180	950	3,280	6,100		3,800	5,500	2,270	500
4	410	500	165	210	920	3,530	6,100		3,800	5,500	2,050	500
5	410	500	165	210	920	3,710	6,100		3,280	5,500	1,910	500
6	410	500	165	210	980	3,590	4,690		3,230	5,500	1,770	500
7	410	500	165	210	1,380	3,380	5,770		3,230	5,500	1,980	500
8	410	500	165	210	1,630	3,600	4,900	5,060	3,180	5,500	2,230	500
9	410	500	165	210	1,700	3,600	4,370		3,180	5,500	2,050	500
10	410	500	165	210	1,630	3,600	4,550		3,130	6,800	1,940	500
11	340	500	165	210	1,420	3,600	4,310		3,130	8,050	2,230	500
12	330	500	165	210	1,350	3,600	4,620		3,250	5,220	2,310	500
13	290	500	165	210	1,520	3,600	4,490		3,300	4,900	3,040	500
14	265	500	165	210	1,740	3,600	4,490		4,000	4,430	8,050	500
15	260	500	165	210	1,770	3,600	4,980		5,300	4,250	4,690	500
16	340	500	165	210	1,700	3,600	5,140		5,060	4,070	3,590	500
17	340	500	165	210	1,630	3,600	5,390		5,140	3,890	3,180	500
18	340	500	165	210	1,630	3,600	9,600		9,050	3,650	5,140	500
19	340	500	165	210	1,630	3,600	6,000		16,000	3,530	9,400	500
20	340	500	165	210	1,580	3,600	6,000		6,800	3,330	12,100	500
21	340	500	165	340	1,420	3,600	6,000		6,800	3,180	6,800	500
22	340	500	165	340	1,380	3,600	6,000		6,800	3,040	4,760	500
23	340	500	165	380	1,420	3,600	6,000		6,800	2,900	4,010	500
24	340	500	185	540	1,560	3,600	6,000		6,800	2,810	3,530	500
25	340	500	185	620	1,800	3,600	6,000		6,800	2,720	3,230	500
26	340	500	185	700	2,190	3,600	6,000		6,800	2,230	1,800	500
27	340	500	185	700	2,430	3,600	6,000		6,800	2,510	1,800	500
28	340	500	185	700	2,680	3,600	6,000		6,800	2,430	1,800	500
29	340		185	950	2,950	3,600	6,000		6,800	2,390	1,800	500
30	340		180	1,040	3,180	3,600	6,000		6,800	2,350	1,800	500
31	340		180		3,530		6,000			2,820		500

NOTE.—Discharge estimated by comparison with records of flow for Long River as follows: Jan. 1-10; Jan. 16 to Mar. 23; Apr. 4-20; June 8 to July 5; July 19 to Sept. 4; Sept. 12-14; Sept. 20 to Oct. 9; Nov. 16-17; and Nov. 26 to Dec. 31. Braced figures show mean discharge for periods included. Discharge Aug. 1-31 estimated 8,500 second-feet.

Monthly discharge of Speel River at Port Snettisham for 1917.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January			356	21,900
February			500	27,800
March			170	10,500
April			329	19,600
May	3,530	920	1,700	105,000
June			3,570	212,000
July			5,670	349,000
August			8,500	523,000
September	16,000		5,120	305,000
October			4,230	260,000
November	12,100		3,550	211,000
December			500	30,700
The year	16,000		2,860	2,080,000

GRINDSTONE CREEK AT TAKU INLET.

LOCATION.—On north shore of Taku Inlet between Point Bishop and Point Salisbury, one-fourth mile west of mouth of Rhine Creek and 11 miles by water from Juneau.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—May 6, 1916, to December 31, 1917.

GAGE.—Stevens continuous water-stage recorder on left bank, 200 feet from tidewater, installed September 16, 1916. A Lietz seven-day graph water-stage recorder was used May 6 to June 17, 1916.

DISCHARGE MEASUREMENTS.—At all stages made by wading either in the channel on the beach, which is exposed at low tide, or 100 feet below gage at high tide.

CHANNEL AND CONTROL.—For a distance of one-fourth mile from tidewater the stream descends in a series of rapids and falls through a narrow, rocky channel. The gage is at upper end of a turbulent pool between two falls, the lower of which forms a well-defined control. When gage was installed, logs were jammed in channel near upper end of pool.

EXTREMES OF DISCHARGE.—1916–17: Maximum stage, 5.33 feet at 5 p. m., August 19, 1917 (discharge, estimated from extension of rating curve, 600 second-feet); minimum stage, −0.03 foot, estimated from climatic records to have occurred April 2, 1917 (discharge, 5 second-feet).

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined below 150 second-feet; extended above 150 second-feet by estimation. Operation of water-stage recorder satisfactory except for periods shown in the footnote to daily discharge table. Daily discharge ascertained by applying to rating table daily gage height determined by inspecting gage-height graph or for days of considerable fluctuation by averaging results obtained by applying to rating table mean gage heights for regular intervals of day. Records excellent except those for periods of break in record and discharge above 150 second-feet, which are fair.

Discharge measurements of Grindstone Creek at Taku Inlet in 1917.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Jan. 5	C. O. Brown	0.23	10.6	Sept. 7	G. H. Canfield	0.73	23
Feb. 14	do	.63	20.5	Nov. 13	do	1.24	68
June 13	G. H. Canfield	1.24	66	Dec. 7	do	.64	21

Daily discharge, in second-feet, of Grindstone Creek at Taku Inlet for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	14	6.8	7.7	5.4	35	100	76	119	......	43	46	28
2	13	6.6	7.5	5.0	27	76	71	78	......	40	37	26
3	12	6.4	7.3	5.5	24	65	79	61	......	46	31	24
4	11	6.4	7.1	11	25	80	128	51	......	72	39	23
5	10	6.6	6.8	11	25	109	98	47	......	65	21	22
6	9.0	8.1	6.6	7.7	27	131	111	47	......	70	52	21
7	8.6	23	6.4	6.4	39	110	205	43	25	168	60	21
8	16	17	6.2	5.7	53	88	115	43	24	105	43	20
9	18	11	6.0	5.5	51	82	84	36	23	99	41	19
10	11	11	6.0	5.5	42	70	73	35	22	94	60	18
11	10	11	5.9	5.5	36	63	65	43	22	80	70	18
12	10	11	5.9	5.5	40	63	82	37	22	67	70	16
13	9.4	12	5.7	5.5	44	67	65	30	29	65	80	14
14	9.0	25	5.9	5.5	49	78	63	32	25	61	196	14
15	8.8	83	6.4	5.9	47	112	60	49	42	55	129	14
16	8.4	44	7.9	6.6	46	90	60	71	29	49	60	14
17	8.2	18	8.1	7.5	46	79	74	70	35	49	46	14
18	8.4	12	8.1	8.4	47	97	118	61	82	50	151	14
19	8.8	11	8.1	9.8	50	107	93	358	118	57	214	14
20	8.2	11	8.2	12	60	95	94	......	83	68	202	14
21	7.9	10	8.2	16	51	96	77	......	67	53	151	13
22	7.3	9.6	8.2	33	46	95	64	......	59	63	102	12
23	6.8	9.2	8.2	21	43	76	78	......	63	70	85	13
24	6.6	9.0	8.1	25	47	68	95	......	53	67	67	13
25	8.2	8.8	7.9	32	52	66	103	......	49	57	75	12
26	9.0	8.4	7.5	32	57	62	128	......	50	49	96	12
27	8.6	8.2	7.1	31	62	61	83	......	46	42	112	11
28	7.7	7.9	6.8	35	65	58	66	......	49	46	62	11
29	6.9	......	6.4	46	70	56	56	......	46	41	39	11
30	6.9	......	6.0	44	72	57	50	......	48	63	33	10
31	6.9	......	5.7	......	142	......	79	......	......	53	......	10

NOTE.—Gage-height record Jan. 5 to Apr. 24 condensed so that it covered only about a foot of record paper; sticking of the supply paper on guides caused paper to feed too slowly; gage-height record for this period redrawn to normal time scale by aid of the peaks and troughs of the condensed graph, readings of staff gage Jan. 5, Feb. 14, and Mar. 16, and comparison with gage-height graphs for Sheep, Gold, and Carlson creeks. Discharge July 15 and 16 interpolated. Gage float caught Aug. 20 to Sept. 6; discharge estimated by comparison with records of flow for Carlson Creek as follows: Aug. 21-31, 125 second-feet; Sept. 1-6, 30 second-feet. Discharge Nov. 18 to Dec. 6 estimated from maximum and minimum stages indicated by the recorder and comparison of gage-height record for this station with that for Carlson Creek. Discharge Dec. 26-31 estimated from weather records.

Monthly discharge of Grindstone Creek at Taku Inlet for 1917.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	18	6.6	9.50	584
February	83	6.4	14.7	816
March	8.2	5.7	7.03	432
April	46	5.0	15.2	904
May	142	24	49.0	3,010
June	131	56	81.9	4,870
July	205	50	86.9	5,340
August	358	30	90.7	5,580
September	118	22	43.0	2,560
October	168	40	64.7	3,980
November	214	21	82.3	4,900
December	28	10	16.0	984
The year	358	5.0	46.9	34,000

CARLSON CREEK AT SUNNY COVE.

LOCATION.—At Sunny Cove on west shore of Taku Inlet, 20 miles by water from Juneau.

DRAINAGE AREA.—22.26 square miles (determined by engineering department of Alaska Gastineau Mining Co. from surveys made by that company).

RECORDS AVAILABLE.—July 18, 1916, to December 31, 1917.

GAGE.—Stevens water-stage recorder on left bank, 2 miles from tidewater; inspected several times a week by employees of the Alaska Gastineau Mining Co.

DISCHARGE MEASUREMENTS.—At high stages, made from cable across river one-half mile downstream from gage; at medium and low stages, by wading 500 feet upstream from gage.

CHANNEL AND CONTROL.—Above the gage the stream meanders in one main channel and several small channels through a flat, sandy basin about a mile long; just below gage channel contracts and stream passes over rocky falls that form a well-defined and permanent control. Point of zero flow, gage height −1.5 feet.

EXTREMES OF DISCHARGE.—1916–17: Maximum stage during the year, 6.65 feet at 4 p. m., August 19, 1917 (discharge, computed from extension of rating curve, 3,800 second-feet); minimum flow estimated from climatic data and hydrographs for streams in near-by drainage basins, 28 second-feet, April 4, 1917.

ICE.—Stage-discharge relation affected by ice January 1 to April 28 and December 1–31.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined between 90 and 2,400 second-feet, extended below 90 second-feet to point of zero flow and above 2,400 second-feet by estimation. Operation of water-stage recorder satisfactory except for a few days; as gage was visited several times a week, breaks in record caused by clock stopping were short. Daily discharge ascertained by applying to rating table daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of the day. Records good except for stages below 90 second-feet and above 2,400 second-feet, for which they are fair.

Discharge measurements of Carlson Creek at Sunny Cove in 1917.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Feb. 27	C. O. Brown	−0.08	[a] 52.8	Sept. 19	G. H. Canfield	4.53	1,970
May 1	do	.38	173	Nov. 13	do	1.30	363

[a] About 1.8 second-feet should be deducted to give flow past the gage. Stage-discharge relation affected by ice.

Daily discharge, in second-feet, of Carlson Creek at Sunny Cove for 1917.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	177	840	1,120	1,720	292	330	268
2	142	620	1,100	832	264	344	196
3	128	495	1,330	525	242	1,300	156
4	125	610	1,120	428	231	692	134
5	136	908	760	408	231	495	128
6	159	885	708	450	231	510	143
7	169	725	1,150	430	223	1,400	151
8	780	570	785	416	204	711	249
9	540	550	585	403	200	1,530	164
10	311	465	620	417	188	964	198
11	238	465	638	672	183	682	248
12	240	585	840	510	212	638	335
13	306	725	666	373	495	558	444
14	360	725	555	408	474	416	2,440
15	350	885	708	955	729	338	931
16	330	708	735	1,200	422	251	360
17	325	690	950	1,190	634	216	265
18	384	780	1,830	1,120	2,080	260	622
19	414	1,020	1,020	2,510	2,520	301	1,550
20	403	800	908	1,550	1,080	249	1,500
21	306	908	638	655	1,400	196	1,000
22	272	930	525	1,270	1,300	168	725
23	274	725	628	885	780	183	480
24	332	725	952	690	492	186	320
25	414	742	1,160	430	330	179	267
26	534	638	1,182	622	453	168	376
27	570	620	708	2,040	342	138	386
28	620	602	495	1,400	527	177	248
29	672	602	430	690	760	216	153
30	655	585	389	436	513	665	136
31	930	....	1,060	338	....	651	....

NOTE.—Because of clock stopping or backwater from ice, discharge estimated from weather records at Juneau and from comparison of hydrograph for this station with those for Gold, Sheep, and Grindstone creeks as follows: Jan. 1–31, 50 second-feet; Feb. 1–28, 80 second-feet; Mar. 1–31, 40 second-feet; April 1–28, 50 second-feet; Nov. 20–21, daily discharge; Dec. 1–31, 64 second-feet.

Monthly discharge of Carlson Creek at Sunny Cove for 1917.

[Drainage area, 22.26 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
January	....	....	50	2.25	2.59	3,070
February	....	....	80	3.59	3.74	4,440
March	....	....	40	1.80	2.08	2,460
April	....	....	60	2.70	3.01	3,570
May	930	125	374	16.8	19.37	23,000
June	1,020	465	704	31.6	35.26	41,900
July	1,830	389	848	38.1	43.93	52,100
August	2,510	338	838	37.6	43.35	51,500
September	2,520	183	601	27.0	30.13	35,800
October	1,530	138	487	21.9	25.25	29,900
November	2,440	128	486	21.8	24.33	28,900
December	....	....	64	2.88	3.32	3,940
The year	2,520	....	388	17.4	236.36	281,000

SHEEP CREEK NEAR THANE.

LOCATION.—At lower end of flat basin, above diversion dam for flume leading to Treadwell power house at beach, and 1 mile by tramway and ore railway from Thane.

DRAINAGE AREA.—4.57 square miles above gaging bridge (measured on United States Geological Survey map of Juneau and vicinity, edition of 1917).

RECORDS AVAILABLE.—July 26, 1916, to December 31, 1917.

GAGE.—Stevens continuous water-stage recorder on right bank at pool formed by an artificial control just below small island three-tenths mile upstream from diversion dam. Recorder inspected once a week by an employee of the Alaska Gastineau Mining Co.

DISCHARGE MEASUREMENTS.—At extremely high stages made from gaging bridge two-tenths mile downstream from gage; at low stages made by wading near bridge section. No streams enter between gage and measuring section, but seepage inflow varies from a small amount to 10 per cent of total flow, the per cent of inflow usually being large after periods of heavy precipitation.

CHANNEL AND CONTROL.—The station is near lower end of flat basin through which the stream meanders in a channel having low banks and bed of sand and gravel. An artificial control was built 2 feet below intake for gage well to confine the flow in one channel during high water and to insure a permanent stage-discharge relation. The spillway of the control at low stages consists of a timber, 16 feet long, set in the bed of the stream. During medium and high stages another timber, 8 feet long, bolted at top near right end, forms part of the control. A 3-foot cut-off wall is driven at upstream face of spillway. There are wing walls at each end and an 8-foot apron extends downstream from control.

EXTREMES OF DISCHARGE.—Maximum stage during year, 2.47 feet at 5 p. m., November 14 (discharge, from extension of rating curve, 580 second-feet); minimum stage, 0.15 foot April 7 (discharge, 0.8 second-foot).

ICE.—Ice forms in the channel above and below but not on the spillway of the control.

ACCURACY.—Stage-discharge relation permanent, but from August 19 to September 7 and September 20–24 intake pipe was obstructed with gravel, so that water surface in well was maintained at level of water surface in creek 10 feet upstream from control by seepage through gravel. Rating curve used August 19 to September 7 and September 20–24 based on three discharge measurements and is fairly well defined below 150 second-feet; curve used remainder of year based on 14 discharge measurements and is well defined below 250 second-feet. Operation of water-stage recorder satisfactory except for short periods indicated in footnote to table of daily discharge. Daily discharge ascertained by applying to rating table daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of the day. Records fair.

Discharge measurements of Sheep Creek near Thane in 1917.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Feb. 22	C. O. Brown	0.70	21.2	Sept. 7	G. H. Canfield	0.83	40
Apr. 7	do	.15	.8	22	do	[a] 1.18	115
May 3	G. H. Canfield	.78	38	26	do	1.02	83
June 5	do	1.17	125	Oct. 3	do	1.10	102
9	do	1.05	95	Dec. 22	do	.53	12.9
July 18	do	1.35	176				

[a] Intake pipe clogged; elevation of water surface in gage well higher than that in river.

Daily discharge, in second-feet, of Sheep Creek near Thane for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	10.8	2.8	17.0	2.2	41	106	98	161	63	62	53	40
2	10.4	2.6	16.5	2.0	38	85	90	90	52	64	53	41
3	9.6	2.8	15.5	1.8	36	70	101	70	48	96	40	36
4	8.8	3.0	15.0	1.8	36	90	128	64	39	110	31	33
5	8.0	3.0	14.5	1.4	36	125	98	66	40	111	41	30
6	7.6	3.0	14.0	1.0	38	139	96	66	42	118	39	27
7	8.8	3.7	13.0	1.0	55	120	176	64	42	222	75	26
8	9.2	7.0	12.5	1.0	88	101	111	60	43	155	55	24
9	9.2	11.2	12.5	1.2	75	93	88	57	43	236	47	22
10	9.2	14.5	12.0	1.2	62	78	80	60	43	152	75	20
11	8.8	15.5	11.2	1.2	53	75	73	73	43	125	80	19
12	8.0	15.5	10.4	1.4	49	75	78	66	45	125	101	18
13	6.7	15.5	10.0	1.4	53	83	66	55	93	106	125	17
14	5.8	17.5	9.6	1.2	60	93	64	55	64	98	387	16
15	4.9	74	10.0	1.2	62	111	73	85	96	80	176	15
16	4.3	62	9.6	1.2	62	88	85	117	62	66	111	15
17	4.0	47	9.2	1.4	64	85	90	111	80	57	93	14
18	3.7	32	8.8	1.6	68	96	167	93	185	55	147	14
19	3.4	27	8.0	2.2	70	111	120	219	216	51	265	13
20	3.2	25	7.0	2.8	68	96	117	208	270	64	265	13
21	2.8	23	6.4	3.7	55	96	96	122	134	51	191	13
22	2.6	22	5.8	5.8	49	98	78	124	124	57	147	12
23	2.2	22	5.5	9.6	47	83	96	114	108	64	120	12
24	1.6	21	5.2	16	43	80	101	100	86	60	93	11
25	2.8	20	4.9	25	62	80	114	80	73	55	78	10
26	4.0	20	4.6	30	75	73	161	82	85	45	80	10
27	3.4	19.0	4.0	31	70	70	104	149	68	43	85	9.6
28	3.2	18.0	3.7	38	60	70	83	144	73	45	68	9.2
29	3.2	......	3.4	43	70	68	73	94	90	41	53	9.2
30	3.0	......	3.0	43	75	70	66	77	78	84	38	9.0
31	3.0	......	2.6	......	141	......	109	67	......	83	......	9.0

Monthly discharge of Sheep Creek near Thane for 1917.

[Drainage area, 4.57 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
January	10.8	1.6	5.68	1.24	1.43	349
February	74	2.6	19.6	4.29	4.47	1,090
March	17	2.6	9.21	2.02	2.33	566
April	43	1.0	9.18	2.01	2.24	546
May	141	36	60.0	13.1	15.10	3,690
June	139	68	90.3	19.8	22.09	5,370
July	176	64	99.4	21.8	25.13	6,110
August	219	55	96.5	21.1	24.33	5,930
September	270	39	84.3	18.4	20.53	5,020
October	236	41	89.7	19.6	22.60	5,520
November	387	31	107	23.4	26.11	6,370
December	41	9.0	18.3	4.00	4.61	1,130
The year	387	1.0	57.6	12.6	170.97	41,700

GOLD CREEK AT JUNEAU.

LOCATION.—At highway bridge at lower end of Last Chance basin, 200 feet upstream from diversion dam of Alaska Electric Light & Power Co., and one-fourth mile from Juneau.

DRAINAGE AREA.—9.47 square miles (determined by engineering department of Alaska Gastineau Mining Co., from surveys made by that company).

RECORDS AVAILABLE.—July 20, 1916, to December 31, 1917.

GAGE.—Stevens continuous water-stage recorder on left bank at upstream side of highway bridge. A staff gage was installed September 19, 1916, on left wing wall of diversion dam 200 feet downstream and used in determining the time of changes in stage-discharge relation at the well gage.

DISCHARGE MEASUREMENTS.—At medium and high stages made from gaging bridge suspended, at right angles to current, from floor of highway bridge; at low stages, made by wading near gage.

CHANNEL AND CONTROL.—Station is at lower end of a flat gravel basin three-fourths mile long. For 20 feet upstream from gage the stream is confined between the abutments of an old bridge, and for 15 feet downstream it is confined between the abutments of present bridge. For a distance of 130 feet farther downstream the stream is confined in a narrow channel which is not subject to overflow. Because of the steep gradient of channel opposite and for 150 feet below gage, a short stretch of the channel immediately below the gage acts as the control. The operation of the head gates of flume at diversion dam, 200 feet downstream, does not affect the stage-discharge relation at gage, but the swift current during high stages shifts the gravel in bed of stream, thereby causing changes in the stage-discharge relation.

EXTREMES OF DISCHARGE.—1916–17: Maximum mean daily discharge, 600 second-feet, August 19, 1917; minimum mean daily discharge, 4 second-feet February 5 and April 1, 1917.

ICE.—Stage-discharge relation affected by ice in December.

DIVERSION.—Water diverted at several points upstream for power development is returned to creek above gage, except about 20 second-feet for 7 months (when there is a surplus over the amount used by the Alaska Electric Light & Power Co., which has the prior right) and 1 second-foot the remainder of the year used by the Alaska Juneau Gold Mining Co. The dam 200 feet downstream diverts water into the flume of the Alaska Electric Light & Power Co.

REGULATION.—No storage reservoir above station that regulates the flow more than a few hours in low water.

ACCURACY.—Stage-discharge relation changed during periods of high water; 11 discharge measurements and 3 simultaneous readings of water-stage recorder and staff gage at diversion dam were made during the period, by use of which rating curves have been constructed which are applicable as follows: January 1 to April 24, well defined; April 25 to August 19, well defined below and fairly well defined above 500 second-feet; August 20 to noon, September 19, poorly defined; September 19–21, poorly defined; September 22 to October 8, poorly defined; October 9 to December 31, well defined. Operation of water-stage recorder satisfactory, except for short periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to the rating table daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging the results obtained by applying to rating table mean gage heights for equal intervals of the day. Records fair.

Discharge measurements of Gold Creek at Juneau in 1917.

Date.	Made by—	Staff gage of dam.	Gage height.[a]	Discharge.	Date.	Made by—	Gage height.[a]	Discharge.
		Feet.	*Feet.*	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Feb. 23	C. O. Brown	....	0.34	19	Sept. 6	G. H. Canfield	1.23	58
Apr. 12	do	....	.01	5.4	20	do	2.39	255
30	do	−0.05	.80	65	25	do	1.65	116
May 5	do	....	.61	44	Oct. 4	do	1.88	151
8	do	.67	1.59	228	Nov. 6	do	.88	46
31	G. H. Canfield	1.03	1.98	350	20	do	2.46	439
Sept. 1	do	....	1.48	96	Dec. 21	do	.33	7.6

[a] Gage at highway bridge.

Daily discharge, in second-feet, of Gold Creek at Juneau for 1917.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	9.0	5.0	13	4.0	58	260	302	462	102	93	79	58
2	9.0	4.7	12	4.4	46	195	266	230	92	85	76	52
3	8.1	4.5	11.5	4.8	51	151	325	162	80	277	62	47
4	7.3	4.3	11.5	5.2	50	190	378	135	93	235	42	43
5	6.1	4.0	11	7.7	43	289	263	127	72	170	55	38
6	5.2	5.0	11	7.0	50	308	273	145	70	145	51	35
7	13	8.0	10	6.1	107	263	411	135	72	395	97	32
8	13	9.0	9.5	5.8	210	202	283	124	59	230	65	28
9	10	11	9.0	5.5	162	180	200	120	51	470	45	25
10	10	13	8.5	5.5	109	145	183	129	50	315	69	23
11	9.5	15	8.5	5.8	83	139	178	197	55	115	105	21
12	9.0	15	8.5	5.5	80	164	197	147	65	186	124	18
13	8.5	17	7.7	5.5	100	183	178	107	160	177	152	16
14	8.1	33	7.7	5.8	118	224	157	116	121	128	587	15
15	7.7	206	7.7	6.7	111	279	192	254	180	101	247	13
16	7.7	86	7.3	7.3	111	213	226	360	100	72	94	10
17	6.0	59	7.7	9.0	114	216	243	325	128	62	69	9
18	7.7	44	7.7	10	129	242	444	260	431	62	179	8
19	7.3	42	7.7	12	135	299	315	600	560	63	446	8
20	6.0	35	7.7	13	135	251	282	348	280	82	505	8
21	6.4	27	7.7	13	102	266	208	235	298	58	362	8
22	5.8	21	7.7	14	91	295	171	235	370	72	279	7
23	5.8	17	7.7	18	90	227	213	185	270	86	177	7
24	10	16	7.7	25	107	202	276	156	170	75	142	7
25	11	14	7.3	38	129	202	302	111	110	58	117	7
26	7.0	13	6.7	43	141	183	376	137	135	48	130	6
27	6.5	14	6.7	46	157	176	224	390	93	41	150	6
28	6.2	13	6.4	54	176	169	171	382	118	46	96	6
29	5.8	....	6.1	65	192	171	133	227	173	51	76	6
30	5.5	....	6.1	68	185	192	118	154	140	151	66	6
31	5.2	....	5.8	....	295	....	280	114	....	158	....	6

NOTE.—Discharge Jan. 3-6 and Jan. 22 to Feb. 11 estimated, because of clock stopping, from weather data and comparison of hydrograph for this station with that for Sheep Creek. Discharge Nov. 29 to Dec. 31 estimated, because stage-discharge relation was affected by ice, from weather records and one discharge measurement.

Monthly discharge of Gold Creek at Juneau for 1917.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January	13.0	5.2	7.85	483
February	206	4.0	27.0	1,500
March	13.0	5.8	8.42	518
April	68	4.0	17.3	1,030
May	295	43	118	7,260
June	308	139	216	12,900
July	444	116	251	15,400
August	600	107	220	13,500
September	560	50	157	9,340
October	470	41	139	8,550
November	587	42	158	9,400
December	58	6	18.7	1,150
The year	600	4.0	112	81,000

STORAGE RESERVOIRS IN SOUTHEASTERN ALASKA.

In 1917 reconnaissance was made of some of the streams in southeastern Alaska for the purpose of ascertaining the location, size, and elevation of lakes which may be used as storage reservoirs. The result of this investigation is shown in the table which follows. Elevations of the lakes above sea level were determined by aneroid barometer. Areas and distances were estimated.

Lakes available for storage reservoirs in southeastern Alaska.

Location of lakes.	Area.	Elevation above sea level.
	Acres.	*Feet.*
First lake above mouth of Mahoney Creek tributary to the west shore of George Inlet, Revillagigedo Island, one-fourth mile from tidewater	600	75
Second lake above mouth of Mahoney Creek, 2 miles from tidewater	180	2,000
A lake 2 miles upstream from mouth of unnamed creek tributary to Thomas Bay near Petersburg. Mouth of creek is 1½ miles north of Wind Point on west shore of Thomas Bay	400	400
First lake above mouth of unnamed creek tributary to head of Cascade Bay, Baranof Island, 300 feet from tidewater	100	80
Second lake above mouth of the foregoing creek, 1½ miles from tidewater at head of Cascade Bay		185
Lake 500 feet above mouth of unnamed creek tributary to southern entrance to Patterson Bay, Baranof Island	500	350
Lake 300 feet above mouth of unnamed creek tributary to head of west arm of Patterson Bay, Baranof Island	200	110
Lake 1,000 feet above mouth of unnamed creek tributary to head of Big Port Walter, Baranof Island	450	500
First lake, one-fourth mile above mouth of unnamed creek tributary to head of Port Armstrong, Baranof Island, near whaling station	200	260
Second lake above mouth of the foregoing creek, 1 mile from tidewater	400	265
A lake, 1 mile above mouth of unnamed creek tributary to head of Davidson Inlet, Kosciusko Island		520

MISCELLANEOUS MEASUREMENTS.

Miscellaneous discharge measurements in southeastern Alaska in 1917.

Date.	Stream.	Tributary to—	Locality.	Discharge.
				Sec.-ft.
Mar. 7	Mahoney Creek..	George Inlet, Revillagigedo Island.	One-fourth mile above first lake, 1¼ miles above beach on west shore of George Inlet 1 mile north of Beaver Falls.	2
Oct. 13	.....do..........	.....do..........	300 feet upstream from beach..........	95
Aug. 9	Unnamed creek..	Thomas Bay, mainland near Petersburg.	Mouth at low tide, 1½ miles north of Wind Point on west shore of Thomas Bay.	45
13	.....do..........	Suloia Bay, Chichagof Island.	Mouth at low tide, at head of small bay at north end of Suloia Bay.	18
14	.....do..........	Cascade Bay, Baranof Island.	At narrows near middle of first lake, half a mile from tidewater at head of Cascade Bay.	528
15	.....do..........	Patterson Bay, Baranof Island.	Mouth at low tide, at south entrance of Patterson Bay.	90
15	.....do..........	.....do..........	Stream at head of small cove near southern entrance of Patterson Bay.	[a] 50
16	.....do..........	.....do..........	Mouth, at low tide, at head of west arm of Patterson Bay.	110
17	.....do..........	Big Port Walter, Baranof Island.	Near outlet of lake on stream at head of Big Port Walter.	72
20	.....do..........	Davidson Inlet, Kosciusko Island.	Half a mile upstream from beach, at head of Davidson Inlet.	57

[a] Estimated.

MINING DEVELOPMENTS IN THE KETCHIKAN DISTRICT.

By Theodore Chapin.

INTRODUCTION.

The mineral output of the Ketchikan district was smaller than in 1916. Six copper mines were in operation and at two other places mills were in course of construction. A molybdenum lode was opened up near Shakan on Prince of Wales Island and is in course of development. One gold lode mine was operated for a part of the year, and gold and silver were also won from ores mined primarily for copper. The decrease in mineral production is due in part to the closing of the Mamie mine for some months during the year, in part to the failure of several small mines to make any production, and to a general decrease in production at nearly all the large mines.

PRODUCTION.

The gold, silver, and copper production of the Ketchikan district is shown in the following table:

Copper, gold, and silver produced in the Ketchikan mining district in 1915, 1916, and 1917.

Year.	Ore mined.	Copper.		Gold.		Silver.		Total value.
		Quantity.	Value.[a]	Quantity.	Value.	Quantity.	Value.[b]	
	Tons.	*Pounds.*		*Fine oz.*		*Fine oz.*		
1915	50,997	1,728,182	$302,431	1,727.38	$35,708	11,666	$5,914	$344,053
1916	76,111	3,526,703	867,569	2,769.61	57,253	19,361	12,640	937,462
1917	41,768	2,643,543	721,686	2,545.71	52,623	20,218	16,658	790,967

[a] Computations based on average price of copper in 1915 ($0.175), 1916 ($0.246), and 1917 ($0.273).
[b] Computations based on average price of silver in 1915 ($0.507), 1916 ($0.658), and 1917 ($0.824).

PRINCE OF WALES ISLAND.

KASAAN BAY AND VICINITY.

The Granby Consolidated Mining, Smelting & Power Co. (Ltd.) were the largest operators in the vicinity of Kasaan Bay. The Mamie mine, which was taken over by the Granby Co. in 1913, was closed down in the spring, and work was increased at the It mine. The ore bodies at the It occur in limestone near the contact of a large intrusive mass of quartz diorite and appear to have formed along the borders of an older dioritic dike now largely altered to epidote and other secondary minerals. The ore occurs as bunches of chalcopyrite in the altered dike and in the garnet rock formed by the replacement of the limestone. The power plant at the beach is equipped with a coal-burning boiler and air compressor. During the summer of 1917 a geologic map of the vicinity was made and prospecting was carried on which has led to the discovery of other surface outcrops.

The Goodro mine near the head of Kasaan Bay changed hands during the year and is now operated by the Salt Chuck Mining Co. No production was made during 1917. Development work was carried on, and a flotation mill that was started in the spring was completed before the end of the year. The mill is situated on the edge of the salt chuck. The ore is trammed from the mine to the mill, dumped into bins, passed over a grizzly into a crusher, and conveyed to a 75-ton bin, from which it is automatically fed to the ball-mill (using four sizes of chilled steel balls), whence it is taken by a bucket conveyor to the flotation tank for treatment. Mixtures of pine tar and creosote will be used. The fines are frothed off and go to settling tanks. A scraper belt conveys the coarse ore and gangue on bottom to a trommel. The oversize from trommel goes to the mill, and the undersize to a Deister-Overstrom table, where the ore is separated from the gangue. The capacity of the mill is 60 tons a day. The ore bodies are in gabbro, and the ore minerals are essentially bornite and chalcocite and lesser amounts of other copper sulphides. The ore also carries gold and traces of platinum and palladium. Mine assays of the concentrates show copper content as high as 81 per cent, indicating the presence of some native copper.

The Rush & Brown mine near the head of Karta Bay was operated on about the usual scale. The mine is developed on two lodes, a contact deposit of copper-bearing magnetite and a shear zone mineralized with copper sulphides. The new working shaft on the sulphide ore body has been deepened to the 350-foot level and drifts extended each side of the shaft. At the foot of the shaft is an ore lens from 2½ to 3½ feet wide composed of high-grade chalcopyrite together with a little pyrite. The entire width of the ore body at this level is not evident but in the upper levels it is from 4 to 14 feet and carries lenses of ore from 2 to 4 feet wide. The magnetite ore body is a contact deposit occurring along the border of intrusive diorite and altered sediments. It has been developed by a glory hole 100 feet deep and by workings on the underground levels for 250 feet in depth. In the fall of 1917 a boiler for a compressor plant was being installed.

The Paul Young prospect is about a mile southwest of the Rush & Brown mine on the first stream west of Iron Creek, at an elevation of 100 feet. It is about three-quarters of a mile northwest of the Venus claim and 2 miles from the coast. The deposit occupies a shear zone that strikes northwest nearly parallel to the stream and is exposed along the northeast bank. The only work done is surface stripping along the stream. The country rock is black slate, and the ore occurs in calcite veins that follow an intrusive porphyry dike. The calcite veins carry chalcopyrite and pyrite, and the bordering black slate is impregnated and veined with these sulphides. The width of the deposits is not evident, but they appear to extend beneath the creek bottom. The water was turned from its course for a short distance to uncover the deposit in the creek bottom, but the exposed rock is again covered with gravel. The deposit is exposed in the creek bank 250 feet lower down. Here the black slate is impregnated with pyrite and chalcopyrite which accompany tiny reticulating quartz veinlets.

The Rich Hill group of claims, comprising the Rich Hill, Magnet, Buffer, Ouray, Interval, and Red Snapper, has recently been opened up and is now being developed by the Granby Co., who have the property bonded. The claims are on Kasaan Peninsula, about 2 miles southeast of Kasaan. The main workings are on the Rich Hill claim and are confined to a single lens of very rich chalcopyrite ore. This lens was opened by a cut 50 feet long and 20 to 30 feet deep and yielded 160 tons of ore, which brought $20,000. The mineralized zone can be traced northwest and southeast of the open pit for some distance, and a short adit is now being run to cut the deposit below the floor of the open cut. On the adjoining claims prospecting has been carried on and a number of mineralized lodes have been opened. On the Ouray claim a wide contact zone extends from the beach to an elevation of 450 feet. The rock of this zone is a garnet-epidote-magnetite contact rock that carries chalcopyrite. Several openings have been made, which disclose bodies of commercial ore.

South of Karta Bay and northwest of Twelvemile Arm, including the vicinity of Hollis, is a mineralized area in which gold lodes predominate. The country rock is a complex assemblage of igneous and sedimentary rocks. The bedded rocks include tuff, breccia, schist, limestone, black slate, argillite, and graywacke, and are cut by a large boss of quartz diorite and associated porphyritic dikes. The lodes are quartz veins that occur in the intrusive and the bedded volcanic rocks as well as in the sediments.

A number of lodes have been opened in this gold quartz belt and several small plants installed, but none has made a large production. This strongly mineralized region has never received the attention which it has deserved, and no doubt will be developed in the future. One large company might consolidate a number of these small properties and operate them to advantage.

The only mine in this region that was operated in 1917 was the Dutton mine, on Harris Creek. The Crackerjack claims join the Ready Bullion and extend south and southeast. On the surface three veins are recognized, known as the lower, middle, and upper veins. These are approximately parallel and form a lode system following intrusive porphyry dikes that cut the black slate. The dikes and black slate strike N. 25° W. and dip 35°–60° SW. The principal work has been done at an elevation of 850 feet at No. 1 tunnel. This tunnel penetrates black slate for 300 feet, until it cuts the vein and drifts on it for 700 feet along the hanging wall of the porphyry dike. The quartz vein borders the porphyry for a footwall and follows a well-defined hanging wall, although above the wall occur parallel quartz stringers that cut pyritized slate, which is said to carry both gold and silver. The hanging-wall vein averages about 5 or 6 feet across and at one place is over 12 feet. Along the footwall of the dike a smaller quartz vein occurs. A number of other adits have been opened on this lode system.

The Lucky Nell claim, formerly known as the Flora and Nellie, is about 8 miles northwest of Hollis on the divide between Maybeso and Harris creeks, at an elevation of about 1,400 feet. The lode is a quartz fissure vein in porphyry. It is being developed by an open cut and two adits with a connecting winze. The principal work has been done on the lower adit, which has been driven along the vein for 500 feet. The vein strikes about N. 70° E. and dips 65°–80° SE. The vein is marked by two strong walls and averages about 4 feet in width. It is strongly metallized with pyrite, chalcopyrite, galena, and sphalerite, and is reported to carry high values in gold and silver.

HETTA INLET.

The Jumbo mine on Copper Mountain, near the head of Hetta Inlet, was operated on about the usual scale but experienced some difficulty in getting shipping facilities for the transportation of ore to the smelter. The mine is developed on large contact deposits along intrusive diorite that forms the footwall of the deposits. The hanging wall is crystalline limestone and metamorphosed sediments. The copper deposits are irregular-shaped bodies of chalcopyrite-pyrrhotite ore and chalcopyrite-magnetite ore set in a gangue of garnet, calcite, epidote, and diopside.

Copper prospects were being opened by Hal Gould on the south end of Sukkwan Island, about 3 miles northeast of Jackson Passage. The prospects occur in a zone of contact schist along the border of the large mass of intrusive granite that occupies the interior of the island. This schist has been prospected along the granite contact for about a mile, and throughout this distance shows more or less mineralization. In places it is impregnated with pyrite and in others is veined with stringers of chalcopyrite and pyrrhotite that follow the schistosity of the rock and cut across it. Only surface work had been done in 1917.

WEST COAST.

Development work was continued on the Big Harbor mine in Trocadero Bay, but no production was made.

A molybdenite lode has recently been opened up near Shakan. The property is three-quarters of a mile south of Shakan, at an elevation of 600 feet. The deposit has been known for several years, but when first discovered the molybdenite was mistaken for galena, and when the assays showed negative results for lead the property was abandoned. It has recently been relocated by W. H. Butt and bonded to the Alaska Treadwell Mining Co., who are installing machinery for its development.

The deposit is a fissure vein of quartz, about 6 feet wide, that cuts diorite but occurs near the contact of the diorite and tuffaceous sediments. The quartz vein contains considerable feldspar, especially along the footwall, where in places it resembles an igneous rock. The diorite from the footwall is also mineralized. The vein carries molybdenite and also chalcopyrite and pyrite. The vein strikes N. 85° E. and 25° S. The deposit is covered by two claims, the Alaska Chief Nos. 1 and 2.

Aside from the output of the Vermont Marble Co., who operated on about the usual scale, there was no production of marble. Development work was continued at the El Capitan quarry, on Dry Pass, for a part of the summer, and a number of diamond-drill holes were put down, aggregating 1,000 feet. The cores show white crystalline marble, with some beds of blue and some of black and white.

GEOLOGY AND MINERAL RESOURCES OF THE WEST COAST OF CHICHAGOF ISLAND.

By R. M. OVERBECK.

INTRODUCTION.

Chichagof Island is the northernmost of the larger islands of the Alexander Archipelago of southeastern Alaska. It lies in the northern part of the Sitka mining district between latitude 57° 22′ and 58° 17′ N., and between longitude 134° 50′ and 136° 33′ W. The geography, geology, and mineral resources of the west coast of the island are discussed in this report. The mining activity in the region during 1917 was as follows: One gold quartz mine was operating; steps were being taken toward opening another during 1917–18; and some development work was being done on a copper-nickel property north of Portlock Harbor, and on copper claims near the head of Pinta Bay. The metals found so far on the west coast are gold, copper, and nickel. An important gypsum mine is on the east side of the island outside the district discussed here.

Investigations of the geology of the west coast of Chichagof Island were made by C. W. Wright[1] in 1905 and by Knopf[2] in 1910. The reports and notebooks of these men have been consulted in the preparation of this report. This report, though supplementary to the earlier work, is in a sense preliminary to a study of the geology of the whole island.

During 1917, about two months of actual field work was done on the west coast of Chichagof Island, and another month was spent in carrying the work along Peril Strait, in making a trip to Sitka, and in making the run from Juneau to the field and from the field to Ketchikan. The field season extended from August 25 to November 9. The party consisted of one geologist and two boatmen. The chief object of the work was the investigation of deposits of the war minerals—copper and nickel. The areal geologic work, therefore, was incidental to the main object of the expedition. The shores of the island from Cross Sound to the head of Hooniah Sound were mapped geologically, but only a small amount of work could be done in the hills back from the shore because of an exceptionally early fall of

[1] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pp. 38–43, 1908.

[2] Knopf, Adolph, The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, 1912.

snow. The base maps used were charts of the Coast and Geodetic Survey, some of which have been published and some of which were being made during 1917. Capt. C. G. Quillian, of the U. S. S. *Patterson*, aided materially in the work of mapping by supplying base maps and the data which had been collected by his parties. Acknowledgments are also due to Mr. Stuart Fleming, Mr. J. Freeburn, Mr. Wm. Freeburn, Mr. T. Baker, Mr. W. H. Roessel, and Mr. Nordley.

GEOGRAPHY.

Chichagof Island and Baranof Island together form a triangular land mass which has its base along Cross Sound and Icy Strait and its vertex 150 miles south-southeast of the center of the base. Peril Strait, which in its narrowest part is only a quarter of a mile wide, separates Chichagof Island from Baranof Island. Lisianski Strait cuts Yacobi Island, the northwest corner of the land mass, from Chichagof Island. Chatham Strait, a long fiord about 7 miles wide, runs along the east side of the island, the Pacific Ocean is on the west, and Cross Sound and Icy Strait are on the north. Chichagof Island is irregularly shaped; its greatest dimension, from northwest to southeast, is about 80 miles. The fiords, Lisianski Inlet, Idaho Inlet, Port Frederick, Tenakee Inlet, Peril Strait, Hooniah Sound, Slocum Arm, and Lisianski Strait, penetrate far into the island and give it a very long shore line. The straightness of these fiords and the parallelism of some of them is a noticeable feature of the map of the island. Two types of shore line are also evident on the map—one the ragged, island-fringed outer coast; the other the straight, relatively unindented shores of the fiords. The water along the outer coast is comparatively shallow, and 16 miles offshore is only 600 feet deep. Along the straight fiord shores the 600-foot depth contour is at most places not more than half a mile from shore. Navigation near the outside coast is somewhat hazardous, owing to the numerous rocks and reefs, but a detailed chart of the southern part of the coast has been published and one of the northern part is being prepared.

The west coast region of Chichagof Island is extremely rugged. The mountains rise steeply to a general elevation of about 2,300 feet and here and there a peak rises to a height of more than 3,000 feet. The mountain slopes are precipitous and in many places give foothold to only the most scanty vegetation. Countless lakes fill the valleys and the hollows between the ridges. Streams are numerous, and owing to the heavy rainfall are large compared to the size of their drainage basins. Most of the streams head in lakes and run over series of waterfalls into the sea.

A prominent physiographic feature of the west coast of the island is the coastal plain, which extends from Cross Sound to Khaz Head at the entrance to Slocum Arm. This plain at Nickel is about 2 miles wide, and has a general elevation near the shore of less than 100 feet and a maximum elevation of about 300 feet. The plain consists of rounded hills and low knobs, which rise above a terrain of swamps and small ponds. The land slopes gently upward toward the inner edge of the plain and then rises abruptly to elevations of over 2,000 feet. A scant growth of jack pine covers the plain in some of its drier portions, and a fair growth of spruce and hemlock covers most of the higher hills. Just south of Nickel this plain leaves the main part of the island, and it is continued in the islands offshore southward to Khaz Head, beyond which the mountains descend steeply into the sea. A continuation of the coastal plain is found beneath the sea in the coastal shelf, which extends offshore for about 16 miles, beyond which the sea bottom descends steeply in the next 4 miles to a depth of 3,300 feet.

The long, narrow arms of the sea, such as Slocum Arm, Lisianski Inlet, Hooniah Sound, and Tenakee Inlet, are typical fiords. The sides are straight and steep, and the water reaches depths such as are not again encountered for 16 miles offshore. Slocum Arm, for example, is nearly 700 feet deep. This fiord shows another characteristic of fiords in that it has a deep central portion and a relatively shallower portion, or threshold, near its entrance. Broad, low valleys extend from the head of the fiords. The one at the head of Slocum Arm was once selected as a mail route, so that mail might be carried from Sitka to Chichagof without necessitating an outside trip. Low valleys connect the heads of Lisianski Inlet with Hooniah Sound and Port Frederick with Tenakee Inlet. Small streams enter all these fiords at their heads. Deep submarine channels can be traced in the submerged coastal shelf for some distance from the entrance of these fiords. Such channels were noted at the entrance to Peril Strait, Slocum Arm, and Lisianski Strait.

A view of the west coast of the island from several miles out at sea shows a number of broad valleys whose ends appear to be shut off from the sea by a relatively low barrier. A near view of one of these valleys north of Nickel from the mountains surrounding it shows the whole floor to be occupied by a lake of apparently great depth. The barrier is a low row of hills about 700 feet high. A stream runs from the lake to the sea over a series of waterfalls. Such a valley, if drowned, would form a typical fiord with its steep sides, its deep central portion, and its threshold, or barrier, at its entrance.

The population of Chichagof Island is small, possibly 800, white and native. Chichagof, the only town on the west coast, has a population of about 200. Tenakee is a health resort on the east side of the island. Gypsum, a mining camp on the east side, has a population of about 50. Hooniah is a native town at the entrance to Port Frederick. There are canneries at Hooniah, on Ford Arm, and

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at Chatham; and new ones are being built at Stag Bay and at Port Althorp. Sawmills have been installed on Suloia Bay and in Pavlof Harbor. Logging is carried on in a small way, for timber is needed in driving fish traps, making boxes, and timbering mines.

Weekly boat service connects the towns on the east and north sides of the island with Juneau. The Chichagoff Mining Co. operates a boat between Chichagof and Juneau, which carries a few passengers and which makes trips about once a week. Sitka, on Baranof Island, is a port of call for some of the larger steamers, and has besides a regular weekly service to Juneau. Motor boats may be hired at Juneau and at Sitka to make the trip to Chichagof.

Prospecting on the west coast of Chichagof Island should be carried on from a motor boat, for the many arms and fiords make much of the island accessible from a small boat. The shores of the island have already been rather extensively prospected, but the country a short distance back from the shore seems to be relatively unexplored and unknown. The west coast of the island is rocky, and the weather is often stormy, but by those with local knowledge of the waters much of this coast may be examined from the smooth water behind the islands. In about 50 miles of coast, from the head of Slocum Arm to the southwest entrance to Lisianski Inlet, only about 8 miles of outside water need be traversed. Almost any point within the island could be reached on a two days' trip.

Timber is in general not abundant in the western part of Chichagof Island. The character and abundance of timber, however, depends on local conditions. Timber line lies anywhere from 1,500 to over 2,000 feet in elevation. Two conditions restrict the growth of the trees, the precipitousness of the slope and the marshiness of the ground. The more central portion of the island, visible from the high peaks near the shore, is almost barren of trees. Much timber near enough to the shore to be dropped into the water has been already cut. Timber for the Chichagoff mine and for the sawmill in Suloia Bay comes from Baranof Island. Spruce, hemlock, and cedar are the principal trees, and their height, thickness, and soundness vary greatly in different localities.

The climate of the region is cool and moist, and precipitation is frequent and heavy. No weather records have been kept for the west coast of Chichagof Island, and since there are great seasonal and local variations in temperature and precipitation, the observations that extend over only a few seasons are of little value. Although the average annual precipitation at Sitka, for instance, is about 88 inches, during the summer of 1917 there was a precipitation in one month of over 23 inches.

The game on the island should furnish the prospector, at certain seasons of the year, with a considerable part of his food supply.

The principal large game is deer and bear. Deer are very plentiful. Minks seem to be rather plentiful, for a number of them were seen during the summer of 1917. Ducks and geese are abundant during certain seasons.

GEOLOGY.

PRINCIPAL FEATURES.

The geology of the west coast of Chichagof Island is complex. This complexity is the result largely of extensive intrusion, which has metamorphosed the rocks cut by the intrusive bodies and has complicated their structure. Both dynamic and contact metamorphic rocks are found along the coast north of Dry Pass and along Peril Strait; dynamic metamorphic rocks prevail in Portlock Harbor and on Slocum Arm. The dynamic metamorphism is probably directly related to the intrusion of the larger igneous bodies. The geology of the island will be discussed under the following heads: (1) Undifferentiated metamorphic rocks; (2) graywacke; (3) igneous rocks; (4) development of the topographic features. The rocks of the undifferentiated metamorphic series are sheared conglomerate, limestone, argillite, tuff, flow rock, and intrusive rock, and several types of schist. No determinable fossils were found in these rocks; and although the rocks constituting this series may be of different ages, they are probably older than Jurassic or Lower Cretaceous. The graywacke series consists of graywacke, of some slaty and argillaceous beds, and of a little greenstone. The igneous rocks are both intrusive rocks and flow rocks. Granite, quartz diorite, diorite, alaskite, aplite, hornblende gabbro, norite, greenstone, and possibly some andesite are the types of rock represented. Quaternary deposits are practically absent, but the results of the action of the ice are remarkably well shown by the topographic features.

UNDIFFERENTIATED METAMORPHIC ROCKS.

DISTRIBUTION AND CHARACTER.

The undifferentiated metamorphic rocks occur on Lisianski Strait and Inlet, in the bays on the east side of Portlock Harbor, and at places on Slocum Arm and on Peril Strait. (See Pl. II.) The quartz-mica schist at the south entrance to Lisianski Strait (at Canoe Pass) and the rocks along the seashore from Canoe Pass to Dry Pass are mapped as graywacke, because gradations from graywacke into these rocks can be traced, and these rocks consequently are believed to be the metamorphic equivalents of the graywacke. The rocks of the east and west shores of the north end of Lisianski Strait and those along Peril Strait and Hooniah Sound, which are of somewhat different appearance from the rocks along the outer coast, may be of different age.

Under the heading of undifferentiated metamorphic rocks will be considered all those rocks that seem to underlie the graywacke. Metamorphosed sedimentary, volcanic, and intrusive rocks are included in the group, but at most places it is difficult and at many places impossible to tell whether the rock was originally sedimentary or igneous. The rocks in their present metamorphosed state are chlorite schist, hornblende schist, schistose greenstone, quartz-mica schist, schistose limestone, sheared conglomerate, and tuff. The chlorite schist, hornblende schist, and schistose greenstone are green and at some places show contorted banding. The quartz-mica schist is a fine-grained dark-brown rock (gray on weathered surface) which breaks into flat pieces, and the original bedding is represented by wavy bands of slightly different shades of brown. The schistose limestone is dark blue where impure and white where pure; the impure variety shows banding and some augen texture, and the white limestone, or marble, is greatly fractured but does not show banding. The sheared conglomerate have augen texture. The tuffs are red, gray, and nearly black, and show shearing and confused and contorted banding.

Green rocks—hornblende schist, chlorite schist, and sheared greenstone—are numerous in the group of the undifferentiated metamorphic rocks. They occur wherever these rocks are found but are particularly abundant in Portlock Harbor. Most of the rocks of Portlock Harbor are sheared greenstone, although in the field it is not always possible to tell the altered greenstone from a green conglomerate or a green graywacke. Some of the greenstones are seen under the microscope to be very amygdaloidal, and these are probably flows; others are porphyritic and fairly coarse grained and may represent either flows or intrusives. Chlorite is the most abundant green mineral to form and in the amygdaloidal greenstones both chlorite and epidote fill the amygdules. Calcite is fairly abundant as an alteration mineral but is not nearly so abundant in these rocks as in the altered greenstones of the Eagle River region. The green schist at the Snowball prospect consists of chlorite and quartz, and its original nature can not be told. The dark-green rocks at the entrance to Lisianski Strait, in Canoe Pass, and near Porcupine Harbor probably represent altered basic intrusives. The green rocks at the head of Sister Lake and at the head of Deep Bay may be greenstone. The light-green chlorite schist at the entrance to Stag Bay and on Soapstone Point are highly altered rocks and do not preserve enough of their original characteristics to enable a definite determination to be made. The rocks on Soapstone Point somewhat resemble greenstones in texture. Variegated black and green rocks were seen at a number of places, but no satisfactory identification of them has yet been made. The apparent abundance of green rock is believed to be due partly to the action of sea water on the rock. At many places where green rocks are exposed at the water line, gray rocks occur in outcrops away from the water line.

The rocks along the shore from Dry Pass to Canoe Pass are chiefly dark-colored schists of rather fine grain and of uniform appearance, in which an abundance of mica (mainly biotite) has developed and in which quartz is also very abundant. At places the typical metamorphic minerals, such as andalusite and corundum, occur. These schists weather light gray and tend to break into rather smooth blocks. They do not show extensive crinkling, such as is seen in some of the other schists. The gradation of this type of schist into the rocks of the graywacke series can be traced along the shores of Dry Pass, and there can be little doubt that this schist represents the product of the alteration of graywacke, and as such it is indicated on the map (Pl. II). A similar type of alteration was found on the outer sides of Hill Island and of Peel Island.

There are at least three beds of limestone in the rocks of the undifferentiated series. One bed, about 50 feet thick, more or less, occurs at the mouth of Didrickson Bay and on both sides of Deep Bay; a thinner bed of dark-bluish impure limestone, in which indeterminate fossils were found, lies north of the entrance to Didrickson Bay and again just within the mouth of Deep Bay. A thin bed of limestone lies close to the contact with graywacke, both in Portlock Harbor and in Slocum Arm. A rather thick bed of limestone occurs on the ridge that runs between Davison Peak and Baker Peak and at the head of Pinta Bay. This bed of limestone can probably be correlated with the so-called limestone "dike" that stretches apparently uninterruptedly from Baker Peak to White Mountain. Marble was found on Peril Strait near Poison Cove, in Ushk Bay, Patterson Bay, and at the head of Hooniah Sound.

The schistose rocks near the north end of Lisianski Strait are mostly obscure, but they are thought to be in large part of sedimentary origin. They are dark and are extensively cut by dikes and by rather abundant quartz and calcite stringers. The rocks along Peril Strait are somewhat similar in appearance, although these are known to be partly sedimentary because of the presence of limestones. At most places it is difficult to differentiate these rocks from the igneous rocks with which they are associated. It would seem that these rocks might be of different age from the rocks of Portlock Harbor, both because they are of somewhat different appearance and because they lie to the east and apparently under the beds of Portlock Harbor.

Many of the gray schistose rocks are indeterminate in character, but some of them are closely associated with flow rocks, and these are believed to be in part tuffs. A rock of this kind from Pinta Bay is seen under the microscope to consist of crushed pieces of fine-grained igneous rocks.

The metamorphic rocks are probably of two types—dynamic-metamorphic rocks and contact-metamorphic rocks. Weathering, as a type of metamorphism, will not be discussed here. By dynamic metamorphism is meant alteration in the rocks, as originally deposited or intruded, brought about by the action of differential pressures. Under differential pressure rock cleavage is developed and new minerals are formed in the original rocks. The rocks consequently lose much of their original character, and rocks entirely different in color, texture, and mineral composition are formed. It is impossible in many specimens to determine what the original character of the rocks really was. In contact-metamorphism changes in the rocks intruded by an igneous body are brought about by pressure due to the intrusion, by rise in temperature, and by addition of material from the igneous body. The results of contact metamorphism and dynamic metamorphism are commonly the same; so that it may be impossible to tell whether a specimen is the result of one or the other process. No attempt has been made here to differentiate the two types.

In the metamorphic rocks under discussion chlorite is one of the most abundant secondary minerals formed, but hornblende, mica, corundum, and staurolite are locally abundant. Schistosity has developed extensively, and where bedding can be recognized it is approximately parallel with the schistosity. Bedding was seen in the quartz-mica schist and in the sheared conglomerates and limestone.

These rocks are naturally faulted and jointed, and secondary cleavage has developed. Faulting was noticed at the entrance to Black Bay. Joints or secondary cleavage planes have at places formed rather extensively, perpendicular to the schistosity. The dip of the schistosity and of the beds at most places on Slocum Arm and in Portlock Harbor is steep toward the southwest; the strike is nearly northwest. Along Lisianski Strait the dip of the schistosity is toward the northeast, and the strike varies between northwest and north. Even at the contact with the batholith the dips are northeast and hence toward the batholith. Along Peril Strait the beds are extensively intruded by bodies of igneous rock, and, as might be expected, strikes and dips differ greatly in direction and amount from place to place.

The present structure of the rocks is thought to be due to the intrusion of a great mass of granodioritic rock on the island, which, in forcing its way up through the rocks, squeezed and folded them. The rocks at most places dip away from this batholith. The apparently anomalous dip of the rocks along Lisianski Strait may have been caused by a still later intrusion of igneous rock represented by the dioritic intrusion at the entrance to the strait or it may have been caused by slumping at the edge of the batholith.

AGE AND CORRELATION.

Rocks of different ages are probably included in the group of undifferentiated metamorphic rocks. No determinable fossils were found in these rocks, and their relationships to rocks of known geologic age are not everywhere clear; consequently their position in the geologic column can not be assigned with any degree of certainty. At all places except one these rocks appear to underlie the graywacke; but as the rocks at this one place where they overlie the graywacke are lithologically similar to the rocks that everywhere else underlie the graywacke, it is assumed that faulting has occurred. At most places transitional beds lie between the typical metamorphic rocks and the typical graywacke. Structurally the two groups appear to be conformable, for the strikes and the dips are the same in both. The underlying beds seem to be more metamorphosed than the graywacke, but metamorphism is a function of the original character of beds that are altered as well as of the intensity of the metamorphosing forces. Very hard quartzose rocks like sandstone would probably undergo less change than the soft and relatively complex volcanic rocks and shaly and calcareous sedimentary rocks. These highly metamorphosed rocks, too, lie nearer the batholith, which is thought to be the cause of much of the metamorphism, than the graywacke. Nothing definite can be known about the relations of the metamorphosed rocks of Lisianski Inlet and Peril Strait to the metamorphosed rocks that immediately underlie the graywacke. The two groups are lithologically different, but this difference may be due either to an original difference in type or to more intensive metamorphism. If the beds along the outer part of Chichagof Island are part of the west limb of an anticline [1] the beds on Peril Strait and Lisianski Inlet, which lie nearer the center of the anticline, would be older than the beds of Slocum Arm and Portlock Harbor and probably of a different geologic age.

Lithologic correlation of these rocks with the rocks of other districts may be suggestive but can not be of great scientific value. In the Juneau district [2] is a series of tuffs, slates, flows, and limestone in which Triassic fossils have been found. Chapin [3] correlates some of these rocks of the Juneau district with the beds along the east side of Gravina Island and some of them with the rocks along the west coast of Gravina Island. The beds along the east side of Gravina Island are thought to be of Triassic and Jurassic age and those along the west coast are of Triassic age. The lithologic similarity of the sections of the Juneau district, of Gravina Island, and of the west coast

[1] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, p. 38, 1918.

[2] Brooks, A. H., unpublished notes.

[3] Chapin, Theodore, unpublished notes.

of Chichagof Island is at once evident. Chapin [1] separates the rocks that immediately underlie the graywackes of Gravina Island into two parts—"a lower series of purely igneous material, mainly coarse pyroclastic rocks and breccias, and an upper series of mixed water-laid tuffs and black slates and limestone, with porphyritic basic rocks of similar composition, evidently partly intrusive and partly explosive." [2] In Portlock Harbor the rocks near the contact are chiefly water-laid and those in the bays are most generally igneous. Tentatively, then, the rocks that underlie the graywacke on the west coast of Chichagof Island are correlated with the rocks that underlie the slate and graywacke of Gravina Island and which are placed by Chapin [3] in the Upper Triassic or Jurassic. The Wrights,[4] however, correlate the series of slate, greenstone, lava, tuff, and other material, on the west coast of Baranof and Chichagof islands, with lithologically similar rocks on Douglas Island, Cleveland Peninsula, and Gravina Island which they class as of Permian or Pennsylvanian age. To the north of Icy Strait, in Glacier Bay, the Silurian is represented by great thicknesses of limestone which are underlain by a thick argillite series of rocks. No thick limestones and no great amount of argillite were seen on the west coast of Chichagof Island. On the east side of Chichagof Island the lower Carboniferous is represented by a thick series of limestone of a distinctive character. No rocks of this type were seen here. These facts do not assist much in determining the age of the rocks, but they at least indicate possible correlations.

GRAYWACKE.

DISTRIBUTION AND CHARACTER.

Graywacke extends along the west coast of Chichagof Island from Peril Strait to Dry Pass. The term graywacke is used here in the sense of a group of rocks in which graywacke is the prevailing rock type. North of Dry Pass the graywacke has been metamorphosed to a quartz-mica schist; south of Peril Strait it continues beyond the region mapped. The graywacke proper forms a band that has a maximum width of about 5 miles, an average width of 3 miles, and a length of 35 miles. The actual width of this band may be greater, for on its western side it passes beneath the sea. The metamorphic graywacke, or quartz-mica schist, extends from Dry Pass to Lisianski Strait, the northern limit of the area mapped, a distance of 7 miles. Exposures of these rocks are almost continuous along the shores within the belt. The outer coast from a point about a mile south

[1] Chapin, Theodore, The structure and stratigraphy of Gravina and Revillagigedo Islands, Alaska: U. S. Geol Survey Prof. Paper 120-D, pp. 83-100, 1918.

[2] Idem, p. 95.

[3] Chapin, Theodore, op. cit.

[4] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, p. 35, 1908.

of Khaz Head to Leo Anchorage could not be approached because of stormy weather, but from its general appearance and from the reports of prospectors it is believed to form a part of the graywacke area and is so mapped.

In the general group term "graywacke" are included, besides graywacke, some slate, argillite, conglomerate, and greenstone. Graywacke is naturally the prevailing rock type, and the other types occur in relatively small amount. Uniformity in appearance characterizes the outcrops of these rocks, which at most places are weathered a somber reddish brown, greenish gray, or ash-gray. The rocks are massive and are greatly fractured and jointed. Where the rather coarse sandy graywacke predominates bedding can rarely be detected, but where the rocks are argillaceous parallel bedding is fairly common. Thin stringers of argillitic material run through the massive graywacke, and these weather out and allow the graywacke to break down into rather large lenticular pieces. At other places series of parallel joints are common, and here the graywacke breaks into large flat-sided blocks.

Variations in outcrop from the one just described naturally exist. In places the beds are fine grained, sandy, and argillaceous, and in these places a type of ribbon structure occurs which is formed by an alternation of sandy and argillaceous beds, an inch or less thick, of somewhat different color. Along the southwest side of Slocum Arm the rocks are typical dark slates which contain concretions of limestone. Near the head of Slocum Arm are dark beds of fine graywacke and argillite, in which fossils were found. On Ford Arm near the head is a very coarse conglomerate. In Ogden Passage a little greenstone is included in the graywacke.

Fresh graywacke is a dark massive rock of medium grain, whose color and granularity do not differ greatly in different specimens. The rock is hard and fresh looking, and in the medium-grained varieties glassy quartz and angular particles of slate set in a dense, dark groundmass can be seen. The rock is an indurated impure sandstone, but the fine-grained varieties may easily be mistaken for a fine-grained igneous rock. A specimen from the mountain between the head of Slocum Arm and Leo Anchorage is a breccia in which are large angular particles of slate in a brownish sandy groundmass. Conglomerate occurs on Ford Arm, in Ogden Passage, and on Slocum Arm. The conglomerate on Ford Arm consists of rounded pebbles and boulders in a sandy matrix. The pebbles in the conglomerate are 3 inches or less in diameter, but many boulders from 3 inches to 6 inches in diameter occur. The pebbles are graywacke, sandstone, chert, light, fine-grained igneous rock, and limestone. Quartz is not abundant. Many pebbles are sheared across. The conglomerate is at least a hundred feet thick here, but it could not be found along its strike on the west side of the Arm. Conglomerates were found in other places, but none could compare with this one in thickness or in coarseness of grain. A conglomerate seen on Peril Strait contains rather abundant pebbles of coarse-grained igneous rock.

The microscope gives a better idea of the composition and texture of the rock than the examination with a hand lens. The graywacke is seen to consist of mineral grains and fragments of rock set in a very fine carbonaceous groundmass of undeterminable material. The grains are somewhat rounded, but characteristically they are angular. The mineral grains are quartz, feldspar, and hornblende. The rock fragments are fine grained and for the most part indeterminate, but some fine-grained igneous rocks were seen. The dark carbonaceous pieces are probably particles of slate. A little calcite and some particles of schist were noted in some of the thin sections.

At fairly close intervals white quartz veins of various sizes cut the rocks of the graywacke series. These quartz veins are of two types—one occurs in shear zones and recements the crushed material, the other, known as "frozen veins" by the prospectors, is composed of simple quartz stringers that cut across the beds of the formation and are not related to recognizable shear zones. Mineralization has taken place in veins of the first type. The "frozen" stringers rarely show the iron stain that indicates the presence of sulphides and possible gold mineralization, and they do not seem to be of more than local extent.

The source of the material of which the graywacke is formed is not known. The angularity of the particles would indicate that they have not been transported for a long distance. The presence of the quartz, of the relatively little-altered feldspar fragments, and of the pieces of fine-grained igneous rock would indicate that an area of igneous rock furnished a part of the material. The conglomerates, however, carry but little coarse-grained igneous material, such as is found in the interior of the island at the present time. As little dark slate is found in the rocks that underlie the graywackes, the source of the particles of slate in the graywackes is not known. It is possible that an unconformity may exist between the two series and that the slaty rocks have been removed by later erosion. The rounded limestone pebbles in the conglomerates might well have been derived from the limestone in the underlying metamorphic rocks. The hornblende may have come from either schist or igneous rocks.

The alteration of the rocks is of two kinds—weathering and contact or dynamic metamorphism. As the rocks have been swept clean rather recently by the ice, weathering has not been extensive. The chief effect of the weather has been the breaking up of the rocks by purely mechanical means, and this has been aided by the weathering out of the argillaceous stringers in the rocks. The chief chemical effect on the graywackes has been to color them slightly reddish, brownish, or greenish. The surfaces are somewhat pitted and gashed where the stringers of the softer material have been removed. On the mountain tops this process has gone a little farther than it has along the seashore. Where the graywackes have been intruded by igneous rocks or where they have undergone great differential pressures they have been altered to fine-grained dark-brown quartz-mica schists. At places where the bedding has been preserved it is seen to coincide rather closely with the secondary structure formed by pressure. The metamorphic minerals, such as andalusite, are particularly abundant in the schist at some places.

STRUCTURE AND THICKNESS.

The graywacke rocks, as previously pointed out (see p. 100), stretch along the west coast of Chichagof Island from Peril Strait to Dry Pass. The actual width of the band of graywacke can not of course be told, as its western boundary lies under the sea. The greatest known width of the belt is 5 miles. The inner contact of the rocks strikes approximately N. 30° W. to Mine Cove, then swings to N. 60° W. in Portlock Harbor, and then N. 30° W. to Dry Pass, beyond which the graywacke has been altered to schist. Graywacke can not be certainly recognized north of Canoe Pass at the entrance to Lisianski Strait. Along the seaward side of the belt on Hill Island, on Kukkan Bay, and at the entrance to Khaz Bay, a schist was found. The schist on Hill Island is believed to be altered graywacke, for the gradation from graywacke to schist can be traced along the north side of Imperial Passage. The agents of metamorphism were active along this outer coast, but whether the metamorphism is due to pressure or to the nearness of a large igneous body could not be told. On the islands at the entrance to Khaz Bay the metamorphism is undoubtedly due to the presence of the igneous body that is seen on some of the islands. The schist on Kukkan Bay appears to be altered greenstone that was intruded into the graywacke.

Reliable strike and dip readings are difficult to get at many places because of the lack of bedding and because of the extensive jointing. In general the strikes lie between west and N. 45° W. A few strikes reach N. 30° W. The dips are almost universally to the south and range from 40° to 70°. At some places the beds stand vertical, and even (in a very few places) dip steeply to the north.

The rocks are greatly fractured and jointed, and it is very often difficult to distinguish bedding from jointing. Faulting is common and extensive, but it can not always be recognized, as the nonhomogeneity of the beds and the frequent occurrence of minor fracturing do not permit one to tell what movement, if any, has taken place. Major faults are recognized by the great quantity of crushed material that occurs in the shear zones, and also by the presence of quartz, which at places has recemented the crushed rock. Such faults are very common and where they have been followed they seem to be persistent. The Chichagoff mine and most of the prospects of the district are located along such faults. The fault in the Chichagoff mine has been followed underground without a break for about a mile, and the strike and the dip of the fault plane are remarkably constant. The Hirst-Chichagof mine lies on another such fault which seems to run nearly parallel to the first one. These crushed zones are of varying width; the same fault zone may be a foot or more wide in one place, and at another it may be 15 or 20 feet wide. Movement along these faults did not take place all at one time, and possibly movement still takes place along them, for much of the quartz along the zones has been crushed and recrushed since its deposition. The dike near the Chichagoff mine and the dike in the upper tunnel of the Hirst mine are crushed. The graywacke in the shear zones is comminuted, and the slaty bands have been reduced to shiny slickensided pieces that look much like pieces of coal. At most places one wall of the zone is well defined and is followed by a sticky clay gouge; the other wall is poorly defined and grades over into the country rocks. The faults dip steeply in the Chichagoff mine and in the Hirst mine. This dip shows only a slight variation. At the Smith prospect the fault plane dips about 62° S., but in depth it flattens to 45° S. All the fault planes so far examined dip to the south.

Strike and dip readings show that the graywacke beds have nearly parallel strikes throughout the belt and that they all dip steeply to the south. It is impossible to interpret the structure of the region from observations over such a limited area, and more work will have to be carried on in the neighboring areas. From the few facts at hand it would seem that the beds may form one limb of an anticline, for they seem to be resting on rocks of greater age. The beds do not possess sufficient peculiarities to enable one to trace recognizable beds and thus to detect reduplication of beds. In such a highly disturbed region reduplication of beds almost surely exists, and this may be due to close folding or to faulting, or to both. Extensive faulting has taken place. The suggestion naturally comes that the structure of the rocks is related to the large intrusive body that makes up the interior of the island. It is interesting to note in this connection that the highly schistose rocks along Lisianski Strait all dip toward that intrusive body. The similarity of the strikes and dips of the graywackes and the older schists suggests a common origin for their later structure—a structure that, in some of the schists, must have been imposed on an earlier structure.

As the structural relations of the rocks are not very definitely known, no determination of their thickness can be made. The belt in its widest part is exposed continuously for 5 miles. Assuming a dip of 60° the resultant thickness of the beds exposed would be 23,000 feet, but there is every reason to believe that reduplication of beds has occurred and that the actual thickness of the exposed formation is much less. On the other hand, it is not possible to tell how far beneath the sea the graywacke extends. The series is apparently thick, although no actual figures can be given. An estimate of the thickness of this series of rocks made by the Wrights,[1] who correlated it with similar rocks on Douglas Island and Glass Peninsula, is 3,000 feet, more or less.

AGE AND CORRELATION.

In a consideration of the age of the graywacke the first question that arises is whether the argillitic graywacke beds along the southwest side of Slocum Arm, which are fossiliferous, should be included in the graywacke series. The reasons for not including them would be that their relationships with the typical graywacke are not known; that they are somewhat different in appearance from the graywacke; and that fossils have not been found anywhere in the typical graywacke, although they were carefully looked for. The reasons for including them are that the rocks are graywackes although of somewhat different appearance; that the pelecypods found, although abundant numerically, seem to be limited to one or two species of *Aucella*, which fact would seem to indicate a peculiarly local condition of deposition (a similar condition apparently of the occurrence of a single fossiliferous bed in a great series of unfossiliferous rocks has been observed at Pybus Bay); and that the rocks appear to be interbedded with tuffs, flows, and limestones similar to those rocks at the base of the typical graywacke. Whether this apparent transition is due to infolding or whether such a transition series to the underlying schist is actually present is not known.

On the peninsula southeast of the Hole in the Wall at Khaz Head the graywacke is massive and coarse grained and breaks down into large, smooth, angular blocks. A little farther down the peninsula, in Slocum Arm, the graywacke becomes finer grained and even somewhat cross-bedded but shows large, rounded pieces of light-colored limestone several inches in diameter and black slate pebbles and slivers. The general tone of the graywacke is greenish gray on the weathered surface. After a short concealed interval comes highly contorted greenish, reddish, and grayish schistose rocks, which are in part

[1] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, p. 35, 1908.

volcanic and in part sedimentary. These rocks extend for 2 miles along the shore with which their strike seems to be nearly parallel. The schistose beds are followed here by a rather massive graywacke, which is at places a grit, and then by the rather fine-grained graywacke in which Jurassic fossils were found. For about a mile the rocks exposed are chiefly the variegated greenish ones of the preceding 2 miles, in which are some argillitic rocks. The occurrence of a limestone bed indicates a sedimentary origin for some of the rocks. Beyond the green rocks is slate. The slaty rocks carry some limestone concretions and throughout most of their extent are markedly parallel banded. The bands are about 2 inches wide and are indicated by differences in color. The slates follow the shore for about a mile and are then succeeded by the fossil-bearing graywacke, which continues to the head of the Arm. A small bed of limestone was found at this second fossil locality.

The contact of these beds with the greenish volcanic and sedimentary beds is believed to lie close to the shore along this side of Slocum Arm. From the strike and dip it would appear that the slates and graywackes lie under the greenish rocks, but faulting has probably disturbed the relationships.

The graywacke extends unbroken along the northeast side of Slocum Arm to a point within 4 miles of the head. A limestone bed, 15 to 25 feet thick, follows the graywacke and is followed in turn by tuffaceous beds, flows, and the contorted green and gray schists. Graywacke occurs in Flat and Hidden coves apparently interbedded with the tuffaceous beds and with the limestone. At one place it even seems to underlie the schist. The strikes and dips observed along this shore would indicate that the graywacke overlay the tuffs and flows.

The section up to the 2,800 and 2,360 foot peaks at the head of the arm shows no graywacke but only highly contorted green and gray schist up to an elevation of 2,390 feet and then greenstone.

In the southeast bay at the head of Ford Arm the graywacke series is interbedded with green and red volcanic rocks. Along the northeast shore of the northwest bay the rocks are schistose and probably are in large part of sedimentary origin. The strikes and dips here would seem to throw the graywackes over the tuffs and schists.

In Sister Lake the underlying rock is a thinly laminated, extremely contorted schist, greenish and grayish in color, and at places very quartzose. The shore of the northeast bay of the lake is almost entirely a light-green schistose rock. In the narrows between the two lakes the rocks are gray schist and chert.

On the eastern side of Lake Anna, near the entrance to the narrows, some greenstone tuff and limestone occur apparently within the graywacke series.

All along the northeast side of Slocum Arm, then, the rocks of the graywacke series appear to overlie the tuff, flows, and schists and in part to be interbedded with the volcanic rocks. The extreme metamorphism of the variegated rocks would seem to point to a greater age for them as compared with the graywacke. The tuffs may well be interbedded with the lower beds of the graywacke series. The relations on the southwest side of the arm may indicate that the fossil beds do not belong to the graywacke series; that faulting has taken place along this side of the arm; or that the volcanic and schistose rocks there are not the same series represented on the north side, but that they are considerably younger and actually do overlie the graywackes. As none of the schistose rocks are fossiliferous and as at no place could the structural relations of the schist to the fossiliferous beds or the fossiliferous beds to the typical graywacke formation be observed, only a surmise of the actual relations can be made now. The question whether the fossiliferous beds should be included with the graywackes has already been considered. The only evidence for faulting, other than that considered below, is the occurrence of brecciated graywacke at the head of the arm about on the line of the supposed fault. The rocks on the outer side of the peninsula could not be visited because of the stormy weather, but they are reported to be graywacke. This is borne out by the graywacke observed at Khaz Head and in Peril Strait. If this is true, then the graywackes of the outer coast would overlie the schistose beds, as they do on the north side of the arm, and a fault along the southwest side would appear probable. So far as lithologic resemblance can be used as a criterion, the schistose rocks on the north and the south sides of the arm are very much alike, and on the lack of other evidence of correlation they would undoubtedly be placed together. On Peril Strait schist is found on the line of strike of the schist on the north side of the arm, and graywacke is found on the strike of the schist south of Slocum Arm.

In Portlock Harbor the contact between the graywacke and the underlying series of rocks is exposed at half a dozen places. In the narrow strait between Portlock Harbor and Ogden Passage a reddish gritty sandstone, which contains angular particles of slate, lies at the base of the graywacke rocks. Under the grit is a bluish-gray limestone about 50 feet thick. On the large island in Portlock Harbor northwest of the entrance to Black Bay the contact is exposed at two places; on the southeast side of the island the contact seems to be somewhat gradational, for the upper beds of the green variegated rocks seem to be somewhat sandy in character; on the northwest side the contact is rather of the same type. The one point of contact on Peel Island shows the graywacke in contact with an intrusive body. At the Snipe Islands the contact passes between the eastern island and the two western ones and is concealed in the narrow strait between them. On the eastern island the rocks are greatly sheared conglomerate, quartzite (?), and limestone. On the southeast side of Hill Island the rocks at the contact are argillitic rocks, limestone, and a sheared conglomerate. On the northwest side of the island the rocks at the contact are greenish schist, or greenstones, and limestone. Beyond this point the rocks all become schistose, and the graywackes are not again recognized as such.

The question whether the metamorphic series and the graywacke series are separated by an unconformity can not be definitely settled. The graywackes rest on rocks that are in part sedimentary. On Slocum Arm the underlying beds are tuffs and limestones; in Portlock Harbor the underlying beds are so greatly altered that tuffs can not be definitely recognized, although many of the beds are extremely obscure and may be tuffs. Limestones are almost universally present under the graywacke in Portlock Harbor. In the absence of fossils it is not possible to say whether the underlying beds of Slocum Arm and those of Portlock Harbor are of the same age. It should be noted that in Slocum Arm the graywacke beds are apparently interbedded with the tuffs of the underlying series, and they do not seem to be so in Portlock Harbor. The strikes and dips of the two series of rocks appear to conform, but the rocks have undergone great structural disturbances since their deposition, and the result of the action of the same force would result in imposing a somewhat similar structure on the rocks of both. The chief reason for placing an unconformity between them would be the great difference that exists in appearance and degree of alteration, but this difference may be a result of the character of the rocks. The most that can be said, then, from field observations is that an unconformity may exist between the two series.

The age of the graywacke, determined by Stanton from fossils collected on the shore of Slocum Arm, is probably Upper Jurassic. The report on the fossils follows:

10147. No. 17AOF7: First prominent bight on southwest side of Slocum Arm, 3 miles southwest of Falcon Arm.

Aucella sp., related to A. fischeriana (D'Orbigny).

Belemnites sp., fragments of a small slender form.

10148. No. 17AOF8: Second prominent bight on southwest side of Slocum Arm, 5 miles southwest of Falcon Arm.

Aucella sp., small distorted specimens possibly belonging to two species, one of which may be the same as the species in 10147.

The form of *Aucella* in these two lots appears to be distinct from the forms identified as *A. piochi* Gabb and *A. crassicollis* Keyserling in previous collections from Pybus Bay, Admiralty Island. The present collections are believed to be of Upper Jurassic age. It should be remembered, however, that the distinction between Jurassic and Lower Cretaceous on the basis of *Aucella* alone is not always safe. It is possible that all the *Aucella*-bearing rocks of southeast Alaska may belong in the same series.

Correlations of the rocks of the graywacke series with similar rocks of southeastern Alaska are at once suggested. The rocks of the Berners formation (Upper Jurassic or Lower Cretaceous) of Eagle River in the Juneau district are lithologically similar to the rocks of the west coast of Chichagof Island, and fossils show them to be of the same age. Knopf [1] believed the Berners formation to be found on the Glass Peninsula and at Point Young on Admiralty Island. That the correlation of these rocks with the rocks of Pybus Bay at the south end of Admiralty Island is open to some doubt is indicated in the report made by Stanton. In the Ketchikan district the rocks would be correlated with the "conglomerate, slate, and graywacke" of Chapin,[2] which are found on Gravina Island and in the western part of the town of Ketchikan and at Wards Cove on Revillagigedo Island. This correlation is suggested by fossils, by lithographic similarity, and by relationship to other rocks. The suggestion has already been made that these rocks may be correlated with the graywacke of the Prince William Sound region, but as nothing conclusive is known about the age of those rocks the correlation will have to remain a suggestion.

IGNEOUS ROCKS.

The largest bodies of igneous rock in the region are those that are believed to be part of the Coast Range batholith. These rocks occupy much of the interior of the island, and in this brief report no attempt can be made to describe the various types that are found. Most of the area mapped is not far from the contact between these rocks and other rocks, and consequently the rocks of the intrusive body are very greatly sheared. Thin sections show that most of these rocks are considerably crushed and are extensively altered. The rocks seem to be normally quartz diorites, but types from granite to hornblendite can be found. A specimen from Stag Bay that in the hand specimen appears to be a greenstone is seen under the microscope to consist of feldspar (near albite), quartz, green hornblende, chlorite, and epidote. This rock was probably originally a diorite. On Lisianski Strait, near Miner Island, the rock is a crushed albite granite. A little farther up the strait the rock consists entirely of crushed, coarsely crystallized hornblende. A specimen taken on Lisianski Inlet consists chiefly of crushed and recemented quartz and a little plagioclase feldspar. The rocks on Peril Strait and in Hooniah Sound seem to be somewhat more basic than the rocks on the west coast. They contain some quartz, plagioclase feldspar (near andesine), hornblende, and the usual alteration minerals. These

[1] Knopf, Adolph, The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, pp. 17-18, 1912.

[2] Chapin, Theodore, The structure and stratigraphy of Gravina and Revillagigedo Islands, Alaska: U. S. Geol. Survey Prof. Paper 120-D, pp. 97-98, 1918.

rocks appear to be similar to the contact rocks of the Coast Range batholith of the mainland, and they are correlated with them. The age of the Coast Range batholith is not yet definitely determined, but it is generally thought to be Jurassic or Cretaceous. In this area these rocks cut the rocks of the metamorphic series, whose age has not been determined.

An intrusive body of large size, which consists of a coarse-grained granite, cuts the greenstones and schists of Morris and Elfendahl lakes. The rocks of this body are very light in color and are of very coarse grain. They are somewhat weathered, but otherwise are not greatly altered. They differ from the other granites of the region in their coarseness of grain, their light color, their uniformity in character, and in the fact that the alkali feldspar is orthoclase instead of albite. Part of the contact between this body and the greenstone was carefully examined, but no signs of mineralization were found.

Coarse granite was found on the Porcupine Islands and on the island that forms the outer side of Cautious Pass. A specimen of the rock shows coarsely granular quartz, feldspar that ranges in composition from albite to albite-oligoclase, greenish biotite, muscovite, garnet, and sericite. This rock is an albite granite. Whether it represents the same period of intrusion as the orthoclase granite above can not be determined.

The rocks represented by the intrusive body at Nickel are somewhat variable. They are fairly light gray but at places become a rather dark brown. Diorite and gabbro (norite) are the chief types represented. Nickel ore occurs with these rocks and a more detailed description of them is given under the discussion of the nickel ores. (See p. 129.) A similar body of diorite occurs on Lisianski Strait north of Canoe Pass.

Dikes are fairly abundant in the region. They cut the graywacke, the rocks of the metamorphic series, and the greenstones. Most of the dikes are rather small and are light in color, and all except the dike at the entrance to Deep Bay seem to be of the same type. One of these dikes occurs on the property of the Chichagoff Mining Co., at the Golden Gate mill, but no dikes were encountered in the mine itself. Another forms the footwall in the lower tunnel of the Hirst prospect. The dikes are rather abundant in the graywacke on Slocum Arm between Ford Arm and Falcon Arm. Similar dikes cut the greenstone at the copper property at the head of Pinta Bay, and dikes that are of somewhat different appearance cut the greenstone on the ridge to the north of Morris Lake. The dike rock in the lower tunnel on Baker Peak is highly mineralized with pyrite, and the chalcopyrite of the upper prospects seems to be in a greatly altered dike of this type.

The dike rocks are fine grained and light in color. The minerals that form the rock can not be determined with the naked eye, but the rocks are light colored, and consequently the ferromagnesian minerals are practically absent. Pyrite is rather abundant in some of the dikes, and these weather deep red-brown on the surface.

Under the microscope these dike rocks are all seen to be rather extensively altered. A specimen of the rock from the Golden Gate mill is coarser grained than most of the dike rocks and seems to be somewhat less altered. These rocks, so far as can be determined, carry a little quartz, plagioclase feldspar, and a few dark minerals. The plagioclase in the dike of the Golden Gate appears to be near albite-oligoclase, and the rock is apparently an aplite. Alteration, chiefly to sericite and to chlorite, is extensive. Although there is a great similarity in appearance of these dike rocks, there is probably considerable variation in their character. The aplite dikes are at most places mineralized rather highly with pyrite, and as a consequence several of them have been staked as prospects. It is not known whether they carry gold.

The dike at the entrance to Deep Bay is of a markedly different type from that of the other dikes. The rock is rather dark in color, and is porphyritic. The phenocrysts are feldspar and hornblende. The groundmass is fairly fine grained, and contains both lath-shaped crystals and closely spaced irregular grains. The feldspar phenocrysts are about labradorite, although some albite appears to be present. This rock is an andesite. The dikes that cut the greenstones north of Morris Lake are of a somewhat similar type.

Greenstones are widespread in the region, including both intrusive and extrusive rocks. As their name implies, they are extensively altered, and it is no longer possible to tell exactly the type of basic rock from which they are derived. As it is not always possible in the field to distinguish the true greenstone from altered sedimentary rocks that are green in color, especially where they have been rendered schistose, no attempt has been made to show on the map all the greenstone areas of the region. Greenstones included with the metamorphic rocks were seen in Portlock Harbor, in Didrickson Bay, and in Deep Bay. The greenstones which have been indicated north of Morris Lake (see Pl. II) appear to be of a different age from the green schists and greenstones included with the schist, for they do not show the excessive metamorphism of the other rocks. They appear to have a rather gentle dip to the east and to rest on the steeply dipping beds of the schistose series. They are massive fine-grained rocks which are in large part amygdaloidal. They are notably homogeneous. Epidote is widespread in the rocks, and small amounts of chalcopyrite are present in nearly every specimen of the greenstone collected. The amygdaloidal character of the greenstone would indicate that it is, in part, a flow. That some may be intrusive, however, is suggested by the fact that in the green schist only a short distance from the supposed contact with the greenstone is a coarse-grained greenstone which appears to cut the schist and is hence of a later age. An amygdaloidal greenstone carrying chalcopyrite occurs on the peak at the head of Slocum Arm. A similar relationship to that on the Baker Ridge is seen in that a limestone bed lies in both places almost at the contact between schist and greenstone. Greenstone is reported from Rust Lake, near Chichagof.

The age of the greenstones is not known. They may be of the same age as the greenstones of the Orca group of Prince William Sound, which are probably of Mesozoic age.

A fresh-looking basalt was seen on Lisianski Strait opposite Miner Island. The rock in outcrop shows columnar jointing, and it has not been greatly disturbed since its deposition. The rock is porphyritic, vesicular, and has a fine-grained groundmass. The phenocrysts are altered hornblende crystals. This body of igneous rock may be the youngest in the region.

DEVELOPMENT OF TOPOGRAPHIC FEATURES.

Most of the physiographic features of Chichagof Island are due primarily to glaciation, although structure and the character of bedrock have had some effect in modifying the action of the ice. The fiords probably owe their straightness and parallelism to the directive action of bedrock structure on the moving ice. The characteristic features of the fiords, the lakes, the hanging valleys, the broad U-shaped valleys, the steepened slopes, the through valleys at the heads of the fiords, and the holes and deepened channels off the coast are all undoubtedly due to the ice action. The coastal plain appears to be a structural feature and to represent an uplift of this part of the coast. Minor topographic features, such as the rounding of the granite peaks and the pointing of the greenstone peaks, are due secondarily to the nature of the bedrock.

MINERAL RESOURCES.

GOLD.

OCCURRENCE.

Prospecting for gold on the west coast of Chichagof Island has been carried on from time to time since 1905. A number of prospects have been located, but at the present time only one mine is being operated. Most of the prospects are along shear zones in the graywacke.

The most active prospecting for gold has been done near Klag Bay. Klag Bay is about 54 miles northwest of Sitka by boat. It is connected with Juneau by a motor boat which makes regular trips about once a week. The center of mining activity is at the head of Klag Bay at Chichagof, where the Chichagoff mine is located. Prospects have been located on Klag Bay, on Mine Cove to the north, and on Slocum Arm to the south. Practically all these prospects are gold quartz prospects, and most of them have been held for a number of years. Only one mine is being operated at the present time, although another may be opened shortly. Gold was first found by a native in 1905 in one of the streams near the head of Klag Bay. He carried the news to Sitka, a small stampede followed, and a number of claims were located. The history of the Klag Bay region has been given by Knopf.[1]

The claims on Klag Bay all lie near the shore. The coast here is similar to that to the north. The coastal plain is confined here chiefly to the islands, which consist of low rounded hills and marshy flats. A line between the coastal plain and the mountain belt passes south of Doolth Mountain, between Lake Anna and Sister Lake, and into the sea at Khaz Head. The shore line is extremely irregular and throughout its extent is rocky, and the bottoms near the shore are foul. Rocks and reefs extend offshore for about 5 miles between Kukkan Bay and The Hole-in-the-Wall. Lake Anna and Sister Lake are tidal basins which can be entered with safety only at slack water. Doolth Mountain, in which the Chichagoff mine lies, is a smooth, rounded mountain about 2,120 feet in elevation.

The rocks of the Klag Bay region are of two general types—the undifferentiated metamorphic rocks and the graywacke. The only igneous rocks seen in the vicinity of Klag Bay (except the altered igneous rocks in the schistose series) were the light-colored dikes, which are fairly abundant in the graywacke. The graywacke, as pointed out above (p. 108), is believed to be of Upper Jurassic age. The age of the dike rocks is not known, but they must be post-Jurassic.

Graywacke is economically the most important rock of the region at the present time, because all the prospects so far located are in graywacke, although there is no apparent reason why mineralization should not have taken place in the schistose series as well. One possible reason for the seeming localization of the mineralization in the graywacke is that the physical properties of the massive graywacke under great forces may have caused it to break with big clean fractures that were of great extent and that furnished excellent pathways for the ore-bearing solutions. The soft schistose rocks, on the other hand, would not give clean breaks or persistent pathways, so the solutions would dissipate through the schist and would not concentrate at any one place. Although the geology of the district appears to be simple, the interpretation of the structure is difficult.

[1] Knopf, Adolph, The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, pp. 18, 23, 1912.

As the beds are not fossiliferous in the Klag Bay region, fossil-bearing horizons can not be traced, and no beds were found that have persistent lithologic characteristics. Observations of the strike and dip show that the beds have a rather constant strike toward the northwest and a steep dip toward the south. The rocks northeast of the slate-graywacke series shown on the map belong to the complicated series of schists and volcanic rocks whose exact nature is in many places difficult to determine.

CHICHAGOFF MINE.

The Chichagoff mine is at the head of Klag Bay. The entrance to the mine is on the southeast side of Doolth Mountain, and the end of the main tunnel is now past the center of the mountain.

Thirty stamps are operated at the mill at the present time, and the ore is concentrated both by amalgamation and by flotation. Electric power is brought from the generating station at the north end of Sister Lake. The source of the power is in Rust Lake, 1¼ miles above the power station on Sister Lake.

The early history of the mine, taken from the report by Knopf,[1] is inserted here.

The ore body was found in 1905, * * * by tracing to its source the quartz float so abundantly strewn in the bed of the small stream. The lode did not outcrop along the shore but was found in place one-quarter of a mile inland, at an elevation of 275 feet. At the outcrop the lode ranged from 2 to 4 feet in width. The float ore was carefully gathered and shipped to the smelter at Tacoma. This ore was rich enough to yield between $15,000 and $20,000. The proceeds were applied to development work and the mine has paid its own way from the start. A drift tunnel 220 feet long was run on the ledge, and two ore shoots were encountered, the second of which was 18 feet wide at a maximum and averaged $63 a ton across this width. Later a second tunnel was driven 162 feet vertically beneath the upper tunnel, commencing behind the mill, which is situated at the beach. Ore was encountered at 800 feet from the portal, apparently belonging to the bottom of the first ore shoot. A raise was put through to the upper tunnel, and the ore thus developed is now being stoped.

The present Chichagoff Mining Co. controls both the original Chichagoff or De Groff mine and the Golden Gate mine. The consolidation took place in 1912. Since Knopf wrote his report it has been definitely proved that both mines are on the same lode.

A few facts collected concerning the occurrence of the ore might be of general interest, as this mine is the only one in the district that has been extensively developed, and as it is probable that if other mines are opened up in the region the occurrence of the ore will be similar. Of course, it can not be argued that because the Chichagoff mine is successful every mine in the district of a similar type, or even one whose ore tenor may be as high or higher than that of the Chichagoff, will be likewise successful. It must be remembered

[1] Knopf, Adolph, The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, p. 23, 1912.

that in mining relatively low grade ore the management of a mine is always an extremely important factor in determining its success or failure.

The Chichagoff ore body is a vein deposit that has formed along a shear zone in the argillitic graywacke. The shear zone is a persistent one, and it has been followed continuously for over 4,500 feet. The strike of the zone is rather constant, and the dip is steep although somewhat variable. The shear zone may range in width from less than a foot to 10 feet. The ore does not occur continuously along the shear zone but is distributed in shoots. Five such shoots have been encountered in the main tunnel of the mine. Three of the shoots have been already worked out. In one of the shoots the ore gave out about 550 feet below sea level; in another at 400 feet. Both shoots reached the surface—one at 230 feet above sea level, the other at 1,370 feet. The shoots are tabular and are irregular in outline. One dips about 80° S. and the other stands about vertical. The third ore shoot was small and is really part of one of the other shoots. The other two ore shoots are not yet fully developed, so their extent is not known.

The gold is associated with the quartz, which is white and glassy in appearance. Where there is no quartz there is no gold, although there may be abundant iron sulphide. Extreme irregularity characterizes the occurrence of the gold; it is irregularly distributed in irregularly shaped ore shoots. The thickness of the vein averages 2½ feet, but the actual thickness differs greatly from place to place. There is said to be no relation between the thickness of the vein and the distribution of the gold. The value of the gold in a thick part of the vein may be high or it may not. It seems to be true, however, that where the quartz contains abundant sulphides it is likely to be richer in gold than at places where the sulphides are not so abundant. Sulphide mineralization and gold mineralization in the quartz seem to be genetically connected, although heavy pyrite mineralization in the black slate does not seem to be related to the gold mineralization. The quartz is in rather lenticular bodies, and their thickness varies greatly in short distances. At places the quartz bodies are twisted about and even seem to be cut off sharply. This feature suggests that movement has taken place subsequent to the formation of the bodies, and this is further borne out by the fact that in thin sections the quartz is seen to be very greatly crushed. In the shoot where the bodies of quartz are very irregular and appear to have been subjected to movement this disturbed part of the body is followed by a regular vein of quartz that has a uniform thickness of about 3 feet. Another characteristic way in which the quartz occurs is in the ribbon structure already described by Knopf.[1] This type of

[1] Knopf, Adolph, op. cit., p. 21.

structure is caused by parallel stringers of quartz, which are separated by black slaty or carbonaceous layers. These stringers of quartz break away so cleanly from the slaty layers that the slaty layer has every appearance of being one of the walls of the shear zone. It seems to be advisable to put in a short crosscut here and there to make sure that the vein is not really thicker than it appears to be.

A thin section of the vein matter shows crushed coarsely granular quartz, which together with some calcite surrounds and replaces the crushed slate and graywacke. Calcite is not abundant, and in the specimen examined was seen only with the fine-grained quartz, which was replacing the country rock. Some of the quartz shows wavy extinction, due to the pressure to which it was subjected. A thin section of the ore which shows free gold, pyrite, galena, and quartz does not exhibit features which would indicate the relative order of formation of the different minerals. The pyrite is well crystallized and fits in with the quartz mosaic in such a way that simultaneous crystallization is suggested. The gold is in the form of a small stringer that appears to cut across a quartz grain, and hence from this single occurrence it would appear to be later than the quartz. A single example of the relationship between minerals is not sufficient, however, to establish a definite order of succession. The galena occurs between the quartz grains, and there is nothing to suggest whether it is older or younger than the quartz, or of the same age. The quartz, although crushed, does not show nearly the same amount of crushing that the dike rocks show; so it seems possible that the gold mineralization took place subsequent to the intrusion of the dike.

The source of the ore-bearing solution is not known, although it probably had an igneous origin. The presence of a possible igneous source is indicated by the dike rocks. The Coast Range batholith is not far away, and that ore-bearing solutions could come from these rocks is shown by the fact that at many other places in southeastern Alaska the rocks near this batholith are mineralized. The distance of the deposits from the contact would not necessarily indicate their distance from the igneous body, which may lie only a short distance under the surface. It is at least probable that the dikes and the ore-bearing solution had a common origin, and that the ore-bearing solution represents a later stage of effusion from the parent igneous mass. There seems to be no good evidence to show that the gold may have been leached from the graywacke and redeposited in the shear zones, for the graywacke is fresh and shows no effect of weathering or leaching.

HIRST PROPERTY.

The Hirst property lies on the northwest side of Doolth Mountain in Mine Cove. The property consists of three claims owned by Bernard

Hirst, of Sitka. These claims, together with the Bahrt claims on the opposite side of Doolth Mountain, are now under lease by the Hirst-Chichagof Mining Co. A considerable amount of work has been done on this property but nothing within the past few years. The Hirst-Chichagof Co. proposes to open the property as soon as financial matters can be arranged.

There are two tunnels on the property—one at an elevation of about 255 feet above sea level, the other at 430 feet. These are called the 250 and the 450 foot levels. The 250-foot or lower tunnel is about 725 feet long; the upper about 427 feet. A tunnel at 100 feet above sea level, which is expected to intersect the ore body at about 900 feet from the entry, is projected.

The rocks of Mine Cove belong to the graywacke series, but they are somewhat more carbonaceous and argillaceous than the rocks on Klag Bay. On the island at the entrance to the cove there is a shear zone cut by numerous quartz and calcite stringers. An old prospect, the Monte Cristo, lies on the main shore just south of this island. Several hundred yards west of the Hirst mine a tunnel about 30 feet long has been driven into the hillside along a small shear zone. A quartz stringer about 6 inches wide at the mouth of the tunnel diminishes at the face to about an inch wide.

The lower tunnel on the Hirst property shows in sections across its face and roof a few inches of soft gray clay gouge, about a foot of crushed rock, through which run quartz stringers parallel to the footwall, and several feet of crushed argillitic rock containing small gnarled quartz stringers a fraction of an inch thick. The crushed slate is very much slickensided and carbonaceous and contains in the carbonaceous material considerable pyrite. A dike of much-altered porphyry, probably alaskite, similar in appearance to the other dikes of the region, runs along the footwall for most of the way through the ore shoot. The band of parallel quartz stringers differs in width from place to place and at the end of the ore shoot disappears entirely. These stringers follow the well-defined footwall. That the quartz was deposited later than the movement that produced the shear zone is shown by the fact that it occupies the shear zone; and that some movement has taken place since the original movement is shown by the crushed condition of the quartz.

In the upper tunnel thin quartz stringers occur in the face. The footwall is hard and quartzitic. Quartz bands are abundant for about 8 inches from the footwall, which here strikes about N. 35° W. and dips about 78° S. The rock toward the hanging wall, as in the lower tunnel, is greatly crushed and contains but little quartz. The width of the band of parallel quartz stringers ranges between a foot and 3 feet in the ore shoot. This quartz occurs chiefly in parallel bands about 3 or 4 inches wide, which are separated from one another by narrow dark bands of argillitic material. Small quartz stringers cut out in places at right angles to the footwall, but these probably do not carry gold. The footwall is at most places a light-colored clayey gouge and is well defined. There is abundant pyrite with this gouge and with the quartz of the gouge. Pyrite is rather abundant, too, in crushed material along the hanging-wall side of the vein. A light-colored dike, possibly 5 feet wide, occurs in the graywacke of the footwall near the north end of the ore shoot. It is cut sharply off by the fault. The lode proper in this tunnel has a maximum width of a little over 3½ feet and a stope length of about 225 feet. The dip of the shoot at its north end is about 79° W. and its pitch is not known.

Quartz crops out on the hillside about 60 feet above the mouth of the upper tunnel, and about a hundred feet higher in the stream some quartz is exposed as stringers in the graywacke.

The quartz in the tunnel does not show much sulphide mineralization. The chief sulphide mineralization occurs in the crushed rock of the hanging-wall side of the vein, but it is generally reported that this sulphide does not carry the gold. The pyrite may be syngenetic—that is, it may have been originally in the slate in the form of iron, and under the physical and chemical conditions to which it was subjected it formed coarsely crystalline pyrite. It might in this way have formed independently of the action of the solution which brought in the gold. One assay, for instance, is reported to show $9 in gold in the quartz portion of the vein and only $0.85 in the pyrite-bearing slaty portion. Values as high as $56 in the upper level and $57 in the lower level are reported by the company. The gold appears to be irregularly distributed. The ore in this mine probably occurs in shoots. New shoots may be expected along the shear zone if it is followed, but nothing can be said about the distance that may have to be traversed before another shoot is reached, or about its tenor.

OTHER PROSPECTS.

A prospect from which some of the richest ore of the region has been taken is the Jumbo claim on the west side of Klag Bay about half a mile south of Chichagof. This is one of a group of four claims that extend over the hill to Ogden Passage, and it was staked in the early days. At the present time the workings consist of a tunnel about 35 feet long and an inclined shaft 48 feet deep that is now filled with water. In the face of the tunnel there is a small crushed zone about 6 inches wide that is filled with crushed slate and small quartz stringers. Two large quartz stringers cut across the face at an angle to the small crushed zone. Pyrite is fairly abundant in association with quartz, and also occurs in stringers that cut the slaty country rock. The country rock is a much-broken argillitic graywacke. The strike and dip of the fault plane is variable. Where measured at the surface it strikes N. 54° W. and dips 62° S. The plane flattens to about 45° S. at the bottom of the incline. The material in the dump shows brecciated slaty particles cemented by quartz in which are rather abundant well-crystallized pyrite, some galena, and some sphalerite. It is said that the quartz which shows rather abundant sphalerite is as a rule not very rich in gold. Some of the best specimens of free gold in the region came from this prospect.

The prospects Sitka No. 1 and No. 2 are on the east slope of Doolth Mountain about a quarter of a mile north of the Chichagoff lode. Development only is reported. The upper tunnel lies at an elevation of about 950 feet. At the entrance to the tunnel in the creek bed a dozen or more quartz stringers cut across the direction of the tunnel. The tunnel is approximately 150 feet long and follows a shear zone of variable width. Almost no quartz occurs in this tunnel. A little pyrite was noted in the crushed rock of the shear zone. The strike of the tunnel is about N. 62° W., and the dip of the fault plane is 52° S. Sticky clay gouge follows the footwall at some places and the hanging wall at other places. The lower tunnel is at an elevation of about 670 feet. The shear zone that it follows strikes about N. 52° W. and dips 52° S. A little quartz occurs in the crushed zone. The footwall is graywacke and the hanging wall is a carbonaceous argillite. At the face of the drift cross stringers of quartz occur in fractures, and a little pyrite mineralization was seen there. The quartz stringers are on the footwall of the shear zone.

The Flora claim lies on the east slope of Doolth Mountain, about 800 feet west of the Golden Gate tunnel of the Chichagof mine. The tunnel is in a shear zone that contains some quartz.

The Bahrt claims, Anna, Rose, and Henrietta, are on the south side of Doolth Mountain at the head of Klag Bay. These claims are thought to lie on the continuation of the Hirst-Chichagof shear zone, and the Hirst-Chichagof Co. has secured a lease on the property.

The Handy property, consisting of two claims, is on the east side of Klag Bay opposite Chichagof. Considerable prospecting has been done on these claims. There is at the present time a tunnel about 45 feet long and an inclined shaft about 175 feet long. Work had been suspended at the time of visit. The dump consists chiefly of carbonaceous slate, most of which is slickensided and highly graphitic. Some pieces of the quartz show mineralization with iron sulphide. The pyrite in most of the specimens occurs at the edge of a quartz band or in the slaty stringers in the quartz. About 40 feet above the tunnel mouth (80 feet above sea level) an outcrop shows quartz. The country rock is graywacke. The quartz stringers are lenticular and are practically confined to the footwall. The strike of the rocks is about N. 50°–70° W. and the dip is very steep to the south. The strike of the Chichagoff shear zone should carry it across the bay somewhere near this point. The work on this prospect was started in September, 1916, and was discontinued in May, 1917.

A prospect is located on the island between Chichagof and the Handy mine. This island has been located a number of times. It is now called the Submarine claim. Its workings consist of a shallow water-filled pit.

Another prospect from which some rather rich specimens have been taken lies just within the entrance to Lake Anna and continues through to Klag Bay. This prospect was located in April, 1914. It lies along a fault zone in slaty rock. Small iron-stained stringers of quartz occur in the rocks on the dump. A remarkably smooth fault plane, which strikes about N. 20° E. and stands about vertical, forms the south side of the tunnel. The crushed zone as exposed in the tunnel is about 3 to 5 feet wide. The tunnel is about 100 feet long, but no recent work has been done in it. Considerable pyrite occurs with the quartz. Some quartz was found which contains pyrite, galena, pyrrhotite, and sphalerite. Several other prospects of the types just described occur in the region, but they were not visited.

Four claims at the head of Falcon Arm extend from the beach to the top of the peak, a distance of about 4,500 feet. A trail runs from the head of Falcon Arm to the claims, and they can also be reached without much difficulty from the head of Ford Arm. The claims are about 14½ miles by water from Chichagof. At an elevation of about 400 feet above the beach a cabin has been built, and a short tunnel has been run in on a mineralized dike. This dike is an altered diorite aplite, and contains rather abundant pyrite. The main outcrop, apparently a mineralized dike, on these claims lies in a narrow gully at about 1,650 feet above sea level. Below the outcrop a tunnel about 30 feet long has been started into the crushed slate and graywacke to intersect the dike. Shots have been put into the outcrops of several other iron-stained dikes.

The geology of the ridge is relatively simple. The country rock is graywacke, which here has been rather extensively intruded by light-colored dikes that range from 3 to 15 feet in width. The dike at the cabin is mineralized with pyrite and is reported to carry gold. The outcrop at 1,550 feet is greatly weathered, and as no development work has been done here its extent or relationships are not known. The prospecting tunnel is in crushed slate, and it does not cut the mineralized dike above it. A few scattered quartz stringers were seen in the tunnel.

Galena, pyrite, and sphalerite occur in stringers in the rock from the outcrop. Samples from this outcrop are reported to carry gold and some silver. The claims were located in the fall of 1916.

A group of four claims is in the angle between Lisianski Strait and Lisianski Inlet, on Yacobi Island. The claims were located in 1917. The quartz vein along which the claims lie was first located about 30 years ago, and a tunnel about 35 feet long was run. It is reported that about $1,100 worth of gold was taken from the tunnel at that time. The exposure of the quartz is at tide level, and it appears to be in a shear zone, associated with a clay gouge. The width of the stringer ranges from less than a foot to about 3 feet. The country rock is a rather basic intrusive that belongs in the Coast Range batholith. A few feet away from the tunnel entrance is a coarsely grained hornblendite. Both the country rock and the quartz are greatly fractured. In the face of the tunnel the quartz has pinched out, but on the hillside at an elevation of about 75 feet, apparently on the strike of the vein, quartz is exposed. The quartz is white, fairly coarse grained, and except for a little chalcopyrite is practically free from sulphides. A little free gold was seen in the pure white quartz.

A gold claim on the north side of Stag Bay, about one-fourth mile northwest of the cannery, was located in 1917. The lode is in diorite and occurs as a quartz vein, which is about 3 feet wide at one place and about 1 foot wide a little lower down and is reported to extend about 200 feet up the cliff. This quartz is said to yield colors when crushed and panned. No development work has been done on the claim. The approximate strike of the quartz stringer is N. 30° E. and the dip about vertical. No metallic minerals were seen in the quartz. Quartz veins of similar appearance cut the diorite at a number of places.

COPPER.

GOLD-COPPER GROUP.

A group of six claims called the Gold-Copper group lies about 3 miles by trail from the head of Pinta Bay. The metals reported from these prospects are gold, silver, copper, and lead. Seven claims were first located in 1910 and were held by the Portlock Harbor Mining Co. This company is said to have failed to do necessary assessment work and the ground was relocated on January 2, 1916, by T. Baker, James Toby, and George Bolyan. Six claims were located and were called the Gold-Copper group. At the present time the claims are under litigation.

The claims are reached by trail from the head of Pinta Bay. Pinta Bay lies about 18 miles northwest of Chichagof, and about 70 miles from Sitka. The bay is a good harbor, as it is protected from the sea by Hill Island, and it has plenty of water. No reliable charts of the region exist at the present time, but it is hoped that one will be published shortly. The claims lie at elevations of 1,370 to 2,360 feet, and a pack trail about 3 miles long connects them with the head of Pinta Bay. A tram about 1½ miles long could be built to connect the prospects with Baker Arm. An abundant supply of water for power is available in the stream that enters Pinta Bay at its head.

The development work on these properties is not extensive. It consists of two tunnels at elevations of 1,360 and 1,440 feet, which were driven by the original holders of the property, the Portlock Harbor Copper Mining Co. The 1,440-foot tunnel is about 130 feet long and has about 30 feet of crosscuts. The 1,360-foot tunnel is about 50 feet long. Recent work has been done at a number of places on the hillside. At the elevation of 1,850 feet there is a shaft about 10 feet deep, at 1,935 feet a cut about 25 feet long, at 1,875 feet a 91-foot tunnel, and at 1,880 feet a small open cut.

The prospects lie near the western edge of the greenstone area shown on the map. (See Pl. II.) The hills to the north are all greenstone, and the rocks along the ridge to the southwest belong to the undifferentiated metamorphic series. The country rock on top of Baker Peak is amygdaloidal greenstone, and that in the immediate neighborhood of the prospects is a hard fine-grained, somewhat sheared greenstone. This rock is very much altered near the lode. Light-gray dikes of fine-grained igneous rock cut the greenstone. The dikes are highly mineralized with pyrite and are so badly altered that their original nature can not be definitely told. They appear under the microscope to be altered aplites. Such iron-stained dikes are rather common on this hill and along the ridge toward the sea. Although mineralization has taken place both in the greenstone and in the dikes, it appears to be connected genetically with the dikes. The source of the copper may be in the greenstone, but the dikes appear to have had some influence on its concentration. Small amounts of chalcopyrite were seen in similar-looking greenstone north of Morris Lake and above Slocum Arm. The chief visible metallic minerals of the lode are pyrite and chalcopyrite. Assays are reported to show gold, silver, and lead.

The most promising showing of ore is in a new cut made in the fall of 1917, in which a zone heavily mineralized with chalcopyrite about 10 feet wide is exposed. At this place the country rock is altered iron-stained greenstone, and the lode rock is altered dike (?) rock impregnated with and cut by stringers of chalcopyrite. This lode rock is followed by about 10 feet of rather massive chalcopyrite. The mineralized zone appears to strike about N. 30°–40° W. and dip 70° W. Along the strike of this zone about 250 feet to the northwest a 10-foot shaft shows a mineralized zone about 2 feet wide.

A small open cut made on a dike about 100 yards east of the tunnel of the new workings discloses a rock strongly mineralized with pyrite. The more highly mineralized portion is about 6 feet wide, and its strike is N. 50°–60° W. This mineralized rock is reported to carry silver and lead.

SNOW SLIDE CLAIMS.

A copper prospect is located in Pinta Bay at the head of Baker Arm. The prospect consists of two claims called the Snow Slide claims. They were located in 1916 by the present locators of the Gold-Copper group. The prospect is on the steep hillside at an elevation of about 650 feet and about 1,100 feet in a straight line from the beach. Substantial cabins have been built on the beach and at the prospect. The outcrop is exposed in the bed of a small stream. It consists of a zone of thin-banded quartzose green schist highly mineralized with pyrite, chalcopyrite, and possibly some pyrrhotite. The zone where exposed is about 6 feet wide. The country rock is green schist. A tunnel 171 feet long has been driven to intersect this mineralized zone, but work on it was stopped before the zone, if it continues in depth, was reached. No very recent work has been done on this prospect.

LITTLE BAY CLAIMS.

At the head of Little Bay, between Dry Pass and Nickel, four claims were located in 1916. The claims extend from the beach up the small creek which runs from Davison Mountain. Assays of specimens from these claims are reported to show copper, silver, gold, and in one specimen a trace of nickel. The only work done at the prospect on the beach consists of a few shots put into the outcrop. The minerals seen in the beach specimens were chalcopyrite and pyrrhotite. These minerals occur in a very fine grained quartzitic rock, whose exact nature is not known. The immediate country rock is not exposed, but the nearest exposed country rock is the granitic and dioritic intrusive body which extends from Dry Pass to Cautious Pass. Near the head of the bay this rock shows considerable variation in character, and it is probable that the contact between the intrusive body and the intruded body is not far away. Owing to the lack of exposures the type of mineralization that has taken place here can not be told. The mineral specimens resemble those from the prospect at Hot Springs more than they do those from Nickel.

CONGRESS CLAIMS.

The Congress claims lie on the west side of Hill Island in the second bight north of Imperial Passage. A trail leads to them from a bight on Imperial Passage. These claims were located or relocated in 1916. The workings consist of a tunnel about 25 feet long, which is on the rocky seashore a few feet above sea level. The country rock is a gray schist, somewhat micaceous and quartzose, and is probably a schistose phase of graywacke. The workings expose a quartzose schist zone body about 11½ feet wide mineralized with chalcopyrite and pyrrhotite. The sulphides coat the thin plates of schist. On the south side of the zone is a band of green chloritic and hornblendic schist, which is somewhat quartzose and contains a few specks of chalcopyrite. On the north side of the zone is a thinly plated and quartzose gray schist. The green schist may represent an altered intrusive with which the mineralization is genetically connected. The type of ore body is similar to that near White Sulphur Springs. (See below.) No very recent work has been done on the prospect.

OTHER PROSPECTS.

A mining claim has been staked on the shore of Bertha Bay about half a mile northwest of White Sulphur Springs. This claim, or claims, was located in 1916. A few shot holes represent the work done. The prospect is on the seashore, which here consists of jagged rocks that rise about 20 feet above the water and which is deeply cut by narrow ravines. Bare rock is exposed for about 50 feet from the edge of the water to the line of vegetation.

The rocks along this shore are very highly metamorphosed, and the ordinary metamorphic minerals, such as andalusite and mica, are highly developed. The nickel-bearing gabbro of the Sea Level property lies about 7,000 feet to the southeast. Granite lies on the Porcupine Islands about 8,000 feet southwest and on the shore about 2,000 feet north. The schist rocks that form the country rock here probably owe their schistose character to the dynamic contact action of the deep-seated intrusive rocks. The schist is dark gray and contorted. At the point of discovery on the shore is a belt of light-colored quartzitic rock, iron-stained in places, which is parallel to the strike of the schistosity. It is separated from the schist by a sharp contact, and faulting may have taken place. This belt of quartz rock disappears under the moss at one end, and at the other end it pinches down to nothing. At the southeast end of the belt the rock in contact with the quartz rock is a medium-grained dark hornblende rock, which seems to be an altered basic intrusive in the schist. Mineralization is in the green rock at the contact and consists of stringers of chalcopyrite and pyrrhotite.

Similar types of mineralization in which chalcopyrite occurs in schist associated with greenstone were seen in Canoe Pass, at the entrance to Khaz Bay, on Hill Island, and in Little Bay. This type is different from that at the Alaska Nickel Mines property, and although the mineral association of chalcopyrite and pyrrhotite is the same, little or no nickel seems to be present. None of these bodies examined appeared to have more than local extent.

NICKEL.[1]

ALASKA NICKEL MINES.

Nickel is known to be present in only one locality on the west coast of Chichagof Island. 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 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. The developments in 1917 consisted of a 180-foot shaft with levels at 80 feet and 180 feet (drifts totaled about 155 feet) and prospect holes at several places. A wharf site and water-power sites 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

[1] Nickel is definitely known to occur at only one other place in Alaska. The occurrence is on Canyon Creek, Copper River valley, and a brief description of the prospect is given in U. S. Geol. Survey Bull. 576, pp. 52-53, 1914.

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 from 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.

The minerals chalcopyrite and pyrrhotite have so often been described and are so common that they are known to all prospectors. Pentlandite, however, is a rare mineral and besides is not often distinguishable from pyrrhotite in an ore specimen. As the mixture of chalcopyrite, pyrrhotite, and pentlandite looks just like the mixture of chalcopyrite and pyrrhotite, the only way of determining definitely whether nickel is present is to make a chemical test. A simple chemical method of testing for nickel is as follows: [1]

Grind to a fine powder a sample—2 or 3 grams (30 to 40 grains); treat in a test tube with a few cubic centimeters of aqua regia (a mixture of 1 part nitric acid and 3 or 4 parts hydrochloric acid), and boil nearly to dryness; then add enough nitric acid and water to dissolve all soluble substances. Filter if necessary. Dilute to

[1] Hess, F. L., Nickel: U. S. Geol. Survey Mineral Resources, 1914, pt. 1, pp. 929-930, 1916.

10–15 cubic centimeters (about one-third the contents of a test tube 6 inches long and three-fourths of an inch in diameter), add a gram or more (half a teaspoonful) of citric acid (solid), and dissolve by heating. Make the solution slightly ammoniacal, noting that it should contain no precipitate. To the slightly ammoniacal solution add about 2 cubic centimeters (a half teaspoonful) of 1 per cent alcoholic solution of dimethylglyoxime. A voluminous scarlet precipitate indicates nickel.

The aqua regia solution is boiled nearly to dryness to remove from it the large excess of acid and anything, such as hydrogen sulphide, that would cause the precipitation of iron, cobalt, nickel, etc., in the ammoniacal solution.

The citric acid will prevent the precipitation of iron and aluminum as hydroxides, but will not prevent the precipitation of sulphides of iron, cobalt, nickel, and some other metals in the ammoniacal solution.

If a brown precipitate of iron forms after the solution is made ammoniacal, it contains an insufficient quantity of citric acid.

At the present time dimethylglyoxime may be difficult to obtain. The price for it is very high, but a small quantity (as much as will go on the blade of a pocket knife) should provide the prospector with enough solution to last a year. If copper is present the acid solution will turn deep blue when ammonia is added to it.

Pentlandite is an iron-nickel sulphide, (Fe, Ni)S. It is brittle and has a hardness of 3.5–4. It has a metallic luster and a light bronze-yellow color. Pentlandite carries about 22 per cent nickel. Except on polished surfaces none could be recognized in the rough hand specimens of the ore.

Niccolite is an arsenide of nickel, NiAs, and contains about 43.9 per cent nickel. It is very brittle and has a pale copper-red color. It was found in small amount lining crevices in the rock.

TYPE.

One of the purposes of the rather close study of a deposit that is not very extensively developed is to determine the type of the deposit if possible and so compare it with known deposits of similar type that have been extensively developed. Much of the experience gained in the development of the known deposit can then be applied to the development of the relatively unknown deposit. One can not argue, however, that if one deposit is large, every one of similar type is equally large. The similarity between the nickel deposit on Chichagof Island and the deposits at Sudbury, Canada, is at once evident.

A comparison between the deposit on Chichagof Island and the Sudbury deposits can best be shown in the form of a comparative table. The description of the Sudbury deposits is drawn largely from the report of the Royal Ontario Nickel Commission.[1]

[1] Report of the Royal Ontario Nickel Commission, pp. 95–286, 1917.

Comparison of Chichagof nickel deposit and the Sudbury deposits.

Alaska Nickel Mines deposit.	Sudbury deposits.
1. Two of the outcrops are marginal in igneous rock, norite or diorite. The relations of the third outcrop are not known.	1. Ore bodies are near or in norite. The chief commercial deposits are marginal bodies outside the norite.
2. Predominating sulphides are pyrrhotite, chalcopyrite, and pentlandite.	2. Same.
3. Ore minerals occur in places as blebs disseminated in norite.	3. Same.
4. Later granitic intrusive bodies cut the norite.	4. Same.
5. In general the rocks at the margin of the large intrusive body appear to be more basic than the rocks at a greater distance from the margin.	5. Same.
6. Barren blocks of rock seem to be included in the ore on the 80-foot level.	6. Ore is rocky.
7. No micropegmatite found. Acidic rocks are chiefly albite bearing.	7. Micropegmatite is abundant.
8. Freshest hypersthene occurs with the ore.	8. Same.
9. Transition from nonore to ore is rather sharp.	9. Transition from nonore to ore is sharp in Creighton ore body.
10. Little secondary quartz and no calcite has been observed.	10. Secondary quartz and calcite is reported from some of the deposits.
11. The shape of the ore body is not known.	11. The shape of the commercial ore bodies is for the most part rudely lenticular. Some are in irregular cylinders or tubes; some are in distinct veins.
12. The sulphides are later than the silicates. The pentlandite is apparently in part later than the pyrrhotite.	12. Same.

The nickel deposits of Chichagof Island and those of Sudbury are seen from the above comparative table to be essentially alike both in the general type of occurrence of the deposits and in the mineralogy of the ores. On the assumption, then, that the two deposits are genetically similar facts determined with regard to the Sudbury deposits may be applied to these deposits. Two types of occurrences have been recognized at Sudbury—"marginal" deposits and "offset" deposits. Of the marginal deposits those that occur in the rocks adjacent to the norite contain the commercially important ore bodies. The ore bodies found on Chichagof Island are in the igneous rock—norite, hornblende gabbro, or diorite—but by analogy there seems to be no reason why the deposits should not be looked for in the adjacent mica schist also. At Sudbury some of the commercial deposits are surrounded by rock in which the ore minerals are disseminated;

on Chichagof, consequently, outcrops of ore bodies should be looked for wherever so-called "disseminated ores" are seen. The outlines of the partly developed ore body on Chichagof have not been sufficiently delimited to afford comparison with any of the Sudbury ore bodies. The ore body appears to stand nearly vertical and to be somewhat disturbed by faulting.

Other points to be noted in prospecting on Chichagof Island are that ore so far has not been found in the very coarse grained dark norite, and that if a very coarse grained diorite—chiefly one containing large hornblende crystals and feldspar—is found, some disseminated ore minerals will be found in the rocks near by. A diorite that resembles the diorite of the nickel intrusive and differs from the other diorites of the region is shown on the map near the southwest entrance to Lisianski Strait, and prospecting may reveal some nickel deposits near this diorite. The irregularity of the occurrence of the Sudbury ore deposits suggests the necessity of careful underground exploration by means of the diamond drill to determine the extent of the ore bodies.

PETROGRAPHY.

As the general type of occurrence of these deposits has already been discussed, a description of some thin sections of rock and polished surfaces of ore will be given here. The deposits are found in a body of medium to coarse grained igneous rock that shows considerable variations in type—variations that extend all the way from granite to gabbro. This igneous body, or bodies, 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.

A thin section of this quartz-mica schist shows biotite in parallel arrangement making up much of the slide; muscovite also occurs, both as the coarse-grained variety and as the fine-grained variety (sericite); quartz is fairly abundant as grains between the mica laths. A more intensely altered phase of this schist taken from the contact with the intrusive body shows a strong development of biotite, quartz, plagioclase (about oligoclase-andesine), garnet, muscovite, and accessory apatite. The minerals all show undulatory extinction. Small grains of zircon surrounded by pleochroic haloes occur in the biotite.

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. A thin section of a specimen of the coarse granite of the type similar to that found in Cautious Pass consists of coarsely granular quartz, feldspar, greenish biotite, muscovite, and garnet. The feldspar is albite and albite-oligoclase. The rock gives evidence of having undergone considerable pressure. The smaller light acidic dikes and bodies that cut the diorite are aplites and granites. The feldspar is albite and oligoclase. One of these dikes shows in thin section quartz, biotite, feldspar, and sericite. The feldspar is variable in composition, showing great variation in a single crystal, and ranges from albite to andesine. The feldspar crystals in the specimens examined show some alteration. One very coarse grained rock has feldspar crystals an inch or more in length. Practically no opaque minerals—sulphides or oxides—are present in these rocks.

The rock that makes up most of the intrusive body falls under the general term of diorite. Different specimens show, however, great variation in color, texture, and mineral composition. The descriptions of only a few specimens can be given. A sample taken about 1,800 feet south of the main nickel outcrop is a light-colored, coarse-grained, somewhat gneissic rock containing a few scattered phenocrysts of feldspar. The microscope shows the rock to be somewhat crushed, although the minerals are relatively fresh in appearance. The mineral constituents of the rock are plagioclase, biotite, garnet, apatite, chlorite, and actinolite (?). The plagioclase crystals are zonal and hence are of variable composition, which ranges from that of oligoclase-andesine to andesine-labradorite. Biotite is almost free of inclusions. A few magnetite grains gathered along the edges of the biotite may represent the alteration of some of the biotite. The chlorite is secondary and replaces the garnet. Many needle-like crystals (actinolite?) occur as inclusions in the garnet and the feldspar. The absence of hornblende is to be noted. This rock is a diorite. Specimens of another type of diorite collected from several places are of a fairly dark greenish-gray rock, which is coarse grained and porphyritic. The thin section shows feldspar and hornblende phenocrysts set in a fairly fine grained groundmass. The feldspar is zonal, is variable in composition, and is considerably altered. The average composition of the feldspar is about andesine. The hornblende phenocrysts are fresh and unaltered. The groundmass consists of altered feldspar, hornblende, and alteration products. Sericite, chlorite (pennine), and a small amount of epidote are the alteration products. A type of diorite that has been noted at a number of places near occurrences of "disseminated ore" is a very coarse grained hornblende-feldspar rock. This rock in thin section shows hornblende crystals an inch long, set in a quartz-feldspar matrix. The hornblende crystals are fresh in appearance but are replaced by a little chlorite; they are lath-shaped and seem to be eaten into or corroded by the feldspar. At one place feldspar or quartz appears to have replaced the whole central portion of the hornblende crystal. The feldspar, which is near oligoclase in composition, is extensively altered and replaced by sericite. Some of the feldspar is broken and shows bent twinning lamellae. This rock is quartz diorite porphyry.

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 coarsely 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 thin section of this type of rock shows it to consist chiefly of altered hornblende and pyroxene. Fresh-looking plagioclase occurs in small amount and is very basic in composition, being near labradorite-bytownite. The hornblende and pyroxene has altered almost entirely to a fine-grained aggregate that may be talc or uralite. Small amounts of biotite, chlorite, and sulphide were also noted. Another specimen of rock taken from a locality near the main nickel outcrop is a hornblende gabbro. The rock is medium to coarse grained and is greenish-gray in color. The light minerals and the dark minerals are nearly equal in amount. The thin section shows a rock consisting of mineral grains one twenty-fifth of an inch or less in diameter. The chief minerals are feldspar and hornblende; accessory minerals are sericite, chlorite, and quartz. The feldspar is near labradorite in composition; the crystals are crushed, show undulatory extinction, and have bent twinning lamellae. The hornblende is pale greenish and yellowish and is not strongly pleochroic. Small stringers of sericite cut and replace the plagioclase. The quartz is present in the form of a stringer that cuts across a feldspar crystal. A specimen of rock from a point about 75 feet from the outcrop of the main ore body is a fresh light-colored hornblende diorite. The thin section shows hornblende, feldspar, and quartz. The hornblende is green and strongly pleochroic and is fresh and somewhat shreddy. The feldspar is partly altered and has the composition of andesine-labradorite. A specimen of the rock from the shaft sunk alongside the main ore body is hornblende gabbro. This rock consists largely of plagioclase that has a composition near that of labradorite. The mafic minerals are interstitial and are chiefly common hornblende. The apparently homogeneous crystals of hornblende in this rock and in many of the other rocks examined are really made up of differently oriented crystals, so that the extinction takes place at different times in different parts of the crystal. A specimen of rock from the 80-foot level, about 10 feet from the shaft, is a dark-greenish medium-grained hornblende gabbro. The microscope shows altered hornblende, plagioclase, and a little sulphide. The hornblende is greatly altered; the feldspar crystals are broken and are cut by stringers of chlorite (?). The composition of the plagioclase is near that of labradorite. Another specimen taken from the 80-foot level, about 30 feet from the shaft, is a coarse-grained greenish hornblende gabbro. The plagioclase crystals, which have a composition about that of labradorite, are somewhat broken and bent and are replaced in part with sericite. Some of the hornblende crystals show bending. 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 is strongly pleochroic. The pyroxene is orthorhombic; it occurs in lath-shaped crystals rounded at the ends and has altered somewhat to hornblende. Where the pyroxene crystals are cut by the ore minerals there is a narrow border of an alteration mineral (sericite?). Pyroxene makes up about one-quarter of the section. The feldspar is plagioclase that has an average composition near that of labradorite. The feldspar is clear and relatively unaltered and shows zonal arrangement. One of the crystals has been broken across, and the fracture is occupied by a differently oriented crystal of plagioclase; another crystal has bent twinning lamellae. A little chlorite was noted replacing the feldspar. 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 thin section of a specimen of the ore consists chiefly of opaque minerals with a little hornblende, pyroxene, and feldspar. The crystals of hornblende and pyroxene are rounded and are replaced in part by the ore minerals, which have entered the cleavage cracks of these minerals. The rounding of the hornblende and the pyroxene crystals may have been caused by their replacement by ore minerals, but this same type of rounding has been noted in specimens of norite and hornblende gabbro in which there are no ore minerals. If selective replacement of feldspar alone had taken place the resulting appearance of the mafic minerals would have been the same.

A polished surface of the ore shows pyrrhotite, pentlandite, and chalcopyrite. The pentlandite is of two kinds, one of which is in large grains that show cleavage and that surround and appear to be later than grains of pyrrhotite, and the other is in stringers, shreds, and patches in the pyrrhotite grains. The grains of pyrrhotite show blading similar to that seen in polished surfaces of chalcopyrite. Chalcopyrite in this particular specimen replaces the gangue minerals more extensively than do the other minerals. 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. At one or two places the pentlandite appears to be possibly later than the pyrrhotite, but at most places there is no indication which mineral was formed later. The same is true with regard to the relations of the chalcopyrite to the pentlandite and pyrrhotite. In places small stringers of pyrrhotite definitely cut chalcopyrite, and there can be no doubt about this particular bit of pyrrhotite being later than the chalcopyrite. Until more evidence is available than is afforded by the polished specimens examined, a decision as to the relative age of the opaque minerals to one another will have to be postponed. They are, however, definitely later than the original silicates.

USES OF NICKEL.[1]

The uses of nickel depend on its properties of toughening, whitening, hardening, increasing the elasticity, and preventing the oxidation of certain alloys; on its own resistance to alteration under atmospheric conditions; its beautiful white luster; the high polish it takes; and the ease with which it is electroplated. As with all other metals, its use depends on the fact that it is isolated from its ores with comparative ease and cheapness. * * *

The crystalline structure of nickel steel is more minute and the modulus of elasticity is about the same as that of carbon steel, and it is harder.

The alloy of iron and nickel known as "invar" is called a steel. Invar containing 36 per cent of nickel is practically without expansion or contraction when exposed to varying temperatures. It is used for scientific instruments, pendulums, and steel tapes.

An alloy of 25 per cent nickel and 75 per cent copper is used in the 5-cent piece or "nickel" of United States coinage. The small coins of Belgium, Denmark, England, France, Sweden, and Switzerland contain some tin and zinc, the Italian coins only tin, and Chilean coins contain copper 70 per cent, nickel 20 per cent, and zinc 10 per cent.[2] Some other countries use pure nickel for their subsidiary coins. From 1857 to 1864 the United States used a composition of 12 per cent nickel and 88 per cent copper in 1-cent pieces, a very much better alloy than that now in use, which is 95 per cent copper and 5 per cent tin and zinc.[3]

Monel metal is an alloy of nickel and copper made by the International Nickel Co. by smelting the Sudbury ores without separating the two metals. As stated by the Bayonne Casting Co. the composition is 67 per cent nickel, 28 per cent copper, and 5 per cent other metals, probably mostly iron and a little cobalt. It has a tensile strength equal to good nickel steel, resists many corrosive agents, and has a color and takes a polish equal to that of nickel. It is used for propellers for warships and smaller craft, including racing motor boats; for valves on high-pressure steam lines; valve stems; pump rods and liners; acid pumps; burning points in enameling and japanning ovens; pickle frames and rods in tin-plate mills; wire cloth; golf-club heads; and roofing materials.

The addition of a small percentage of nickel makes a silver-white alloy with copper, and considerable quantities of nickel are used in the alloy known as German silver, used for the more valuable metal. German silver is used direct for table ware and other utensils and as a base for silver-plated ware.

Nichrome is a proprietary name for an alloy of nickel and chromium whch was first used for resistance wires in electrical work. It stands temperatures considerably above a red heat with little oxidation and without melting, so that it is used in small resistance furnaces in place of platinum. It is also used for chemist's triangles, etc.,

[1] Hess, F. L., Nickel: U. S. Geol. Survey Mineral Resources, 1915, pt. 1, pp. 761–763, 766, 1917.
[2] Brannt, W. T., The metallic alloys, pp. 307–308, 1908.
[3] Ann. Rept. Director of Mint, 1911, p. 9, 1912.

for making carbonizing pots, and in wire cloth for dipping baskets where articles are to be dipped in acid solutions. * * *

Great quantities of nickel are used for plating iron and other articles where a beautiful protective finish is desired.

It seems remarkable that, with its toughness, resistance to corrosion, and good color, pure nickel cooking utensils are not manufactured.

HOT SPRINGS.

Two hot-spring localities were visited in the western part of Chichagof Island. Both places had been previously visited by Waring[1] and are described as follows:

HOT SPRINGS ON NORTH ARM OF PERIL STRAIT.

On the north shore, about three-quarters of a mile eastward from the head of North Arm of Peril Strait (Hooniah Sound), heated water issues at about half-tide level from the mussel and kelp covered rocks. As the warm water rises beneath or flows into the cold sea water, its presence is betrayed by convection currents, which give an oily appearance to the surface; but when examined at low tide the warm water has no noticeable taste nor odor. There is only a little bubbling, as of gas, and a small amount of dark-green vegetable growth, either algae or a seaweed.

The three principal springs found issue from fissures in the rock, separated by spaces of 5 and 2 feet, about 100 yards northwest of a small cold-water stream. The temperature of the springs was 101° F., and their flow per minute, as near as it could be measured, was, respectively, about 1½ gallons, a quarter of a gallon, and three-quarters of a gallon, but the discharge appeared to diminish as the tide fell, perhaps in part because of the draining off of contaminating sea water from the adjacent rocks above the springs, but probably in greater part because of the lowering of the hydrostatic pressure by the falling tide and the escape of the warm water from lower crevices.

The analysis of the water of the largest of the three springs * * * shows that it has a high total mineral content and is of the sodium sulphate type. Although the sample collected contained considerable chloride it seems not to have been greatly contaminated with sea water left in the moss and gravel by the receding tide, for if it had been so contaminated it would have contained more chloride than sulphate.

Beneath a low cemented gravel bank, near a large boulder 100 yards northwest of the principal group of springs, slightly warmer water (temperature 103° F.) forms oil-like convection currents over an area of several square yards in the adjacent bay water, but the outlet of this spring lowers with the tide, so that its discharge is not measurable. No other warm springs were found in a search extending from the head of the bay to a point a quarter of a mile east of the cold-water stream near the main spring group.

Cliffs of massive granitic material rise from the narrow bouldery talus slope along the shore. In the main the rock seems to be comparatively unaltered, but near the springs there is a zone, possibly a dike, of fractured and altered dioritic rock. In the hand specimen this material shows considerable epidote and chlorite, products of the alteration of the original hornblende, and F. L. Hess, of the United States Geological Survey, noted that it contains much sphene. The escape of the spring water, probably heated either by the depth from which it rises or by chemical reactions in the altered rock, is apparently facilitated by the presence of this fractured mass of rock in the larger mass of intrusive crystalline material of the region.

Because of their inconspicuous issuance and their inaccessible location for bathing, the springs are little known, and no attempt has been made to improve them.

[1] Waring, G. A., Mineral springs of Alaska: U. S. Geol. Survey Water-Supply Paper 418, pp. 33-35, 1917.

HOONIAH WARM SPRINGS.

Hooniah Warm Springs are on the oceanward coast of Chichagof Island, about 70 miles northwest of Sitka. They may be reached by launch in calm weather, but as the coast is rocky and there is usually a heavy surf they have not been often visited. A log bathhouse or sweat chamber has been built over the principal spring, however, and the locality is the occasional camping place of hunters and trappers. The springs are in a small rock cove, in which much driftwood is cast up on a beach of large rounded stones.

The principal spring issues at the edge of the forest, a few feet above the limit of drift logs and about 25 yards from and 15 feet above normal high-tide level. The water issues at a temperature of 111° F. from a vertical opening the size of one's hand, in dark, hard schistose rock. After flowing through a natural rock pool, over which the bath chamber has been built, the discharge—30 gallons a minute—cascades down to tidewater.

The spring water tastes only faintly sulphureted, and there appears to be no escape of gas. A noticeable bubbling in the water below a small cascade in the run-off channel is probably due to air trapped in the cascade rather than to gas escaping from the water. Much pale salmon-colored to white, stringy algal growth forms along the run-off channel, as is usual at sulphureted warm springs.

The analysis of water from this spring * * * shows that it is a moderately concentrated sodium chloride water containing considerable sulphate. Silica forms more than a third of the total content, possibly in part as a soluble silicate.

A second spring, with a temperature of 110° F. and a discharge of about a gallon a minute, issues among the cobbles 20 yards east of and 7 feet lower than the main spring, and vapor, possibly from the same spring or fissure, issues from openings in the forest soil 15 yards shoreward. A third spring, with a temperature of 84° F. and a flow of half a gallon a minute, rises with slight bubbling in the muck of a small stream channel 50 yards west of the principal spring.

Conditions at the main spring, where the water appears to issue directly from a fissure in the schist, indicate that the thermal water rises along such seams in the rock, which dips 80° S. 20° W. The abnormal temperature of the water may be due solely to the depth from which it rises, but it seems probable that it is due, in part at least, to the presence of intrusive rocks, which form a wide zone east of the springs. The schist from which the warm water issues is a common alteration phase of the Paleozoic or Mesozoic sediments near their contact with intrusive rocks throughout southeastern Alaska.

The hot springs on the north arm of Peril Strait (Hooniah Sound) were visited at high tide, so the actual openings could not be observed. These springs issue at or near a contact, for although the rocks on both sides of the arm for several miles are granite, the small island just south of the spring is composed of marble. Other springs probably occur on the hillside, for steam could be seen rising now and then above the trees several hundred feet up the slope. Time was not available for an extended search for these springs. The writer was told of these springs by an old Indian, who said that he had found them 40 years ago.

The White Sulphur Springs, formerly called the Hooniah Warm Springs, have been surveyed by the Forestry Bureau, and some attempt is being made to attract attention to them. Two cabins have been built, and a bathhouse has been constructed over a pool made in the native rock. This work was started in the fall of 1916. The temperature in the bath is 100° to 105° F. A good trail runs to the small bay at Nickel.

The water issues from fissures in the schist. The schist is a dark-gray contorted rock, which contains large metamorphic minerals—mica, garnet, staurolite, corundum, and others. It seems to have undergone later movement, for it is broken and recemented. Light and dark colored dikes cut the schist. The nature of the coastal plain to the east is for the most part concealed by muskeg swamps, but the few exposures show the same type of schist. A fairly large body of igneous rock occurs about 4,500 feet southeast of the springs, and a smaller body about 3,500 feet northwest. The rock of the Porcupine Islands off the coast, 1½ miles southwest of the springs, is schist intruded with granite rocks. Copper-nickel ore occurs in the igneous body to the southeast, and a copper-nickel (?) claim has been located about 2,000 feet northwest of the springs.

A hot spring is reported by Waring from Lisianski Inlet, but this spring was not found.

PLATINUM-BEARING AURIFEROUS GRAVELS OF CHISTOCHINA RIVER.

By Theodore Chapin.

INTRODUCTION.

Slate Creek is the best known of a number of productive gold-bearing placer streams on the headwaters of Chistochina River, on the south side of the Alaska Range, in the upper Copper River basin. The other gold-bearing streams are Ruby Gulch, Chisna River, and Lime Creek, all of which are within a few miles of Slate Creek.

GEOLOGY.

CARBONIFEROUS ROCKS.

The oldest rocks of the region are the Chisna and Mankomen formations, both of Carboniferous age. As originally described, the Chisna formation, the older, consists of tuffs, quartzites, and conglomerates; the Mankomen formation is essentially black slate and limestone.

TERTIARY CONGLOMERATE.

Unconformably overlying the Mankomen rocks is a conglomerate composed essentially of well-rounded boulders of amygdaloidal greenstone, diorite, and quartz, with lesser amounts of black slate, limestone, schist, and porphyry. It is commonly of a brick-red color, due to the solutions of iron oxide that have penetrated it, and is known locally as the red conglomerate. The greenstone pebbles are the most permeable of the boulders and are often almost entirely weathered, containing only a small core of unaltered rock. The diorite pebbles are less permeable, but they generally contain a stained shell and are extensively fractured in parallel planes across the boulders. These fracture planes appear to have been channels of solution, and along each plane, although the boulder shows no displacement, is a polished surface resembling a slickenside. The conglomerate contains locally a great many boulders of Mankomen rocks, both slate and limestone, but no Chisna rocks.

Fault blocks of similar conglomerate (see fig. 1), one of which occurs in the bed of Slate Creek and a parallel one that extends from the head of Ruby Creek westward to John Grosh Gulch, and an

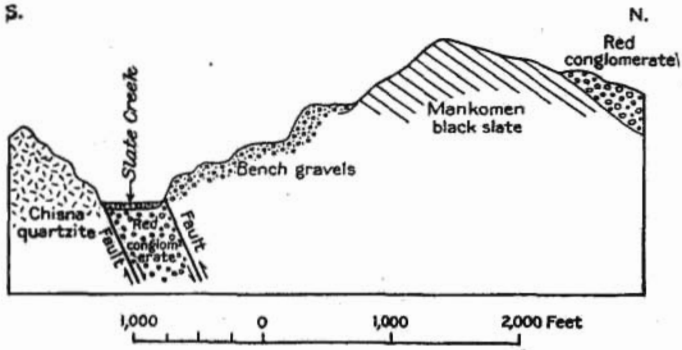

FIGURE 1.—Structure section across Slate Creek 1½ miles above its mouth.

unknown distance beyond, are believed to be composed of rocks of the same formation and have reached their present position through faulting. These rocks are not believed by the miners to be the same formation as the auriferous conglomerate that caps the ridge at the head of Miller Gulch. The conglomerate of the fault blocks is not known to carry any appreciable amount of gold, but it does contain a little sandstone and shale that carries thin seams of coal in places. The conglomerate on the ridge above Miller Gulch and Big Four Gulch is called "wash" by the miners, owing to the presence of a thick covering of residual detritus made up of rounded boulders derived from the conglomerate. The firmly cemented conglomerate, however, is exposed in a number of places. The difference in the content of gold is easily explained by the fact that the conglomerate at the head of Miller Gulch lies at the normal base of the conglomerate, where the heavy minerals would naturally be concentrated, whereas in the fault blocks of conglomerate the base is nowhere exposed. The presence of the coal seams in the fault blocks but not on the Miller-Big Four divide, and at other places where the conglomerate rests normally upon other rocks, is easily explained by the fact that the rocks exposed in the fault blocks represent a higher part of the section. The contact of the conglomerate with the Chisna formation on Slate Creek is a fault. At the head of Miller Gulch the conglomerate unconformably overlies the Mankomen formation and on Ruby Creek and John Grosh Gulch it occupies a fault block that has dropped down between Mankomen rocks on both sides. This conglomerate on Slate Creek probably belongs to the Gakona formation, of Eocene age, as mapped by Moffit[1] in the Chistochina district.

[1] Moffit, F. H., U. S. Geol. Survey Bull. 498, 1912.

GLACIAL GRAVELS AND STREAM GRAVELS.

The bench gravels of glacial origin and the stream gravels are younger formations than the Tertiary conglomerate and are of special interest on account of their valuable deposits of gold and platinum.

DISTRIBUTION OF THE FORMATIONS AND STRUCTURE.

The distribution of the formations is dependent upon the structure. (See fig. 1, p. 138.) The Chisna formation, which at this place is made up of quartzite, tuffaceous conglomerate, and breccia, occupies an area south of Slate Creek. It is bordered by a fault that extends along the south bank of the valley of Slate Creek. This appears to be one of a system of parallel faults that extend in an east-west direction and dip toward the north. Four main faults which were observed show two downfaulted blocks of conglomerate inclosed between Mankomen and Chisna rocks. The main fault appears to be the one on the south side of Slate Creek, which has brought into contact the Carboniferous Chisna rocks and the Tertiary conglomerate. One of the downfaulted blocks of conglomerate is about coincident with the bed of Slate Creek. A parallel block of downthrown conglomerate extends across the heads of Ruby Creek and John Grosh Gulch. Along the upper contact of each of these fault blocks there was thrust faulting, so that at present the Carboniferous rocks of the Mankomen formation actually overlie the Tertiary conglomerate.

OCCURRENCE OF GOLD AND PLATINUM.

Gold and platinum occur in three formations (see fig. 1, p. 138) and appear to represent three stages of concentration. The original bedrock source of the gold and platinum is not known, as lodes of neither metal have been found in this region. The first concentration appears to be the "red conglomerate," which represents a cemented gold and platinum bearing gravel. A second concentration is found in the glacial gravels that form high benches on the south side of Slate Creek. These benches are made up of material derived by the erosion of the conglomerate and other rocks. The third concentration has taken place in the stream gravels. These three formations, the Tertiary conglomerate, the bench gravels, and the stream gravels, all of which carry both gold and platinum, are regarded as promising sources of these metals. The stream gravels are very rich in gold and have been worked for a number of years. The bench gravels have not been extensively tested, but rich deposits of gold that occur within the bench deposits have been mined at a profit, and recent prospecting and sampling at a number of places indicate that there are very large deposits of this gravel which can be worked at a profit when sufficient water is available for washing it. There is less chance of finding workable deposits in the conglomerate, but recent prospecting has shown that it, too, may be profitably mined for gold and platinum.

The gold and platinum usually occur together and appear to have the same source as far back as the rocks of the region record their history. There are no near-by basic rocks from which the platinum is likely to have been derived. The only basic rocks present are some small dikes that cut the platinum-bearing conglomerates.

MINING.

The output of gold on Slate Creek in 1917 is estimated at $100,000. No assays or other tests have been made to determine the relative amount of platinum accompanying the gold, but it is estimated to be a little over 1 per cent of the volume of the gold. As the amount of platinum bears such a small proportion to that of the gold, its increased production is not easy to bring about.

In 1917 the principal productive mining was on Slate Creek, where two hydraulic plants were in operation but a number of outfits were mining on a small scale. The M. E. W. Gold Mining Co., operated by J. M. Elmer, F. B. Walker, and Ross B. Watkins, was the largest producer. The M. E. W. property comprises more than 20 claims and extends from a point near the moraine of Chistochina glacier, at the mouth of Slate Creek, to the lower end of the claims of the Jack Miller estate, near the mouth of Miller Gulch. It includes also claims near the divide of Slate Creek and Chisna River, claims on Big Four Creek, and bench claims on Slate Creek that extend to the ridge between Pyramid Peak and the head of Miller Gulch. Options were taken in 1914, and the property was acquired during the following year and prospecting and drilling were done. Most of the season in 1916 was also spent in dead work, but a short run was made and $9,000 worth of gold taken out. A cut 1,300 feet long was made along the south bank of Slate Creek from the mouth to the present position of the open cut. A flume and ditch was also constructed to bring in the water for hydraulicking. This ditch takes water from Chistochina glacier about a mile above the mouth of Slate Creek and at present supplies 1,500 inches of water, which is utilized by three giants. Two giants are used to move gravels at the sluice head and one to stack tailings. A head of 125 feet is maintained at the open cut and 175 feet at the tailings giant. It is planned to develop more water power on the west side of Chistochina glacier and bring it across the moraine.

In 1917 work was commenced June 15 and continued until September. Work at the time of the writer's visit had been largely confined to two open cuts on Slate Creek. The deposits are in part in virgin ground and in part in rich gravels which had been once partly worked by the hand method of shoveling into sluice boxes. The old method never proved satisfactory, for the gradient of the stream is too low to admit of easy disposal of tailings, and floods often interfered with the work.

Besides the productive mining on Slate Creek, assessment and development work has been continued on Big Four Creek and on the bench gravels of Slate Creek. The bench gravels contain extensive deposits of gold and platinum, and from their elevated position could be easily hydraulicked when water is obtained.

The claims of the Jack Miller estate were worked on about the usual scale. Twelve men were employed and bench gravels at the mouth of Miller Gulch were hydraulicked. Above the Jack Miller claims three or four small outfits were occupied in groundsluicing and shoveling in. No productive mining was in progress on any of the other creeks.

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MINING ON PRINCE WILLIAM SOUND.

By BERTRAND L. JOHNSON.

GENERAL FEATURES.

The mineralization of the closely folded rock beds that border Prince William Sound introduced into them a considerable variety of minerals, among which were gold, silver, chalcopyrite, chalmersite, pyrite, pyrrhotite, arsenopyrite, galena, sphalerite, stibnite, quartz, epidote, albite, chlorite, calcite, and ankerite. The valuable metals of the ores of this region are copper, gold, and silver. The gold thus far observed is native. The copper occurs chiefly as chalcopyrite, but another copper-iron sulphide, chalmersite, which contains about 23½ per cent of copper, has been recognized at properties on Solomon Gulch, Landlocked Bay, and Knight Island. Silver has been noted as an alloy of the native gold and is also associated with some of the copper ores, but in what combinations is not known.

The ore deposits of this region may be broadly grouped into two classes—copper deposits and gold-bearing quartz lodes. The mineral associations in both gold and copper deposits are in general the same. The copper mines produce large quantities of gold or silver or both, and the gold-quartz lodes contain very small quantities of chalcopyrite.

The gold quartz ores are free milling. They are crushed locally in small stamp or roller mills and the concentrates are shipped to smelters. The copper ores are sulphides and require smelting, with or without previous concentration. At one plant a flotation process is in operation. As no local smelters are available, the copper ores are shipped to smelters at Tacoma, Wash., and Anyox, British Columbia, where their copper, gold, and silver contents are recovered.

The productive mines on Prince William Sound in 1917, so far as known, included nine copper and eight gold mines. A much larger quantity of copper ore than of gold-bearing quartz was mined and treated, and the total value of the metals obtained from the copper ores was several times that of the metals from the gold quartz ores. The value of the total mineral output of the Prince William Sound region in 1917 was $4,667,929, compared with $2,975,200 in 1916.

COPPER MINING.

GENERAL CONDITIONS.

Copper mining was actively carried on in the Prince William Sound region in 1917 and a large production of copper was made. The regular producers, the Kennecott Copper Corporation at Latouche; the Ellamar Mining Co., at Ellamar; and the Granby Consolidated Mining, Smelting & Power Co. (Ltd.), owner of the Midas mine in the Valdez district, made large shipments as usual. Considerable ore was also shipped by the Latouche Copper Mining Co. from the Blackbird group on Latouche Island; the Alaska Mines Corporation controlling the Schlosser property, on Port Fidalgo; the Fidalgo Mining Co., on Port Fidalgo; and the Dickey Copper Co., on Port Fidalgo. Small shipments were reported from the property of Harry Moore on Knight Island and from that of the Patten Cooperating Co. The Threeman Mining Co., on Landlocked Bay, which has shipped much ore in previous years, made no shipments in 1917. Development work was done on some of the nonproducing properties and assessment work is reported on many others. Crude ore was shipped from all the producing properties and in addition copper-bearing flotation concentrates were shipped from the Beatson-Bonanza mine, on Latouche Island. The copper-bearing mineral in all the ore shipped was chalcopyrite. Much of the copper ore mined also carries either gold or silver or both.

WORK DONE DURING THE YEAR.

LATOUCHE AND KNIGHT ISLANDS.

Large operations were in progress at the Beatson Bonanza mine of the Kennecott Copper Corporation throughout the year; the enlargement of the milling plant to a capacity of 1,600 tons daily was in progress, with consequent changes in power plant and mine. An average force of 345 men was employed by the company during the year. A large amusement hall, including moving pictures, bowling alleys, and clubrooms for the use of the employees, was completed early in the year. Other surface improvements included a new store and warehouse, several new houses, a new compressor plant and building, and some small buildings and sheds. The head frame of the shaft was framed during the winter and erected in the spring. Three Diesel engines were installed in the power plant. The capacity of the shipping bunkers was doubled. Additional crushing and flotation equipment was installed in the mill.

A new shaft was completed and put in operation during the year, and a hoist capable of handling 5-ton skips was installed. The main haulage ways and drifts were widened to accommodate larger cars, and two 4½-ton storage-battery electric locomotives were installed.

A 500-ton concrete ore pocket was also finished. A big manway raise was completed between the main level and the top of the ore bluff. Considerable diamond-drill work was done during the year, some of it on the 100-foot level. No other work was done on this lower level during the year. The normal development work was in progress through the rest of the mine, and stoping operations were carried on between the main haulage level and the surface and eastward into the hill above the bluff pit level.

The Blackbird claim of the Latouche Copper Mining Co. on Latouche Island was opened up and operated by Mr. W. A. Dickey. This claim lies just to the north of the Beatson-Bonanza mine, and the deposit under development on the Blackbird appears to lie in the northward extension of the same mineralized zone which includes the Beatson-Bonanza. Considerable underground development work, done both on the main-tunnel level and between this level and the surface, has developed an ore-bearing zone reported to be from 12 to 50 feet in width and said to be traceable underground for 700 feet. During the year crosscuts and drifts were run to the extent of 300 feet, and four stopes were opened up. Operations were in progress from June to October, inclusive. In October about 25 men were employed. A new wharf was erected during the year, a new blacksmith shop was built at the mouth of the tunnel, and repair work was done on other buildings and the tram line. Several shipments of ore were made from the property during 1917. The last previous shipment was in 1907.

Little was done on the other copper properties on Latouche Island. No development work in known to have been done on the Reynolds Alaska Development Co.'s property on Horseshoe Bay or on the property of the Seattle-Alaska Copper Co. on Montgomery Bay.

On Knight Island no productive operations were in progress. The largest developments were on Rua Cove at the Copper Bullion claims (Rua property), which had previously been taken over by Mr. W. A. Dickey. A cabin and a house were erected near the shore of the cove, another building was completed at the upper camp, and a new blacksmith shop was built at the mouth of the tunnel. A small water-power plant, with a two-drill compressor and two drills, was also installed. Underground work completed during the year totaled about 600 feet of tunnel and crosscuts. An average force of 10 men was employed during the summer. Operations were discontinued for the year on September 14, 1917, after a large body of low-grade copper ore had been partly blocked out.

Some of the pyrrhotite ores of Mummy and Drier bays are reported to carry nickel, and during the season short tunnels were driven on the nickel-bearing lodes and some diamond drilling was done.

On the Copper Coin group on Drier Bay a small wharf was erected in the spring, and a compressor and supplies were placed on the ground but not installed. Only two or three men were at work on the property during the year, and no underground work is known to have been done.

On the Pandora group on the Bay of Isles the only work done in 1917 consisted of some open cuts. This lead is now reported traceable a little over 1,000 feet.

Small shipments of copper ore are reported from the Copper Queen claim on Hogan Bay and from a property of Harry Moore on Drier Bay.

UNAKWIK INLET, WELLS BAY, LONG BAY, AND GLACIER ISLAND.

A new copper discovery, on property called the Globe claims, was made back of Long Bay during 1917. The ore body is reported to be of low grade, several feet in width, and two claims in length. No development work was done.

On Cedar Bay, the Lenora group of five claims was surveyed for patent in 1917. Very little underground development work was done during the year. Three men were at work on the property for three months in the spring, and about 75 feet of tunnel was driven. A small force of men is also reported to have worked underground on the property late in the fall. Only assessment work is reported on other properties in this vicinity.

On Glacier Island assessment work is reported on the Portsmouth and Scotia Bell claims of Jens Jensen. The ore body lies a little more than half a mile south of Finski Bay. The country rock is greenstone, and the ore minerals consist of quartz, epidote, pyrite, and chalcopyrite. Some development work has been done on mineralized showings along a pronounced gully which apparently follows a large shear zone. The lower tunnel, which has about 225 feet of workings, is at an elevation of about 250 feet. The main drift, 150 feet in length, is on a shattered zone along a nearly north-south break that shows only a thin trace of gouge. This fracture dips 65° W. The maximum mineralized width of the shattered greenstone is about 3½ feet, and the mineralization appears to be traceable about 60 feet. The ore is a hard, shattered greenstone firmly cemented by sulphide-bearing quartz. A crosscut to the west encountered a mineralized shear zone that strikes N. 20° E. and dips 70° W., along which about 30 feet of drifts have been driven. A width of 10 feet of slightly cupriferous pyrite is reported to have been cut at one point in this shear, which may be the main shear followed by the gulch. The upper tunnel, at about 500 feet elevation, is driven 30 feet on a mineralized shear zone that outcrops on the east side of the gulch.

This showing is not traceable very far on the surface. The face of the tunnel shows 4 feet of shattered greenstone cemented by much quartz that carries sulphides, chiefly chalcopyrite. A streak of nearly solid chalcopyrite, which has a maximum width of 3 inches, runs along the hanging wall. Just over the mouth of this tunnel this shear strikes N. 5° W. and dips about 65° W., and the mineralized portion of the shear has a width of 5 to 12 inches.

Between these two tunnels there are some mineralized outcrops on which a little open-cut work has been done. The mineral deposit in each place is in a sheared or shattered greenstone and has a width of 1 to 6 feet, but the mineralization is traced only short distances by the present development work.

PORT VALDEZ DISTRICT.

The Midas mine of the Granby Consolidated Mining, Smelting & Power Co., on Solomon Gulch, was actively developed during the year and was one of the important shippers of crude copper ore of the Prince William Sound region. An average force of about 50 men were employed during the year on the property. Surface improvements consisted of the erection of a new cook and bunk house and some open-cut work. The principal underground developments consisted in the sinking of an inclined winze, which has a dip of 60°, from No. 2 adit to a depth of 100 feet. No. 1 adit was also extended and considerable drifting done.

A detailed account of the geology of this copper deposit and the copper-bearing area of the Port Valdez and Jack Bay district in which it is found is given elsewhere in this bulletin (pp. 157–173).

ELLAMAR DISTRICT.

The plant of the Ellamar Mining Co. was operated steadily the entire year except for shutdowns of two weeks in the summer and a few days in December. An average force of a little over 100 men was employed during the year. Surface improvements consisted of the erection of a social hall, the construction of a new warehouse on the dock, the shifting of the pump house to a new location in the glory hole, and the installation of foundations for a new power house. Most of the underground work this year has been between the surface and the 200-foot level. The water level was down to a few feet below the 500-foot level and the 500-foot level was open, but no work was being done on that level during 1917. Some work was done on the 100, 200, 300, and 400 foot levels, but stoping operations were confined to stopes between the 300-foot level and the surface. Some diamond drilling was also done. Regular shipments were continued as usual.

No shipments were made from the property of the Threeman Mining Co., on Landlocked Bay, and only one man is reported to have been at work on the property during the year.

On the property of the Hemple Copper Mining Co. on Landlocked Bay development work started in May. Six men were at work during the summer, but on October 1 the crew was reduced to three men. Work was temporarily stopped early in October but is said to have been resumed again about December 15. The work done up to October was all in tunnel No. 1 and consisted in driving a 110-foot crosscut, which cut a slightly mineralized shear zone at its inner end. On October 8 the shear zone showed a width of 8 feet, but at that date the inner wall of the shear had not been encountered. This shear strikes N. 70° W. and dips to the east.

Up to October 1 no work had been done in 1917 on the property of the Landlock Bay Copper Mining Co., on Landlocked Bay.

Twenty-two men are reported to have been at work early in the spring on the property of the Standard Copper Mines Co., near the entrance to Landlocked Bay. Later in the season a force of only 10 men was employed and for a period of about a month during the summer only 1 man was retained on the property. On October 8 only the watchman was on the ground. A new cookhouse and bunk house were erected on the mountain side, and a small building was put up at one of the tunnel mouths. The tram was also fixed and was operated during the summer. Some underground work was also done. The wharf was repaired, but no shipments of ore were made during the year.

Only assessment work is reported on the Buckeye group on Landlocked Bay.

PORT FIDALGO.

Development work was in progress at two of the copper mines on Port Fidalgo, and shipments of ore are reported from all three mines. The Fidalgo Mining Co. worked steadily with an average force of 7 or 8 men and with a maximum number of about 13 throughout the year. Considerable underground development work was done, and some ore was shipped. Stoping operations were carried out between tunnels Nos. 1 and 2 and above tunnel No. 2. Tunnel No. 2 was extended and a crosscut already started was driven about 150 feet toward a new lead to the east. A new lower tunnel (started in 1916) was extended to a length of 300 feet. Considerable stripping was also done on the new lead.

The Alaska Mines Corporation operated the old Schlosser property continuously throughout the year with a crew of 27 to 33 men. Underground work was done on four levels, and stoping operations were carried on over several of the levels. The ore deposit consists of lenses of sulphides occupying a linked system of shears. The ore zone as now developed has a width of 100 feet and strikes about N. 20° E. and dips nearly vertically. The ore shoots pitch to the north parallel to the hillside. Several hundred feet of development work besides stoping is reported to have been done in 1917.

The Dickey Copper Co., owner of the Mason and Gleason claims on Irish Cove, is not known to have operated during the year, although a shipment of ore is said to have been made from this property.

Ed. Banzer is reported to have done a little work on a copper property near the head of Port Fidalgo, but no details are available at present.

CORDOVA AND VICINITY.

Development was in progress during part of 1917 on a copper property on Fleming Spit. The operations were in charge of Mr. R. E. Hutchinson. The company, the Tacoma-Cordova Mines Co., employed a force of three or four men from June to September, inclusive. Considerable work was done in two tunnels about 250 feet apart vertically, and a number of open cuts were made on the outcrop of the ore body under development.

GOLD MINING.

GENERAL CONDITIONS.

The gold produced in the Prince William Sound region, other than that obtained from the gold-bearing copper ores, comes from both gold quartz lodes and gold placers. The placer deposits are few, small, and irregularly distributed. They are worked only intermittently, on a very small scale, and contribute little to the gold production. The producing gold quartz lodes are in the Port Wells and the Port Valdez districts. The Granite mine, on Port Wells, and the Cliff and Ramsay-Rutherford mines in the Port Valdez district are the largest producers.

WORK DONE DURING THE YEAR.

PORT WELLS DISTRICT.

The Granite mine was the most productive property in the Port Wells district in 1917 as in the previous years. This property was in operation during the spring, but milling was stopped about the middle of May, and all operations were discontinued on June 1. About 40 men are said to have been employed during the spring operations. The property is to remain shut down until water power can be installed.

The Thomas-Culross Mining Co., on Culross Island, completed the installation of a milling plant early in the spring, and the mill was in operation during a part of the season. From 5 to 20 men are said to have been employed. A small shipment of ore is also said to have been made to the Tacoma smelter.

The Alaska Homestake Mining Co., whose property is on Harriman Fiord, report the installation of a 12-ton gyratory mill, crusher, and concentrator in 1917. The mill is said to have been operated only a few days. Development work on the property at the close of 1917 is said to consist of an upper tunnel 225 feet long, a shaft 67 feet deep, and a lower tunnel 150 feet long connected with the shaft. About 18 men were employed on the property during the season.

A new mill and aerial tram were erected on the Sweepstakes property on Harriman Fiord in 1917 but were not operated.

On the Hermann-Eaton property on Bettles Bay a water-power plant, air compressor, and machine drills were installed. A crosscut tunnel several hundred feet in length, driven at an elevation of about 350 feet, is said to have intersected the lead on the claims late in the fall. From 5 to 9 men were employed on the property at different times during the year. The property was closed down for the year early in October.

Development work is reported to have been in progress on the Banner group on Bettles Bay, and the adit tunnel on that property is said to have been extended to a length of over 400 feet.

Three hundred feet of development work is reported on the Wagner & Johnson group at Golden.

At the Osceola group on College Fiord drifting was continued on the lead, and the tunnel is said to have been extended 200 feet during the summer to a total length of about 400 feet. Five men were employed on the property, and operations were in progress only during the summer.

A crosscut tunnel was driven on the property of Chris Pedersen on Pigot Bay and a little drifting done on a lead in the tunnel.

Two men were engaged in development work on the Tomboy group on Pigot Bay.

Assessment work is said to have been done on many other properties.

PORT VALDEZ DISTRICT.

The producing properties in 1917 in the Port Valdez district included the Cliff, Ramsay-Rutherford, Valdez Gold, Cube, and Slide. Development work was in progress on a few other properties, and the annual assessment was done on many others.

The Cliff mine operated throughout the year, although the mill was run only intermittently. During January and February 18 to 20 men were employed, and the remainder of the year about 9 men. As the shaft and lower levels were flooded, all underground work was confined to the 100-foot level and the levels above and to the stopes between these levels. About 450 feet of drifts and crosscuts are reported to have been driven during 1917.

The Ramsay-Rutherford, after operating during part of the year, closed down early in June. The mill is reported to have been in operation from January 1 to June 4, although not running continuously. Mining operations ceased June 7. From 13 to 19 men were employed at different times during the season. Surface improvements are said to have consisted in the installation of an air compressor. Underground about 150 feet of drifting is reported on the lower levels. Stoping operations were carried on between several of the levels.

The Valdez Gold Co. reports only assessment work. From 5 to 7 men were at work on the property during July, August, and part of September. A very few tons of ore was milled and only a little underground work was done.

The Cube Mining Co. operated its mill during February and part of March and also for about a month beginning May 7. About 25 men were employed during the spring. The property was closed down early in July.

A small shipment of ore was made from the Slide gold quartz claim near the head of Mineral Creek during the year.

On the Alaska Gold Hill, formerly known as the Black Diamond property, 5 or 6 men were employed from January to September, two buildings were erected, and also a blacksmith shop at the tunnel mouth. This shop was later torn down. The upper tunnel was extended to a length of 605 feet.

The Valdez Mining Co. let a contract late in the fall to extend the lower tunnel on their Valdez Glacier property a distance of 75 feet.

Some development work is also said to have been in progress during the year on the property of the Patten Mining Co. near Swanport with a force of 6 or 7 men.

On the Shoup Glacier properties a little development work was in progress. Two men were at work on the Nymond property, and about 100 feet of tunnel is said to have been driven. Work was also done on the Olson and McDonald properties.

At the Gold King mine on Columbia Glacier 4 men were at work up to the end of April. The mill was not run. Late in the fall it is reported that a contract was let for sinking 50 feet farther a winze which had been sunk 15 feet during the spring developments.

At the Mayfield on Columbia Glacier 2 men did the annual assessment work, which is reported to have consisted in driving an additional 20 feet in the upper tunnel.

MINERAL RESOURCES OF JACK BAY DISTRICT AND VICINITY, PRINCE WILLIAM SOUND.

By Bertrand L. Johnson.

INTRODUCTION.

The object of this preliminary report is to describe briefly the distribution, geologic relations, and characteristics of the mineral deposits of the Jack Bay district and the adjacent area surrounding the upper portion of the adjoining valley of Solomon Gulch. A brief presentation of the geographic factors immediately bearing on the economic development of the mineral deposits of these areas precedes a short summary of the geology. The general description of the mineral deposits is followed by detailed descriptions of the few ore bodies which have so far been found. A more complete account of the geology and mineral resources of these areas will be incorporated in the final report on the Port Valdez and Jack Bay districts now in preparation.

Detailed geologic mapping of the Jack Bay district and vicinity was done in the summer of 1917. Several trips had been made in previous years, however, to the area adjacent to the Midas copper mine, near the head of Solomon Gulch, in order to study the mineralization of that area while studying the geology and mineral resources of the adjacent Port Valdez district, and in 1912 the writer was associated with Mr. S. R. Capps in a study of the geology and mineral deposits of the Ellamar district, which adjoins the Jack Bay district on the south.

GEOGRAPHY.

The Jack Bay district comprises the small part of the Chugach Mountains that borders the northeast corner of Prince William Sound, which is drained by the several streams entering Jack Bay. (See fig. 2.) This report also discusses the mountainous area that surrounds the head of Solomon Gulch and Allison Creek, the waters of which flow off the northern slopes of the mountains bordering the north side of the south arm of Jack Bay into Port Valdez. The area under consideration adjoins on the north the mountainous Port Valdez district and on the south the less rugged Ellamar district. The western limit is the broad Valdez Arm of Prince William Sound.

This area is one of strong relief. The Chugach Mountains, which inclose Jack Bay, rise from sea level to elevations ranging from 3,000 to nearly 6,000 feet. The lower hills and mountains bordering the entrance to Jack Bay and the western portion of the ridge between the two arms of Jack Bay have the rounded characteristic forms of glacially overridden hills. The high peaks and ridges which surround the headwaters of the streams that drain into the heads of

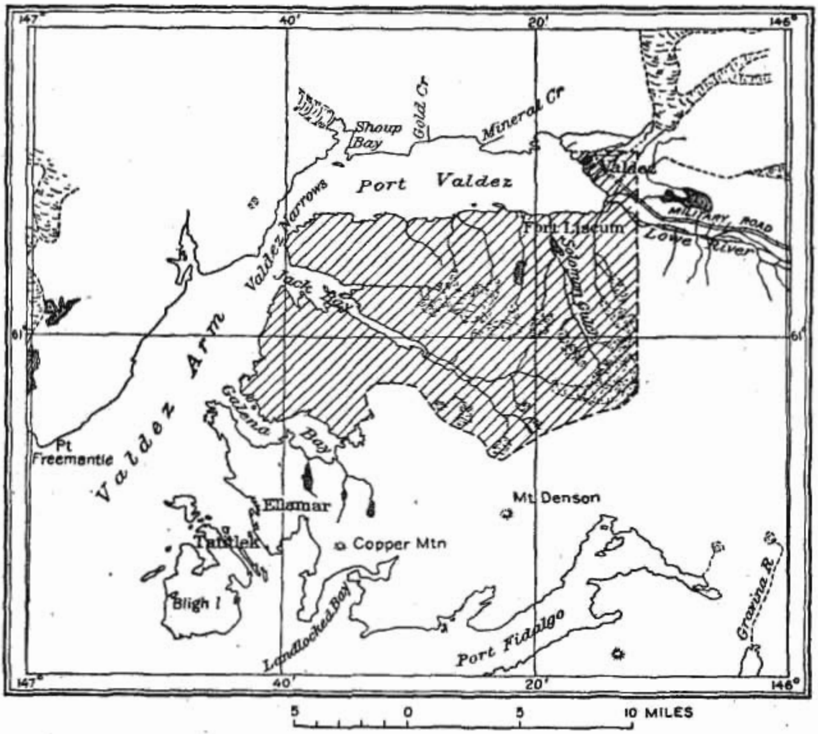


FIGURE 2.—Index map showing location of the Jack Bay district.

both arms of the bay, however, are sharp and pinnacled, and remnants of the glacial sculptors of this rugged alpine topography rest in their ice-carved basins and feed many of the larger streams. In marked contrast to the rugged topography of most of the district are the flat gravel-covered lowlands at the heads of both arms of Jack Bay and the long, narrow gravel-floored basin of Solomon Gulch.

Glaciers cover a relatively small part of the district but feed many of the larger streams. They are all of the alpine type. One through glacier lies in a col that connects Solomon Gulch with the headwaters of the main stream that drains into the south arm of Jack Bay, and another in cols that connect Sawmill Creek and a parallel stream adjacent to it on the west with the valley of a stream that enters the head of the north fork of Jack Bay. The remaining glaciers are valley-head glaciers or lie in cirques along the valley walls and are concentrated chiefly along the north side of the ridge on the north side of the south arm of Jack Bay.

The shore line of both arms of Jack Bay is smooth and even. The shores are steep, in may places precipitous, and rocky, with few islands except along the westward continuation of the range which separates the two forks of Jack Bay. The heads of both arms are filled by tidal mud flats sloping up into the gravel-covered flood plains of glacial streams. Small deltas lie at the mouths of some of the other streams. Near Valdez Arm two small wide-mouthed coves indent the southern shore of Jack Bay.

The drainage of the Jack Bay district enters one or the other arm of Jack Bay. Solomon Gulch and Allison Creek flow northward into Port Valdez. The streams that enter Jack Bay are all less than 6 miles in length and drain narrow, steep-sided glaciated valleys. Solomon Gulch is about 7½ miles and Allison Creek a little over 4 miles in length. All these streams derive a considerable part of their water supply from melting snow or ice, and the stream flow is subject to wide variations during the year. Two power plants have been in operation on the lower end of Solomon Gulch in the Port Valdez district in recent years, but there are none in the Jack Bay district. There are some small undeveloped water powers in the Jack Bay district.

The climate of the Jack Bay district closely resembles that of the adjacent Port Valdez district. Both districts are somewhat colder and drier than the more southern parts of Prince William Sound, which are more directly exposed to the influence of the Pacific Ocean. Numerical comparisons of the climatic factors of these two districts can not be made, however, because of the lack of weather observations within the area here referred to as the Jack Bay district. At Valdez and Fort Liscum, situated at sea level, in the Port Valdez district, weather records extend over a considerable period of time. These records show a total annual precipitation of about 56 inches at Valdez and 74 inches at Fort Liscum; the annual snowfall at Fort Liscum is at least 30 feet. The average temperature for the three summer months in the Port Valdez district is 52° F. and for the three winter months 21° F. Similarly situated portions of the Jack Bay district would appear to have a slightly greater rainfall and to be slightly warmer, owing to the somewhat greater exposure of this district to the ameliorating influences of the Pacific Ocean. Climatic conditions in the higher portions of the district are much more severe.

Only that portion of the area covered by this report which immediately borders the shores of Jack Bay and Valdez Arm is forested.

The upper limit of timber extends from a few hundred feet above sea level in the bottom of the valley at the head of the north arm of Jack Bay to elevations of about 1,750 feet near the mouth of the bay. Spruce and hemlock greatly predominate, and only a few cottonwoods are found. The local timber from this and adjacent districts is suitable for mine workings and rough lumber, but the better grades of lumber are brought from Seattle. All of the timbered portion of the Jack Bay district lies within the Chugach National Forest. Those portions of Allison Creek and Solomon Gulch valleys covered by this report are not timbered.

The larger animals reported to be native to this area include the bear, mountain goat, and mountain sheep. Both the goats and the sheep are said to have been obtained in the high mountains surrounding the head of Jack Bay, but only goats were seen during the present field season. Evidences of bears are plentiful in many places and both brown and black bears are reported.

Wolverines, marmots, weasels, and porcupines are native to the area. Squirrels and rabbits are found in the adjacent Port Valdez district and probably range over parts of this area. Mink, marten, otter, and other small fur-bearing animals found in the adjacent districts are probably also to be obtained here, although no evidences of their presence were seen in the summer of 1917.

Ptarmigan live in the portions of the region above timber line, and grouse are found in the spruce forests. Geese, ducks, sandpipers, and other waterfowl and shore birds are obtainable here in season. Bald eagles, owls, cormorants, gulls, terns, magpies, blue jays, ravens, crows, divers, and smaller birds are abundant.

Several varieties of salmon are caught in Jack Bay for the canneries at Valdez, Cordova, and Port Nellie Juan. Salmon trout, bass, and flounders are also obtained. Blackfish and whales are occasionally reported in the waters of Valdez Arm. Seals are common, both in Jack Bay and Valdez Arm. The waters of the glacier streams flowing into the head of Jack Bay are milky from suspended rock flour, but the salmon ascend these streams for at least short distances. The few clear-water streams that enter the bay appear to be too precipitous in gradient to offer shelter to fresh-water fish.

Valdez, the supply point of the Jack Bay district and for those portions of the Port Valdez district covered by this report, lies at the head of Port Valdez. The town has a population of several hundred and is provided with wharves, bank, hotels, stores, public schools, telephones, and electric lights. A good stock of supplies is kept on hand, and prices are not high, except for fuel. In the past the town has suffered from occasional floods of the streams from the Valdez Glacier, but it is now protected by a dike that was built in 1913-14.

Valdez is the coastal terminus of the Valdez-Fairbanks military road. It is connected by cable with Seward, Cordova, Juneau, and other points on the Alaska coast and with Seattle, and by telegraph with Fairbanks. Port Valdez is open to navigation throughout the year. Valdez can be reached in six days by steamer from Seattle. Two companies operate steamers to Valdez, giving a summer service of about eight times a month and a winter service of four to six times a month. Freight charges in 1916 between Seattle and Valdez ranged from $3 to $45 a ton according to classification. Passenger rates in 1917 between Seattle and Valdez were as follows: First-class, upper deck, $50; first-class, lower deck, $47.50, and second-class, $30. Regular stops in the Port Valdez district are Valdez and Fort Liscum, but there is also a wharf at the Midas mine. There are no stops in the Jack Bay district.

Transportation along the coast is effected largely by the use of gasoline launches, which can usually be hired for $10 to $30 a day. Regular service is maintained between Valdez and Fort Liscum by the post boat and between the wharf of the Granby Consolidated Mining, Smelting & Power Co. (Ltd.) and Valdez by the company launch.

Much of the Jack Bay district and the adjacent portions of the Port Valdez district are but a short distance from tidewater. The Midas mine and the country adjacent to the Solomon Basin are readily reached from the wagon road which has been built from a point on the south side of Port Valdez a short distance east of Fort Liscum up into Solomon Basin. There are no roads in the Jack Bay district, and but one prospect is connected with tidewater by a trail. An aerial tram operated by the Granby Consolidated Mining, Smelting & Power Co. (Ltd.) between its wharf on Port Valdez and the Midas mine near the head of Solomon Gulch is used only for the transfer of ore and supplies.

GEOLOGY.

DIVISIONS OF THE ROCKS.

The Jack Bay district lies in the southern part of the Chugach Mountains, which, in those portions bordering Prince William Sound, consist of folded and faulted Mesozoic (?) rocks—graywackes, argillites, slates, and subordinate amounts of conglomerates and dark-colored limestones—altered in places to schistose types and intruded at diverse points by granites and basic igneous rocks of Mesozoic or Tertiary age. (See Pl. III.)

The sedimentary rocks of the Prince William Sound region were subdivided by the earlier geologists [1] into two great divisions—the Valdez and Orca groups. The Valdez group was described as consisting principally of graywacke and slate, and it was presumed to be older, more metamorphosed, and to lie unconformably beneath another great series of sediments of somewhat similar lithologic character, named the Orca group. The Orca rocks were stated to consist of interbedded slates and graywackes with extensive basic lava flows and thick conglomerate beds. The Valdez group was mapped as occurring on the northern and western shores of the sound, whereas the Orca rocks outcropped on the eastern shore and also formed the islands of the sound. The Jack Bay district lies within the Valdez group of these writers. It includes, however, some small areas of greenstone of the Orca group and on its southern border an area of conglomerate probably also of Orca age.

ROCKS OF THE VALDEZ GROUP.

LITHOLOGIC SUBDIVISIONS.

The rocks of the Valdez group in the Jack Bay district are all regionally metamorphosed types of sedimentary rocks. The variety is not great and but two lithologic subdivisions have been made, the graywackes and the black slates. A thick black slate formation on the east side of Valdez Arm between Jack and Galena bays appears to underlie the massive graywackes south of Jack Bay. Broad bands of black slates and argillite, however, also occur interbedded with the massive graywackes. In fact, all gradations exist, both in texture and in thickness of beds, for the rocks range from slates to conglomerates and the beds from narrow alternating bands of slate and graywacke to massive members of both rocks. The areas mapped as slate are underlain dominantly by slate and argillite together with minor amounts of graywacke. The graywacke areas are underlain dominantly by graywackes but in places contain a greater or less proportion of slates and argillites.

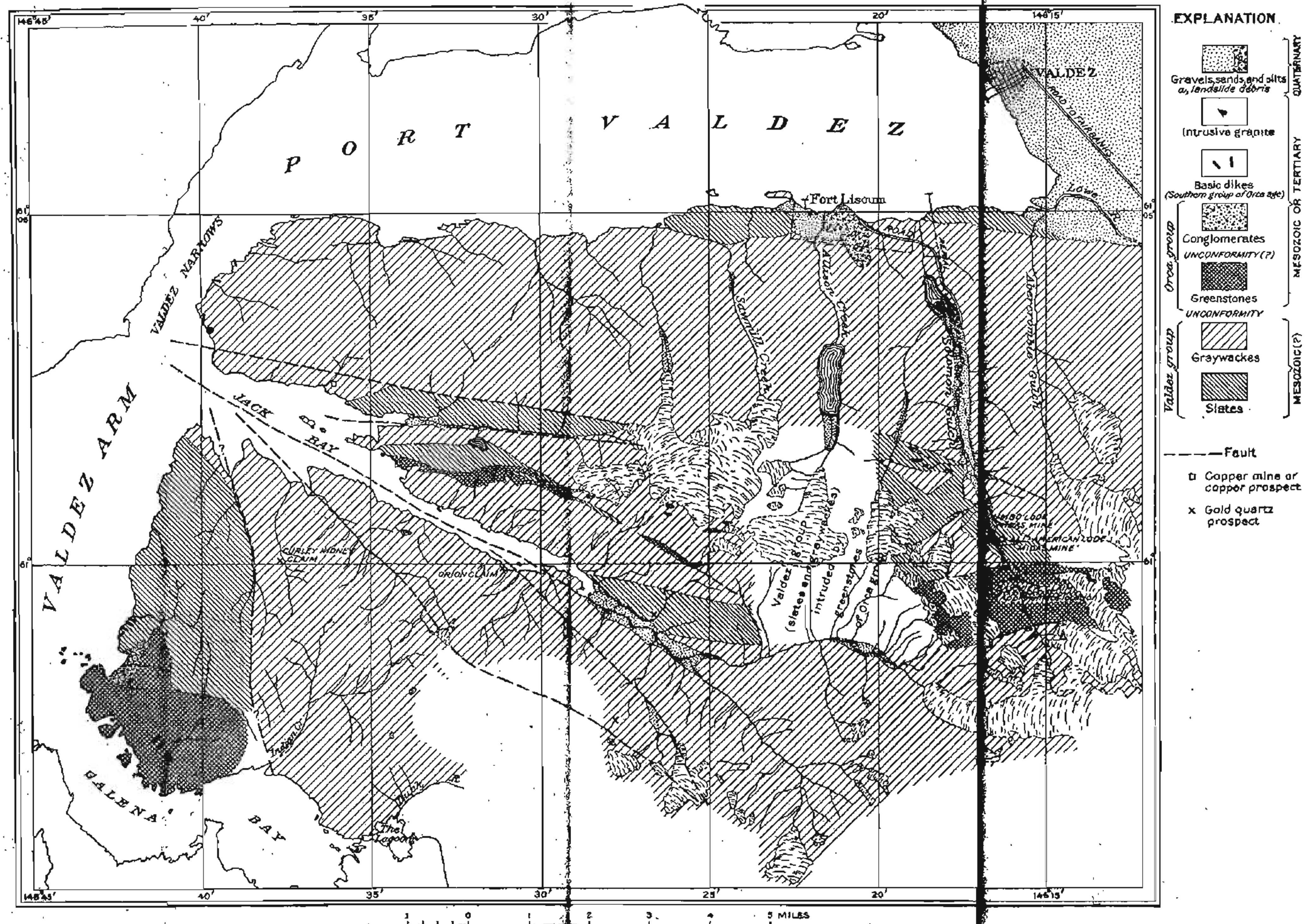
THE GRAYWACKES.

The graywackes and argillites cover a much larger portion of the area considered in this report than any of the other formations. They cover the entire portion of the Jack Bay district south of Jack Bay except for the small areas of slate and greenstone along Valdez Arm,

[1] 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., p. 7, pp. 404–417, 1900.

Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska: U. S. Geol. Survey special publication, pp. 32–40, 1901.

Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, pp. 11, 20–33, 51–52, 1910.



GEOLOGIC SKETCH MAP OF JACK BAY AND VICINITY.

most of the northern part of this district, and much of the central portion between the two arms of Jack Bay and around the head of Solomon Gulch. The rocks grade from fine conglomeratic graywackes in a few places through gray to dark-gray coarse-grained graywackes containing feldspathic material to the darker fine-grained argillites and slates. The formation is largely made up of graywacke, but the proportion of the other types of rocks differs widely. The area south of the south arm of Jack Bay contains very little argillite and slate, but these two types are very abundant in the graywacke series between the two arms of Jack Bay and are quite abundant in the northern part of the district and along the middle section of the Solomon Gulch valley. The graywackes in most places are well bedded, and the thickness of individual beds ranges from a few inches to many feet. Most of the rocks are rather fine grained and are composed of subangular fragments of quartz and plagioclase feldspar, comparatively little decomposed, in a carbonaceous, calcareous, and argillaceous matrix. At one place in the mountains between the arms of Jack Bay a rather coarse grained graywacke contained numerous flat fragments of a mottled light-greenish chlorite schist. Locally the graywackes adjacent to the igneous intrusions and also at some other places have been slightly altered to a reddish-brown biotite-bearing graywacke.

BLACK SLATES.

The black slates are best developed along the east coast of Valdez Arm between Jack and Galena bays, along the north side of the streams draining into the heads of both arms of Jack Bay, and near the Midas mine on Solomon Gulch. The slates are dark-gray to black, very fine grained rocks and in many places have exceptionally well-developed slaty cleavage. A small amount of interbedded graywacke and argillite occurs in this formation. Many of the areas that contain slate have been intruded by the greenstones of the Orca group, and the slates adjacent to these intrusions have been altered to rocks resembling hornstones and charts or to knotenschiefer. The knotenschiefer are especially prominent at the head of Solomon Gulch. Many of the smaller greenstone intrusives in the slates in some of the disturbed areas have become schistose, their schistosity paralleling the cleavage of the slates. Some of the areas of slate in the vicinity of the greenstone intrusives have been mineralized.

AGE OF THE VALDEZ GROUP.

The age of sedimentary rocks here assigned to the Valdez group is not definitely known. The present determination of a probable Mesozoic age for these rocks rests upon the unsatisfactory evidence of one fossil, a worm tube, *Terebellina palachei* Ulrich, which was found in 1917 in the massive graywacke series on the south side of Jack Bay. Similar tubes have been found by Grant in the black slates just north of the entrance to Galena Bay. These fossils are not diagnostic and serve only to determine the possible age of the containing rocks within wide limits. The present knowledge of this fossil appears to indicate a post-Triassic and probably Mesozoic age for it and for the containing rocks.

ROCKS OF THE ORCA GROUP.

LITHOLOGIC SUBDIVISIONS.

The Orca group includes both sedimentary and igneous rocks and consists of a thick series of basic lava flows, many basic intrusive bodies genetically related to the extrusives, and contemporaneous sediments. The intrusive phases of the igneous rocks are more abundant than the extrusive in this area, although the latter type are represented, to a certain extent at least, in the greenstone area just north of the entrance to Galena Bay. All these igneous rocks are now largely altered to greenstones. No Orca sediments other than the conglomerates have been recognized. These conglomerates, which lie above the greenstone and contain pebbles derived from it, are tentatively placed in the Orca group. The presence of the greenstone pebbles in the conglomerate can not positively be construed as indicating an unconformity between the lavas and the conglomerate, for the flows may have been partly subaerial, erupted contemporaneously with the deposition of the conglomerate, and the greenstone boulders and pebbles may have been obtained from those portions of the flows exposed above sea level or near enough to sea level to suffer erosion.

GREENSTONES.

All the igneous rocks of this area are in this preliminary report grouped under the general term "greenstones." These greenstones and their schistose equivalents, the green schists, are the derivatives of basic igneous rocks of both intrusive and extrusive types. They comprise flows, dikes, sills, bosses, and some large irregular intrusive masses. These basic rocks in many parts of this area intruded the graywackes and slates of the Valdez group, showing a marked preference for the slates. In the southwestern part of the Jack Bay district and in the adjacent Ellamar district they broke through the crust and flowed out over the surface of the sedimentary rocks.

The largest single mass of greenstone lying within the area covered by this report crosses the head of Solomon Gulch a short distance above the Midas mine. This mass is known to extend in an east and west direction from the crest of the divide between the Solomon Gulch and Jack Bay drainage far up on the eastern slope of the valley of Solomon Gulch, and it probably extends beyond the area mapped for a considerable distance. Its width at the bottom of Solomon Gulch is 1 mile. Many sills of greenstone lie parallel to the contact in the slates and graywackes along the southern border of this mass.

A small part of the immense greenstone area of the Ellamar district extends into the southwestern part of this area just north of the mouth of Galena Bay. It is surrounded on the north and northeast by slates and is partly overlain on the west by a small area of conglomerate. Inclusions of black slate occur in this greenstone along its western shore southwest of the conglomerate area. Ellipsoidal flow structures are visible in places on the western slope of this mass and also along the shore. Several basic dikes and sills, probably of the same age as the main body of the greenstone, cut the slates on the eastern shore of Valdez Arm just north of this large greenstone mass.

A long, narrow mass of greenstone 3 miles in length, of irregular width and only one-fourth mile wide in its widest place, has intruded the slates and graywackes in the western part of the mountains between the arms of Jack Bay. It contains many inclusions of the country rock, some of which are slightly mineralized. Numerous sills and dikes occur in the mountains a little farther east.

A small boss of greenstone about 1,000 feet in diameter lies in the slates just south of the Jumbo lode of the Midas mine. Near the All-American lode, also on the same property, sills and dikes, and some small irregular masses of greenstone are intrusive into the slate and argillite country rock and are well exposed in the canyon of Solomon Gulch to the west of that ore body.

The greenstones are all fine grained. The textures include aphanitic, finely porphyritic, diabasic, and schistose. Diabasic textures were observed in the dikes, in the sills, and in some of the larger masses. Some of the dikes have aphanitic contacts and dense, fine-grained, or finely porphyritic centers. The color of the greenstones ranges from light greenish gray to dark green. The fine-grained dike rocks are nearly black and in some places have lighter purplish-gray contacts. The schistose greenstones of the large area at the head of Solomon Gulch are dark green. In some places the original structure and texture have been completely masked by the schistosity developed by the shearing of the greenstones by later movements, so that the rocks in many places now appear as light-green bands of chlorite schist. This schistosity often occurs in sills and dikes in the slates.

The greenstones are slightly mineralized in some places. Chalcopyrite, pyrrhotite, pyrite, ankerite, and quartz were noted. The outcrops of these mineralized greenstones are usually rusty.

CONGLOMERATES.

The largest exposure of conglomerate at present considered as of Orca age in the Jack Bay district lies along the eastern side of a small cove in the east side of Valdez Arm, about 1 mile north of Galena Bay. The only other occurrence of conglomerate of this age within this district is near by on a small island, one of the outer islands of the group at the north side of the entrance to Galena Bay and about a mile west of the first-mentioned locality. The large exposure along the eastern shore of the cove north of Galena Bay is about 1 mile in length and has a maximum width, near its southern end, of three-tenths of a mile. The conglomerate rests in a marked depression within the arms of the older slates and graywackes and the greenstones of the Orca group and lies on the western slope of the large greenstone mass forming the hills to the southeast. It is best exposed along the shore of the cove. The vertical bluff at the south end of the cove decreases in elevation and slope northward to a low, gently sloping outcrop at the north end of the bay. The general tone of the rock is a dark bluish gray, and it resembles in many ways an indurated dark-colored till.

The conglomerate near the southern end of the bluff is a massive coarse-grained heterogeneous mixture with no sign of bedding. There are abundant angular to subangular boulders of all sizes, the largest of which are several feet in diameter. Most of the boulders, however, are small and less than a foot in diameter. They consist chiefly of greenstone, graywacke, slate, and argillite. A few small, exceptionally well rounded pebbles of siliceous argillite are found. The greenstone boulders appear most abundantly in the lower part of the southern end of the bluff. To the northward the conglomerate is finer grained, and a few thin lenticular beds of graywacke 1 to 4 inches thick, which strike N. 30°–45° E. and dip 12°–25° W., appear in the conglomerate. The pebbles in the conglomerate at the north end of the bluff are mostly 1 to 2 inches in diameter, although in places larger boulders occur.

Except for the greenstone boulders, which weather a light yellowish brown, the pebbles, boulders, and matrix are all dark. The matrix of the conglomerate is predominantly argillaceous.

AGE OF THE ORCA GROUP.

No definite evidence is available regarding the age of the Orca rocks of this area. The greenstones intrude the Mesozoic (?) rocks of the Valdez group, so that it can be said that they are post-Valdez in age, but further than this no definite statements can be made, and it can only be stated that the volcanic activity took place either in the Jurassic or in some later period of the Mesozoic or Tertiary.

There is no paleontologic evidence available as to the age of the conglomerates. From lithologic and stratigraphic evidence they appear to be younger than the greenstones and may possibly be separated from them by an unconformity.

QUATERNARY DEPOSITS.

The Quaternary deposits, which were laid down by water and ice during an epoch of glaciation that has not yet closed are the youngest sediments of the district. The area has experienced intense glacial erosion, and most of the material eroded was carried by the ice far beyond the confines of the district. The Quaternary deposits consequently cover relatively small areas and rest unconformably on the glacial abraded surfaces of the igneous and consolidated sedimentary rocks of the district. They consist of unconsolidated material. The materials of these deposits were derived largely by the erosion of local glaciers from the bedrock of the area and consist dominantly of graywacke, argillite, slate, conglomerate, and greenstone. A small percentage of foreign material, however, is included, as is indicated by the presence of boulders of granitic and dioritic character on the eastern shore of Valdez Arm between Jack and Galena bays. No intrusions of the character of these boulders are known in place in the Jack Bay or Port Valdez districts.

The unconsolidated Quaternary sediments consist of glacial deposits; the gravel, sand, and silt deposits of the present glacial streams; small marine sand spits, short, narrow, barrier beaches, and little beaches filling the smaller indentations in the shore line; alluvial fans; and rather inconspicuous accumulations of talus.

A thin, patchy mantle or veneer of glacial till—a heterogeneous mixture of boulders and pebbles in a fine, compact sticky blue clay—covers the lower-lying parts of the district, and low bluffs of till a few feet in elevation front the shore in places on Halibut Point and the shore to the west and south.

The fluvioglacial deposits were laid down by anastomosing and aggrading overloaded glacial streams from valley glaciers, and their deposition in front of the retreating ice tongues is still in progress. They consist of washed boulders, pebbles, gravels, sand, and silt, derived from the graywacke, argillite, greenstones, and conglomerate bedrock, and occupy long, narrow, glacially excavated rock basins, as on Solomon Gulch and on the main creek flowing into the head of the north arm of Jack Bay, or they form outwash delta plains which fill the heads of both arms of Jack Bay.

On the geologic map (Pl. III, p. 158) only the larger fluvioglacial areas of Jack Bay and Solomon Gulch, the few small alluvial fans which occur at the mouths of some of the streams discharging into Jack Bay, and a sand spit in the southwestern part of the district, near Galena Bay, are indicated by the Quaternary pattern. The glacial deposits, as they are too small and patchy to completely mask the underlying bedrock, are not mapped.

MINERAL RESOURCES.

GENERAL FEATURES.

The mineral resources of the Jack Bay district and those portions of the adjacent Port Valdez district covered by this report consist of lode deposits which contain copper, gold, and silver. In the following discussions of the relations of the ore deposits, two types of ores, copper-bearing sulphide ores and gold quartz ores, are recognized. At present only the copper ores are mined, but all the valuable metals mentioned are obtained from them. The copper ore of the Midas mine, the only productive property of the area under consideration, contains in addition to its copper content considerable amounts of gold and silver. No facilities are available locally for the smelting of these base ores, and the copper ore from the Midas mine, in the past, after being hand-sorted, has been shipped, for further treatment and for the recovery of its valuable contents, to the smelter of the Granby Consolidated Mining, Smelting & Power Co. (Ltd.), at Anyox, British Columbia, and to the smelter of the Tacoma Smelting Co., at Tacoma, Wash. But few gold-bearing quartz veins have been discovered, and none of those yet found have been of sufficient present or prospective value to justify extensive development work on them. Some of the quartz veins contain chalcopyrite, the valuable copper mineral in the copper-bearing sulphide ores, but the amount present in these quartz veins is very small, and it is of no value as a source of copper.

The first mineral location in this area was made in 1901 by H. E. Ellis, when he staked what is now known as the All-American lode of the Midas. A little development work was done on this lode in 1905. The following year the Jumbo lode of the Midas property was located. This lode received considerable attention under different owners in 1911, 1912, and 1913. In October, 1913, the present owners of the Midas, the Granby Consolidated Mining, Smelting & Power Co. (Ltd.), purchased the property and have brought it to its present position as an important copper producer of the Prince William Sound region. As a result of the gold quartz boom in the Port Valdez district in 1910 and 1911, the adjacent Jack Bay district received considerable attention. Few discoveries of gold quartz veins were made, however, in this rather barren-looking district, and little development work was done on the lodes found. Some slightly mineralized copper showings were staked on which short tunnels were driven, but the general belief that this portion of Prince William

Sound was underlain by auriferous rocks of the Valdez group appears to have hindered the search for copper lodes and the development of the known copper deposits.

At present the Midas mine is the only property that is actively and continuously worked, and assessment work is being done on only a few other properties.

The area considered in this report lies entirely within the Valdez recording district, the recording office of which is at Valdez.

GEOGRAPHIC DISTRIBUTION OF THE ORE DEPOSITS.

The Jack Bay district and that portion of the Port Valdez district covered by this report lie between the Port Valdez gold quartz district on the north and the Ellamar copper district on the south and immediately adjoin both districts. Both copper-bearing sulphide deposits and gold quartz veins occur in this area. The copper mineralization is restricted to two small areas, one of which lies between the two arms of Jack Bay and the other surrounds the upper end of Solomon Gulch and extends into the adjacent valleys. Copper deposits of proved economic value have thus far been found only within the Solomon Gulch area. The gold-bearing quartz veins lie mostly to the south of the south arm of Jack Bay, although a small vein was observed in the broad slate band north of the head of this arm.

The mineralization has a known vertical range of at least 2,500 feet, extending from sea level in the Orion quartz claim and the copper prospect on the north shore of the south arm of Jack Bay to the Bayview copper prospect nearly 2,000 feet above sea level on Solomon Gulch and the gold quartz veins south of Jack Bay at an elevation of about 2,500 feet. Both gold and copper prospects occur at intermediate levels. The Midas mine is at an elevation of about 800 feet.

The only regularly producing property within the area discussed in this report is the Midas mine of the Granby Consolidated Mining, Smelting & Power Co. (Ltd.), near the head of Solomon Gulch. No shipments of ore are known to have been made either to smelters or to custom mills from any of the gold or copper prospects of this area.

GEOLOGIC RELATIONS OF THE ORE DEPOSITS.

The copper deposits are closely associated with masses of intrusive greenstone. They occur either in shear zones in the greenstones or in near-by sedimentary rocks, or else as mineralized inclusions of sedimentary rocks in the greenstones. They furthermore appear to favor the black slates and argillites rather than the graywackes. In the adjacent Ellamar district the black slates include some impure dark limestones, and it is not improbable that some as yet unrecognized dark limestones may likewise occur in the black slate series of this area and in the Midas mine much of the sulphide impregnation and replacement may be the result of the action of sheared calcareous sediments upon the mineralizing solutions.

The gold quartz deposits occupy simple fissures. Most of them are in the folded and faulted massive graywacke series south of the south arm of Jack Bay, but one occupies a fissure that cuts the broad band of black slates on the north side of the head of that arm of Jack Bay. Three of the quartz veins measured strike nearly north and south. The other two had strikes of N. 40° E. and N. 75° W. The dips range from 60° to vertical. The veins are narrow, not exceeding 3 feet. The character of the country rock appears to have had little if any chemical effect upon the deposition of the few gold quartz lodes of the district. The country rock of the veins, however, has been somewhat affected by the mineralizing solutions and now in some places is impregnated with pyrite.

The mineralogy of both types of ore is simple; the minerals are few and are common to most of the properties of that type. Two small mineralized shear zones on Solomon Gulch, however, in addition to the minerals usually found in the copper deposits, contain chalmersite, $CuFe_2S_3$, a rare copper-iron sulphide that carries about 23.5 per cent of copper, which has not yet been observed in the other copper-bearing ores of this area.

The economically important copper-bearing mineral is chalcopyrite. Gold and silver both occur in the copper ores and also in the gold quartz veins. The gold is probably native. In the gold quartz veins the silver is alloyed with the gold. The combination in which the silver occurs in the copper ores is not known.

The original metallic minerals of the copper ores are chalcopyrite, chalmersite, pyrrhotite, pyrite, sphalerite, arsenopyrite, galena, gold, and silver. The nonmetallic minerals associated with these minerals in the copper ores are quartz and calcite. In the gold quartz veins arsenopyrite, pyrrhotite, pyrite, gold, and silver are the ore minerals, and quartz was the only gangue mineral noted. Limonite occurs in the weathered outcrops of both gold and copper deposits but most abundantly on those of the copper deposits.

In all the mineral deposits of this area which were examined the primary sulphides are exposed at or very near the surface, although the outcrops of the ore bodies have in places been slightly modified by the postglacial oxidation of the sulphides in the veins since the comparatively recent glaciation of this area.

GENESIS OF THE ORE DEPOSITS.

Two distinct periods of mineralization are now thought to exist in the Prince William Sound region, one in which gold quartz veins were formed in association with the intrusion of granites and the other in which copper ores were deposited in connection with the intrusion of large greenstone masses. The Jack Bay district lies between one of the typical gold quartz districts of the Prince William Sound region, the Port Valdez district, and a typical copper district, the Ellamar district. In the adjacent Port Valdez district the gold-bearing quartz veins appear to be genetically related to small bosses of granite. In the Ellamar copper district on the south the copper deposits are associated with greenstones and are probably genetically related to them. In the Ellamar district, also, there are a few gold-bearing quartz veins which appear to have the same relations to the greenstones as the copper deposits and which were probably formed during the same period of mineralization as the copper deposits and by solutions from the same source. In the Jack Bay district and in those parts of the Port Valdez district considered here the copper deposits are associated with greenstones and the mineralizing solutions which deposited the copper deposits appear to have been genetically related to these basic intrusive rocks. The few quartz veins may likewise owe their origin to these same mineralizing solutions or they may be of the same age and origin as the gold quartz veins of the Port Valdez district. The evidence at hand is not conclusive.

SUGGESTIONS FOR PROSPECTING.

The possibility of finding gold quartz lodes of economic importance in the future in this area appears slight. Though the area is much fissured and a few of these fissures are known to be filled with slightly mineralized quartz, the small granite bosses and acidic dikes with which the gold-bearing quartz veins of this region are usually associated are lacking. Several of these bosses and dikes occur in the adjacent Port Valdez gold district, however, and some of the mineralizing solutions which formed the gold lodes of that district may possibly have traveled far enough along the many fissures of the region to enter and fill some of the numerous fractures of the Jack Bay area.

The chances for copper prospecting are better, although most of the area is underlain by massive graywackes which offer little if any inducement to the copper prospector. The most favorable situations in which to search for copper lodes would seem to be in the black slate and argillite areas, which are in the vicinity of masses of intrusive greenstones.

MINES AND PROSPECTS.

SOLOMON GULCH PROPERTIES.

MIDAS MINE.

The Midas copper mine, now the property of the Granby Consolidated Mining, Smelting & Power Co. (Ltd.), of Canada, is on the west side of Solomon Gulch, about 4½ miles from Port Valdez, and at an elevation of about 800 feet above sea level. The property covers two separate ore deposits. The Jumbo lode, where the present extensive developments are being made, is on the west side of the valley near the head of the broad gravel flat which fills Solomon Basin and at the base of the high mountain ridge which forms the west wall of the valley of Solomon Gulch. The All-American lode is about half a mile upstream from this locality and in the middle of the valley bottom just above the head of the gravel flat. The nearest available standing timber is about 4½ miles away, near the lower end of Solomon Gulch.

The All-American lode was originally located by H. E. Ellis as "King Solomon's Copper Mines Nos. 1 and 2" in 1901. It was later located by C. G. Debney and relocated in 1904 by him as the All-American Nos. 1 and 2. In 1905 an option on the claims was given to B. D. Brown and P. J. L. Parker, and in the summer of that year a shaft and crosscut totaling 150 feet were driven by them on this group. The Jumbo lode was located in 1906 by Mary G. Debney. In 1911 J. A. Carson procured an option on the property and later assigned it to A. E. Grigsby and T. J. Devinney, who transferred their interests to the Midas Copper Co. in July, 1912. Some development work was done in 1911 and 1912, and about 100 tons of copper ore was shipped to the Tacoma smelter in 1912. The Midas Copper Co. bonded the property to the Alaska Development & Mineral Co. from September 21, 1912, to June 27, 1913. Considerable underground work was done by this company before the property was turned back to the owners. In October, 1913, the Midas Copper Co. sold the property to the present owners, the Granby Consolidated Mining, Smelting & Power Co. (Ltd.), of Canada, who started development work the following spring. The first shipment of ore under the present ownership was made in August, 1916, and the mine has been an important shipper ever since. A maximum force of 130 men were employed during the construction of the tram line. The average force employed on the property in 1917 was 50 men.

The principal method of transportation of supplies between the Midas mine and the wharf is an 80-bucket Riblet tram line, 5¼ miles in length. The erection of the tram line was started in May, 1914. Work on it was discontinued on September 1, 1914, as a result of the European war and was not started again until the following April. The tram line was first put in operation in August, 1915, and has been operated much of the time since. The tram line is driven by a 35-horsepower 220-volt two-phase General Electric motor, current for which is furnished by the local electric-light plant on Solomon Gulch.

All passenger travel between the mine and the camp on the shore is over the trail to the foot of the reservoir and then either over the wagon road to the shore near Fort Liscum or over one of two trails to the wharf.

Surface improvements on the property include a wagon road from the shore of Port Valdez to the mine; an aerial tram, 5¼ miles in length, from the bay to the mine; a wharf and 3,000-ton storage bins at the coast terminal of the tram; several buildings on the shore near the wharf; ore bunkers, blacksmith shop, cook and bunk house, five cottages, sheds, and an air-compressor building at the mine. A 200-horsepower Diesel engine was installed at the mine in 1916 and furnishes all the power needed at the mine at present. This engine is used to drive a 160-horsepower Imperial-type Ingersoll-Rand air compressor and a 54-kilowatt 125-volt direct-current generator, which furnishes light for the camp buildings and the mine and power for the sorting belt and various small machinery.

The underground developments on the principal ore body, the Jumbo lode, total nearly 4,000 feet in length and consist chiefly of four tunnels, 500 to 900 feet in length, driven largely in the ore-bearing zone; several raises; stopes between the three lower tunnels; and an inclined winze with a dip of 60°, which starts in No. 2 tunnel and extends to a depth of 100 feet. The vertical interval between the lowest and highest tunnel is 290 feet. Considerable open-cut work and stripping has also been done on the east side of the valley in an attempt to trace the eastward extension of this lode. On the All-American lode there are some shallow shafts and open cuts. The underground work on this group, which was done in 1905, is said to total about 150 feet.

The Jumbo and All-American lodes lie within a broad band, composed dominantly of black slates, which has been intruded at several places by small bosses, sills, and dikes of greenstone. Interbedded with the black slates are also argillites, cherts, graywackes, and quartzites. Schistose phases of these rocks have resulted from the extensive deformation to which they have been subjected. This slate band crosses Solomon Gulch in a general southeasterly direction, but the individual strikes of the bedding recorded at different places range from S. 70° E. to S. 83° E. The dips of the beds are from 40° to 67° N. This slate band appears to grade upward rather abruptly to the northeast into a graywacke series, the individual beds of graywacke ranging from a few inches to more than 20 feet in thickness. On the southwest the slate band is apparently faulted against the massive heavy-bedded graywackes of the peak southwest of the mine. A large boss of greenstone crops out within the slate band on the west side of Solomon Gulch, immediately south of the Jumbo lode. Numerous sills, dikes, and lenses of greenstone are exposed along both sides of the canyon just west of the All-American workings.

The present developments show two apparently distinct ore bodies—the Jumbo lode on the west side of the valley, where the present extensive developments are being made, and the All-American lode about half a mile upstream from this locality, in the middle of the valley bottom. Both deposits occur in mineralized shear zones. The Jumbo lead has been traced for over 800 feet into the hill by the tunnels. On the surface the highest showing of ore is about 650 feet above the lower tunnel. The general strike of the crushed zone appears to be a little north of east, but the strikes of individual shears within the major shear zone range from N. 75° W. to S. 62° W. and the dips range from 40° to 70° N. The lead splits in the two lower adits, the branches having strikes of N. 75° W. and S. 65° W. The width of the ore-bearing shear underground ranges from a few inches to 20 feet, but the average width of ore is between 3 and 4 feet. An overthrust fault occurs in the graywackes along the probable extension of the Jumbo lead to the southwest and may be the continuation of the Jumbo break. The All-American lode appears as a sulphide-impregnated shear zone in the sedimentary rocks on the north side of the greenstone intrusions which are exposed in the canyon near by. The ore body strikes a little south of east and dips 60° N. The mineralized zone is wider than the Jumbo lode, and the ore in this zone is said to be of lower grade than that in the developed ore body of the Jumbo. The outcrop of the All-American lode as exposed by the open cuts has a width of about 25 feet.

The ores are partly replacements and impregnations of the crushed country rocks and partly the result of cementation of small fractures by the ore minerals. The sulphide minerals present are pyrite, chalcopyrite, pyrrhotite, and sphalerite. Abundant beds of fine-grained pyrite are found in places. A little quartz is associated with the sulphides, and in the driving of the lower tunnel on the Jumbo lode lenses of quartz which had a maximum thickness of 1 foot were encountered. Sulphide-bearing quartz stringers are also reported to occur along the footwall of the shear zone on this lode. Gold and silver are reported in assays of the ores, but neither metal has been observed in specimens. Some limonite has resulted from the superficial oxidation of the iron-bearing sulphides, and malachite stains from the carbonation of the chalcopyrite.

BAYVIEW CLAIM.

The Bayview copper claim has been staked recently on a mineralized zone in the large greenstone area that crosses the head of Solomon Gulch. The claim is on the west side of Solomon Gulch, near the foot of a hanging glacier at an elevation of about 2,500 feet and about 1½ miles south of the Midas mine.

OTHER COPPER DEPOSITS ON SOLOMON GULCH.

Small sulphide lenses that carry chalcopyrite and chalmersite occur in short, narrow shear zones in the graywackes and slates along the southern contact of the large intrusive greenstone mass at the head of Solomon Gulch. These mineralized shears were found in similar places on both sides of the valley. The mineralization is too slight to be of economic importance but is of scientific interest as furnishing the only occurrence as yet known of the rare copper mineral chalmersite ($CuFe_2S_3$) in the Port Valdez or Jack Bay districts. Other minerals present in these small shears are chalcopyrite, quartz, and limonite.

JACK BAY PROPERTIES.

COPPER PROSPECTS ON JACK BAY.

A tunnel about 40 feet in length has been driven at an elevation of 600 feet on the north side of the north arm of Jack Bay to the northeast of the large island between the two arms of Jack Bay. The country rock is a fine-grained bedded graywacke. The tunnel is driven on a shear zone that strikes N. 10° E. and dips 70° W. The tunnel is driven at the foot of a bluff at the lower exposed end of the shear, which shows in the face of the bluff above the tunnel for about 50 feet with a width of 2 to 4 feet. The walls of the shear are free and well defined and have a thin gouge in some places. The filling of the shear zone is not very badly sheared, and the shear is only slightly mineralized. The sulphides present in the ore are arsenopyrite, chalcopyrite, pyrrhotite, sphalerite, and galena. Quartz, calcite, and the crushed and altered country rock are the nonmetallic components of the ore. Some of the quartz occurs as small stringers. Limonite is present in the weathered ore.

A small mass of greenstone intrudes the sedimentary rocks on the north side of the south arm of Jack Bay about 1 mile east of the tip of the point between the two arms of the bay. Many inclusions of the slate and argillite country rock are contained in this greenstone, and these inclusions are slightly metamorphosed and mineralized. The mineralization, however, everywhere appears very much too slight for the mineralized rock to constitute a possible ore body. These mineralized inclusions have been located as copper prospects, and in one of the larger inclusions a tunnel 25 feet in length and with a 25-foot approach has been driven a few feet above high tide. Pyrite, pyrrhotite, chalcopyrite, sphalerite, and a very little quartz are recognizable in the mineralized rock at this locality.

Some mineralization appears in the sedimentary rocks along the northern contact of the intrusive greenstone mass on the crest of the divide between the two arms of Jack Bay, but this mineralization seems slight. Apparently, too, it has not attracted prospectors, as no evidence of development work was seen on any of the rusty croppings.

Slightly mineralized float—iron-stained metamorphosed slates that carry specks of chalcopyrite and pyrrhotite—was found in creek wash from the broad area of slate along the north side of the flat at the head of the south fork of Jack Bay. Heavily mineralized float that carries chalcopyrite and galena is said to have been found on Friday Creek. The lead from which this float came has not been located, and it is not known whether this lead outcrops within the valley of Friday Creek or whether the float was carried into that valley from the eastern portions of the Jack Bay district by the glaciers.

GOLD QUARTZ PROSPECTS.

Curly Kidney prospect.—The Curly Kidney claim was located by E. Rohrbach in 1910 in the valley of a small unnamed creek flowing into Jack Bay from the south about 2 miles east of the entrance. A 25-foot tunnel has been driven on the west bank of the creek at an elevation of about 600 feet above sea level, and some stripping has been done in the canyon a little farther upstream. The country rock is dominantly graywacke accompanied by a little argillite. The tunnel is driven in a southerly direction on a shear zone 2 to 4 feet in width, which strikes S. 5° E. and dips about 80° E. This shear is very slightly mineralized. There is a small amount of quartz in very small stringers and a little pyrite both in the quartz and in the sheared material. The main showing on the property appears to be farther upstream in the bottom of the stream canyon at an elevation of 670 feet, on what is probably one of a system of closely linked shear zones. The strike of this shear zone is about north and south, the dip nearly vertical, and the width as exposed is from 2 to 10 feet and probably wider in places, where at present the shear is not fully exposed. This shear contains a few lenses and stringers of quartz which have a maximum thickness of 3 feet. These stringers and lenses are short, and most of them are only a few inches thick. In most of the shear no quartz is visible at all. Arsenopyrite was the only sulphide seen in the ore. Assays of the ore are reported by the owner to show gold in the quartz.

Orion claim.—The Orion claim is at sea level on the south side of the south arm of Jack Bay about 1½ miles from the head of the bay. The country rock is graywacke and a little argillite. About 75 feet of underground work has been done on the claim on a curving lead that outcrops on the shore. This lead is traceable about 25 feet across the beach and for about 50 feet in the tunnel. The outer end strikes N. 6° W. and dips 70° W. From 1 to 10 inches of quartz is visible in the lead, and this in places shows secondary banding parallel to well-defined walls. Arsenopyrite, pyrrhotite, and quartz were the only minerals observed in the ore.

Other gold quartz prospects.—A well-defined quartz vein, 6 inches to 3 feet in thickness, was observed at an elevation of 2,500 feet in the west wall of a small cirque the drainage from which is tributary from the south to the stream that enters the head of the south fork of Jack Bay, about 1½ miles east of the head of the bay. The vein strikes N. 40° E. and dips 60° W., crosscutting the bedding of massive fine-grained graywackes, and is traceable several hundred feet by local outcrops. The walls break free. The lead does not appear to be very well mineralized. Quartz, arsenopyrite, and limonite were the only minerals seen in the ore. The presence of traces of gold, however, is reported to have been shown by assays. The quartz shows secondary banding parallel to the walls in some places.

A smaller quartz vein, only a few inches wide but traceable for a considerable distance, crops out near the divide on the side of the ridge that fronts on Galena Bay.

A small quartz vein 2 inches thick cuts the thick black slate series on the north side of the flat at the head of the south fork of Jack Bay. The vein crops out in the west wall of the canyon of a stream at an elevation of 100 feet and at a distance of 1¼ miles from the head of the bay. The bedding and cleavage of the slates here strike S. 75° E. and dip 60° N. The vein strikes north and dips 55° W. Chalcopyrite and pyrrhotite were the only metallic minerals observed in the ore.

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MINING IN CENTRAL AND NORTHERN KENAI PENINSULA.

By Bertrand L. Johnson.

INTRODUCTION.

The mineral production of central and northern Kenai Peninsula comes entirely from gold quartz lodes and placers. Very little gold quartz mining was in progress during 1917, and placer operations were restricted to a few streams.

GOLD QUARTZ MINING.

The producing gold lodes in 1917 were in the Moose Pass district, on Porcupine Creek, and in the Hope district. The Kenai Alaska, one of the large producers of former years, did not operate; both the mine and the mill were closed down. In the Moose Pass district a small mill, operated by water power, was installed on the Ronan & James property on Summit Creek, and several tons of ore were milled. The installation of this mill was started June 15, and all operations ceased on the property for the year on October 26. Underground operations consisted in the driving of 100 feet of tunnel and the removal of the ore, which was later milled. Surface improvements also included the erection of an aerial tramway between the mine and the mill. Present underground developments on the property consist of a 137-foot crosscut to the lead, a 210-foot drift on the vein, an 85-foot raise to the surface at the point where the lead was struck, and a 30-foot shaft on the outcrop of the ore body.

On the Gilpatrick property, in Moose Pass, two men were at work, and some ore was milled in an arrastre which had been erected in previous years on this property.

On the Columbia and Ophir claims, also in the Moose Pass district, only 12 feet of tunnel was driven during the year, and the mill on this property was not operated. Only assessment work is reported on the Beatrice and Sampson claims.

On Porcupine Creek two or three men were said to have been at work on the Bluebell and Primrose claims in 1917, and a few tons of ore are reported to have been mined and milled at the small mills on this creek.

Some underground work was done on a gold lode property on Grant Lake, and the ore mined was milled in the arrastre on this property.

The mill on the Lucky Strike property on Palmer Creek, near Hope, was operated from July 1 to October 1, one shift a day. The mine also was operated from June 1 to October 1.

GOLD PLACER OPERATIONS.

Placer operations were in progress on Resurrection, Crow, Mills, Winner, Canyon, Cooper, and Stetson creeks. Large mining operations were in progress only on Resurrection and Crow creeks.

On Resurrection Creek several hydraulic outfits are said to have been operating. The Mathison Mining Co. operated from June 6 to September 18 with a crew of nine men. E. E. Carson hydraulicked stream gravels from May 10 to July 2 with a crew of two men. The Pearsons and the St. Louis Mining & Milling Co. are also reported to have worked, but no data are available regarding their operations. Practically all these placer camps suffered greater or less damage during a heavy rain and wind storm which passed over the Kenai Peninsula early in September, 1917.

A large crew was at work on the Crow Creek placer property during the summer, and considerable work was done. This property is said to have suffered extensively also in the September storm. On Winner Creek, a tributary of Glacier Creek, Axel Lindblad operated from June 1 to September 28.

On Mills Creek Robert Michaelson worked alone throughout the year, driving a tunnel, now 96 feet in length, in an old channel of Mills Creek. Fred Matz, on this same creek, groundsluiced on his placer claim from June 1 to October 1.

The Dunfranwald Gold Mines carried on extensive development work near the junction of Canyon Creek and East Fork preparatory to actual mining operations. This work is said to have consisted of the construction of ditches, dams, and flumes. Some development work was also done on the Lynx Creek gravels.

The major operation on Canyon Creek was at the property of the Kenai Peninsula Placer Mines, where the installation of a hydraulic plant is said to have been completed in September. The crew employed at this property during the season comprised 30 to 40 men, and they were engaged in opening up bench gravels on the left limit of the creek.

Small hydraulic operations are reported on Cooper and Stetson creeks. The property of the Kenai Mining & Milling Co. at the mouth of Cooper Creek was not in operation.

Two men were at work on the Getchell claims on Gulch Creek, mining the old creek channel gravels by hydraulic methods.

GOLD LODE MINING IN THE WILLOW CREEK DISTRICT.

By Stephen R. Capps.

INTRODUCTION.

Gold mining in the Willow Creek district in 1917 was confined to the exploitation of the quartz lodes, from which almost the entire production has been won for several years. Although the first gold recovered from this area was gained by placer mining, the workable placers were soon exhausted, and of recent years their output has been negligible. The production from this camp in 1917 was made by four mines. Two of these mines, the Gold Bullion and the Alaska Free Gold, have been in operation for many years and have produced the bulk of the output of the district. The Independence mine, which has for years been a producer, was idle in 1917; though the mill was used to crush some ore from a near-by property. In 1916 a mill was erected and put into operation on the Mabel, and in 1917 a mill was completed on the property of the Talkeetna Gold Mining Co. To summarize these conditions, in 1917 there were five quartz mills in the district, of which three were operated steadily and two at intervals, and another small prospecting mill was ready to be set up. A report on the Willow Creek district, comprising a description of the geology and an account of the mining developments through 1913, has been published.[1] A later summary of the progress of mining through 1915 has also been issued.[2] The following notes on the properties are incomplete but are intended to supplement the previously published reports by carrying forward the account of the progress of mining to the fall of 1917.

In the accompanying table the production of the district is given by years. The large production of 1914 is due to the fact that during that year the cyanidation of accumulated tailings was begun, and the gold so recovered came in part from ores previously mined. In 1915 and 1916 the two cyanide plants were operated principally on the current tailings. In 1917, as a result of the high price of potassium cyanide, considerable quantities of tailings were ponded for storage, to await a time of more favorable operating costs.

[1] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, 1915.
[2] Capps, S. R., Gold mining in the Willow Creek district: U. S. Geol. Survey Bull. 642, pp. 195-200, 1916.

Gold and silver produced at lode mines in Willow Creek district, 1908–1917.

Year.	Gold.		Silver.[a]	
	Quantity (ounces).	Value.	Quantity (ounces).	Commercial value.
1908	87.08	$1,800	6.28	$3.64
1909	1,015.87	21,000	80.25	41.73
1910	1,320.15	27,290	104.29	56.31
1911	2,505.82	51,800	197.95	109.91
1912	4,673.02	96,600	369.07	226.97
1913	4,883.94	100,960	385.83	233.42
1914	14,376.28	297,184	1,330.00	735.00
1915	11,961.55	247,267	811.00	421.00
1916	14,473.46	299,193	1,468.00	967.00
1917	9,466.17	195,662	713.00	586.00

[a] The silver content recovered from the gold bullion is estimated.

GOLD BULLION MINING CO.

The Gold Bullion mine was operated throughout the open season of 1917. Milling was begun on June 1, and the 12-stamp mill was operated at different proportions of its capacity, the rate depending upon the water supply. During the month of June the ore was supplied from the old No. 2 tunnel, but from July 1 to the end of the season all ore milled was taken from the Gold Dust tunnels 8, 9, 11, and 12. About 65 men were employed, of whom 50 were at the mine and 15 at the mill and camp. At the mine no mechanical power is used, and hand drilling is still relied upon. Hydraulic power is obtained for the mill and to operate a part of the cable tram. The water supply, however, has always been inadequate, and the quantity of ore crushed in any year has been determined in large part by the amount of power available. In 1916 five 1,050-pound stamps were added to the mill, making a total of 12 stamps, and a pipe line and small Pelton wheel were installed, using water brought from a small stream on the mountain to the south of the mill under a head of 425 feet, thus adding notably to the milling capacity.

The cyanide plant for the treatment of the sands was installed in 1914 and has operated satisfactorily. The sands accumulated before the installation of the cyanide plant have now been leached and the current mill product is being handled systematically. The plant has six leaching tanks, one of 37 and five of 30 tons capacity, and three other tanks for solutions. The product treated is coarser than that formerly handled, and an extraction of about 78 per cent is reported; the slimes are stored for possible future treatment. The concentrates from the mill are now also cyanided on the ground and the precipitates are all retorted, so that the only product shipped is bullion.

Several faults that add difficulty to the recovery of ore have recently been encountered in mining. One of these faults is exposed in Gold

Dust tunnels No. 8 and No. 10 and in the No. 3 raise in tunnel No. 8, and no ore has been found beyond it. Another fault in the old No. 2 tunnel cuts off the ore in several drifts and is said to show a displacement of 50 feet.

Exploratory work was done in 1917 on a surface showing of rich quartz in a saddle of the Craigie-Willow Creek divide, near the east end of the Gold Bullion claims, in the hope of locating the vein in place. About 20 tons of loose ore was picked up at this locality and taken by pack horses to a chute in the Gold Dust workings.

The progress of underground mining on this property to September, 1917, may be briefly summarized as follows: The old No. 2 tunnel has now over 3,300 feet of workings in addition to the stopes. Gold Dust tunnel No. 11, started in 1916, extends over 200 feet in a southerly direction and has three southwest drifts of an aggregate length of 550 feet. Gold Dust tunnel No. 12 lies approximately 180 feet west of No. 11 and is about 150 feet long, with a southwest drift 60 feet long. Gold Dust tunnels 11, 10, and 8 are now connected. No. 10 is 215 feet long, and much ground between it and No. 11 is stoped out. Old tunnel No. 9 is now caved and a new No. 9 has been driven to a length of 90 feet. The ground between the old and the new No. 9 tunnels is worked out. The main No. 8 tunnel is 225 feet long and has four southeast drifts that aggregate 430 feet of tunnel in addition to stopes.

Plans are under way to connect the Gold Dust No. 12 tunnel underground with the main No. 2 adit, thus making it possible to haul all ore from the Gold Dust workings by an underground tram to the head of the wire tram at the mouth of No. 2. This work would make it possible to eliminate one cable tramway and a surface tram line, both of which can be operated only during the open season from July 1 to October 1 and would lengthen the possible mining season. It was also proposed to drive the south drift of No. 2 tunnel through to the Willow Creek side of the mountain, to make accessible certain ores there that can not now be economically taken to the mill.

ALASKA FREE GOLD MINING CO.

Milling was commenced at the mine of the Alaska Free Gold Mining Co. on May 20, 1917, and was continued throughout the summer and fall, except for one month when operations were suspended on account of labor trouble. Before the strike both of the two Lane mills were operated for 24 hours a day for about a month, but since the resumption of operations only one mill has been turning. About 25 men have been employed on an average, and the mill has worked three shifts, but the mine has run only a single day shift. Considerable improvements have been made on the property since 1915.

A comfortable bunk house and a mess house have been built on the mountain near the workings, thus eliminating a high climb daily of the entire mining force. All the men now live at the mine except the mill crew of five men. A 16-horsepower Fairbanks-Morse gasoline engine and an Ingersoll-Rand compressor have also been installed at the upper camp to supply power for an Ingersoll-Rand jack hammer. One man now does all the drilling and blasting and is said to replace 12 hand drillers. The cyanide plant was idle in 1917, as the increased cost of chemicals had greatly increased operating expenses. The sands are ponded for future treatment. In September, 1917, the No. 8 tunnel was 225 feet long, the No. 9 tunnel 100 feet long, and the crosscut 175 feet long. A new 150-foot tunnel has also been driven, and new stopes have been made in all these workings. At the time of the visit the ore was being taken from surface workings on the outcrop of the main vein south of the open cut that was made in 1915.

INDEPENDENCE GOLD MINES CO.

As a result of increased operating costs no mining was done in 1917 on the property of the Independence mine. In 1916 an adit was driven below the old working tunnel to intercept the vein at a lower level. The vein was reached at a distance of 278 feet from the portal and was followed for 28 feet, but although its average thickness was 2 feet the gold content of the portion mined was less than that required to pay costs of mining and treatment. In 1916 a No. 2 Denver Chilean mill, which has a proved milling capacity of 36 tons of ore crushed to 40 mesh, was installed. In 1917 the pipe line that supplies the Pelton wheel was extended to a total length of about 1,100 feet, giving a head of 210 feet at the wheel. A temporary arrangement was made with the owners of the Gold Cord prospect for the use of the mill, a tramway was erected to the Gold Cord workings, and a few hundred tons of ore was milled.

Considerable prospecting, including several open cuts and a 33-foot tunnel on the east bank of Fishhook Creek, has been done in the endeavor to locate new ore bodies. The northward strike of the Gold Cord vein indicates that the extension of the vein may cross the Independence property, and this possibility has stimulated prospecting.

GOLD CORD MINING, MILLING & POWER CO.

The Gold Cord Mining, Milling & Power Co. has nine claims on upper Fishhook Creek, located on a quartz vein discovered in the fall of 1915 by Byron and Charles Bartholf. Developments in September, 1917, included cook and bunk tents, 245 feet of underground workings, and a wire-cable tram with two buckets of 500 pounds capacity, supported by four towers, that connects the workings with the quartz mill of the Independence mine, at a distance of 2,400 feet. The slope from the mine to the mill is insufficient for gravity operation of the tram, and power for the tram is supplied from the mill.

The Gold Cord ore body consists of a main vein, the so-called "blue lode," of blue-gray to greenish quartz mottled with white, which strikes in a general north-south direction and dips 40°–44° W. The vein ranges in width from 2 to 9 feet or more and cuts the diorite, that is, the country rock, for all the mines of this district. The quartz contains scattered specks and bunches of arsenopyrite and pyrite and some visible free gold. Near the portal of the tunnel the "blue lode" is apparently crossed, at an acute angle, by a vein of white quartz that strikes west of north and dips west. At the time of visit this portion of the tunnel was partly covered by timbers and lagging, and the conditions could not be satisfactorily determined.

The ore from this mine is said to carry encouraging amounts of gold, but a mill test of a few hundred tons is said to have yielded only a part of the gold content upon the amalgamation plates, the remainder being so entangled with sulphides that further treatment will be necessary for its recovery.

MABEL MINING, MILLING & POWER CO.

The Mabel mine and mill were operated throughout the open season of 1917, beginning May 23, and about 18 men were employed, of whom 14 were working in the mine and 4 at the mill. This property was equipped in the winter of 1915–16 with a 2-bucket wire-cable tramway 3,500 feet in length, which has a vertical drop of about 1,500 feet, connecting the mine with the mill, in which a Denver Chilean mill and crusher of about 15 tons capacity were installed. Power is obtained from a 13-inch turbine wheel that is operated by water procured from Archangel Creek through a ditch half a mile long and supplied to the wheel under a 30-foot head. After leaving the amalgamation tables the tailings are ponded for future chemical treatment. The underground workings in September, 1917, consisted of an upper tunnel 200 feet long, not including stopes, and a lower tunnel 260 feet long. From a hasty examination it appears that the workings show two distinct veins, generally parallel and about 70 feet apart, which strike northeast and dip about 30° NW., and a third vein that is quite flat and connects the other two. This flat vein has not been followed beyond its intersection with the two northwestward-dipping veins. The underground work has demonstrated a marked tendency of the veins to pinch and swell within short distances. Gold is also irregularly distributed in the veins, but for the last two years the mill has been supplied to capacity with ore of good grade. Near the surface cropping of the main vein and above the upper tunnel a small stringer of very high grade ore has been exploited. This stringer consists of banded white to rusty quartz that contains patches of sulphides, stains of copper carbonate, and abundant visible free gold. It is generally reported in this district that this high-grade ore contains gold tellurides, but samples selected by the owners as their typical "telluride ore" upon analysis in the chemical laboratory of the United States Geological Survey failed to show any trace of tellurium.

TALKEETNA GOLD MINING CO.

The property of the old Matanuska Gold Mining Co., in the upper basin of Fairangel Creek, was purchased in the fall of 1915 by the Talkeetna Gold Mining Co. The property was equipped in 1917 with a Denver Chilean mill of about 12½ tons crushing capacity, operated by a Pelton wheel working under an 85-foot head. The present water supply is inadequate during part of the season, but it is planned to extend the intake pipe line to give a head of 125 feet or more at the mill. Ore is brought to the mill from the mine by a wire-cable tramway composed of two sections. The upper section, carried by ⅝-inch cable, with one supporting tower, is 1,500 feet long and runs from the mine to an angle station. The lower section carries the ore from the angle station to the mill, a distance of 600 feet. Comfortable quarters for the men have been erected both at the mill and at the mine, and an average of 15 men were employed in 1917. In September, 1917, the main tunnel had a length of 60 feet. The tunnel was driven on a vein which near the surface showed a width of 1 to 3 feet but which in the breast of the tunnel was only 2 to 6 inches wide. Another tunnel, on a second vein, had a length of over 100 feet. The veins on this property, as elsewhere in the district, show a tendency to pinch and swell within short distances.

KELLY-WILLOW CREEK PROSPECT.

The Kelly-Willow Creek ground comprises five full claims and three fractional claims that lie north of the Independence Gold Mines property and adjoin it. The owners report five distinct quartz veins, all showing a tendency to lie in parallel planes. Two of these veins are near the summit of Independence Mountain, one is considered to be the extension of the Independence vein, and of the two others one lies 300 feet above and the other 200 feet below the Independence vein. Development work has been directed, in large part, toward proving the continuity of the Independence vein and toward the location in it of pay shoots. The workings consist of a number of open cuts and two short tunnels 20 and 25 feet long. The open cuts seem to prove that the Independence vein is continuous northward for many hundred feet beyond the boundaries of the Independence property, and according to reports it carries gold throughout its length, locally in encouraging amounts. The general strike of the vein is N. 23° W. and the dip 35° SW.

RAY-WALLACE MINING CO.

The Ray-Wallace Mining Co. has acquired a lease on the old Rosenthal property that lies on the high ridge which borders the basin of Fishhook Creek on the east. The old tunnel on the property is reported to have reached a length of 330 feet in 1917, and a new tunnel, on the Trickster claim, had been driven a distance of 30 feet to intersect a vein that crops out above, but it had not yet cut the vein. A new vein, on the Morning Star claim, has been uncovered by several open cuts. It strikes nearly due east and dips about 55° S. and shows a maximum of 6 inches of quartz and a foot or more of crushed and oxidized vein matter. The quartz contains some pyrite and arsenopyrite and some dark material in spots which is said to contain tellurides but which upon chemical analysis failed to give a trace of tellurium. The owners of this property plan to install a cable tram and a mill in the winter of 1917–18.

MOHAWK MINING CO.

The Mohawk Mining Co., which is incorporated as a stock company, has eight claims in the upper basin of Sidney Creek, a tributary of Archangel Creek from the south. The main vein has been developed by two tunnels, one about 70 feet above the other. The lower tunnel, 30 feet long, failed to penetrate through the loose detrital material. The upper tunnel, which is 160 feet long, is now partly caved in. It follows a band of decayed diorite and gouge in which is some white banded quartz that shows arsenopyrite. The vein pinches and swells and is said to show a maximum thickness of 30 inches of quartz, though at the breast the quartz vein was only 6 to 8 inches wide. The vein strikes N. 35° W. and dips 45° SW. Average assays of the vein matter are said to have given promising returns in gold, but the percentage of the gold content that can be recovered by amalgamation can be determined only by mill tests on a considerable amount of ore. It is said that milling equipment for this property had been purchased, but it was not installed in 1917.

NORTHWESTERN MINE.

A group of 13 claims, called the Northwestern mine, has been located on the west side of Moose Creek, about 3 miles above the canyon through which that stream emerges from the mountains. The ore body lies on a high mountain ridge, about 1,600 feet above Moose Creek, at an elevation of about 3,800 feet. A horse trail leads up Moose Creek from its mouth, through the canyon, and from the valley bottom below the ore body a steep switchback foot trail leads to the prospect.

The country rock in this vicinity exhibits a gneissic phase of the diorite mass that forms a large part of the Talkeetna Mountains. Near the south ridge of this mass, from Moose Creek westward across the basin of Little Susitna River, the intrusive rock has a more or less well-developed gneissic structure and locally shows a pronounced banding. Certain phases are also highly hornblendic. A short distance south of the property here described Tertiary arkoses overlap and conceal the gneissic and granitic rocks. The ore body, which is conspicuous on account of a rusty red gossan, has been developed by open cuts, strippings, and a 33-foot tunnel. It has been formed through the replacement of the gneissic rock by sulphides, chiefly pyrrhotite, pyrite, and chalcopyrite. Sphalerite is also reported. The banding of the gneiss, although somewhat wavy and twisted, has a general strike of N. 60°–75° W. and a dip of 65° S. to vertical, and the ore body lies parallel to the gneissic structure. As shown by the workings, the area of heavy mineralization appears to have a thickness of 25 to 30 feet, and disseminated sulphides occur for considerable distances on either side. The body of massive sulphides has been exposed by open cuts along the strike for at least 80 feet, and gossan shows beyond the cuts in both directions. Within this ore body the sulphides range in abundance from scattered specks disseminated without any marked arrangement in rather massive diorite to bands of sulphides that follow the banding of gneissic materials and to massive sulphide masses in which no gangue or country rock appears. Each of the three principal sulphides—pyrite, pyrrhotite, and chalcopyrite—occurs in places in large, nearly pure aggregates, but more commonly the three are intermingled. The tunnel penetrates through the gossan into sulphides that are unoxidized, except along joints and cracks down which surface waters have circulated. No one was resident on this property at the time of visit but assay certificates supplied by the principal owner showed from 0.04 to 0.08 ounce of gold and 0.8 to 1.2 ounces of silver to the ton, and from a trace to 5.6 per cent of copper. One assay also showed the presence of 0.03 per cent of nickel.

OTHER PROSPECTS.

In addition to the properties described above, there are many prospects in this region on which some work has been done. Some of these prospects were visited by the writer in 1917. Concerning others that he could not examine within the time available, information from sources that were believed to be reliable was obtained. The following notes include such information as seems worth publishing.

The so-called Jap claims, on upper Willow Creek, have been leased, and work was continued on two tunnels. On the Eagle claim

No. 2 the tunnel in the fall of 1917 was 200 feet long, with a 25-foot crosscut and a 50-foot winze. The vein is said to be 6 feet wide between walls, and the quartz vein matter averages 12 inches wide and is said to carry gold in commercial quantities. On the Mary claim is a tunnel 100 feet long on a quartz vein that is reported to average 2 feet wide but to be of rather low grade. Near the portal of this tunnel a winze has been started on a quartz stringer that is said to be rich in gold.

The Bluebird claim, south of the Gold Cord, has been developed by numerous open cuts and a 30-foot shaft. The shaft is reported to show a large body of quartz that contains visible free gold.

A group of four claims, also known as the Gold Cord, for the owners believe them to contain the northward extension of the Gold Cord vein opened in the head of Fishhook Creek valley, has been staked in the upper basin of Sidney Creek. Open cuts show a few inches of white quartz that contains stains of copper carbonate and is said to carry visible free gold.

Smith & Sutherland hold four claims in the southeastern portion of the Sidney Creek basin. It is reported that a 40-foot tunnel driven on this property has now caved in.

Little work was done in 1917 on the Arch group. The old inclined tunnel is caved, and another 80-foot tunnel driven at a lower point on the same vein has now caved 50 feet from the portal and is inaccessible.

The Webbfoot group of two claims, lying on the south side of Archangel Creek and west of Sydney Creek, has been developed by a large amount of stripping along the outcrop of the vein. The vein is said to show an average width of several feet of quartz and to carry encouraging amounts in gold.

The Alaska Quartz group of two claims, on the mountain ridge between Archangel and Reed creeks, has been prospected by two tunnels 20 feet and 212 feet long. In the longer tunnel the vein carries 16 inches of quartz at the portal, but the quartz pinches out about 40 feet from the portal, and beyond that point the tunnel was driven along a slip zone that contains gouge.

The Babcock-McCoy claims, on Reed Creek, are developed by open cuts and by a 100-foot tunnel. The open cuts are said to show a vein that ranges from a few inches to 9 feet in thickness and that is said to carry promising amounts of gold. The tunnel, driven to intersect the vein at some distance below the cropping, has not yet reached the vein.

The Little Gem group of three claims lies on the east side of upper Archangel Creek. Two tunnels, the upper 25 feet and the lower 60 feet long, have been driven on the vein, which in the workings shows a maximum width of 8 inches. The vein carries a very rich streak of ore, from half an inch to 2 inches wide, in which visible gold is abundantly present. The owners have on the ground a 5-ton Buster Brown mill and a 4-horsepower Moline gasoline engine, with hemp rope for a tramway, although none of this equipment was installed in September, 1917.

The Hillis group of three claims, commonly known as the Fern-Goodell property, is situated in the upper basin of Archangel Creek. An adit tunnel that has a total length of 96 feet was driven 40 feet to the vein, which was followed for 56 feet in an attempt to find an ore shoot that crops out on the surface. The vein in the tunnel is reported to have a maximum width of 5½ feet and to carry some gold throughout, with a particularly rich streak a few inches wide on the hanging wall. The vein quartz is white and shows arsenopyrite and some gold, and the richest ore is mottled with bluish spots. Tellurides have been reported from this property, but their presence has not yet been conclusively proved.

Vein quartz, carrying considerable molybdenite, has been found in at least two localities in the Archangel Creek basin. One of these localities is in the upper basin of Fairangel Creek, and the other is on the divide between Archangel and Purches creeks. Neither locality was visited by the writer, and the extent of the deposits has not been determined.

The Good Hope lode, on the east side of lower Reed Creek, was staked in 1916. It has been exposed in two large open cuts and is said to show a strong vein, several feet wide, from which a few colors of free gold may be panned.

The Galena-Gold group of three claims was staked in 1917 on the head of Purches Creek. Little development work has been done, and neither the width nor the length of the ore body has been determined, but it is said that at least 1 foot of good ore, containing chalcopyrite, pyrite, galena, and free gold, shows on the surface.

The Jessie B group of two claims lies in the upper basin of Peters Creek. The vein is reported to be from 2 to 5 feet wide, and specimens of ore show quartz stained with copper carbonates and iron oxide. The vein matter is said to show free gold upon panning, and a considerable amount of ore is said to have been mined and stacked during the progress of development work.

MINERAL RESOURCES OF THE WESTERN TALKEETNA MOUNTAINS.

By Stephen R. Capps.

INTRODUCTION.

The limits of the region here called the western Talkeetna Mountains are somewhat arbitrarily drawn. It includes that portion of the Talkeetna mountain mass that lies west of a sinuous line extending from the head of Little Susitna River northward along the rugged crest of the mountains and embraces the basins of a number of westward-flowing tributaries of Susitna River and the basins of Sheep River and Iron Creek, two tributaries of Talkeetna River.

Although the Willow Creek gold mining district is geologically and topographically a part of this region, it is excluded from the area here treated, as a separate account of its mining activities is given elsewhere. (See pp. 177–186.)

Systematic surveys were begun in this part of Alaska in 1898, when G. H. Eldridge[1] and Robert Muldrow, of the United States Geological Survey, ascended the Susitna basin to Broad Pass and obtained the first accurate information concerning the geography of that great river system. During that same year W. C. Mendenhall,[2] while attached to a War Department expedition in charge of Capt. F. W. Glenn, ascended Matanuska River to its head and proceeded northeastward to Delta River, thus skirting the Talkeetna Mountains on the south and east. The next notable survey in the region here discussed was carried out in 1906, when R. H. Sargent and Sidney Paige,[3] of the United States Geological Survey, ascended Matanuska River and Chickaloon Creek, ascended Talkeetna River to Sheep River, and thence followed the west flank of the mountains southward to Knik Arm. Their topographic and geologic surveys thus completely surrounded the western Talkeetna Mountains but left inclosed within their route of travel a large unmapped area. In 1910 F. J. Katz[4] spent a few days in the Willow Creek district, and in 1913 S. R. Capps[5] made a detailed study of that area.

[1] **Eldridge, G. H.**, A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 1–29, 1900.

[2] **Mendenhall, W. C.**, A reconnaissance from Resurrection Bay to Tanana River, Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 31–264, 1900.

[3] **Paige, Sidney**, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, 1907.

[4] **Katz, F. J.**, A reconnaissance of the Willow Creek gold region: U. S. Geol. Survey Bull. 480, pp. 139–152, 1911.

[5] **Capps, S. R.**, The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, 1915.

On the Government railroad in progress of construction from Seward to Tanana River, rails were laid by the fall of 1917 from Turnagain Arm northward as far as Montana Creek, and the branch line up Matanuska Valley was in operation to the Chickaloon coal field. Upon the laying of a stretch of track along the north shore of Turnagain Arm, now rapidly approaching completion, rail transportation will be available from Seward to points well up Susitna Valley, and the area thus supplied will expand as construction proceeds northward.

The western Talkeetna Mountains have long been considered to offer a promising field for the prospector. In 1897 the first gold-placer claims were staked on Willow Creek, and although the workable ground proved to be of small area, considerable gold was produced. In 1906 gold quartz was discovered in the Willow Creek district, and since that time the production of lode gold has steadily increased. From time to time prospectors attempted to extend the productive area of the Willow Creek district northward, and some encouraging quartz veins were found, but the cost in time and money of getting supplies into that area grew prohibitive as the distance from the water increased, and no serious attempts were made to develop mines north of the basins of Willow Creek and Little Susitna River.

The passage of a bill by Congress authorizing a Government railroad up Susitna Valley and the progress of construction on this project greatly encouraged both prospectors and those seeking agricultural lands in this hitherto remote area, and it became desirable to complete topographic and geologic surveys along the route to be served by the railroad. Accordingly, in 1915, J. W. Bagley, of the United States Geological Survey, carried out a reconnaissance topographic survey in the western Talkeetna Mountains, covering an area of 835 square miles previously unsurveyed. In 1917 the writer, in addition to other duties, was assigned to the task of studying the more important mineral resources of that area and of mapping the areal geology in so far as time for that work was available. After returning from a few weeks' visit to the upper Chulitna basin, the field party, consisting of the geologist, a cook, and two packers, with seven pack horses, left Talkeetna on July 29 and ascended the valley of Talkeetna River and of Iron Creek to the vicinity of the numerous lode prospects in that basin. Two weeks was spent in a study of the prospects and of the geologic conditions of that vicinity, after which the party proceeded southward through the mountains. Only 16 days was available for the areal geologic mapping of several hundred square miles of rugged mountains, but much of that area is occupied by a single geologic unit, and it is believed that the general distribution of formations, as shown on the map (Pl. IV), is approximately correct in its larger features.

The conclusions reached in this paper are based on a preliminary study of the data gathered and are subject to modifications in the more complete report now in preparation.

GENERAL FEATURES OF THE REGION.

GEOGRAPHY.

The region here described as the western Talkeetna Mountains is, as its name implies, predominantly an area of high relief. On its eastern border the summit peaks of the mountain mass reach elevations of 7,000 to 8,800 feet and nourish many glaciers, the largest of which has a length of 12 miles. Farther west the mountains decrease somewhat in height but are extremely rugged and steep for an average distance of 20 miles from the divide. Within that area the land forms are characteristically those of a severely glaciated mountain mass in crystalline rocks with multitudes of cirque basins and relatively straight, troughlike trunk valleys.

As the Susitna lowlands are approached the mountain topography undergoes a sharp change of type. The ragged sky line of the higher mountains disappears, and the interstream ridges on the western mountain flank have rounded contours and plateau-like surfaces up to an elevation of 3,000 feet or more. Many facts prove that this series of plateaus, which may be regarded as a high beach now dissected, was once overridden by the northward-moving ice of the great Susitna glacier, and its subdued topography and rounded forms are due, at least in part, to the erosive effects of that ice mass.

On their western flank the Talkeetna Mountains merge gradually into the Susitna lowlands. Susitna River flows southward through a broad structural basin that is bordered on the east by the Talkeetna Mountains and their northward extension and on the west by the Alaska Range and its foothills.

Between these two mountain masses this lowland has a width of about 50 miles in the latitude of Kashwitna River but narrows to a width of 20 miles at Talkeetna. From it irregular projections extend up the valleys of the larger tributary streams. Along the axis of this basin the relief is slight, and the gradient southward to tidewater is gentle. Talkeetna, at the mouth of Talkeetna River, is 80 miles from the head of Cook Inlet, yet its elevation above sea level is only 350 feet. The flatness of the valley floor is relieved only by rolling morainic hills and by the comparatively shallow trenches of the streams that cross it. Toward its borders the relief increases, the stream trenches are of greater depth, and the rolling lowland merges into the flanks of the foothills and the mountain ranges.

The area here treated contributes all its drainage to Susitna River. More than half of the region is drained directly to the Susitna by Willow and Little Willow creeks, Kashwitna River, and Montana and Sunshine creeks, all of which head in the mountains and flow westward to emerge into the lowlands through which they flow to join the Susitna. Sheep River and Iron Creek both head in glaciers at the summit of the range and flow in parallel courses northwestward to join Talkeetna River 16 and 30 miles, respectively, above its mouth.

GLACIATION.

The higher parts of the Talkeetna Mountains reach above the level of perpetual snow and nourish a large number of glaciers. A considerable portion of the waters of Kashwitna and Sheep rivers and Iron Creek is supplied by the melting ice fields, and Montana Creek receives enough glacial drainage to cloud its waters in summer. As measured by the standards of the neighboring Chugach and Alaska ranges all the glaciers in the Talkeetna Mountains are of small size, occupy only the extreme heads of the cirques, and are of simple form. Of those on the west slope of the mountains only three of four are of the type that comprises a somewhat extended main lobe fed by numerous tributaries.

The largest glacier in the Talkeetna Mountains is that in which Sheep River heads. The upper basin of Sheep River is encircled by the highest peaks of the range, and the northern slopes are protected from solar radiation, so that conditions are especially favorable for the accumulation of glacial ice. In addition to the main glacier there are more than thirty smaller ice fields over half a mile long that send their water to Sheep River. The Kashwitna and Iron Creek basins also contain numerous glaciers.

Although glaciers are so numerous in the range, the present glaciers are altogether insignificant as compared with the great ice fields that once covered this area. During the earlier period of glaciation all the mountain valleys were filled to the brim with glacial ice, so that only the highest peaks and ridges projected above its surface. This ice moved slowly down the valleys to join the enormous glaciers that occupied Susitna Valley. Some idea of the volume of the former Susitna glacier may be gained from the statement that at the mouth of Kashwitna River the glacier at one time reached a thickness of close to 4,000 feet and had a width of over 50 miles.

ROUTES OF TRAVEL.

Although not far distant from tidewater, the western Talkeetna Mountains have always been rather difficult of access, and few white men had traveled in them until the beginning of construction on the railroad gave promise of improved transportation to the region. Two routes of approach to the mountains have been followed, one by boat or sled up Susitna River and its tributaries and the other along the flank of the mountains northward from Willow Creek, the route chosen by any particular party being determined by the time of year when the trip was to be made and the means of transportation available. Most prospectors and trappers in interior Alaska prefer to travel in winter by dog sled, when the frozen streams and the mantle of snow make it possible to haul heavy loads with the least effort and equipment. Trading stations and stores have long been maintained at Knik, on Knik Arm, and at Susitna station, on Susitna River near the mouth of the Yentna. A trading station was also operated for some years at the mouth of Talkeetna River but was abandoned in 1911. Winter travelers obtained supplies from one of these places and sledded them up the valleys to the chosen prospecting or trapping ground. In summer Susitna River is navigable for high-powered, shallow-draft boats as far north as the mouth of Indian River, and construction camps have been established at intervals along the line of the railroad by the Alaskan Engineering Commission. Talkeetna, a considerable village, including, in addition to the buildings of the commission, several stores and many dwellings, has sprung up at the mouth of Talkeetna River, and transportation by boat was obtainable in 1917 to the mouth of Indian River. The tributaries of Susitna River from the east, however, are not navigable for power boats. Kashwitna and Talkeetna rivers may be ascended for some distance by poling boat, but the swift current and shoal waters of these streams make navigation by small boat difficult and dangerous.

The only feasible land route for summer travel up the east side of Susitna Valley has been along the flank of the mountain pass. The Susitna lowlands contain much swampy ground and dense thickets of brush, so that very great difficulties were encountered in endeavoring to travel through them with horses. The higher parts of the mountains are much too rugged to permit taking horses across them from one east-west valley to another, so that a route between these two extremes must be chosen. Two such routes have been followed with pack trains in 1906, 1916, and 1917 by Geological Survey parties and present no insurmountable difficulties. Between the east-west valleys the broad, timberless benches afford good footing, and trails have been cut across the brushy valley slopes.

In 1917 construction work on the Government railroad was pushed rapidly, and by the fall of that year rails were laid to Montana Creek and the grade was practically complete to Talkeetna. Trails and wagon roads that roughly followed the railroad survey through the lowlands had been built, and thus a route of great natural difficulty became the main highway of travel. Completion of the railroad to Talkeetna, and the consequent building of trails and wagon roads up the main valleys leading into the mountains, should within a few years make the whole of this region easy of access.

VEGETATION.

A sharp contrast exists between the thick timber and brush of parts of the lowland areas of this region and the barren slopes of the higher mountains. The Susitna lowland is thickly wooded with trees wherever the ground is fairly well drained. Thus there is a heavy growth of cottonwood and spruce along the banks of all the streams, and of spruce and birch on the rolling hills of the lowland and the slopes of the mountain flanks. Groves of cottonwood trees, many of which reach a diameter of 3 or 4 feet, grow in favorable localities in the stream flats, and birch and spruce trees attain 2 feet in diameter on the slopes. Within the lowland area, however, there are many places in which drainage is sluggish and which are characterized by marshes, entirely barren of trees or containing only stunted, scrubby spruce trees. The same distribution of thick timber interspersed with areas of scattered stunted trees and barren marshes is found in the valleys of the tributary streams. Timber line has, in general, an elevation of about 2,000 feet; below that elevation well-drained lands are timbered, but above it few trees grow. Although, locally, cottonwood and spruce trees of sufficient size to furnish saw logs are found, the timber is for the most part too small and of too poor quality to supply lumber for any but local uses, and no lumber industry of magnitude is likely to be developed. There is a possibility, however, that considerable areas of cottonwood and spruce that lie near the largest streams will sometime furnish materials for a wood-pulp industry.

Within the timber of the lowlands there is commonly a thick growth of willow and alder brush, and these bushes grow at a considerably greater elevation than the trees, so that there is generally a belt of thick brush above timber line. The brush affords fuel for the camper at many places where trees are lacking, but the dense growth greatly impedes travel, and the man traveling with horses who leaves the few poorly defined trails must do much trail chopping to penetrate the thickets.

Grass for forage for horses is abundant throughout the region, and camping grounds can nearly everywhere be found where horses will obtain sufficient grass for their needs. A variety of grass locally known as red top is particularly abundant near timber line, and over large areas it grows in thick stands to a height of 5 or 6 feet. While green it furnishes good forage for stock, but upon freezing in the fall it loses its nourishing qualities. An even better forage grass known as bunch grass occurs in places, usually above timber line.

GAME.

The big-game animals of this region include moose, caribou, sheep, and bear. Moose are generally distributed throughout the lowlands and range wherever trees and brush grow. Caribou range in the areas above timber line, particularly in the northeast part of this region, although they are nowhere abundant. The white bighorn sheep is found in the highest mountains, particularly in the headward basins of Sheep River and Iron Creek. Black bears live in and near timbered areas, and brown and grizzly bears may be seen almost anywhere, as they range the higher mountains and also visit the stream valleys during the salmon run.

Rabbits and ptarmigan are very abundant during some years, but their numbers vary greatly from season to season, and in 1917 few were seen. Some fur-bearing animals, including fox, lynx, mink, and marten, are captured each winter. Salmon run up Susitna River and most of its tributaries to spawn, and practically all streams not clouded with glacial silt are stocked with grayling and trout.

POPULATION.

There are settlements of natives at Knik, Susitna station, and Talkeetna, and from these villages hunters and trappers have long made expeditions into the mountains for fur and meat, yet the visible evidences of their occupancy are meager. The Indian transports his few belongings by dog sled in winter, following the frozen streams, and in summer uses a boat or loads his effects upon his dogs, himself, and his family. He chops no trail but makes detours around obstructions, and his trails are of little use to the white man who travels with horses.

Only within the last year or two have there been any permanent white inhabitants in the mountainous portions of this region. A single group of claims was staked on Iron Creek in 1910 and has been visited yearly by the owners since that time, but no permanent buildings were constructed, and the only white visitors to the mountains were a few prospectors and trappers. Within the last few years, however, many mining claims have been located in the Iron Creek basin, and some prospects are known in Montana, Kashwitna, Peters, and Purches basins. Some log cabins have been constructed, and the number of permanent residents will increase as railroad construction stimulates prospecting and mining.

Susitna station has long been a permanent settlement of whites and natives. Talkeetna has had white inhabitants at intervals and is now an established village.

Since 1915, the development of an agricultural population around Knik Arm and in Matanuska Valley has proceeded rapidly, and in 1917 a large quantity of agricultural produce was raised there. Undoubtedly this development will extend up Susitna Valley, where much land has farming possibilities, and a gradually increasing agricultural population may be expected in this region.

GENERAL GEOLOGY.

CHARACTER OF THE ROCKS.

The striking feature that at once becomes apparent on inspection of the geologic map of the western Talkeetna Mountains is the great predominance of igneous materials over sedimentary rocks. Great areas of deep-seated granitic intrusives, older deformed lava flows, and little-disturbed Tertiary lavas occupy almost all the region in which the hard rocks are exposed, and the granitic rocks and older lavas doubtless extend westward beneath the mantle of unconsolidated materials. Except for a narrow and interrupted belt of sediments that crosses the basins of Sheep River and Iron Creek and a few isolated outliers of this group of sediments, with some materials of sedimentary origin intimately intruded by granitic rocks in the area between lower Sheep River and Iron Creek, the entire western Talkeetna Mountains are composed of igneous materials. As has already been stated, the areal geologic mapping of this whole region was done hastily, for the prime object of the writer's visit to the Susitna basin was the investigation of the mineral resources of several widely separated localities. Time was therefore lacking for a careful tracing of the contacts between the formations, and more careful and painstaking work probably will make considerable modifications in the geologic boundaries as here given. It is believed, however, that the general outlines of the areas occupied by the different rock types are shown in approximately their proper position.

In many areas sedimentary rocks that contain determinable fossils give the geologist certain tie points from which he can draw conclusions as to the age of the rock formations with which he deals. In this region, however, no fossils have been found. The few sedimentary rocks examined are highly metamorphic, and this metamorphism included deformation and recrystallization, so that any fossils which the rocks may have once contained have been largely or completely destroyed. By their very nature the igneous rocks are unlikely to contain recognizable organic remains, so the age determination of the rocks in this area must be inferred from their correlation, upon lithologic or structural grounds, with other formations in surrounding regions where more satisfactory age determinations have been made.

MICA SCHIST.

The oldest rocks known within the Talkeetna Mountain area are the mica schists that occur on the south flank of the Willow Creek basin. These schists have been described elsewhere[1] and are not

[1] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, pp. 26-30, 1915.

known to occur in the region here discussed, but it is of interest to note that they are of pre-Jurassic age and constitute one of the formations into which the granitic materials were intruded.

LIMESTONES, MARBLES, SHALES, SLATES, AND QUARTZITIC SEDIMENTS.

As shown on the geologic map (Pl. IV) a narrow and interrupted belt of sediments occurs at the contact of the granitic rocks with the andesite-greenstones in the basins of Iron Creek and Sheep River. Small outlying patches of these sediments also occur both in the granitic rocks and in the andesite. The most conspicuous member of the group of sediments is a heavy bed of blue-gray limestone that forms prominent cliffs on the north side of Iron Creek, on the Middle Fork of Iron Creek, and at the head of Prospect Creek. It has in places a thickness of at least 600 feet and from a distance appears to be massive. Close examination, however, shows that the rock has been greatly sheared and in part recrystallized. Upon weathering it breaks down into small prismatic bits and is seamed with thin films of calcite along the lines of cleavage. Within the limestone there are local masses of completely recrystallized material that now appears as beautiful pure-white marble. Associated with the limestone and overlying it there is in places a considerable thickness of shales, slates, and quartzitic beds that represent metamorphosed clastic materials.

A few miles south of Sheep River this group of sediments occurs in a narrow northeast-southwest belt. There the limestones have been completely altered to white and green contorted and banded marble, and the clastic beds to siliceous schists and quartzites. Fossils have nowhere been found in these sediments, and their age is not definitely known, but from a somewhat similar association of limestones, shales, and lava flows in the upper Chulitna region, where the limestones are of Triassic age, it is suggested that the sediments here described may prove to be Triassic.

ANDESITE-GREENSTONES.

A considerable belt of territory, extending from the basin of Iron Creek southward to the basins of Montana Creek and Kashwitna River, is occupied mainly by lava flows that are dominantly andesite-greenstones. These rocks are bordered on the southeast in part by the series of limestones, marbles, and associated sediments and in part by an intrusive contact with the granitic rocks. The northwest border of the andesite-greenstones has not been carefully traced out but is believed to be an intrusive contact with granitic materials. The characteristic phase of this material consists of a medium-grained blue-gray or greenish-gray rock full of amygdules filled with greenish-yellow epidote. The epidote commonly displays a radial, spherulitic structure. Associated with the amygdaloidal rocks that were poured out as lava flows are local bodies of somewhat coarser grained dark-gray or black greenstones that probably represent an intrusive phase of the same period of igneous activity and may mark the location of vents through which the lavas reached the surface. The andesite-greenstones are of especial economic importance in the Iron Creek district, for it is in those rocks that the copper prospects of that basin have been found. Structurally the andesite-greenstones overlie the limestones, marbles, and associated sediments. Paige[1] has described similar rocks, associated with abundant dacites, rhyolites, and tuffs, that occupy a large area in the upper Talkeetna basin. The area here shown (Pl. IV) as occupied by andesite-greenstones is directly connected both to the northeast and southwest with the areas mapped by Paige. No definite evidence of the age of the greenstones was procured by the writer in 1917, but in the extensions of this area, in the upper Talkeetna basin, Paige obtained evidence that led him to classify the rocks as lower Middle Jurassic, and that age determination was later modified to Lower Jurassic.

GRANITIC ROCKS.

The dominant geologic feature of the Talkeetna Mountains is the great mass of granitic intrusive rocks that occupies a large portion of this region. These rocks form a main roughly circular area, measuring about 50 miles in diameter, and some smaller areas around the periphery of the central mass. The largest of these smaller areas lies for the most part in the lower Talkeetna basin and measures at least 12 by 15 miles. As shown on the map (Pl. IV), the higher portions of this mountain mass are composed exclusively of granitic materials, and the rugged character of the mountain peaks, with their multitudes of ragged pinnacles and serrate ridges, is due to the influence that this rock type has exerted upon the forms produced by erosion.

The granitic rocks are in general coarse-grained gray to pink diorites and granites and show a considerable range in texture and composition. Throughout most of the area in which they occur they are massive, little altered, and free from the effects of metamorphism. In some localities, however, they have been metamorphosed and show all gradations from unaltered massive materials through banded gneisses to hornblende schists. Within those areas in which metamorphism has occurred there is a larger proportion of dark hornblendic rocks.

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 16-19, 1907.

Structurally the granitic materials are found in intrusive contact with the mica schists of the Willow Creek district, with the limestones and shales of Sheep River and Iron Creek basins, and with the andesite-greenstones of those areas. They are therefore younger than all those formations. They are unconformably overlain by the Tertiary lavas of upper Iron Creek and by the early Tertiary sediments of the lower Matanuska basin and so are known to be pre-Tertiary. The evidence is still insufficient to prove their exact age, but there seems to be little doubt that they are Mesozoic, and although they have generally been referred to the Middle Jurassic are now believed to be of Lower Jurassic age.

TERTIARY SEDIMENTS.

Tertiary sediments, including arkoses, conglomerates, sands, shales, and lignitic coal, occur at many localities around the borders of the Susitna basin. In general the outcrops occur along the flanks of the surrounding mountains or as isolated areas in which the Tertiary beds are surrounded by later unconsolidated materials and for the most part covered by them. The area of Tertiary deposits shown on the map (Pl. IV) is small, but the economic value of the formation is disproportionate to its area, for the lignitic coal beds that are present in many places offer possibilities of the development of a valuable fuel supply. The best-known occurrence of this formation is in the Matanuska Valley, where a considerable area is underlain by workable coal beds. Farther west and north the beds are less conspicuous, and their distribution is not so well known. On the south flank of the Bald Mountain ridge, which separates the Willow Creek basin from the eastward-trending portion of Little Susitna River valley, there is a large area of arkoses and conglomerates of Tertiary age which contains no lignite beds that are known to be extensive. An excavation on the railroad line, in the spring of 1917, 2 miles west of the Little Susitna bridge, showed Tertiary beds, and in the summer of that year it was reported that a lignite bed was uncovered there. Lignite-bearing Tertiary beds are reported on the west flank of the Talkeetna Mountains in the basins of Willow Creek and Kashwitna River, but these localities were not visited, and the area and thickness of the formation are not known.

Similarly unconsolidated Tertiary sands and shales, which contain a thick lignite bed, are reported on lower Chunilna Creek, a southward-flowing tributary of Talkeetna River, 4 miles above its mouth. What is probably the western extension of that same field lies along the east bank of Susitna River, from 7 to 12 miles above the mouth of the Talkeetna, and was briefly examined. In that locality, a distance of several miles, the river flows against a bluff composed of blue-gray sands, blue clays, a little sandstone, and some lignite. Good exposures of undisturbed material are scarce, and above the bluff the surface is covered by younger unconsolidated deposits. A 2-foot bed of fairly good lignite was seen, and scattered detrital materials indicate that other lignite beds occur in the same section. It is reported that at one locality a 4-foot bed is exposed, and the coal-bearing area is said to extend to the west side of the river. The coal-bearing beds are believed to be of Eocene age.

TERTIARY LAVAS.

The deposition of the Tertiary sediments was interrupted from time to time by the ejection of basaltic lavas, and a large volume of this material was poured out after the last of the Tertiary sediments were laid down. Thus, in the Willow Creek district thin basal flows are conformably interbedded with Tertiary arkoses. The greatest development of these lavas, however, took place somewhat later, when large areas, including most of the earlier formations, were buried beneath extensive flows of basalt. These lavas reach their greatest development, in the area here discussed, in the upper basin of Iron Creek, where they form a nearly horizontal capping over many ridges and lie upon an erosion surface that was developed on both granitic rocks and greenstones. The basalt flows are of Tertiary age. Some are apparently Eocene, but for the most part they are believed to be post-Eocene.

UNCONSOLIDATED DEPOSITS.

The unconsolidated deposits include glacial morainal materials, glacial outwash gravels of both present and past glaciers, and the detrital materials of the present stream flats. As the earlier glaciers reached so great a development in this region, filling the Susitna basin to a height of over 4,000 feet and completely covering all the lower slopes of the mountains, the deposits left by them cover a large area and have a considerable vertical range. On the map (Pl. IV) the distribution of those materials is shown only in the localities where they are present in sufficient thickness to conceal the identity of the underlying formations. Glacial materials have been recognized over a much wider area, but in places where the area and thickness of the material are small and where the character of the underlying rocks could be determined with little uncertainty the glacial materials were not shown on the map. During the withdrawal of the old glaciers large volumes of outwash gravels and sands were deposited over the lowlands, and these materials are still present in the form of gravel plains, locally dissected by the streams to form benches or terraces. The gravels along the flood plains of the present streams are composed both of the outwash from the present glaciers and of the products of normal weathering and erosion by streams.

ECONOMIC GEOLOGY.

GENERAL FEATURES.

The first discovery of valuable mineral deposits in this general region was made in 1897, when gold placer gravels were found in the Willow Creek basin. The area of workable gold placer deposits proved to be small, but their discovery led to prospecting for the lodes from which the gold came, which resulted in the finding, in 1906, of the lode on which the Alaska Free Gold mine is located. This discovery was soon followed by others, and a permanent gold lode camp, which had produced over $1,000,000 by the end of 1916, was established. All the producing mines in this district are confined within a small area, but there has been more or less consistent prospecting in the mountains north of the producing area, and some promising gold lodes have been discovered but await improved transportation for further development.

In 1910 claims were staked on the Copper Queen lode, on Iron Creek, and assessment work has been done on that property each year since. By 1916 it became apparent that rail transportation up Susitna Valley was soon to be realized, and a number of men went into the basin of Iron Creek, and many claims were staked on copper and gold bearing lodes, and the activity was continued in 1917. More or less work was done on 15 or 20 groups of claims, and a large number of additional claims were staked. In August, 1917, about 20 men were prospecting or carrying on development work in the Iron Creek basin.

At the time of the writer's visit, in August, 1917, the Iron Creek district could be reached only by a poor trail that offered difficulties even for a pack horse. Supplies for the prospectors were therefore limited to articles that had been brought in by sled during the preceding winter or to such materials as could be transported during the summer by pack horse. As a consequence of the remoteness of the district only the simplest forms of prospecting were carried out and even a small amount of development work demanded a large outlay of time and money. The ore bodies are opened only by rather shallow open cuts, and no attempt has been made to sink shafts or drive tunnels. In many places, too, the undisturbed bedrock near the ore outcrops is covered with vegetation or loose surficial material, so that it was difficult or impossible to determine either the size or the geologic relations of the ore bodies. No property in the district had at that time any mass of ore which a conservative mining engineer would consider as being blocked out.

The prospects examined were believed to be valuable for their content of copper or of copper and gold. Most of the ore bodies are due to the replacement, along zones of faulting and shearing, of andesite-greenstone by metallic minerals, but one or two have some of the aspects of contact-metamorphic deposits, though they lie at some distance from the contact of the diorite and greenstone. So far as is known the content of the ores in free gold is not sufficient to justify the installation of crushing and amalgamating machinery on the ground. The base character of the ore will necessitate smelting for the recovery of the copper and gold. Furthermore, the ores contain large amounts of metallic minerals in addition to those which carry the copper and gold, so that concentration, to reduce the weight and bulk of the ores shipped, is likely to offer difficulties. Locally there are bodies of nearly pure copper sulphides that need little concentration, but no large bodies of ore of this type have been developed, and the properties that develop into mines will probably prove to contain large bodies of ore of moderate richness. The imperative need of a mining camp of this type is therefore cheap transportation, and that can be obtained for this camp only by the construction of a branch line of the Government railroad either up Talkeetna River and Iron Creek, or up the Talkeetna to Sheep River and up that stream to and through the divide at Rainbow Lake and thence to the vicinity of the junction of the main forks of Iron Creek.

PROSPECTS.

The following descriptions of prospects are based on observations made in August, 1917. An attempt was made to visit all those properties on which any considerable amount of development work had been done or on which the owners were at work at the time of the writer's visit. The properties visited are described in order, from west to east. A large number of claims have been staked in the district on which little work has been done, and time was not available to visit all of these.

COPPER QUEEN GROUP.

The Copper Queen group includes two claims that lie on the north side of Iron Creek, 2 miles below the mouth of East Fork. These claims were staked in 1910 by A. O. Wells, Frank Wells, and John Coffee and cover the first lode discovery in the Iron Creek district. The ore body lies in a rock bluff on the bank of Iron Creek, and all the work done on it is in the valley bottom. Developments have been confined to stripping the vegetation from the ore body and to the excavation of a shallow open cut. The country rock is an amygdaloidal andesite-greenstone, in which the amygdules are filled with greenish-yellow epidote. The ore body, which lies along a zone of shearing and crushing that strikes N. 10° E. and stands nearly vertical, has been formed by the replacement of the sheared andesite. In the open cut this sheared zone is heavily mineralized throughout a width of 21 feet across the strike, though within that distance there are many large lenticular horses of nearly barren country rock. Pyrite, arsenopyrite, and chalcopyrite are the common metallic minerals and occur as nearly pure masses of one or the other of these sulphides or intimately intergrown with one another. The ore is generally banded parallel to the direction of the shear zone and in places consists of parallel alternating bands of country rock, pyrite, and chalcopyrite. Some quartz is present in the ore as gangue but is not abundant. Scattered specks and blotches of sulphides occur both in the horses within the ore body and in the wall rock for some distance back from the zone of shearing. The owners report that this ore body is valuable for its gold as well as its copper content, picked samples having shown upon assay several dollars a ton in gold, in addition to the copper.

COPPER KING GROUP.

The Copper King group comprises six claims that lie on the south valley wall of Iron Creek opposite the mouth of East Fork. The principal workings lie at an elevation of about 3,300 feet, 1,500 feet above the valley bottom. Development work on the property has been directed to the excavation of a large number of trenches and open cuts in the attempt to demonstrate the presence of a long continuous ore body. These open cuts show that the andesite-greenstone country rock is cut by a shear zone that strikes northeast and dips about 60° E., in which the sheared material has been replaced in part by metallic minerals and some quartz. The shear ranges from 6 to 20 feet in width, and the degree of replacement of the sheared andesite-greenstone differs greatly from place to place. The best showing of ore was in a large open cut that had been excavated down to undisturbed bedrock. In this cut, through a width of 9 feet across the strike of the shear zone, abundant chalcopyrite and specular hematite with some pyrite and a little quartz were exposed. The ore is banded parallel to the direction of the shear zone and consists of alternating bands of nearly pure chalcopyrite, specular hematite intergrown with quartz, and pyrite. The individual bands are more or less discontinuous, and the characteristic mineral of one band may be present in small amounts in the other bands. Another cut near by shows several feet of nearly pure hematite with only small amounts of sulphides. Locally some quartz is present in the shear zone in small distinct veins. The ore from this group of claims is said to carry only small amounts of gold and silver.

COPPER WONDER GROUP.

The Copper Wonder group comprises seven claims that lie on the south slope of the Iron Creek valley, south of the mouth of Middle Fork. These claims were first staked in June, 1917, and the only development work done by August of that year was the excavation of three open cuts in the bluffs of Alder Gulch, at an elevation of about 2,500 feet. These cuts show a zone of strong shearing in andesite-greenstone country rock, but the ground has been much disturbed, and in the shallow excavation the strike and dip of the shear zone could not be definitely determined. In the larger open cut the andesite-greenstone is seen to be much altered along the shear zone, in which there is a heavy deposit of specular hematite, together with some pyrite and bunches of chalcopyrite as large as one's fist. A little quartz was also noted as a gangue mineral. The hematite has a thickness of 2 to 3 feet through an exposed vertical distance of 20 feet, and there is considerable copper carbonate stain in the altered shear-zone material. Scattered specks of sulphides were seen in the andesite country rock outside of the shear zone.

PHOENIX GROUP.

The Phoenix group includes three claims on Hyphen Gulch, a small tributary of Iron Creek from the northeast, a little more than a mile above the mouth of Middle Fork. The only locality at which any noteworthy excavation had been made was at an elevation of 3,600 feet, where an open cut showed a small shear zone, 2 to 3 inches wide, in andesite-greenstone. This shear zone, or line of faulting, strikes S. 30° W. and dips 65° NW. and contains gouge and decomposed materials with a little quartz and some copper carbonate stains. The andesite-greenstone wall rock is, however, much stained with copper carbonate and has locally been partly replaced by chalcopyrite, bornite, specular hematite, and quartz. The bornite is closely associated with chalcopyrite and is apparently a surface occurrence only, for a shallow excavation made at the best showing of bornite showed little bornite at a depth of a few feet below the surface but an increasing abundance of chalcopyrite. A number of narrow veins of nearly pure hematite with little associated sulphides have been found on this property.

BLUE LODE GROUP.

The Blue Lode group of five claims lies on the south side of the valley of Middle Fork of Iron Creek, about 2½ miles above the mouth of that stream and 1 mile northeast of the Phoenix group. The principal excavation is at an elevation of 4,200 feet, where a large open cut has been made along a fault or shear zone about 2 feet wide that strikes N. 16° E. and dips 80° W. This zone is filled with gouge, fine crushed and decomposed material, and some quartz that contains chalcopyrite. The wall rock of this shear zone is andesite-greenstone, which has locally been replaced by specks and bunches of bornite and chalcopyrite. An andesite-greenstone cliff above the excavation shows abundant stains of azurite and malachite. Broken surfaces of the surface wall rock show bornite and chalcopyrite intimately intermingled, but a few feet below the surface the bornite becomes relatively scarce and chalcopyrite predominates, suggesting that the bornite occupies only a shallow zone of enrichment and that at greater depth the chalcopyrite will prove to be the prevailing sulphide. Another open cut farther down the mountain shows chalcopyrite but no bornite. This property was staked only a few weeks before it was visited, and too little development work had been done to determine either the size of the ore body or its character at depth.

EASTVIEW GROUP.

The Eastview group of two claims lies in the basin of Middle Fork of Iron Creek half a mile southeast of the Blue Lode group and about the same distance northeast of the Phoenix, at an elevation of 4,500 feet. The country rock is andesite-greenstone, and the workings include three open cuts, from which have been taken large lumps of banded quartz, hematite, and chalcopyrite. In these lumps of ore chalcopyrite is locally abundant, but as none of the cuts had been carried down to undisturbed bedrock at the time of the writer's visit, no ore in place was seen, and nothing is definitely known about the size or position of the ore body.

TALKEETNA GROUP.

The Talkeetna group of nine claims lies in the valley of Prospect Creek, about 2 miles above the mouth of that stream. The claims were staked in the spring of 1916, and their exploration and development have been limited to strippings and open cuts made in the endeavor to show the character of the ore in place. At the time of the writer's visit eight men were employed on this property. The main ore body is on the claim known as Talkeetna No. 2, where an extensive gossan on the steep mountain slope, at an elevation of 4,200 feet, renders the ore deposit conspicuous from a distance. A number of trenches and open cuts have been excavated through this gossan, but these have been made for the purpose of ascertaining the character of the unoxidized ore body, and no consistent effort has been made to outline the area of mineralization or to determine its structure and relations. The country rock is an amygdaloidal andesite-greenstone, and the amygdules are filled with epidote. This greenstone is cut by a shear zone that strikes approximately east and west and dips 75° N. The shear zone has acted as a channel for the circulation of mineralizing solutions, and the sheared material, as well as the massive wall rocks, have been in part replaced by specular hematite, chalcopyrite, pyrite, and quartz. The area of heavy mineralization, as well as could be determined from the workings, is several hundred feet long and is locally at least 30 feet thick. Its long dimension is parallel to the strike of the shear zone, which itself lies almost parallel to the steep mountain face, so that the ore is exposed on the surface through a vertical distance of at least 50 feet. The gossan is only a few feet thick and is abundantly stained with copper carbonate.

Specular hematite is by far the most abundant metallic mineral and occurs in massive aggregates many feet thick, in which the only other conspicuous mineral is granular quartz that is intimately intergrown with the hematite. Another abundant type of ore consists of an intergrown aggregate of hematite, chalcopyrite, and quartz that forms the matrix of a breccia and surrounds angular fragments of andesite-greenstone, themselves partly replaced by iron and copper minerals. Elsewhere the ore consists of sheared and schistose andesite-greenstone largely replaced by metallic minerals, which is banded with small quartz veinlets that include the same minerals—pyrite, chalcopyrite, and hematite. Veinlets of ore shoot off from the main ore body into the country rock, and sulphides and hematite are widely disseminated in the country rock for some distance on both sides of the shear zone. These claims are being prospected as a source of copper, and a large amount of work must be done before a proper estimate can be made of the amount of copper ore of any particular grade that is available. The principal copper mineral, chalcopyrite, differs greatly in abundance from place to place within the ore body. Locally hematite is present to the almost complete exclusion of the sulphides. Elsewhere chalcopyrite forms the bulk of the ore. In some places the chalcopyrite crystals are surrounded by a thin zone of hematite and that by quartz. It is reported that assays show from less than 1 per cent to 8 per cent of copper and small amounts of gold and silver. Underground exploration alone can determine the character and metallic content of this ore body with depth, but the great size of the deposit may make possible the development of a mine even with a comparatively low grade of ore.

Shallow excavations have been made on croppings of metallic minerals on claims No. 3 and No. 7 of this same group, on the north side of Prospect Creek, where a number of open cuts, for the most part shallow and in disturbed ground, show similar ores, which have the same association of pyrite, hematite, and chalcopyrite.

OTHER PROSPECTS.

A number of claims, or groups of claims, in addition to those described above, have been staked in the basin of Iron Creek, but on most of them little development work had been done, and the restrictions of time imposed upon the writer made it possible to visit only those properties that had been furthest developed. The location of many of these groups is shown on the accompanying map (Pl. IV).

Vigorous prospecting in this district has been carried on only since the spring of 1916, and many of the claims were staked in 1917, so that the amount of work which has been done on any property is not necessarily an index of the value of the ore deposit, and some of the properties not visited and not described specifically may be of greater merit than some of those that are more fully described here. The possibilities for the discovery of still other ore deposits in this area have by no means been exhausted, and it is likely that other ore bodies more valuable than any yet discovered may be found. A large area in the basins of Sheep River, Montana Creek, and Kashwitna River has received scant attention. Hand specimens of rich copper and gold ores have been brought out from this area by prospectors, but the localities from which they came could not be learned, and the deposits were not visited by the writer. Late in the summer of 1917 reports were circulated of the discovery, on a northward-flowing tributary of Talkeetna River opposite the upper basin of Iron Creek, of a large dike the surface croppings of which yielded gold upon panning, and which was said to show an encouraging gold content upon assay. A considerable number of prospectors visited the locality, and many claims were staked, but the lateness of the season prevented a thorough prospecting of the deposit, and its commercial value is yet to be demonstrated. The next few years will probably witness increasing activity in prospecting in the western Talkeetna Mountains, and there is every promise that some producing mines will be developed.

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MINERAL RESOURCES OF THE UPPER CHULITNA REGION.

By Stephen R. Capps.

INTRODUCTION.

The area here referred to as the upper Chulitna region includes what has generally been called the Broad Pass mining district. The prospects that have attracted considerable attention to this part of Alaska lie 15 to 30 miles southwest of Broad Pass, and that pass can be seen only in the distance. Furthermore, the term "Broad Pass region"[1] has already been used to describe an area including the headwaters of Nenana River and a part of the upper Susitna basin. In order to avoid confusion, therefore, the area here discussed is termed the upper Chulitna region. It lies on the southeast slope of the Alaska Range between meridians 149° and 150° west longitude and parallels 62° 45′ and 63° 15′ north latitude.

Although a few prospectors and explorers had penetrated to this part of Alaska, no systematic surveys had been extended to it until 1898, when, through the discovery of the rich gold placers in the Canadian Klondike, interest in Alaska was stimulated and a number of surveying expeditions were dispatched by the United States Army and the Geological Survey to different parts of the Territory. One of these expeditions, a Geological Survey party in charge of G. H. Eldridge and Robert Muldrow, ascended Susitna River to Indian River and proceeded thence northeastward through the upper Chulitna basin to the headwaters of Nenana River. The map published as a result of their expedition[2] gave the first authentic geographic information about a large area on the upper Susitna basin. In 1902 A. H. Brooks, of the Geological Survey, explored the west and north flank of the Alaska Range from the head of Skwentna River to the Nenana, and between that year and 1912 several mountaineering, exploring, and railroad survey parties reached some part of this district but left no records that were available for the public. Among the more noteworthy of these explorations was that conducted by F. A. Cook, who in 1903 pushed southward across the range with pack horses through a pass lying somewhere between Muldrow

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

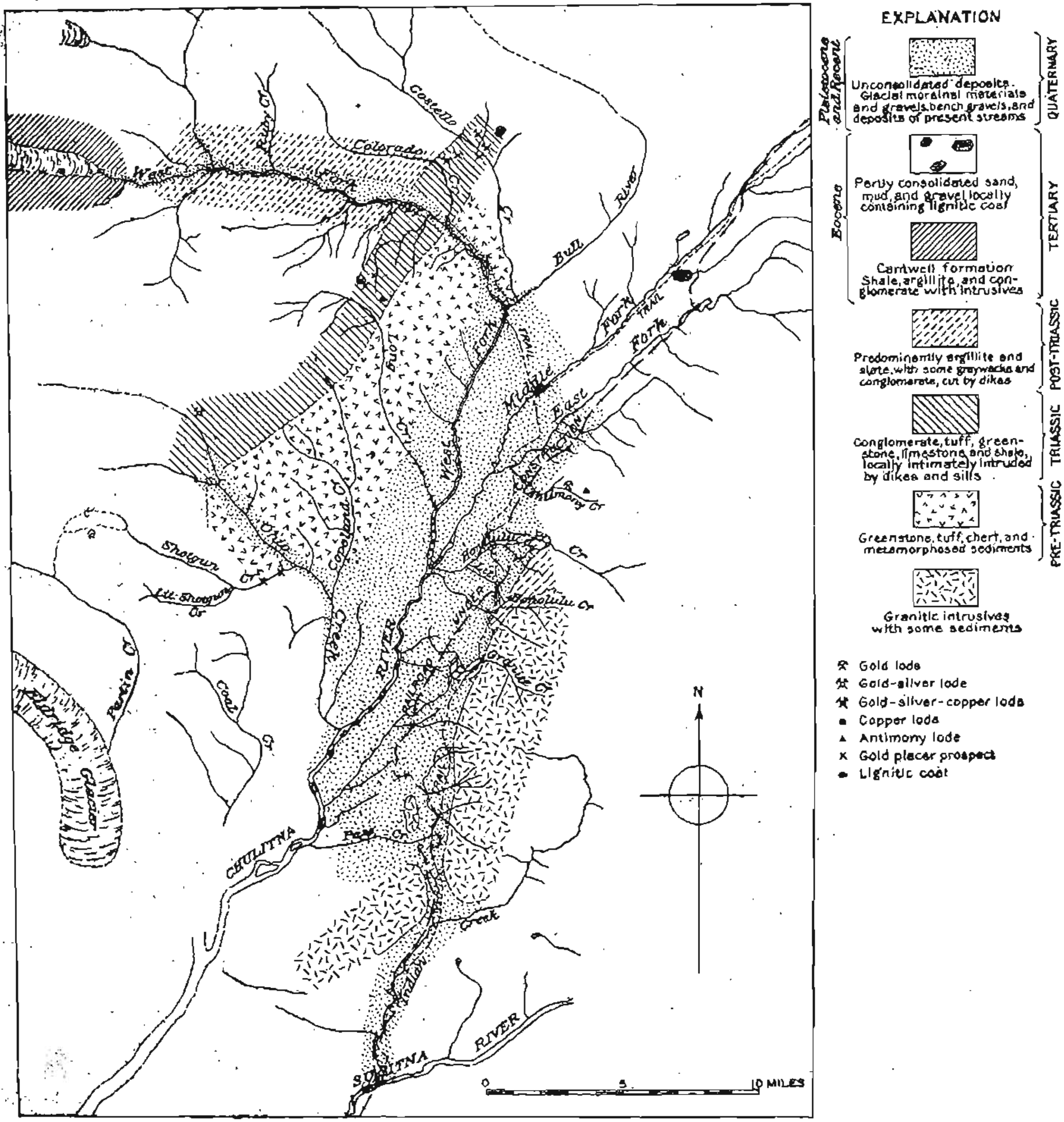
[2] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, map 3, 1900.

Glacier and Nenana River. His account of the journey is not clear, and he made no accurate survey, but as nearly as can be determined he crossed an ice-filled pass at the head of Teklanika River and descended Bull River to the Chulitna. It is reported that the first discovery of placer gold in this district was made by John Coffee in 1907 on Bryn Mawr Creek, and many lode claims were staked in the basin of West Fork of Chulitna River in 1909. In 1912 a mountaineering expedition, conducted by Herschel C. Parker and Belmore Browne, ascended Susitna and Chulitna rivers and what is now called Ohio Creek by dog sled, crossed a high, glacier-filled pass to the West Fork of Chulitna Glacier, and from the head of that glacier penetrated across another divide to the north slope of the Alaska Range. The sketch map of their route constitutes the first published record of the drainage along their line of travel through the range. In 1913 F. H. Moffit [1] and J. W. Bagley, of the Geological Survey, mapped both the geology and topography of an area extending from Broad Pass eastward to the West Fork of Susitna Glacier, and in 1914 D. L. Reaburn, of the Alaskan Engineering Commission,[2] mapped the topography along the line of the Government railroad survey between the mouth of Indian River and Broad Pass.

For several years development work has been done on a number of lode claims in the upper Chulitna basin, and encouraging reports have been circulated concerning large bodies of gold ore there. This area, at present so remote, will become readily accessible upon the completion of the Government railroad now in progress of construction between Seward, on the coast, and Fairbanks, on Tanana River. It was therefore deemed advisable to make at least a hasty geologic investigation of the area, to determine the geologic conditions of the ore bodies and the probabilities of the development in this area of producing mines. Upon the entrance of the United States into the European war, a large number of the topographers of the Geological Survey were called upon for military work, and no topographer was available for making a topographic survey of the region, but the maps of the Alaskan Engineering Commission along the main Chulitna Valley furnished control from which foot traverse and compass sketching could be carried westward. Plans were therefore made for a geologic party to visit this area during the summer of 1917, and the writer was assigned to carry them into effect. The season's work was to include investigations in other parts of the Susitna basin as well, so that only a short time could be spent in this area. The party, consisting of the geologist and three camp hands, with seven pack horses, left Anchorage by railroad on June 18 for Matanuska, from which the horses were driven over the

[1] Moffit, F. H., op. cit., Pls. I and II.

[2] Reports of the Alaskan Engineering Commission for the period from Mar. 12, 1914, to Dec. 31, 1915: 64th Cong., 1st sess., H. Doc. 610, pt. 2, map 6, 1916.



GEOLOGIC SKETCH MAP OF THE UPPER CHULITNA REGION.

trail to the terminus of the rails, at that time at Little Susitna River. From that point the pack train followed the construction road and trails along the general route of the railroad survey up Susitna and Chulitna valleys to Middle Fork of Chulitna River, where a trail branching off to the northwest leads up West Fork of Chulitna River to the vicinity of the lode prospects. In all a period of only 24 days was spent between the time of departure from Indian River and the return to that place. During this time all the prospects in West Fork of Chulitna and Ohio Creek basins on which any considerable development work has been done were visited and the larger features of the geology of the area were mapped. The southeastward-flowing tributaries of Chulitna River have not yet been accurately surveyed, and the position of the drainage lines, shown on the accompanying sketch map (Pl. V), as determined by foot and compass traverse, can be considered as only approximate.

As already stated, the information on which this report is based was procured in the course of a hasty visit to the region, and during practically the whole time the weather conditions were very bad. The areas of the different geologic formations, as shown on the map (Pl. V), are therefore subject to revision when more detailed field work is done.

GENERAL FEATURES OF THE REGION.

GEOGRAPHY.

The upper Chulitna region consists essentially of the valley of Chulitna River, a broad northeast-southwest basin, which is bordered on both sides by rugged mountains. At a point just west of Chulitna Pass Chulitna River flows at an elevation of 1,200 feet, and at Broad Pass the basin floor rises to a height of about 2,400 feet. The southeast margin of the Chulitna basin lies only a few miles away from the river and is formed by a ridge of sharp and rugged peaks that rise to heights of 5,000 to 6,000 feet. The streams that drain this ridge are all of moderate size, and their water is clear, indicating the absence of any large glaciers in those mountains. To the northwest the Chulitna basin is of a different character, for it includes a long section of the southeast slope of the Alaska Range. There the lateral spurs of the main range begin only a short distance back from Chulitna River and become constantly higher and more inaccessible toward the crest of the range, 20 to 35 miles from the river. All the larger tributary streams from the Alaska Range, including Ohio Creek, West Fork of Chulitna River, Bull River, and their principal tributaries, carry glacial waters, and large areas in the valley heads are occupied by glacial ice. In the rugged ice-filled portion of the range travel is difficult and hazardous, and a large area is still entirely unexplored.

GLACIATION.

The portion of the Alaska Range that drains to Chulitna River is characterized by the number and large size of its existing glaciers and by the pronounced manner in which the surface forms have been modeled by the greater glaciers of earlier times, of which the present ice tongues are the remnants. The southeast side of the Alaska Range nourishes some of the largest alpine glaciers of the continent. Two of these glaciers, tributaries of Chulitna River though lying south of the area here discussed, are several miles wide and probably over 30 miles long. In the region with which this report is concerned the larger streams that drain from the Alaska Range, including Ohio and Copeland creeks and West Fork of Chulitna and Bull rivers, as well as their larger tributaries, are glacier-fed. The size of the glaciers is determined by the altitude of the surrounding mountains and the area of the catchment basins.

There can be no doubt that the present glaciers are small compared with those that occupied this region in times past. At the time of greatest glaciation, ice from the Alaska Range moved southward down Chulitna and Susitna valleys, was augmented by other glaciers from the Talkeetna and Kenai mountains, and pushed down the Cook Inlet depression at least as far as the Forelands. Thus the entire Susitna basin was a great ice field and was connected to the east by way of the upper Susitna basin with a similar ice field that filled the Copper River basin. In order to drain southward, as it did, this glacier must have had a surface slope to the south of steeper gradient than that of the present valley floor, so that in the area here discussed the glacial ice must have reached a great thickness, and this conclusion is verified by evidence of ice sculpture high on the flanks of Chulitna Valley. The divide between West Fork of Chulitna River and Long Creek was overridden by glacial ice to an elevation of at least 4,500 feet, 2,300 feet above the valley of West Fork, directly to the north. The east wall of Chulitna Valley near Antimony Creek also shows erosion by a southward-moving glacier to a height of much more than 4,000 feet. In the lack of an accurate topographic map of this region as a whole it is not yet possible to outline the area reached by the glaciers at the time of their greatest extension, but it is certain that at that time only the high peaks and ridges of the mountains projected above the ice and that from the crest of the Alaska Range to the Pacific Ocean the area of land above the ice was very much less than the area of the glaciers.

ROUTES OF TRAVEL.

The upper Chulitna region has always been difficult of access, and those who have visited it have done so only at the cost of much time and effort. The Alaskan prospector knows no barriers of distance or bad trail if he is convinced that his chosen field offers a fair chance for the discovery of valuable minerals, but the time consumed in going to and from a remote area must be subtracted from the total season available for prospecting, and the actual time spent in the search for valuable ground is short when the trail to it is long and arduous. Heretofore two distinct methods of transportation, or a combination of the two, have been chiefly employed by those who have visited the region. The most favored has been the use of dog sleds up the frozen streams in winter. Supplies were procured from Talkeetna, where a store was maintained for some years, from Susitna station, or from Knik. A considerable part of the prospecting was done by a group of men who brought their supplies in during the fall, trapped for fur in the winter, and spent the summer in prospecting. Summer traveling was done for the most part by launch or poling boat up Susitna River to the mouth of Indian River, and thence by trail up Indian River through Chulitna Pass and up Chulitna Valley, crossing East and Middle forks to West Fork near the mouth of Bull River. A few parties came in by pack train from Knik Arm, following the west flank of the Talkeetna Mountains to Talkeetna River and crossing that stream to ascend Susitna Valley to Indian River. This method of travel was slow and costly and was used for the most part by surveying parties, whose work was a study of the entire route rather than an effort to reach the upper Chulitna by the easiest means.

In the spring of 1915 active construction on the Government railroad, which is planned to extend from Seward to Fairbanks, was commenced, and the town of Anchorage was established as a base of supplies. During that year the work was for the most part confined to the areas bordering Knik and Turnagain arms and to the construction of a branch line to the coal fields of Matanuska Valley, but in 1916 and 1917 construction was carried on along the main line, up Susitna Valley, and power boats were operated for transporting passengers and freight up Susitna River to the mouth of Indian River. In June, 1917, the rails extended to the railroad crossing of Little Susitna River 174 miles from Seward, and stretches of wagon road, connected by trail, followed the railroad route as far north as Talkeetna River. Above the Talkeetna a passable trail for pack horses was available all the way to West Fork of Chulitna River. By the end of 1917 it was reported that the rails were in place as far north as Montana Creek, 210 miles from Seward, and much of the railroad grade was completed as far as Dead Horse, about halfway between Talkeetna and Indian rivers. As soon as construction is completed to Broad Pass, the upper Chulitna district will become easily accessible, and the improved transportation will greatly stimulate mining and prospecting.

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A favorable pass across the Alaska Range at the head of West Fork of Chulitna River has been used for sledding supplies across the range in winter and has been crossed by pack trains in summer. It is necessary to ascend the glacier at the head of West Fork of Chulitna River for a distance of 10 or 12 miles to a low pass, which leads perhaps 2 miles down another small glacier to the edge of Muldrow Glacier, which is followed northward for about 10 miles to the north base of the Alaska Range. The route presents no insurmountable difficulties late in summer, though travel would be difficult until the soft snow has disappeared from the surface of the glacier. The distance from the last spruce timber on West Fork of Chulitna River to the first brush near Muldrow Glacier is about 20 miles, and under favorable conditions the trip may be made by pack train in one day.

The completion of the railroad will make the region easily accessible from points on Tanana River by way of Nenana River.

VEGETATION.

In the upper Chulitna region timber is confined to the valleys of the principal streams. The valley of Chulitna River has a growth of trees, mainly spruce, but including some cottonwood and birch, up to an average altitude of 2,000 feet above sea level, though locally trees grow above that altitude and considerable areas below 2,000 feet are untimbered. In the valleys tributary to the Chulitna through from the northwest a fringe of trees extends along the lower valley walls to an elevation of perhaps 2,500 feet. Thus spruce groves composed of trees reaching a foot or more in diameter are present on West Fork of Chulitna River to a point within 2 miles of the glacier in which the stream heads, and Ohio Creek has patches of good cottonwood and spruce trees for about 2 miles above the mouth of Christy Creek, whereas Copeland, Long, Colorado, and Costello creeks, with steeper gradients, follow timberless valleys in their upper courses, and even brush of sufficient size to supply the moderate needs of the camper is lacking.

There is little timber in the Chulitna basin that is fit for other than local uses. Patches of cottonwood trees, in the bottoms of the larger streams, will supply logs as much as 4 feet in diameter, and these will furnish a small number of saw logs. The spruce and birch trees are generally small, few attaining a diameter of more than 2 feet, and although they will furnish cabin logs, mining timbers, cordwood, and an inferior grade of lumber, the products of the forests will be used only locally.

Grass sufficient for forage can generally be found throughout the region. There are considerable areas of marshy bench lands and of spruce-covered bottoms in which the prevailing ground cover is ing salmon. Without doubt the natives at times ascend the tributaries of Chulitna River on hunting or trapping expeditions, but they have left little evidence of their visits. During the summer of 1917 no natives were encountered by the Geological Survey party north of Talkeetna River.

GENERAL GEOLOGY.

CHARACTER OF THE ROCKS.

The rocks of the upper Chulitna region consist of a wide range of materials that have undergone different degrees of metamorphism. They include cherts, slates, and highly metamorphosed tuffs; less altered shales, graywackes, limestones, and tuffs; closely folded shales and graywackes; a thick series of shales and conglomerates; partly consolidated sands and clays with associated lignite; and several types of unconsolidated glacial and stream deposits. Igneous rocks are also present as basic lava flows, as dikes and sills, and as large intrusive masses. As shown on the map (Pl. V), the largest bodies of intrusive rock within the area visited lie between Chulitna and Susitna rivers. Northwest of Chulitna River the Alaska Range proper shows on its flank a considerable amount of fragmental volcanic material in the form of tuffs, associated with normal sediments. Farther to the northwest the main range is composed predominantly of sedimentary beds.

The distribution of the geologic formations, as they have now been differentiated, is shown on the map (Pl. V). The mapping, however, was done in the course of a hasty trip of only three weeks, the principal object of which was the visiting of the numerous mining claims. During the mapping it rained almost constantly. In this area the geology is by no means simple, and the grouping together of certain lithologic units and the areas assigned to them can be considered as only tentative and will be considerably modified when more detailed studies are made. A base map was available only along the main Chulitna Valley. The main portion of the Alaska Range, from Chulitna River to the crest, is unmapped, and much of it is still unexplored. The drainage lines shown on the map as solid lines were taken from the surveys of the Alaskan Engineering Commission. The drainage shown in broken lines was mapped by foot traverse during the progress of the geologic work in 1917.

STRUCTURE.

The dominant structural trend of the rocks on the southeast flank of the Alaska Range is north-northeast, parallel to the axis of the range and to the broad trough of the Chulitna. A part of this structure was developed during the growth of the present mountain range, and the structural features of the little-consolidated Tertiary lignite beds may be attributed entirely to those mountain-building movements. The growth of the present range, however, took place in post-Mesozoic time. The Mesozoic and older rocks are more strongly metamorphosed than the Tertiary lignite-bearing beds, and their structure must therefore be in part ascribed to movements that antedated the last mountain-forming processes. Indeed, in examining the formations it is seen that each is more severely metamorphosed than the one succeeding it. It is therefore evident that the site of the Alaska Range has long been a zone of weakness along which folding has taken place from time to time, and the present mountains are but the topographic expression of the latest of the earth movements. Folding and faulting have both been operative in forming this massive range, and severe earthquakes in recent years suggest that even now the same slow forces are at work and that mountain growth still continues.

SEDIMENTARY AND METAMORPHIC ROCKS.

GREENSTONE TUFFS, SLATES, AND CHERTS.

What appears to be the oldest group of rocks in the area here described comprises greenstone tuffs, cherts, and slates that form the front of the mountain range northwest of Chulitna River. These rocks crop out at intervals along the valley of West Fork of Chulitna River below the mouth of Colorado Creek and appear also on Long, Copeland, and Ohio creeks in the areas indicated on the map (Pl. V). These rocks are prevailingly so metamorphosed and altered that their original character is difficult to determine in the hand specimens. At many places in which comparatively fresh and unaltered material can be obtained the characteristic rock consists of a multitude of fragments of basic dull-green to faint-purple lavas inclosed in a matrix of finer material of the same sort. The fragments are generally angular and of irregular shape and range in size from microscopic grains to pieces several inches in diameter. These rocks are composed of fragmental material that was ejected violently from volcanic vents and accumulated in thick deposits, presumably in bodies of standing water. Their water-laid character is inferred not from any characteristic of the tuffs themselves, for they are free from any evidence of assortment of the materials, but from the association with the tuff beds of large amounts of chert and slate or argillite. At places the cherts and slates are notable members of the group, preponderating over the tuffs. Elsewhere they occur as thinner layers or lenses in areas where the tuffs are the prevailing rock. It is apparent that the normal processes of sedimentation, which resulted in the formation of the slates and cherts, were interrupted from time to time by volcanic outbursts, during which large quantities of fragmental volcanic material were ejected and accumulated rapidly in the near-by waters.

Between these periods of volcanic activity the normal sediments were laid down. The dark-gray to black slates occur in thin beds, alternating with light-green, gray, or blue-gray cherts.

No fossils were found in this group of tuffs, slates, and cherts, and their age is not definitely known. As will be shown later, however, they are known to be overlain by other materials from which Triassic fossils were obtained. The structural relation between this group and the Triassic rocks has not been fully determined, but they are believed to be unconformable. If that conclusion is correct, the tuffs and associated slates and cherts are pre-Triassic and probably Paleozoic. No closer age determination is justifiable on the basis of our present knowledge.

TRIASSIC TUFFS, LIMESTONES AND SHALES, AND LAVA FLOWS.

Economically the most important group of rocks in the district is a series of Triassic tuffs, limestones, shales, and basic lava flows with minor amounts of conglomerate and graywacke, which apparently lies unconformably upon the beds already described. Most of the mineralized lodes so far discovered occur in these rocks. The approximate position of the contact between this group and the underlying group composed of greenstone, tuff, slate, and chert (see Pl. V) crosses West Fork of Chulitna River a short distance below the mouth of Colorado and Bryn Mawr creeks, runs southwestward across the valleys of Long and Copeland creeks, and crosses Ohio Creek just above the mouth of Christy Creek. Between Costello and Long creeks the relations between the two groups of rocks are not clear, for the surface is generally covered with vegetation, and intrusive dikes and sills are unusually abundant. Farther south better exposures are available, and on Ohio Creek an excellent section is exhibited. There the older group of tuffs, slates, and cherts forms the walls of the lower valley as far northwest as Christy Creek, where it appears to lie unconformably beneath a heavy bed of conspicuous red tuff and agglomerate. This red tuff is the basal member of a group of rocks that has an aggregate thickness of several thousand feet and includes tuffs, agglomerates, conglomerates, amygdaloidal greenstone flows, and massive limestone beds. The tuffs range in texture from fine-grained rocks that resemble red sandstone, through coarser rocks composed of angular fragments from one-eighth to 1 inch in diameter, to coarse agglomerates containing fragments of volcanic débris several inches across. They range in color from vivid red, in which the composing fragments are chiefly jaspilite, through green and purple shades. In some of the tuffs the fragments all appear to be sharply angular in outline; in others some fragments are angular and others partly rounded. These tuffs grade, by scarcely perceptible variations, into rocks composed largely of beautifully rounded quartz pebbles the size of a pea, so that characteristic tuffs and typical conglomerates are apparently connected by a series of intermediate rocks. On upper Ohio Creek five distinct and massive limestone beds form conspicuous features of the landscape. One of these beds yielded fossils that were determined by T. W. Stanton to be of Triassic age, and several other collections of fossils, taken from boulders in the bed of Copeland Creek, all appear to be of the same age. The tuff beds, so abundant in the lower portions of this group of rocks, give place to amygdaloidal lava flows in the higher parts of the group, and on Ohio Creek a considerable thickness of lava flows appears above the uppermost limestone bed.

On West Fork of Chulitna River the section, though presenting certain features in common with that on Ohio Creek, is greatly different in detail. The red and green tuffs are present at the base and appear at the Riverside claims along Bryn Mawr Creek and on the claims of the Golden Zone group. The abundant intrusive material, in dikes and sills, has altered the surrounding rocks by contact metamorphism, and as a result the limestones, here inconspicuous, are generally changed to marble, and white, cream, and bluish cherts appear. The amygdaloidal greenstones, so abundant on upper Ohio Creek, are relatively scarce on West Fork of Chulitna River, where the group is overlain by a heavy body of black argillites, slates, and graywackes.

ARGILLITES, SLATES, AND GRAYWACKES.

A conspicuous group of rocks that crop out along the valley of West Fork of Chulitna River and forms a large element of the Alaska Range is composed predominantly of black argillite, together with minor amounts of graywacke and some fine conglomerate. Its extent along the strike, from northeast to southwest, has not been determined, but from the width of the belt across the strike, as exposed on West Fork of Chulitna River for a distance of over 7 miles, it seems certain that these rocks are of wide distribution. Their thickness as measured across the strike can not, however, be regarded as the normal thickness of the group, for there is abundant evidence of close folding and faulting. The general structural trend is northeast, and the dips average 45° or more and are prevailingly to the northwest. Intrusive dikes and sills are present throughout this group of sediments. Apparently this group of rocks lies structurally above the group of Triassic tuffs, limestones, shales, and lavas, though the relations between the two groups were not observed. Neither was it possible in the brief time available for the study to determine the relations of this group of rocks to the overlying formation, which, as will be shown, is probably of early Tertiary age. The only conclusion that can now be drawn is that these beds are younger than that portion of the Triassic represented by the fossiliferous limestones and older than Eocene.

Certain other black argillites, slates, and graywackes occur on the east side of Chulitna River and were observed from Granite Creek to Antimony Creek. These rocks are in general more highly metamorphic than the rocks of West Fork of Chulitna River, just described, but are here included with that group, though the correlation is only tentative.

Eldridge[1] described a group of slates exposed along Susitna River for a distance of 50 miles, which he termed the Susitna slates, but he made no statement as to their probable age. Brooks[2] described a similar belt of rocks in Kichatna Valley that he believed to be "of unknown age, but probably chiefly Paleozoic." Capps[3] found the same belt of rocks to be continuous from the Kichatna locality of Brooks northeastward and traced it almost to the area described by Eldridge. He classified the rocks as probably of Paleozoic or Mesozoic age. Throughout that distance the slates, argillites, and graywackes of this group are perhaps the most abundant single element in the flank of the Alaska Range. The present investigation has disclosed the fact that a similar formation is prominent in the headwaters of Chulitna River, and although the correlation is by no means certain, it seems probable that the rocks there are a continuation of series of similar rocks mapped farther south. The evidence that the beds of the upper Chulitna are of Mesozoic age indicates a similar age for the great belt of rocks extending to the southwest, if future studies prove the stratigraphic continuity between the two localities.

CANTWELL FORMATION.

In the upper valley of West Fork of Chulitna River the valley walls for some distance above and below the terminus of the glacier in which that stream heads are composed of conglomerates, impure sandstones, grits, and shales. The beds are gray to black. Conglomerates, in unusual abundance, occur throughout the formation. Among the included pebbles argillites, graywackes, and slates are most conspicuous, but pebbles of other rocks and of quartz are also present. Much of the conglomerate is fine, the pebbles averaging only a small fraction of an inch in diameter, but some coarser beds, inclosing boulders as much as a foot in diameter, were seen. The matrix consists of an impure gray sand or grit. All gradations are apparent in coarseness of bed, from coarse conglomerate through fine conglomerates and grits to sandstones and shales.

In the general make-up of this group of sediments there is an unmistakable resemblance to the Cantwell formation in the headwater

[1] Eldridge, G. H., A reconnaissance in Susitna basin and adjacent territory, Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 15-16, 1900.

[2] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 67-68, 1911.

[3] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, pp. 24-28, 1913.

region of Nenana River, as described by Moffit,[1] and in the upper Toklat basin as described by Capps.[2] In those localities the beds have been determined, on the basis of fossil plant remains, to be of Eocene age, and as the area here described is directly along the strike and only a few miles away from the Toklat locality, and as the lithologic aspect of the rocks, although unusual, is the same at these localities, the beds of upper West Fork of Chulitna River are referred with little hesitancy to the Cantwell formation. The Cantwell formation is generally folded, tilted, and faulted and is cut by intrusive rocks. In places lava flows are interbedded with the sediments. The stratigraphic and structural evidence and the degree of induration seem to indicate that these beds may be older than the Eocene.

COAL-BEARING TERTIARY BEDS.

The next succeeding formation that has been recognized in this region comprises the Tertiary coal-bearing deposits that occur at scattered localities throughout the Susitna basin. These beds include unconsolidated or slightly consolidated shales or clays, sands, gravels, conglomerates, and some lignitic coal. With the area here described the coal-bearing formation was seen at only two localities, and at these its exposures are small, but the presence of pieces of lignite on the gravel bars of both East and Middle forks of Chulitna River indicates that the formation occurs on both of those streams and that it may be of considerable extent beneath the deposits of younger gravels. The coal-bearing formation crops out as a bluff of fairly firm conglomerate at the trail crossing of Middle Fork of Chulitna River, but no lignite was seen there. On Coal Creek, a small tributary of Costello Creek, shales and sands, with lignitic coal, occur. They are described below (pp. 231–232).

The age of the lignite-bearing formation throughout the Susitna basin has generally been regarded as Eocene. Some uncertainty, however, has arisen during the last few years, for on the evidence of the fossil plant remains obtained from the Cantwell formation that also has been classified as Eocene. Throughout the area in which it has been recognized the Cantwell formation consists of dark, completely indurated rocks, which, though carrying a small amount of carbonaceous material, have nowhere been found to contain valuable coal beds. The Cantwell beds are also generally much tilted and deformed. The coal-bearing Tertiary beds, by contrast, are everywhere light in color and are generally little consolidated and only mildly deformed. In both lithologic character and structure they differ greatly from the Cantwell formation and are certainly younger

[1] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 40–49, 1915.
[2] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 37–44, 1919.

than the Cantwell. There can be but little doubt, however, that the lignite-bearing beds of the upper Chulitna basin are to be correlated with similar deposits that occur at intervals throughout that basin and that have been classed as of Eocene age.

UNCONSOLIDATED DEPOSITS.

The unconsolidated deposits include a variety of relatively young sediments, including the morainal materials dropped directly by glaciers; bench or high-level gravels, mainly laid down by the streams that carried the outwash from the ancient greater glaciers; and the gravels of the present stream flats, composed in part of the outwash from existing glaciers and in part of the products of normal stream erosion. All these deposits are undeformed. Recognizable moraines were seen only near the lower ends of the glaciers in which the tributaries from the Alaska Range head, but a layer of unassorted glacial *till*, composed of blue clay studded with boulders and angular fragments of rock, was seen at many places and may be expected generally throughout those parts of the lowlands that have escaped vigorous stream erosion. The bench gravels are strongly developed along the main Chulitna and in the lower valleys of its large tributaries and are especially conspicuous from the trail where it crosses Little Honolulu and Honolulu creeks and East Fork of Chulitna River. At all these places the bench gravels are yellowish from oxidation and are capped by bluish, unoxidized glacial till. The present stream gravels, composed in part of glacial outwash and the reworked bench gravels and glacial materials, include also the products of present-day rock weathering and erosion.

IGNEOUS ROCKS.

The only mass of intrusive rock of sufficient size to map separately, in an investigation such as that on which the present report is based, is a large body of granitic material that lies on the east side of Chulitna Valley and extends from a point below the mouth of Indian River northward to the vicinity of Honolulu Creek. It is composed of gray to pink diorite and granite, of medium to coarse grain, and is bordered on the east by black slates and by unconsolidated materials. The area shown on the map (Pl. V) as occupied by granitic intrusive rocks includes also some large bodies of slate that were caught up and inclosed by the molten rock when it was injected, but time was not available for tracing out the outlines of these slate bodies. Dikes of granite and diorite also radiate from this central mass in all directions and ramify through the neighboring formations. Indeed, acidic dike rocks that may be related to this large intrusive mass cut all the formations already described except the Tertiary coal-bearing formation and the younger unconsolidated materials. The granitic intrusive rocks of the Alaska Range and of the Talkeetna Mountains have generally been referred to a period of extensive intrusion in Lower Jurassic time, and the rocks here described are of similar character and possibly of the same age. This age determination is not considered final, however, for if the dike rocks that cut the Cantwell are referable to the same period of intrusion as the large granitic bodies east of Chulitna River, and the Eocene age of the Cantwell is accepted, the date of the intrusion must be post-Eocene. At present the evidence is not sufficiently conclusive to justify a definite age determination for the granitic intrusives as a whole.

The group of tuffs and sediments from which Triassic fossils were collected contains large amounts of basic lavas, already referred to, and some basic dikes that were observed may be related to the same period of igneous activity as the lavas.

ECONOMIC GEOLOGY.

HISTORY OF MINING AND PROSPECTING.

Little information has been published concerning the early history of prospecting in the upper Chulitna region, and the date of the arrival of the first prospectors there is not known to the writer. Certainly the discovery of workable gold placer gravels on Valdez Creek, a headward tributary of Susitna River, in 1903, stimulated prospecting in the upper basin of the Susitna, and it is likely that in the following years some adventurous pioneers made their way into the Chulitna basin, but no valuable discoveries of gold were made, and the region remained generally unknown. So far as could be learned, the first claim was staked in this region by John Coffee on Bryn Mawr Creek in 1907, and that claim was worked by the owner in 1909. It is also reported that the first lode claim, the Golden Zone, was staked in 1909, although the present owners date their holding from 1912. The Northern Light lode was discovered in 1911, and during the years 1911 and 1912 practically all the claims that are now held and many other claims later relinquished were first staked. The only valuable mineral actually recovered from this region has been a small amount of placer gold, which was taken from the head of Bryn Mawr Creek. Most of the interest in the region centers on the lodes, which contain gold, copper, and antimony in encouraging amounts. The ores are not free milling, however, and the prospective value of the lodes is in their possibility of producing a large tonnage of ore of moderate richness rather than small quantities of high-grade ore. For the development of properties of this kind good transportation is a prime essential, both for the bringing in of supplies and equipment and for the shipment of the mined ore or concentrates to a smelter. The remoteness and difficulty of access of the upper Chulitna region has so far effectually prevented any lode mining, but the transportation to be furnished by the Government railroad should make it possible to produce metal from those properties that carry ores of sufficient richness to pay charges for mining, transportation, and smelting.

LODE DEPOSITS.

GENERAL FEATURES.

No ore from the lode deposits of the upper Chulitna region has yet been reduced, and as a consequence no commercial production of metals has been made, so that all the lode properties are still to be classified as prospects. Active development work has been carried out on eight or ten groups of claims, however, and a lesser amount of prospecting has been done on several other properties. The fact that no producing mines have yet been developed in no way reflects upon the character of the ore deposits or upon the industry and initiative of the prospectors, for the lack of anything more than the crudest and most expensive means of transportation would have prevented the mining of all but the richest bonanza deposits. The real test of the merits of the properties will come when the Government railroad is finished and the best transportation that can be hoped for is available. Then, if the richness of the ore bodies justifies it, mines will be opened.

Most of the claims in this region were staked and are held by men of small means, who have been compelled to finance their prospecting ventures in the summer by their earnings during the rest of the year. As the simplest mining supplies have been brought to this remote country only at great cost of money, time, and effort, the amount of work accomplished in opening up the ore deposits is small, yet it represents the utmost zeal and enthusiasm on the part of men who have worked under discouraging conditions.

The accompanying sketch map (Pl. V) shows that with the exception of a single prospect on Antimony Creek, east of Chulitna River, all the lode prospects in the upper Chulitna region lie along a nearly straight line, near the contact between the older greenstone tuffs, cherts, and metamorphic sediments on the east and the Triassic tuffs, limestones, and shales on the west, and all lie within the Triassic materials. Aside from the lode claims on Ohio Creek, which are of somewhat different character, the claims that have received most attention lie in a narrow northeast-southwest belt about 7 miles long, cut across almost centrally by West Fork of Chulitna River.

It is a significant fact that in that part of the group of Triassic tuffs and sediments in which the ore bodies occur calcareous rocks are present, either as limestone, marble, or limy shale. Furthermore, in the vicinity of the ore bodies there is an unusual amount of igneous material, injected as dikes into the tuffs, limestones, and shales. The ore bodies themselves, as imperfectly exposed in the scanty workings, are not sharply outlined and have not generally a definite veinlike character. They appear to be irregular masses in which the mineralization is heavy in places but fades out into less mineralized country rock in all directions. Indeed, scattered specks of sulphides can be found in these rocks over wide areas. The principal metallic minerals recognized include arsenopyrite, pyrite, sphalerite, chalcopyrite, pyrrhotite, stibnite, and galena, and assay returns show the presence of gold. Some small, distinct veins cut the ore bodies, and these carry sulphides in a gangue of calcite or quartz, or both, but most of the ore seems to consist of sulphides that have replaced limy rocks, or else it occurs as disseminated sulphides in different types of material, including tuffs, cherts, limestones, and the dike rocks themselves. The information at hand, therefore, indicates that as the result of the intrusion of acidic dikes the intruded rocks suffered some contact metamorphism. Mineralized solutions from the igneous mass penetrated the neighboring rocks and replaced certain of the limy beds. The calcareous beds were not alone affected, however, for sulphide-bearing solutions also penetrated certain tuff and chert beds and replaced portions of these with sulphides, but the larger ore bodies, as at present exposed, seem to represent the replacement of calcareous sediments by metallic sulphides.

One great disadvantage under which the prospectors in the upper Chulitna region have labored is the difficulty of obtaining assay returns with sufficient promptness to guide the progress of development work. In ore of this character the gold content, upon which the value of the ore largely depends, can not be determined without assaying, and the difficulty of travel to and from the region has usually resulted in compelling the prospector to have only a single group of assays made at the end of his season's development work. Such assays are too often made of picked samples of ore, rather than of average samples across an entire ore body, and the prospector is thus in danger of deceiving himself in regard to the average tenor of the ore.

In the following notes those lode prospects on which any considerable amount of development work has been done are described in the order in which they lie from northeast to southwest.

LODE PROSPECTS.

Northern Light group.—The Northern Light group consists of three claims on the northeast side of Costello Creek, a short distance below the mouth of Camp Creek. These claims were first staked by A. O. Wells, Frank Wells, and Joe Focket in 1911 and are still held by these men together with some additional partners, who later bought interest in the ground. The mineralized area first attracted attention on account of the rusty red discoloration of the outcrops. The country rock comprises a confused assemblage of volcanic tuffs, impure limestones, and shales, cut by dike rocks. Much of the rock is so badly altered that its original character is obscure, but tuffs, sediments, and ore are highly calcareous, and even the dike rocks contain calcium carbonate. The area of strongest mineralization is irregular in outline and has a greatest width of about 30 feet. The mineralized rock strikes about N. 65° W. and dips 70° SE. It is apparently the result of the replacement of a limy bed by sulphides and contains veins and bunches of quartz. This limy bed appears to lie between metamorphic tuffs, which the owners term the hanging wall, and a finely granular dike rock that forms the footwall. A tunnel 64 feet long has been driven into the highly stained bluff of Costello Creek through material that everywhere contains finely disseminated sulphides. At the time of the writer's visit, in July, 1917, the breast of the tunnel showed a quartz vein 6 inches to 1 foot thick, highly mineralized. Within the mineralized zone there are many horses of the footwall rock that are comparatively lean in sulphides, though gold and silver have been found in assays of the country rock on both sides the area of heaviest mineralization, which has been traced along the surface for a distance of about 800 feet. The metallic minerals that have been recognized include arsenopyrite, pyrite, chalcopyrite, sphalerite, and a little stibnite, and assays are said to show the presence of gold and silver in encouraging amounts.

Lucrative group.—The Lucrative group, consisting of five claims, lies on Costello Creek near the mouth of Camp Creek. The only development work that was seen consists of a tunnel 15 feet long that is driven into a bluff on the west side of Camp Creek, about 1,500 feet above its mouth. The tunnel, which runs S. 70° W., follows the strike of a rusty, mineralized, vertically dipping quartz stockwork in a mass of intrusive rock. The stockwork, as shown in the tunnel, is 15 to 18 inches wide, is much fractured and broken, and is bordered on each side by a sharply defined wall, along which movement has taken place, as shown by slickensides and gouge. The principal mineralization consisted in the formation of abundant arsenopyrite in bluish banded quartz, with some specks of chalcopyrite. The owners were not on this property at the time of the writer's visit, and no information was obtained concerning the content of the ore in gold or silver.

Silver King group.—The Silver King group, consisting of two claims—the Silver King and Silver King Extension—lies on the northeast side of Colorado Creek about 1½ miles above the mouth of that stream. This ground had been located in previous years, but the title had lapsed, and it was staked by the present owner in March, 1917. At the time of the writer's visit development work on this ground had been confined to the excavation of a number of open cuts. These cuts nowhere penetrated to solid, undisturbed ground, so that the geologic structure of the ore deposit could not be determined with accuracy. As shown by the shallow excavations the center of mineralization appears to be in a dike that is highly altered. The dike probably cuts calcareous sediments, for it contains much calcite, and both the dike rock and the ore effervesce freely upon the application of dilute hydrochloric acid. The outlines of the ore body had not been determined, but there is apparently a large mass of material that contains abundant sulphides. The sulphides that were recognized include arsenopyrite, pyrite, chalcopyrite, pyrrhotite, and stibnite, both in massive aggregates and finely disseminated throughout the country rock. Small calcite veinlets were observed, and in one cut a body of massive stibnite from 6 inches to 1 foot thick that strikes about east and west and dips 23° S. is exposed. No assays were available, and the content of the ore in gold and silver was not known.

Riverside group.—The Riverside group comprises several claims that adjoin West Fork of Chulitna River on its southwest side, about a mile above the mouth of Bryn Mawr Creek. Developments in 1917 included half a dozen large open cuts, a shaft 15 feet deep, and two tunnels, one 10 feet long and the other of unknown length, now caved in. All these workings are at the base of a steep rock bluff, at the edge of the broad gravel flat of West Fork of Chulitna River. The rocks exposed consist predominantly of steeply dipping green to red tuffs, with which are associated pale-pink, green, and blue-gray cherts, locally banded; rusty gray and white marble; and abundant dikes of medium-grained acidic intrusive rocks. The tuffs are hard and dense and range in texture from fine-grained to very coarse. The marbles and cherts are less abundant but are visible in several of the open cuts. Tuffs, cherts, and calcareous beds are all more or less altered by contact metamorphism, as a result of their intimate intrusion by the dike rocks.

The openings that have been made on these claims are unconnected, and the surface between them is covered by vegetation and by loose glacial deposits and talus, so that little can now be said in regard to the geologic relations and extent of the mineralized area. Such data as could be obtained, however, indicate that here, as at other places in the district, the mineralization is the result of the replacement of calcareous beds by quartz and metallic sulphides, introduced by mineralizing solutions that were related to the intruded dike rocks. The ore examined consists of a rusty quartz gangue full of vugs into which project quartz prisms terminated by rhombohedrons.

Abundant sulphides, including arsenopyrite, pyrite, chalcopyrite, galena, and probably sphalerite are inclosed by the quartz gangue, and specks of these sulphides occur without quartz gangue in marble, tuffs, and dike rocks. A little green copper carbonate stain was noted. It is reported that average assays taken over a zone in the marble 12 feet wide yielded several dollars a ton in gold and silver.

Lindfors group.—The Lindfors group includes three claims, known as the Hill Top, Morning Glory, and Lucky Strike, all lying at the head of Bryn Mawr Creek and adjoining the Golden Zone group. This ground was staked in 1913, and the developments consist of a number of open cuts and strippings along both bluffs of Bryn Mawr Creek. No underground work had been done on these claims in July, 1917. The country rock, as exposed in the creek bluffs and the open cuts, consists of a group of altered materials, the original character of some of which is obscure. Tuffs, marbles, and dike rocks in different stages of alteration were noted, and all contain some disseminated sulphides. It is evident that on these claims the mineralization was due to the replacement of calcareous sediments by quartz and sulphides and to the impregnation of different types of country rock with sulphides introduced in connection with the intrusion of acidic dikes. Apparently the intrusion was followed by a period of pneumatolytic alteration of both the dikes and the rock into which they were intruded, and some metallic minerals may have been introduced at that time. One open cut shows a vein of massive arsenopyrite from 4 to 20 inches thick that lies between a much decomposed dike and some altered tuffs. Another cut showed a considerable area in which disseminated sulphides and some small sulphide-bearing quartz veinlets, containing also a brown-weathering carbonate that is probably ankerite, cut through much altered calcareous materials. Arsenopyrite, pyrite, chalcopyrite, and sphalerite were recognized, and it is reported that some rich assays have been obtained and that large quantities of materials carry encouraging amounts of gold.

Golden Zone group.—The Golden Zone group includes three claims in the upper basin of Bryn Mawr Creek, adjoining the Lindfors group on the northwest. The claims were staked in 1912, attention having been attracted to this locality by the presence of a large hill, the rock of which is oxidized to a rusty red and is conspicuous for a long distance. This hill on examination proves to be composed of a body of acidic rock that is intruded into an assemblage of materials including tuff, marble, and shale. The intrusive mass is generally impregnated with scattered specks of sulphides, but locally the mineralization is heavy, and the rock is cut by many small quartz veinlets. In places the intrusive material is massive and appears fresh in hand specimens, but in the more heavily mineralized portion it is much altered and broken into slabs 3 to 8 inches thick, separated by layers of pulverulent material stained by iron oxide and copper carbonate. The developments include many small open cuts, one large cut 120 feet long, and 221 feet of underground workings. The large open cut shows altered and rusty intrusive material that contains disseminated sulphides and a little quartz, and an average sample through the whole cut is said to have yielded an encouraging amount of gold and silver. The tunnel, which was driven in a northwest direction on the slope of the hill toward Bryn Mawr Creek is straight for 137 feet and at a point 82 feet from the portal has a crosscut to the southwest 84 feet long. The main tunnel was driven through an altered and generally decomposed mass of dike rock in which iron and copper sulphides are generally disseminated and are especially abundant along cracks, joints, and slip zones. Some bunches and stringers of quartz are present in the dike rock. The crosscut follows a slip zone which contains gouge. Some white to buff soft calcareous material was also excavated from the tunnel. The metallic minerals that have been recognized on this property include arsenopyrite, pyrite, sphalerite, chalcopyrite, galena, malachite, and probably stibnite. It is reported that assays of the average material removed from the tunnel show several dollars a ton in gold and silver, and some rather high assays were procured. No one was resident on this property when it was visited in July, 1917.

Hector group.—The Hector group includes two claims that lie on the Long Creek side of the divide between Long Creek and West Fork of Chulitna River, opposite the head of Bryn Mawr Creek. The ground was staked in 1914, and the developments include only a number of shallow open cuts. These cuts were made on small rock exposures that projected through a covering of vegetation and of surficial materials, so that no large surface of bedrock was available for examination, either for deciphering the geologic relations or for determining the extent of the ore bodies. The rocks examined include more or less altered materials that are probably the metamorphic equivalents of siliceous shales, graywackes, and tuffs. The finer beds are banded white, brown, and green cherts, interbedded with dense graywackes and argillites. The beds strike S. 75°–80° W. and have steep dips, generally to the northwest. The whole assemblage has been intimately cut by acidic intrusive rocks, which form dikes of considerable size and are locally interleaved in thin layers with the sediments. The cherts are highly siliceous, but all the other materials have an appreciable content of calcium carbonate, and both the graywackes and the dike rocks effervesce freely with dilute hydrochloric acid.

The principal ore body, as exposed in a shallow trench, consists of chalcopyrite and pyrrhotite, intimately mixed, disseminated through the coarser sediments and the dike rocks. A trench shows mineralization over a distance of 30 feet across the bedding, and other openings along the strike show abundant sulphides 250 feet from the principal opening. The sulphides replace certain beds and occur in the dike rocks themselves. Chert beds that cut through the mineralized area are almost free from sulphides. The sulphides range in abundance from scattered small specks of chalcopyrite and pyrrhotite to masses of sulphides in which little rock is visible. Some small quartz and calcite veinlets cut the ore, but the degree of mineralization seems to be independent of their presence. Assays of the best ore are said to have yielded 17 per cent of copper, but development has not yet proceeded far enough to determine the probable size of the ore body or the influence of depth upon the character and degree of mineralization.

Ready Cash group.—The Ready Cash group, which is reported to include nine claims, lies on the northeast side of Ohio Creek about 3 miles above the mouth of Christy Creek. At the time of the writer's visit, in July, 1917, no one was resident on these claims, and none of the owners were seen in the country, so that the only information gathered was that procured in a brief study of the workings that could be found by following trails from the camp site. The country rock in the vicinity of the workings consists of interbedded argillites, graywackes, and greenstone tuffs, all more or less metamorphosed. The local structure is generally difficult to determine, but the prevailing larger structural features strike somewhat east of north and in general dip rather steeply eastward. Apparently the attention of the prospectors was attracted to this locality by a quartz vein that crops out conspicuously on the east wall of a small gulch that is tributary to Ohio Creek from the north. This vein, which cuts altered slates, graywackes, and tuffs, is 8 to 10 feet wide, strikes N. 15° E., and dips vertically. It is rusty and shows some stains of copper carbonate. A short distance down the mountain an adit tunnel 170 feet long was driven in a direction S. 80° E., apparently for the purpose of cutting the quartz vein at depth. The breast of the tunnel had not yet reached the vein exposed on the surface, but in the tunnel a few small quartz veins from 1 to 3 inches wide were intersected. No data were obtained concerning the assay values of the ores at this property.

It is reported that another tunnel 75 feet long has been driven on this property a short distance downstream from the tunnel already mentioned and on the same vein as that which the 170-foot tunnel was meant to cut. The vein is said to be from 12 to 15 inches wide, to carry abundant galena, and to show high assays in silver. Pieces of ore which were found at the entrance to the long tunnel but which presumably come from the other tunnel show quartz with some calcite that carries abundant arsenopyrite, pyrite, chalcopyrite, and galena.

North Carolina group.—The North Carolina group includes several claims that lie in the upper basin of Antimony Creek, a small tributary of East Fork of Chulitna River that joins that stream from the east at the trail crossing, 1 mile above the mouth of East Fork. Mining developments include a log cabin, in the highest patch of timber on the creek, two tunnels, 40 and 10 feet long, and a number of open cuts and strippings.

The mouth of Antimony Creek has an elevation of approximately 1,625 feet above sea level. About 3 miles above the mouth of the stream, at an elevation of 2,700 feet, a 40-foot tunnel has been driven into the steep north bluff of the valley, about 75 feet above the creek, on a claim called North Carolina No. 3. The tunnel follows the footwall contact of a 3-foot basic dike with the shale, impure limestone, and graywacke country rock. The dike strikes S. 65° W. and dips 60° SE., and the sediments have about the same strike but dip more gently. The tunnel is timbered and lagged and is caved at the breast, so that no opportunity was afforded to study the conditions of structure and mineralization in it. It is reported that at the breast there is a gouge-filled slip zone, in which are scattered cubes and bunches of pyrite in the gouge. Pieces of ore found on the dump show abundant pyrite, which occurs as veins or streaks in the altered shales or argillites. The sulphide streaks are highly calcareous, and where the shales that carry the sulphides are more siliceous they contain tiny films and veinlets of calcite. Some secondary crystalline calcite also occurs surrounded by pyrite. The pyrite is probably due to the replacement of limy sediments by mineralized solutions that circulated along a fault zone. Assays are said to show the presence of small amounts of gold.

Farther up Antimony Creek, on the top of the bordering ridge on the north, at an elevation of about 4,000 feet, a 10-foot tunnel has been driven on a claim known as North Carolina No. 5. This tunnel penetrates black argillites, slates, and graywackes that on the surface are so weathered and disturbed that their structure is not determinable. The tunnel is timbered and is caved at the breast, so that the geologic conditions encountered in driving it could not be determined. An ore pile at the mouth of the tunnel contains several tons of massive stibnite ore that includes both finely granular stibnite and a mixture of the granular sulphide with acicular crystals. In some specimens there is a considerable admixture of granular quartz through the stibnite, but other pieces show massive sulphide with no visible gangue. Small amounts of yellow and reddish secondary oxidation products, probably stibiconite and kermesite, were noted on weathered surfaces and in fractures in the ore, and some rusty quartz is associated with it. The owners report that the stibnite occurs in lenses or kidneys that have a maximum thickness of 2 feet and are only a few feet long and that lie parallel in the vein. They report also that the stibnite carries some gold.

Other prospects.—In addition to the prospects already described, on which a considerable amount of systematic development work has been done, there are within the upper Chulitna region a number of claims or groups of claims that show different degrees of mineralization and on which the annual assessment work has been done for some years. On most of these claims too little work has been done to outline the ore bodies or to reveal the conditions or extent of the mineralization. The following notes mention those properties in this class to which the writer's attention was directed:

The Center Star group of two claims lies northeast of the Silver King group and on a line between it and the Northern Light property. The openings, which include several small open cuts and strippings, show a bluish dike rock in which disseminated arsenopyrite, pyrite, and chalcopyrite were recognized.

The Flaurier group of five claims adjoins the Riverside group on the west. The country rock includes the same group of cherts, argillites, tuffs, and possibly limestone cut by dikes that have already been described as occurring at the Riverside group. Open cuts show altered, rusty materials that locally contain considerable quantities of sulphides, which seem to be scattered through the rock by impregnation rather than to occur as a segregated replacement deposit. Assays taken over a considerable area of this material are said to show a few dollars in gold and silver to the ton.

The Jumbo is a fractional claim adjoining the Riverside and lying 2,000 feet southwest of West Fork of Chulitna River. On this claim a large open cut shows a fine-grained conglomerate in which are bunches and specks of sulphides, mainly pyrrhotite but with some pyrite and chalcopyrite.

The Golden Zone Extension group includes some claims that lie adjacent to the Golden Zone group on the southwest. Prospecting has been carried on by the opening of a number of long, shallow trenches, which for the most part fail to penetrate through the loose surficial material to undisturbed bedrock. The underlying rock apparently consists of altered tuff, chert, and argillites cut by dike rocks, in which there is locally some disseminated arsenopyrite.

It is reported that a large number of claims have been staked on the main northern branch of West Fork of Chulitna River for manganese. The manganese is said to occur in seams in slate and serpentine. The surface ores are all soft and decomposed, and no excavations have been made that show the character of the manganese ore at depth.

GOLD PLACER MINES AND PROSPECTS.

In the upper Chulitna region, as in most other unexplored countries, the efforts of the earliest prospectors were directed to the search for easily mined gold placer deposits, and in 1907 the first claims located in this region were staked for placer gold, on upper Bryn Mawr Creek. In 1909 some mining was done on this ground, and a small amount of gold was recovered. Prospecting for gold placer gravels has continued since that time, and although gold has been found at many places, it has nowhere been found in sufficient amount to warrant mining under the conditions imposed by the remoteness and difficulty of access of the region.

In 1917 some prospecting for gold was done on West Fork of Chulitna River, but no workable deposits were found. Two men continued the attempt to discover a pay streak on lower Shotgun Creek, a tributary of lower Ohio Creek from the west. Encouraging amounts of gold have been found at that locality, and several persons have at one time or another attempted to mine there, but so far without success.

The gravels of Gold Creek, a tributary that joins Susitna River from the east 2 miles below the mouth of Indian River, have long been known to be auriferous, and attempts to mine them have been made at intervals by different men. A small amount of gold has been recovered, but no ground rich enough to yield a profit to the miners has yet been found.

Some gold has from time to time been won from the bars of Susitna River near the mouth of Gold Creek and a short distance below Deadhorse Hill. This gold was all fine and occurred near the top of the stream-gravel deposits. Deeper holes sunk through the gold-bearing gravels failed to show any increase in the amount of gold with depth but rather a decrease.

COAL.

As has already been stated, coal-bearing Tertiary beds are widely distributed throughout the basin of Susitna River and are known to occur at two localities in the upper Chulitna region. The only one of these localities that was visited in 1917 lies near the head of Coal Creek, a small stream that flows into Camp Creek, which in turn is tributary to Costello Creek from the northeast. There the bluffs show a section of Tertiary shale and lignite. At the time of the writer's visit, in July, 1917, a snow bank covered much of the outcrop, and the surface of the beds was partly masked by detritus, but in a vertical section of 24 feet three lignite beds, 6, 5, and 9 feet thick, separated by shale beds, were seen. A 15-foot tunnel, driven on one coal bed, shows a 6-foot face of bright black lignite of fair quality.

Neither the top nor the bottom of this bed was seen in the tunnel, so the thickness certainly exceeds 6 feet. The coal beds dip about 14° E. The area of the coal field is not known, for exposures are few, but the coal is apparently limited on the west by Camp Creek and is said to crop out at least 1,200 feet east of the tunnel. This lignite has had a small local use by the prospectors for fuel for camps and as forge coal.

It is reported that Tertiary deposits containing a lignite bed several feet thick crop out in the valley of a tributary of Middle Fork of Chulitna River, about 11 miles above the junction of East and Middle forks, between the trail and the line of the railroad survey, and coal-bearing beds are said to crop out on Coal Creek, a southeastward-flowing tributary of the Chulitna, south of Ohio Creek.

PLATINUM-BEARING GOLD PLACERS OF THE KAHILTNA VALLEY.

By J. B. Mertie, Jr.

INTRODUCTION.

The valley of Kahiltna River includes an area about 80 miles long and from 5 to 20 miles wide, which begins at the confluence of Kahiltna and Yentna rivers and extends somewhat west of north to the crest of the Alaska Range. This strip of territory, aggregating about 1,000 square miles, forms the central part of the Yentna district. Cache Creek and its tributaries and the headwater tributaries of Peters Creek constitute the present center of mining activity in the Kahiltna Valley.

The exploratory expeditions of Spurr [1] and Eldridge [2] in 1898 and of Brooks [3] in 1902 yielded the first geographic and geologic knowledge of Yentna and Susitna rivers, but Kahiltna River and its tributaries were not visited by these earlier workers. The first authentic geographic knowledge of the Kahiltna Valley was obtained in 1906, when the area now known as the Yentna district was mapped topographically by R. W. Porter, working independently of the Geological Survey. In 1911 Capps [4] visited the Yentna district, including the valley of Kahiltna River, and made numerous corrections and additions to the topographic mapping of Porter, and two years later his reconnaissance topographic and geologic map of the region was published.

Placer mining began in the Cache Creek and Peters Creek basins in 1905 and has continued to the present time. Capps, in addition to his geologic work in this district, also studied the gold placers and reported on their occurrence, origin, and value.

The Kahiltna Valley, including Cache and Peters creeks, was visited by the writer in September, 1917, with two objects in view. First, platinum had been recently reported from gold placers at several localities along the lower part of Kahiltna River, and the

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 31-264, 1900.

[2] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: Idem, pp. 1-30.

[3] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, 1911.

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

United States Geological Survey desired to investigate these occurrences of platinum and determine, if possible, their significance and value, as well as to search for other platinum-bearing gravels; second, it was desirable to learn the amount of mining development which had taken place during the preceding six years and thus to bring up to date the record of the placer-mining industry in this district. These objectives were accomplished in a trip of 27 days, starting from and returning to Anchorage.

The writer takes this opportunity to acknowledge gratefully the hospitality and cordial cooperation of the mining men in the Cache Creek district. Special thanks are due to Messrs. Harris and Murray, of the Cache Creek Dredging Co. and the Cache Creek Mining Co., respectively, for many favors received.

GEOGRAPHY.

The geographic features of the Yentna district have already been stated in some detail by Capps,[1] and the following notes are written only as a summary of the data for Kahiltna Valley. Kahiltna River has its source in Kahiltna Glacier, from which a number of glacial streams emerge and flow for miles as a system of anastomosing channels over an aggraded flood plain of sand and gravel but gradually unite downstream to form the main river. A main channel may be said to begin at the mouth of Treasure Creek, about 7 miles in an air line from the foot of the glacier, but even from this point downstream to the flats the river flows through many sloughs over a wide flood plain. At the Kahiltna Flats the main channel and sloughs unite and spread out across the valley bottom to form a wide expanse of shallow water and shifting sand bars, through which a shallow-draft poling boat in many places has difficulty in finding a channel. Below the flats the main channel is well defined, though in places sloughs cause islands in the river. At a point 20 miles in an air line below the glacier, at Camp 2, the river enters a canyon and cuts through the Eocene coal-bearing formation for several miles in a series of rapids. Below the mouth of Peters Creek the river is incised in the coal-bearing rocks at many places and is a swift stream, which here and there flows in a gorge. A stretch of several miles of this character at the lower end of the Kahiltna is sometimes referred to as the lower canyon of the Kahiltna. The length of Kahiltna River, from Kahiltna Glacier to its junction with Yentna River, is about 42 miles in an air line, though much more than that by the windings of the stream.

All the larger tributaries of Kahiltna River, with the exception of Treasure Creek, enter from the east side of the valley and drain

[1] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, pp. 11-22, 1913.

the Dutch, Peters, and Little Peters hills. Named in order downstream, they are Granite, Cache, Hungryman, Bear, and Peters creeks, of which Cache and Peters creeks are the largest. These eastern tributaries of Kahiltna River emerge from the hills in gorges, of which the lower canyon of Cache Creek is typical, and flow over the Kahiltna flood plain to join the main river. The east side of the Dutch and Peters hills is drained by Tokichitna River and its tributaries, which head against the headwater tributaries of Peters and Granite creeks.

The Dutch, Peters, and Little Peters hills form a kite-shaped area that is bounded on the northeast by the valley floor of Tokichitna River, on the southeast by the wide alluvial flats of Chulitna and Susitna rivers, on the southwest by the Kahiltna flood plain and Kahiltna Glacier, and on the northwest by Dutch Creek, a tributary of Granite Creek, and the upper Tokichitna tributaries. These three groups of hills, which include the Cache Creek mining district, cover an area of about 300 square miles adjoining what may be termed the upper Kahiltna basin. The lower Kahiltna Valley may be said to begin at the mouth of Peters Creek and to extend to Yentna River. The Dutch Hills rise to an elevation of over 4,000 feet, the Peters Hills between 3,000 and 4,000 feet, and the Little Peters Hills only 2,000 feet. A wide trough-shaped depression of glacial origin, occupied by Cache Creek and the headwater tributaries of Peters Creek and lying for the most part between elevations of 2,000 to 2,400 feet, separates the Dutch Hills from the Peters Hills to the south. The Peters Hills are separated from the Little Peters Hills by a wide, high, level flat at the heads of Hungryman and Bear creeks.

The valley floor of Kahiltna River and its eastward continuation into the Susitna Flats constitute the lowland area of Kahiltna Valley. These lowlands consist of wide stretches of level alluvium, with some low rolling hills, separated usually from one another by lakes, swamps, or sluggish meandering streams. The lower Kahiltna Valley ranges in elevation from 200 to 500 feet; the elevation at the foot of Kahiltna Glacier is about 800 feet. In general, the lowland areas are timbered and densely overgrown by low brush.

The only settlement in the lower Kahiltna Valley is McDougall, on the north bank of Yentna River about 8 miles above the mouth of the Kahiltna. The nearest post office is at Susitna, on the east bank of Susitna River at the mouth of the Yentna, 29 miles in an air line from McDougall. About 100 men are engaged in mining in the Kahiltna Valley, chiefly in the valleys of Cache and Peters creeks.

GEOLOGY.

SLATE AND GRAYWACKE SERIES.

The larger geologic units of Kahiltna Valley have already been described and mapped by Capps [1] and are shown on the geologic sketch map in this report (Pl. VI). The oldest rock formation known in the valley is a series of slates and graywackes, with certain phyllitic and quartzitic phases, which forms the predominating country rock of the Dutch, Peters, and Little Peters hills and extends to the northeast and southeast along the south flank of the Alaska Range. With regard to the lithologic character of these rocks, particularly in the Dutch and Peters hills, Capps [2] writes as follows:

> They consist chiefly of black to gray slates and phyllites, in many places carbonaceous, and beds of graywacke, which range from fine-grained to coarse gritty rocks. In some places the rocks are massive, with argillites instead of slates, but the foliated types are much more widespread than the massive types. It is difficult to estimate just what proportion of the whole series is formed by the graywacke beds. Many sections show great thicknesses of the slaty phases, with very little graywacke present. At other localities the graywackes preponderate, occurring in thick, massive beds that show little foliation or schistosity and that are often mistaken by the miners for fine-grained dike rocks, which they closely resemble. The whole series is much jointed, the graywackes less closely than the slates, which are in many places broken into long prismatic pieces by sets of intersecting joints.

Of the slates in general Capps [2] further says:

> Evidences of mineralization are widespread in these rocks. A characteristic phase of the slates in many places throughout the region contains small cubical cavities, the largest a quarter of an inch in diameter, formed by the leaching out of cubes of iron pyrite, the rock being discolored for some distance around each cavity. Some of the graywacke beds also show the presence of much finely disseminated pyrite.

The slate and graywacke series is greatly folded and faulted and exhibits great variation in strike and dip. The average strike, however, is about N. 60° E., and the general dip is at a high angle to the south. On account of the irregularity of structure and the lack of knowledge of these rocks over a large area, no reliable estimate of thickness can be made other than the statement, as given by Capps,[3] that the series is several thousand feet thick.

This slate and graywacke series was correlated by Capps [3] with a similar series of rocks observed by Brooks [4] in the valley of Kichatna River and with the Susitna slate described by Eldridge,[5] and for lack of conclusive evidence it was assigned provisionally to the Paleozoic or Mesozoic. During the season of 1917 two fossil shells

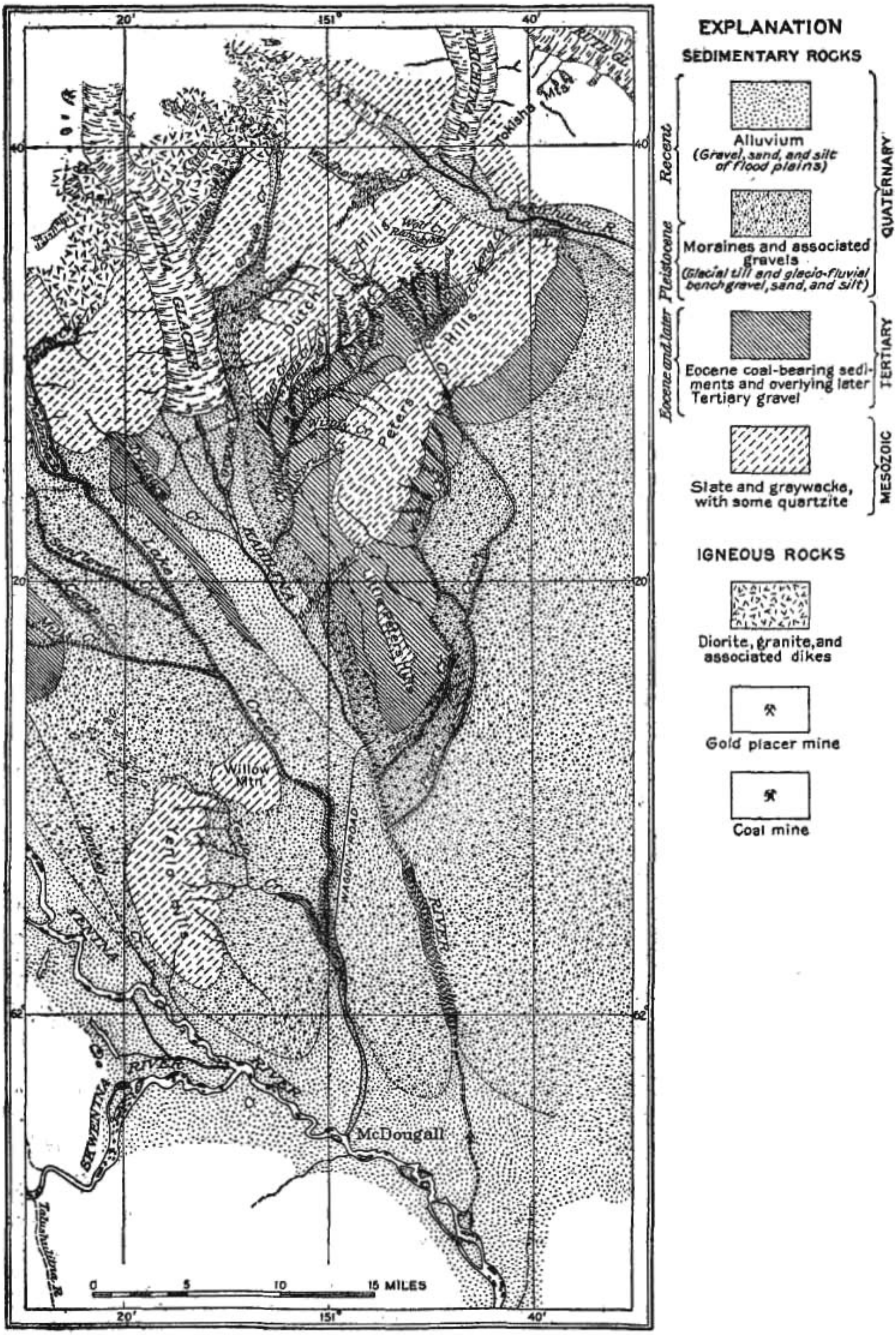
[1] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, pp. 22–47, 1913.

[2] Idem, p. 25.

[3] Idem, p. 27.

[4] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 67–68, 1911.

[5] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 15–16, 1900.



GEOLOGIC SKETCH MAP OF THE KAHILTNA VALLEY.

little difficulty is encountered in identifying them. The beds consist predominantly of unconsolidated or loosely consolidated clays and sands, containing layers of fine pebbles, and commonly some lignitic coal. Even where the surface is covered with vegetation pieces of lignite in the stream beds often serve to indicate the presence of these deposits. At the few localities where the relation between the Eocene sediments and the underlying slates could be studied, the slates and graywackes have been deeply weathered and decayed, the slates having broken down to a bluish-white kaolinic clay and the graywackes changed to a soft gritty sandstone before the overlying materials were deposited. It is often difficult to determine the point at which the clay shales of the Tertiary succeed the residual clays of the slate series. The coal-bearing sediments consist of alternating clays, sands, and fine gravels, the beds in most places being little consolidated, though here and there a coarser layer has been cemented into a rather fine conglomerate or grit. At a bluff on the east bank of Susitna River at Susitna station there is an outcrop of a coarse-grained conglomerate which Spurr refers provisionally to the Kenai formation, of Eocene age, but nothing similar to this rock was seen in the Yentna region.

Lignitic coal occurs in the Tertiary rocks in many places. All of the coal examined was rather fibrous and woody, of a brown to black color, and is of little value except as a source of local fuel supply. The beds examined are from a few inches to 12 feet in thickness.

Structurally, the coal-bearing rocks are distinct from the slate and graywacke series in that they are only loosely consolidated and, although folded, show only to a small degree the effects of metamorphism. Only exceptionally are the coal-bearing beds inclined at high angles, as for instance about 2½ miles below the canyon on Peters Creek, where these rocks and their included coal beds dip 70° NW. and strike N. 45° E. The folding is, in general, of the broad, open type, and the rocks are only imperfectly indurated. Their thickness is not definitely known but is believed to exceed 1,000 feet.

The overlying gravel has been described by Capps [1] as follows:

The gravels are rudely stratified, as though by streams, the largest boulders being about 1 foot in diameter, but most of the pebbles measure from 2 to 4 inches through and are mixed with much sandy material. A large variety of rocks is represented by the pebbles—slates, graywackes, black and gray conglomerates, and quartz are present as well as diorites and many other types of igneous rocks. The deposit throughout its thickness shows a yellowish color due to oxidation, but the yellow color is evidently only a coating on the pebbles, for it has disappeared from the materials that have been rehandled by streams. The great age of these gravels is attested by their decayed condition, many of the pebbles being so rotten that they crumble and fall to pieces when disturbed, although they must have been hard and firm when they were rounded and deposited by the streams.

The gravels, where seen by the writer on Gopher Creek, formed a rotten conglomerate made up in the main of greatly decayed pebbles a few inches in diameter, though cobbles as large as 18 inches were also seen. This conglomerate formed the bedrock underlying the stream placers at the upper end of Gopher Creek. The total thickness of the gravel is unknown, but at least 600 feet of such rock was seen by Capps [2] in the upper part of Treasure Creek.

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[1] Capps, S. R., op. cit., p. 34.

[2] Idem, p. 35.

QUATERNARY SYSTEM.

With the advent of Quaternary time there came a gradual change in climatic conditions, which resulted in the development of glaciers in this area on a large scale. The glaciers gradually extended from the Alaska Range southward to Cook Inlet, filling the valleys and covering all the prominent hills in Kahiltna Valley. The Peters and Dutch hills, if not actually overridden by ice, were covered by a névé of snow and ice which contributed to the surrounding ice sheet. This ice advance, which occurred during Pleistocene time and perhaps extended into Recent time, was finally stopped by further climatic changes, and the ice fields began to disappear. It is probable that the retreat of the ice was rhythmic in character—that is, the glacier alternately retreated and advanced—with a cumulative net loss that resulted eventually in the entire disappearance of the ice fields and the restriction of the ice to the present valley glaciers.

During the glacial epoch great physiographic changes took place. The details of the pre-Quaternary topography were entirely obliterated by the action of the ice and topography characteristic of a glaciated area was developed. Old stream valleys were scoured out and broadened into wide U-shaped valleys, and the hills were smoothed and rounded by overriding ice. The Alaska Range, the accumulating ground of the snow and ice, was rendered more rugged and precipitous than before, owing to "bergschrund" sapping on the high ridges. When the ice fields finally disappeared normal stream erosion again became effective, with the result that the glacial topography is now in the process of retransformation to the pre-Quaternary type. The gorges and canyons in Kahiltna River and its tributaries are an index of the degree to which normal stream erosion has been reestablished. Such gorges, though conspicuous, are relatively minor features of the present topography, and the old glaciated outlines still remain the dominating topographic features.

These erosional processes have resulted necessarily in the development of several types of detrital deposits. During the period of glacial action and in the subsequent retreat of the glaciers the débris eroded by the action of the ice was deposited in moraines of different kinds, of which the ground moraines that were formed under the lower reaches of the ice field are best preserved. Terminal moraines at the ends of the glaciers appear for the most part to have been removed, either as they formed or shortly afterward, by glacial streams that issued from beneath the ice. The morainal material removed by the glacial streams was distributed over a wide area adjacent to the glaciers and subsequently, as the streams entrenched themselves in it, formed the bench gravels contiguous to the present streams. These bench gravels, which consist of reworked glacio-fluviatile deposits, are essentially similar to the morainal material except that the detritus is more or less rounded and much of the finer silt, or glacial mud, has been carried away by the transporting streams. The lower portions of the bench deposits carry the larger boulders and the upper portions the smaller boulders, cobbles, and pebbles. On Cache Creek a short distance above the mouth of Nugget Creek the bench gravels have an average size of about 5 inches, but some of those at the base of the deposits are as much as 3 feet in diameter.

As the glaciers retreated and the streams began to adjust themselves in the vacated valleys, the irregular glacial gradients were gradually transformed by alluviation at some places and stream erosion at others into normal or approximately normal stream gradients, with the characteristic water grades and headward steepening. This process has resulted in the development of the present alluvial deposits in the overdeepened glacial troughs and of canyons in the valley protuberances. There is little difference between the bench and stream gravels except that the process of stream sorting has been carried still further in the stream gravels. The coarser parts of the bench gravels, which the streams have been unable to handle, remain in the headwater alluvial deposits, and the finer materials have been deposited progressively downstream. In the lower courses of the large rivers the present alluvium is largely silt and fine sand.

MINERAL RESOURCES.

VALUABLE MINERALS PRESENT.

Placer gold is the only mineral that has been exploited on a commercial scale in the valley of Kahiltna River up to the present time. Other minerals of value, however, including principally platinum, cassiterite (tin oxide), and scheelite (calcium tungstate), have been found in the placer sands, and it is possible that some of these may later be produced in commercial amounts. Provision should be made for the recovery of platinum in the gold placers, where it is found in any considerable amount, and the district should be further prospected for workable deposits of placer platinum. Heavy concentrates of cassiterite from the placer sands were noted at certain localities, and search should be made for their bedrock sources. The presence of scheelite in the placers, although it is not plentiful, indicates the presence of tungsten ore south of the Alaska Range and should be remembered when prospecting for lode deposits. The Eocene coal deposits have already been used locally as a source of fuel and power

ECONOMIC CONDITIONS.

The central supply for Kahiltna Valley and vicinity is the town of Anchorage, at the head of Cook Inlet. From that point passengers and freight are transported by launches across the inlet and up Susitna River to the mouth of the Yentna, where the trading station of Susitna is located. On account of present construction work on the Government railroad up Susitna Valley a small steamboat owned by the Government plies regularly between Anchorage and up-river points on the Susitna, stopping at Susitna station. Light-draft launches navigate Yentna River to a point above the mouth of the Kichatna but seldom go above the trading station of McDougall, at the mouth of Lake Creek, which is the supply depot for Kahiltna Valley. A wagon road begins at McDougall, follows up the east side of the Lake Creek valley for about 15 miles, and then leads across into Kahiltna Valley, reaching Kahiltna River at Camp 2, about 26 miles in an air line above its mouth. A bridge spans the river at this point. Camp 2 is connected with the Cache Creek district by a soft, difficult trail. During the summer of 1917 the Cache Creek Dredging Co. operated a small boat, fitted with a gasoline engine, on Kahiltna River, transporting freight from Camp 2 to the mouth of Cache Creek, where it was conveyed by wagon up the canyon to the dredge, a distance of about 7 miles. A new wagon road, which has been surveyed from Talkeetna on the Government railroad to Cache Creek and vicinity, will when completed greatly facilitate communication with Kahiltna Valley.

The transportation of supplies into Kahiltna Valley is at present slow, laborious, and costly. The freight rate by water from Anchorage to McDougall was $15 a ton in 1917, and the commercial charge for winter dog-sled freighting from McDougall to Cache Creek is 8 to 10 cents a pound, though by the use of bobsleds and horses this may be reduced to 4 cents a pound. An extra charge of 2 to 5 cents a pound is made for taking supplies to the headwater tributaries of Cache and Peters creeks. The commercial freight rate in summer from McDougall to Cache Creek is 35 cents a pound, of which about 25 cents represents the actual cost. The minimum cost of freighting, therefore, from Anchorage to Cache Creek is $95 a ton. The new wagon road to Cache Creek used in conjunction with rail transportation from Anchorage to Talkeetna should materially reduce the cost of supplies and will also make the district more accessible than heretofore.

Timber for use in mining is not in great demand in Kahiltna Valley, for little underground work is done, and most of the placer mining is accomplished by hydraulic plants. The dredge on Cache Creek uses coal to generate power. Wood is used chiefly as fuel for heating, and for this as well as for lumber and other necessities there is an abundance of timber. Spruce 24 inches in diameter and cottonwood as large as 5 feet in diameter are available[1] in the lowlands, but little timber grows above an elevation of 2,000 feet. The Cache Creek mining district, on account of its general elevation above 2,000 feet, is at a disadvantage because the wood needed must be brought up from the timbered valleys below.

Water for hydraulicking is taken from the streams at some distance above the placer ground and led by ditches to the hydraulic pipes. The rainfall and stream flow are adequate to supply plenty of water with the required pressure at most of the mining plants. Numerous good power sites for hydroelectric plants are available in the canyons of different streams and particularly in the lower valley of Cache Creek below the mouth of Spruce Creek, where a large and unfailing flow of water falls about 500 feet within a mile and a half or less.

The standard wage in the Cache Creek district in 1917 was $5 a day and board for eight hours of labor, and winchmen, cooks, and other specialized workmen were paid $6 a day and board. On the basis of a charge of $1.50 a day for each man for the cost and preparation of food, the total cost of unskilled labor amounted to 81 cents an hour and for skilled labor 94 cents an hour.

PLACER DEPOSITS.

CACHE CREEK BASIN.

GENERAL FEATURES.

Cache Creek and its tributaries drain the western part of the glacial trough which separates the Peters Hills from the Dutch Hills. The main creek rises in the Dutch Hills, flows in a general southwesterly direction for 18 miles, and empties into Kahiltna River about 13 miles below the glacier. Cache Creek has a number of tributaries, of which those entering from the northwest are the larger and the more important as producers of placer gold. The largest of those named in order downstream are Nugget, Thunder, Falls, and Dollar creeks. The southwestward-flowing tributaries in order downstream are Trout, Long, Windy, and Spruce creeks, of which only Windy and Spruce creeks have gold placers worthy of attention. The basin of Cache Creek embraces an area of about 75 square miles.

In the upper part the basin of Cache Creek is a wide, open U-shaped glaciated valley, with a floor of soft coal-bearing rocks of Kenai age, into which Cache Creek has incised a V-shaped gorge that ranges from 250 to 300 feet in depth throughout its length. The tributaries of Cache Creek, including also upper Cache Creek, lie in the hard slate and graywacke that form the sides of the valley and have not been incised so deeply. For this reason canyons have developed

[1] Capps, S. R., op. cit., p. 18.

on the lower courses of the tributaries, in order to join the slate and graywacke valleys with the more deeply incised valley of Cache Creek. Cache Creek also has cut a canyon in its lower valley in order to reach on a water grade the more deeply scoured valley of Kahiltna River.

The glacial trough that forms the upper basin of Cache Creek has an elevation of nearly 2,400 feet in the upper valley. Cache Creek at its mouth has an elevation of about 600 feet, thus showing a fall of 100 feet to the mile for the length of the stream. The fall in the upper valley is considerably less than this but is counterbalanced by a heavy fall in the lower valley or canyon of Cache Creek.

The location of the gold placer mines under operation in the Kahiltna Valley, including also those on Cache and Peters creeks, is shown on the map (Pl. VI).

CACHE CREEK.

CREEK PLACERS.

There are two sources of placer gold in the valley of Cache Creek—one in the glacial till and gravel that overlie the Eocene coal-bearing rocks in the broad valley and form the benches along the creek, and the other in the present stream gravels, which have been derived in large measure from the erosion of the glacial débris of the benches.

Little is known concerning the distribution, number, and character of pay streaks in the reworked glacial débris. This material, though largely till, has also zones of washed gravel and boulders, showing that stream as well as glacial action has effected its present distribution. The glacial till is composed of unsorted rocks and boulders of all sizes, showing usually little or no water action, together with a great amount of fine clay or glacial mud. Gold is distributed throughout the glacial material in greater or less amount, but true pay streaks are lacking on account of the paucity of the action of water, with its consequent sorting of material and concentration of the heavy metals and minerals. At some localities, more particularly where the action of water has played a more important part in the formation of the deposits, there is a slight concentration of the gold, so that the deposits may be mined at a profit on a small scale. There seems to be no regularity, however, in the distribution of the placers in the bench deposits, and no method is known whereby they may be located by physiographic deduction. At some places in the Cache Creek district quite unsorted glacial till has been mined by placer-mining methods and yielded a profit, but such occurrences must be regarded as altogether fortuitous—that is, as deposits of till which happened to be derived from rich gold lodes and suffered little distribution prior to their final deposition. It is estimated that the content of gold in the more favored localities on the benches may average 10 cents a cubic yard. The future of the Cache Creek district as a mining center is dependent on the mining of these low-grade bench deposits by large-scale hydraulic methods. By large-scale operation and economic management it may be possible to mine such placers for as little as 4 or 5 cents a cubic yard, particularly after communication has been established with the Government railroad and the district becomes more accessible.

The present stream gravels have so far formed the more attractive field for placer mining on Cache Creek. Gold was first discovered in 1906 on Discovery claim in the upper canyon of Cache Creek, and placer-mining operations have been carried on intermittently since that time in the creek placers. The creek placers at the canyon were examined in 1911 by Capps,[1] who reported as follows on their distribution and character:

The ground worked was that of the present stream flat, and the gravels moved range from 4 to 7 feet in depth and lie on slate bedrock. There are some large boulders present, but most of them can be handled by one man. A short distance below the canyon the slate bedrock gives place to the materials of the coal-bearing series, which change character within short distances, ranging from a fairly firm, gritty sandstone to soft clay shales. The pay streak is said to be rather well defined in the canyon and for a short distance below it but soon spreads out in the wider valley below and is difficult to trace. The gold is rather unevenly distributed, for, though most of it is found on bedrock, the degree of its concentration depends somewhat on the character of the bedrock, the harder strata having retained it better than the softer. No records have been kept which would show the gold content of the gravels to the cubic yard or to the square yard of bedrock, but it is reported that the returns have averaged about $10 a day for each man employed. The sluice boxes, 14 inches wide, are set on a grade of 5 inches to the box length. The gravels are ground-sluiced to a depth within a foot or so of bedrock by the aid of canvas hose and water under pressure from the bench to the southwest, the rest of the gravel being shoveled in and bedrock cleaned by hand. The stream at Discovery claim can be depended upon to run a sluice head of water for the boxes used throughout the season, and most of the time it flows two sluice heads. The gold is coarse, bright, and somewhat worn, though many pieces are rough, and some cubes of crystalline gold have been found. Pieces worth $20 have been taken from this claim, and only about one-third of the gold recovered will pass through a 16-mesh screen.

The coarseness of the gold and the roughness of some of it indicate that it has traveled no great distance from its bedrock source. It must originally have come from the quartz veinlets of the slate and graywacke series in the upper part of the Cache Creek valley or at the head of Bird Creek, for the upper valley at one time contained a vigorous glacier, and ice also came into it from the head of Bird Creek across a low divide. This glacier eroded its basin and doubtless scattered and removed any preglacial gold which may have been concentrated in its upper portion. No ground carrying paying quantities of gold has been discovered above the canyon of Cache Creek. Toward the mouth of the slate valley the ice scour was less severe, as the glacier joined a large sluggish ice sheet in the broad basin between Dutch and Peters hills. Here the valley deepening was not pronounced, and a part of the material

[1] Capps, S R., op. cit., pp. 54-55.

picked up by the ice in the upper valley was dropped. It may be that the glacial deposits here covered up portions of the preglacial channel of Cache Creek without disturbing them. When the glacier melted away, the stream cut through the glacial deposits and at and below the canyon intrenched itself into the slates and the softer beds to the east. In the rehandling of the glacier material any gold that it contained was concentrated in the stream bed, and if the valley was cut through any undisturbed portions of the old preglacial channel these too would have contributed to the richness of the present placer deposits.

In 1916 the Cache Creek Dredging Co., operating under a lease from the Cache Creek Mining Co., built a dredge and began work on Cache Creek in the placer ground owned by the latter company. Beginning at the mouth of Windy Creek, the dredge had worked upstream three-quarters of a mile by the fall of 1917. The pay streak is from 150 to 300 feet wide and is believed to extend upstream for several miles. The depth of the gravels ranges from 3 to 7 feet, averaging perhaps 4½ feet, and the bedrock is the soft, loosely consolidated Eocene sand, clay, and gravel. Practically all the gold is taken from the gravels, but it is necessary for the dredge to remove bedrock in shallow ground in order to excavate a channel sufficiently deep in which to float. The problem of working in shallow ground will probably be accentuated as the work continues upstream and may ultimately render necessary the reconstruction of the dredge or the purchase of a new one of lighter draft.

The gold recovered by the Cache Creek dredge is a composite of the gold from various tributaries and can not be said to belong to any definite type. The assay value ranges from $17.60 to $17.80 an ounce. Though more waterworn than the gold in streams like Thunder Creek, owing to its further transportation, the Cache Creek gold nevertheless shows in its lack of well-rounded edges the fact that it has undergone comparatively little transportation. Some very angular gold recovered is doubtless derived from the weathering of near-by gravel banks of glacio-fluviatile origin, and the generally small proportion of well-rounded gold indicates that little of the gold has traveled very far. The gravel banks of the Cache Creek basin must be considered the source of most of the gold, as far as the present stream is concerned, though there are good reasons for believing that some of the gold has entered the placers from bedrock subsequent to the retreat of the glaciers. The ultimate or bedrock source of the gold, however, is harder to decipher on account of glacial action, which has laid down a mantle of detrital material that conceals most of the original bedrock and is itself by no means so susceptible to physiographic interpretation as stream detritus would be. It is believed both by Capps [1] and the writer that the bedrock source of the Cache Creek gold is confined mainly to the near-by hills—first, because the Cache Creek glacial trough appears to have been filled with a sluggish ice sheet, which favored a minimum of glacial transportation, and, second, because the slate and graywacke bedrock in the basins of Cache and Peters creeks, particularly in the Dutch Hills, yields positive evidence of gold mineralization at several localities.

A small amount of platinum metals, about 0.003 per cent of the gold by weight and less than 0.02 per cent of the gold in value, is also recovered. The platinum grains are small, few of them exceeding 1 millimeter in size, and most of them are thin and flaky. Two kinds of platinum metals appear to be present. The more common type is a dark-gray to bronzy metal, which carries probably the main content of platinum. The second variety consists of bright silvery grains and commonly shows what appear to be crystalline outlines. This variety is believed to be mainly iridosmium. On page 258 is given an analysis of the platinum metals received from Poorman Creek, in the Peters Creek basin, and it is most likely that this analysis is also a fair index of the character of the platinum metals on Cache Creek. On account of the flaky character of the platinum it is probable that the recovery made by the dredge in the sluice line does not fairly represent the platinum content of the placers; but, on the other hand, it is unlikely that enough platinum is present in the placers to make the installation of more refined methods for its recovery worth while.

As an indication of possible minerals of value in the territory drained by Cache Creek the concentrates or heavy minerals caught with the precious metals are also of interest. Examination of the concentrates from Cache Creek has revealed ilmenite, magnetite, cassiterite (tin oxide), zircon, quartz, garnet, limonite, pyrite, and scheelite (calcium tungstate). The presence of cassiterite and scheelite is worthy of particular mention, for the ores of tin and tungsten have heretofore been found chiefly north of the Alaska Range, in interior Alaska.

The dredge operating on Cache Creek is one of the flume type, with buckets of 7½ cubic feet and a daily capacity of 2,000 cubic yards. Power is supplied by a steam boiler, under which coal is used for fuel. The coal is mined on Cache Creek at the mouth of Short Creek and is hauled by teams to the point where the dredge is operating and lightered on board to the boiler. A steam electric or hydroelectric plant is contemplated, and either should materially lessen the ultimate cost of mining. Prospecting is carried ahead of the dredge by means of an 8-horsepower gasoline drill. The dredge in 1917 was handicapped by a short season and by two heavy floods in Cache Creek, both of which did much damage and caused the loss of considerable time. The second period of high water, which occurred in

[1] Capps, S. R., op. cit., p. 54, 1913.

September, was particularly disastrous on Cache Creek and its tributaries, and the highest known water marks for Kahiltna and Yentna rivers were surpassed.

BENCH PLACERS.

On upper Cache Creek, just above the mouth of Gold Creek, the bench gravels on the left bank of the creek, at an elevation of 2,300 feet, were being worked in 1917 by hydraulicking. The bedrock at this locality is composed of Eocene coal-bearing sediments and consists mainly of sandstone, with some clay shale and conglomerate and coal seams. The bedrock surface is decidedly irregular, and good-sized "pot-holes" are exposed as the surface is uncovered. A lens of conglomerate covered by a seam of brown to black iron hydroxide forms the bedrock surface at one place, and on this irregular surface coarse gold is found. Much of the gold, particularly the coarse gold, occurs on such iron-stained bedrock surfaces, as well as in similar unstained gravel beds higher up in the placer body. Some gold, however, is distributed throughout the gravels.

Most of the gravel is well rounded, with comparatively little subangular material. The average size of the gravel is about 4 or 5 inches, though boulders a foot in diameter are common, and others as large as 3 feet were seen. A body of heavier gravel wash, about 7 feet thick, lies next to bedrock. It is apparent that such bench gravels have undergone a high degree of stream sorting and are clearly to be distinguished from the glacio-fluviatile bench gravels at other localities in this vicinity, as, for instance, on Bird Creek.

A clay seam which has some interest is exposed in the cut at this property. This seam is about three-fourths of an inch thick, strikes N. 22° W. and dips 78° W., and cuts through both the bench gravels and the underlying bedrock. To the east of this seam the gravels are well rounded, as above described, but to the west the detritus is comparatively unsorted and bears more resemblance to till than to a fluviatile deposit. It seems certain that this seam of clay is a fault gouge and indicates that fault movements have taken place subsequent to the deposition of the bench gravels.

The gold at this property is bright and little worn, and the largest piece so far recovered was worth $1.40. The assay value is about $17.50 an ounce. Considerable heavy sand is recovered with the gold, and samples of this sand contain ilmenite, magnetite, garnet, zircon, quartz, and pyrite.

About 1,500 cubic yards of gravel had been hydraulicked and sluiced at this locality by the early part of September, 1917. Water is taken from Cache Creek and Columbia Gulch. One man was at work at this property.

Still farther upstream, where the old pack trail along the south side of the Dutch Hills crosses Cache Creek, hydraulicking of the bench deposits was in progress. This deposit, though showing plainly the effect of water action, is not nearly so well assorted as the one just described. It may be considered to be intermediate in character between the glacio-fluviatile material and the well-washed bench gravels. The deposit is about 35 feet thick, and the lower 12 feet is subangular wash. Overlying this wash is 12 feet of blue glacial mud containing angular unsorted boulders, above which lies 8 feet of the same material stained brown by surface oxidation. The bedrock is slate, which continued downstream for several hundred feet before the Eocene coal-bearing formation begins. The gold is said to be distributed in the lower 12 feet of washed gravel, but little gold is present on the slate bedrock.

The gold is coarse and rather angular. The coarsest piece so far found is valued at $9. The concentrates are composed chiefly of pyrite, with subordinate amounts of magnetite, arsenopyrite, quartz, and scheelite.

One man was working this placer. Farther downstream preparations were being made to open another bench deposit, and for this purpose a ditch 1,000 feet long had been dug, giving a head of 40 feet.

NUGGET CREEK.

Nugget Creek has been described by Capps[1] as follows:

> Nugget Creek is the uppermost large tributary of Cache Creek, joining it a few miles below its head. Its source is in the Dutch Hills, through which it flows in a wide, straight, U-shaped valley, which shows strongly the erosive action of the great glacier that once occupied it. In the hills the basin of Nugget Creek is composed of the rocks of the slate and graywacke series, and the stream flows in a postglacial canyon, which is shallow toward the valley head but narrower and deeper downstream. At the point where it leaves the slate hills the creek occupies a canyon cut 200 feet into the rocks, but at the base of the hills the slates give place to the softer rocks of the coal-bearing series, and through these the stream has widened its gorge, though the valley walls are high and steep throughout the remainder of its course to Cache Creek.

During the summer of 1917 one plant was engaged in working the creek placers below the mouth of the canyon, on claim No. 4 below Discovery, about 1,000 feet below the mouth of the canyon, along the west side of the creek. The bedrock is the coal-bearing formation, chiefly conglomerate composed of pebbles, cobbles, and boulders of a graywacke, made up of fragments of flint, chert, and slate. Overlying the bedrock is a thickness of 7 to 8 feet of gravel, in the lower part of which and on the bedrock itself is found most of the gold. The gold is coarse and is neither angular nor well rounded. The minerals collected with the gold in the sluice boxes include quartz, magnetite, cassiterite, pyrite, garnet, and zircon.

[1] Capps, S. R., op. cit., p. 58.

This deposit is mined by hydraulicking. Two nozzles are used, one for hydraulicking the gravels and the other for stacking the tailings. Water is taken from Nugget Creek at a point some distance above the canyon, and a pressure of 200 feet is thus obtained. The gravel is washed toward shear boards and thence into a line of sluice boxes. Six men were at work on this property. The owners intend to work out the creek placers on both the east and west sides of the creek and then to turn their attention to the benches on the west side. In spite of floods and adverse mining conditions, 5,000 square feet of bedrock was cleaned at this property in 1917.

One man was also at work on a bench on the east side of Nugget Creek, about 200 feet above the creek. A cut about 300 feet long and 12 feet wide had been made, and 9 feet of gravels removed. The lower 4 feet consists of heavy, well-washed boulders. Most of the gold is moderately coarse, though some of it is fine, and is rather rough. The concentrates recovered with the gold consist mainly of pyrite, with some magnetite, arsenopyrite, quartz, and a few grains of scheelite. This gravel was hydraulicked by a nozzle under a head of 50 feet, with water taken from a ditch 3 miles long.

THUNDER CREEK.

Capps[1] thus describes Thunder Creek:

> Thunder Creek heads in the slates and graywackes of the Dutch Hills, near Nugget Creek. On leaving the hills it bends to the south, following the general direction of the Cache Creek valley, and joins Cache Creek 3½ miles below the mouth of Nugget Creek. In its course below the hills it is intrenched below the level of the surrounding plateau, its valley lying for the most part in the beds of the coal-bearing series. For a portion of its length, however, it has cut through the softer sediments into a ridge of underlying slates. The bedrock, therefore, varies in different portions of the stream's course.

During the summer of 1917 one large hydraulic plant was operating on Thunder Creek, on the Battle-Axe Association ground, about 1½ miles below Discovery claim. A number of low benches along the west side of the creek have been worked out, and present operations are confined to a high bench on the east side, about 150 feet above the creek level.

The gravel deposit at this locality is 80 feet thick and resembles considerably the gravel bank on Cache Creek, above the mouth of Gold Creek, in that the gravel shows the effect of much water action. The lower 40 feet is much iron-stained, and layers of hard iron hydroxide cement near the bottom render this part of the deposit more resistant to the nozzle. Overlying the lower 40 feet is a body of fine, well-washed gravel 8 feet thick in a dark-blue clay cement, overlain in turn by a yellow gravel deposit much like the lower part.

[1] Capps, S. R., op. cit., p. 61.

This placer body is most remarkable, however, on account of the peculiar character of the underlying bedrock. The coal-bearing formation is considered to be the bedrock, though hydraulic operations have cut through it in places, exposing a much weathered phase of the slate and graywacke series, which projects upward as reefs. It is evident, therefore, that the coal-bearing formation forms only a thin mantle upon the slate and graywacke series. This mantle of soft bedrock constitutes the puzzling feature. In general, the rock at this locality is a brown clay, locally carrying thin streaks of coal, which strikes N. 40° E. and dips 35° NW., or toward Thunder Creek. Two well-defined beds of quartzose material, however, interbedded with the clay rock, and these beds carry coarse angular gold. The giant has little effect on this material, but on exposure to the air it slacks and flows away in a muddy ooze. These quartzose seams are composed largely of angular fragments of a much weathered and disintegrated gold quartz and a minor amount of well-rounded quartz pebbles, cemented in a white clayey material, which on close examination proves also to consist largely of fine fragments of quartz—that is, it is a siliceous clay. Thin seams of coal also are found in these siliceous seams, together with fine fragments of coal in all orientations, resembling washed material. A considerable proportion of the gold recovered at this plant comes from this siliceous clay, and even the adjoining brown clay contains a little gold. Two such siliceous deposits, each averaging about 12 feet in thickness, are exposed in the cut, about 50 feet apart stratigraphically. Both these deposits can be traced downstream, and in that direction they appear to lie farther apart. Seams of clay gouge that strike N. 80° W. and dip 85° N. cut these seams, as well as the other coal-bearing sediments, showing the presence of later faulting.

It is difficult to formulate a satisfactory genetic interpretation of these siliceous beds. The angular shape of the quartz fragments and particularly the lack of admixture with other detrital material point unmistakably to a minimum of transportation in the formation of these deposits. On the other hand, the presence of even a small percentage of rounded quartz pebbles indicates that the action of water was certainly a factor in their formation, and the presence of coal seams also relates them to the detrital Eocene sediments. One fact that must have an important bearing is the evidence of deep residual weathering at this locality during the deposition of the coal-bearing sediments. The slate and graywacke under these coal-bearing beds are extremely decayed, being altered almost to the condition of a clay. Some of the quartz pebbles in the quartzose seams were also found to be badly disintegrated and ready to fall apart into angular fragments when separated from the clay matrix. Moreover, the matrix, when viewed under the microscope, is seen to be composed of subangular to rounded grains of decayed cloudy quartz. All the evidence indicates that these quartzose seams are the result of deep residual weathering, with a minimum of water transportation, and the only logical inference is that some large gold-bearing quartz veins are present in the slate and graywacke series under the Eocene coal-bearing mantle at no great distance from this locality. It is not safe, however, to say that such quartz veins will be uncovered by following the quartzose beds in any particular direction, for too little is known of the conditions of deposition or of the direction from which the detrital material came. Neither is it safe to infer that the quartz veins when uncovered will prove to be comparable in content of gold with the derived detrital material, for much surface enrichment must have occurred in such deep weathering. If representative samples of the quartz fragments and pebbles could be obtained, quite free of the matrix, assays of the material might yield an approximate indication of the gold content of the original vein material.

The gold recovered at this plant is coarse and bright, and most of it is angular, only about 2 per cent being rounded. The assays range from $17.50 to $18.15 an ounce and average perhaps $18. The largest pieces of gold recovered from the gravel banks were valued at about $10 or $12, but a nugget worth $100 has been taken from the Eocene quartzose seams. The concentrates recovered with the gold are composed of quartz, ilmenite, magnetite, garnet, zircon, pyrite, arsenopyrite, cassiterite, and a few grains of scheelite.

Twelve men were employed at this plant early in the summer of 1917, but some of them left toward the end of the season. Three other operators were placer mining in a small way on the Battle-Axe Association ground—two below this plant, working low benches along Thunder Creek, and one upstream, working in the creek placers. Considerable native copper has been found in the bed of Thunder Creek at the upper plant.

FALLS CREEK.

Falls Creek is described by Capps[1] as follows:

> Falls Creek is the next important tributary of Cache Creek south of Thunder Creek. It heads in the slates and graywackes of the Dutch Hills, flows in a course roughly parallel to that of Thunder Creek, and joins Cache Creek about three-fourths mile south of it. At the point where it passes from the slates to the beds of the coal-bearing series it has developed a narrow canyon and a waterfall, which suggested its name. Gold was first mined on Falls Creek in 1905, in the canyon cut through the slates, and the stream afforded considerable production for a few years. In the narrower portion of the canyon the difficulties of diverting the creek prevented mining except for a short time in the spring when the volume of the stream was small.

[1] Capps, S. R., op. cit., p. 62.

done under a head of 200 feet, and when conditions are favorable about 1,000 cubic yards of material can be put through the boxes in a day.

WINDY CREEK.

Windy Creek rises in the Peters Hills and flows in a general westerly course to join Cache Creek between Falls and Dollar creeks. It is the only tributary of Cache Creek from the southeast side of the valley that has been found to carry placer gold in economic amounts.

The placer is a bench deposit about 80 feet above the creek level, on the left side, consisting of 160 to 180 feet of glacio-fluviatile material. The lower 40 to 60 feet consists of gravel, of which the lower 6 feet is iron-stained and firmly cemented. This body of gravel is overlain by 100 feet of blue mud containing large angular boulders, and this in turn is covered by 20 feet of gravel which extends to the surface. The gravel in general averages 5 inches in diameter, though boulders from 1 to 3 feet in diameter are uncovered. The bedrock is clay and sandrock of the coal-bearing formation. Most of the gold occurs in the lower 6 feet of the deposit and is fine and flaky, the largest piece recovered being valued at $1.85. The concentrates are composed of pyrite, quartz, ilmenite, magnetite, garnet, limonite, arsenopyrite, zircon, and a little cassiterite. Pyrite is particularly abundant in the upper gravel bed. Native copper in small amount and scheelite are also reported from the concentrates.

This great bank of gravel and mud is washed down by two nozzles, of 4 and 5 inches diameter respectively, with a head of 225 feet. High and low line ditches from Windy, Little Windy (a fork of Windy), and Fox creeks supply the necessary water. Between 300,000 and 400,000 cubic yards of material was hydraulicked at this property in 1917. Four men were employed.

PETERS CREEK BASIN.

PETERS CREEK.

Peters Creek rises in the Dutch Hills, flows for 17 miles to the southeast, cuts through the Peters Hills in a narrow gorge, and then flows in a direction south of west for about 19 miles to join Kahiltna River about 5 miles below Camp 2. That part of Peters Creek which drains the Dutch and Peters hills—that is, the upper 12 miles—is the scene of placer mining in this drainage basin and is the subject of discussion in this paper. Peters Creek in its lower valley flows in a flat, open-timbered country, over the outwash of glacio-fluviatile deposits.

The chief headwater tributaries of Peters Creek are Cottonwood Creek, which enters from the northeast, and Bird Creek, which enters from the west 4 miles upstream. Poorman and Willow creeks are important tributaries of Cottonwood Creek and enter from the northwest side of the valley. Cottonwood, Willow, and Poorman creeks really drain the northeastward extension of the Cache Creek glaciated trough, whereas Bird Creek and the extreme headwater tributaries of Peters Creek cut back into the Dutch Hills. A low saddle west of the mouth of Cottonwood Creek separates Peters Creek from the headwaters of Cache Creek, and a similar low saddle separates the head of Cottonwood Creek from Long Creek, a tributary of Tokichitna River.

Capps [1] describes the physiographic features of Peters Creek as follows:

Peters Creek occupies a valley intermediate between Kahiltna and Tokichitna rivers and in its upper portion is roughly parallel to these two streams. It heads in a broad, severely glaciated, U-shaped valley in the Dutch Hills, turns at a right angle to cross the Cache Creek plateau, crosses the Peters Hills through a deep transverse trough, and enters the broad lowland of the Susitna Valley, the west edge of which it follows to its junction with Kahiltna River. Its total length is more than 35 miles. In its course through the higher parts of the Dutch Hills it flows in the bottom of the glacial trough in a channel which has been notched little or not at all into the slates and graywackes of the hills. In the more easily eroded coal-bearing beds of the Cache Creek plateau it has intrenched itself deeply in a canyon-like valley that extends headward into the slates for some distance above the mouth of Bird Creek, and a similar canyon extends for more than a mile up Bird Creek. The downward slope of the Cache Creek plateau toward Peters Hills causes the stream valley to become shallower and wider in that direction, but on entering the valley through these hills the creek again flows through a rock canyon. This second slate canyon terminates at the east border of the Peters Hills, the stream once more flowing between valley walls of the coal-bearing series and the banks gradually becoming lower downstream through the little-known area of the Susitna lowland to the south and east.

No placer mining was being done on Peters Creek in 1917, but prospecting was in progress along the benches and in the stream gravels at the lower end of the Peters Hills canyon, and below this locality. About 2 miles of claims in this vicinity have been leased by one operator, and it is expected that these placers will be thoroughly prospected in 1918.

With regard to the discovery of gold on Peters Creek and particularly with reference to the earlier work done in and near this canyon, Capps [2] writes as follows:

Gold was discovered at a number of places on Peters Creek and its affluents in 1905, and mining has been done on that creek each summer since that time. In 1911 work was in progress at two places on the main stream. At the mouth of the canyon, through Peters Hills, a short distance above the point at which the stream passes from the slates onto the soft bedrock, two men were mining on a bench about 30 feet above the stream level, where a few feet of gravel lie on a slate bedrock. Water under a pressure of 70 feet, brought by ditch and canvas hose, was used for piping the gravels into the sluice boxes. The gravels contain rather abundant boulders. At the time

[1] Capps, S. R., op. cit., pp. 63-64. [2] Idem, pp. 64-65.

the place was visited some of the ground was still frozen. The gold, which is for the most part concentrated on bedrock, is coarse, flat, worn, and somewhat rusty, and gives evidence of having traveled some distance from its source. The largest nugget found weighed 9 pennyweights, and the gold assays about $17.75 to the ounce. The ground worked in 1910 was a short distance downstream from that worked in 1911, on a bench only a few feet above the stream. The bedrock at this place is a hard, rusty dike intruded into the slates. Prospect holes in the creek gravels below the canyon show placer gold on a soft bedrock, but the gradient of the creek is too low and the ground too deep to permit mining by pick and shovel methods.

The bedrock source of the gold in lower Peters Creek is still open to queston, but this gold, like that in the other parts of this district, was doubtless derived from the quartz stringers in the slates and graywackes. In lower Peters Creek some of the gold may have come directly from the rocks of Peters Hills, through which the valley is cut, but as gold is found in the stream gravels above Peters Hills and up to the head of the stream it seems probable that the present placers are in large part the product of reconcentration of gold that was scoured from the upper tributaries of the streams by glacial ice, scattered throughout the valley, and again reconcentrated by post-glacial erosion.

About three-fourths mile below the mouth of Bird Creek, at the lower end of the upper rock canyon of Peters Creek, two men were mining in 1911 near the contact of the slates with the soft bedrock. A dike of a crystalline intrusive rock crosses Peters Creek at this place. The creek gravels average about 6 feet in depth and the gold values are concentrated on or near bedrock. At the time the creek was visited in 1911 little ground had been mined, but the claims between the mouth of the canyon and Bird Creek are said to have produced a few thousand dollars altogether.

In 1916 the creek gravels on a bar west of the creek itself, about 2,000 feet below the mouth of the canyon, were mined by two men. A cut 700 feet long and 48 feet wide was worked by open-cut methods, and the material was shoveled into sluice boxes in three 16-foot cuts. The depth to bedrock was 4 feet but increased rather abruptly on each side of the cut. This cut is an old watercourse of Peters Creek. The ground is reported to have yielded $1 a cubic yard of gravel mined. Downstream from this cut a number of prospect holes have been begun, but at a depth of 5 or 6 feet water was encountered and the work ceased. The bedrock, however, is known to be composed of the Eocene coal-bearing formation, consisting of sandstone, shale, and lignitic coal beds. If the drill shows that this lower ground is favorable, it may perhaps be worked profitably by dredging. About three-quarters of a mile below the canyon the valley floor that is suitable for dredging is about 1,200 feet wide, and the canyon is a fine power site.

At the lower end of the canyon, at an elevation of 1,880 feet on the west side, the contact between the slate and graywacke series and the coal-bearing formation is exposed. The slate and graywacke formation at this locality strikes N. 70° W. and dips 30° N., though the original strike for this vicinity is probably more nearly N. 55° E., and the dip is steep to the northwest, as seen farther up in the canyon. Numerous diabase dikes cut the slate and graywacke and weather out conchoidally as "niggerheads." Quartz veinlets and stringers are also numerous.

In this vicinity—that is, at the lower end of the canyon—a small bench placer about 15 feet above the creek and embracing about 5,000 square feet was hydraulicked in 1915 or 1916. The overburden comprises 3 feet of gravel and 3 feet of overlying soil. Farther from the stream the overburden is heavier, and the work was discontinued. A similar bench about 50 to 80 feet above the creek bed was worked in 1916, and about 20,000 feet of bedrock was cleaned. It is possible that a larger hydraulic plant could be installed here and could work the deeper and heavier bench gravels at a profit.

POORMAN CREEK.

The headwaters of Poorman Creek rise in and cut through the rock of the slate and graywacke series, but the coal-bearing formation begins a short distance downstream and continues to the mouth. Discovery claim lies at the contact between the slate and graywacke series and the coal-bearing formation. Twenty-four claims, covering practically the whole creek, are now owned by two men, who are working this ground every year. In 1917 most of the work was done on claim No. 1 below Discovery and a smaller amount on Discovery and claim No. 1 above Discovery.

On claim No. 1 below Discovery a bench deposit was worked. This deposit consisted of 25 feet of gravel, lying upon a bedrock composed of Eocene conglomerate and clay shale. The lower part of the gravel is a heavier wash than the upper part and contains boulders 1 foot in diameter and some as large as 4 feet. It is also much iron stained. The upper part is made up of finer gravel and contains a number of beds of peat several inches thick. Much of the gold is found in the lower part of the gravel and on bedrock. About 2,500 square feet of bedrock, aggregating about 2,300 cubic yards of gravel, was hydraulicked on this bench in 1917. Water is usually scarce, and the hydraulicking has to be done intermittently, when the dam upstream fills with water.

Also on claim No. 1 below Discovery, but upstream from the bench deposit just described, at the mouth of Dandy Creek, a tributary of Poorman Creek, two men worked the creek gravels by hydraulicking. The bedrock is composed of Eocene conglomerate, and the overburden is about 10 feet thick. The pay streak, which ranges in width on Poorman Creek from 6 to 150 feet, is here at its widest. Some hydraulic mining also was done on Poorman Creek above the mouth of Dandy Creek.

The gold recovered from the upper end of Discovery claim and from claim No. 1 above Discovery is coarse, shotty, and rather dark in color, and some of it is much iron stained. The bench gold is similar but a little coarser. The gold from Poorman Creek at the mouth of Dandy Creek is brighter, finer, and more flaky. The bright gold is valued at $17.70 to $17.78 an ounce before melting, and the dark gold is worth somewhat more.

The concentrates taken with Poorman Creek gold are of special interest on account of their content of platinum and tin. A mixed sample of the concentrates taken from bench and creek placers showed the presence of garnet, cassiterite, zircon, magnetite, ilmenite, pyrite, quartz, and platinum. This sample, after examination by the writer, was submitted to Ledoux & Co., of New York, who report the presence of 36.54 per cent of tin—that is, the sample must have contained about 46 per cent of cassiterite. The cassiterite is present as small crystals, none of which in the sample examined exceeded a quarter of an inch in diameter. Another sample of concentrates, which weighed 647 grains and which was the very heaviest of the pannings and represented perhaps a five-hundredth concentration of the first sample, was found to have a considerable amount of platinum metals, perhaps 100 grains.

The platinum metals from Poorman Creek are essentially similar to those from Cache Creek. Two kinds were obtained—the dark-gray to bronze flat, flaky pieces, which presumably are largely platinum, and the bright, silvery, commonly crystalline variety, which is supposed to be chiefly iridium and osmium. A sample weighing 41.6 grains was picked by hand from the heavy concentrates above mentioned and was submitted to the chemical laboratory of the United States Geological Survey for complete analysis. R. C. Wells, the analyst, reports as follows:

Analysis of sample of platinum metals from Poorman Creek.

Silica, *etc*	1.0
Iridosmium	32.0
Iridium	11.3
Rhodium	1.4
Platinum	47.3
Iron	5.2
Gold	1.5
Palladium	Trace.
Copper	.1
Nickel	.03
Zinc and silver	Trace.
	99.83

Specific gravity of sample, 18.1.

More platinum was seen on Poorman Creek than at any other place in the Kahiltna Valley, yet even at this locality it is doubtful whether enough platinum is available to make its recovery on a commercial scale worth while.

Poorman Creek shows evidence of intensive mineralization. On Discovery claim, at the contact of the slate and graywacke series with the coal-bearing formation, the slate strikes N. 35° E. and dips 55° NW. A dike of soda rhyolite porphyry cuts the slate just above the contact, and others crop out farther upstream. The porphyry consists of phenocrysts of quartz and albite in a fine-grained, much altered groundmass of the same material, and both phenocrysts and groundmass show the result of later sericitization (replacement by sericite). Mineralized quartz veins and stringers commonly accompany these dikes. In claim No. 1 above Discovery the slate bedrock is soft, decomposed, and much mineralized by pyrite. This zone of mineralization in upper Poorman Creek appears to extend into the Willow Creek and Long Creek basins and must have had a strong influence on the placers at those localities. It can not be doubted that some of the placer gold on Poorman Creek has been concentrated directly from sources in mineralized bedrock subsequent to the retreat of the ice, although concentration from the glacio-fluviatile deposits certainly took a major part in the process. One fact that bears on the localized origin of the gold on Poorman Creek is the recent discovery of a gold-bearing gravel channel in the coal-bearing sediments just above their contact with the slate and graywacke series. The value and extent of this channel have not been investigated, but the very fact of its existence indicates that some of the gold was localized in this drainage basin, for no means of transportation other than water was effective in the coal-forming epoch. The origin of the platinum metals is not known.

WILLOW CREEK.

On Willow Creek placer mining was carried on by one operator at two different localities—on Ruby Creek, a headwater tributary of Willow Creek that enters from the east side, and on the main Willow Creek some distance downstream.

On Ruby Creek, where most of the summer's work was done, the present stream gravels were being worked in a pay channel at least 30 feet wide, in which 4 feet of gravel lies upon Eocene coal-bearing bedrock. The gold is found largely on the bedrock. About 400 feet of the creek bed, or about 12,000 feet of bedrock, was worked by the hydraulic nozzle in 1917. On Willow Creek the gravel was shoveled into boxes.

The gold is rather fine, flaky, and bright. It resembles very much the gold from Poorman Creek at the mouth of Dandy Creek, though it is a little finer. Platinum in small amount was noticed with the gold, though it may be considered negligible as a commercial product. The concentrates collected with the gold in the sluice boxes are made up of garnet, magnetite, ilmenite, zircon, cassiterite, pyrite, and quartz. A sample of these concentrates was submitted to Ledoux & Co., of New York, who report the presence of 20.03 per cent of tin, hence the concentrates must consist of about 25 per cent cassiterite. The cassiterite is of the same character as that found on Poorman Creek—that is, it consists of small crystalline grains.

On Gopher Creek, another headwater tributary of Willow Creek, which enters from the west side, another man was hydraulicking the creek gravels. A cut 1,200 feet long and 40 feet wide had been worked, exposing Eocene bedrock in the lower part of the cut and slate bedrock in the upper part. At the upper end of the cut two subsidiary pay channels that cross the main channel were discovered, and plans for future work involve the working of a left-side bench in the hope of finding a continuation of these channels. The overburden in the cut is about 4 feet thick, and the gold lies chiefly on bedrock. A preglacial conglomerate, composed of greatly decayed pebbles of all kinds, the largest 18 inches in diameter, was observed at the upper end of the cut. The gold is rather fine, the largest nugget so far recovered being valued at $4. An interesting exhibit from this placer consisted of a specimen in which native gold and lead were intimately intergrown.

BIRD CREEK.

At the lower end of Bird Creek, about two claim lengths from the mouth of the creek, one man was engaged in 1917 in working a bench deposit on the north side of the creek and about 50 feet above it. The bedrock is composed of slate and is overlain by a gravel deposit which is 8 feet thick at the north side of the cut and decreases to a few inches toward the creek. The bedrock is very uneven, owing partly to the high tilt of the slate and partly to erosional potholes. The best paying material is found mainly on the bedrock. The gold is coarse, dark, and iron stained. The largest nugget so far recovered weighed 1 ounce. A soda rhyolite porphyry dike crosses Bird Creek just above the bench, and numerous quartz stringers occur in the slate bedrock. Mining is done by means of a hydraulic nozzle, but the bedrock is picked, cleaned, and shoveled into the boxes by hand.

One claim length farther upstream on Bird Creek another man was at work on the St. Louis bench, on the south side of the creek. The bench is 50 feet above the creek level, and a 40-foot head is used in hydraulicking the deposit.

The gold placer body on the St. Louis bench is quite different from any in the Peters Creek basin previously described, and so far as any workable placer in the Cache Creek district is concerned it is correlatable only with the glacio-fluviatile auriferous deposit on Windy Creek, in the Cache Creek basin. This deposit seems to be purely of glacio-fluviatile origin and consists of 50 to 75 feet of glacial mud and angular to subangular boulders of all sizes, resting upon a much broken, decayed, and uneven-surfaced slate. The upper 10 feet is stained yellowish brown from the effect of surface oxidation. Gold is distributed rather evenly throughout the placer body, with no particular concentration at or near bedrock.

The gold is both coarse and fine but is almost universally angular, only about 1 or 2 per cent being worn. One pretty specimen of dendritic gold and others of wire gold, all quite unworn, have been recovered. As a rule the gold is dark in color, and the largest nuggets are deeply iron stained. A piece of gold worth $12 is the largest so far found.

The concentrates contain about 95 per cent of pyrite, both in cubical and massive form. The few remaining constituents include arsenopyrite, magnetite, and a very little scheelite. A little native copper is also found occasionally in the concentrates.

TOKICHITNA BASIN.

LONG CREEK.

Long Creek heads against Cottonwood and Poorman creeks and flows northeastward for about 6 miles to join the Tokichitna a short distance above Home Lake. Its drainage basin lies entirely within the area of the slate and graywacke series. In 1917 one man was engaged in placer mining on Canyon Creek, a small headwater tributary of Long Creek that enters from the west. Both Canyon Creek and Long Creek above the mouth of Canyon Creek cut through the slate in gorges.

The valley floor of Canyon Creek in the gorge is from 8 to 30 feet wide, and the pay channel has a greatest width of 7 to 15 feet, averaging perhaps 6 feet but narrowing in places to 1 foot. A cut 600 feet long in this channel was mined in 1917, the placer being shoveled into sluice boxes. At the upper end of the cut the gravel is only 2 feet thick, but it increases to 8 feet at the lower end. Most of the gravels are in the form of cobbles averaging 6 inches in diameter, though boulders as large as 2 feet are present. The gold, which is coarse, lies for the most part on or near bedrock, and much of it is iron stained. The largest nugget found was worth $34, but pieces worth from $1 to $3 are common. A few small grains of platinum were observed with the gold and in the heavy sands.

The concentrates include magnetite, ilmenite, garnet, zircon, cassiterite, specularite, quartz, and occasionally a little platinum. In a sample of the heaviest of these minerals, panned from the general run of concentrates, some fine specimens of crystalline cassiterite, with quite unworn edges, were noticed.

At the lower end of the cut on Canyon Creek a zone of soft, clayey decomposed slate about 50 feet wide is exposed, which is cut by quartz stringers and visibly mineralized by pyrite. This zone trends N. 15° E., the general trend of the slaty cleavage at this locality. At the head of Long Creek acidic dikes and numerous quartz stringers cut the slate. It is believed that much of the Long Creek gold in the present creek placers has been concentrated directly from mineralized bedrock in this vicinity, rather than from the glacio-fluviatile deposits.

KAHILTNA RIVER.

In 1917 prospecting for gold and platinum placers was carried on at two localities on Kahiltna River—one about 3 miles by stream below the mouth of Peters Creek, where five men were at work; the other 30 miles downstream, where seven men were employed.

The bedrock at the upper camp is the coal-bearing formation, composed of iron-stained sandrock, blue clay with included woody material, and numerous lenses of fine iron-stained conglomerate. This formation is exposed above and below the camp in the bluffs along the river. Beds of lignitic coal are also present in this vicinity. The extreme width of the gravel channel is several hundred yards, but the boundaries of a definite pay channel had not yet been determined at the time of the writer's visit. Along the east side of the river, near the water's edge, the gravel is 6 feet thick, but farther back, in the timber, it is 9 feet to bedrock. Seven drill holes had been sunk to bedrock, and the gravels were found to range from a few inches to 2 feet in diameter. There is said to be a heavy concentration of black sand in the gravel. The gold is very fine, as the coarsest pieces are worth 1 or 2 cents, and it is said to be worth a trifle over $18 an ounce after melting. Platinum is also reported in these gravels.

Mining on a very small scale has been carried on intermittently for a number of years along the bars of Kahiltna River, and some fairly rich spots have been found, particularly on the bars projecting into the river at sharp turns. Sholan Bar at this upper camp contains some surficial placer of this character. Thirty pans of gravel, panned for the writer, contained considerable fine gold and a few grains of platinum. The concentrates taken in these 30 pans consisted of garnet, magnetite, ilmenite, zircon, and quartz. It is believed by the present prospectors that a good chance exists of finding similar amounts of gold, but more particularly platinum, in the deeper gravels extending to bedrock. The content of free platinum, however, appears to be small, and the writer finds no evidence to support the idea that platinum is present in chemical combination with other minerals of the concentrates.

At the lower camp on Kahiltna River seven men were engaged in prospecting and related work. Forty-five claims are owned and options are held on 36 others in the vicinity of this lower camp by the same owners as at the upper camp. Prospecting has been done chiefly at the bars along the river by hand methods and by means of two gasoline drills of 4 and 8 horsepower. Thirteen drill holes had been sunk by September, 1917.

The lower camp is on the west side of Kahiltna River just above the mouth of Beaver Creek, a small tributary entering the river about 8 miles above the Yentna. At Round Bend Bar, on the east side of the Kahiltna about 8 miles above the camp, about $1,500 in gold was rocked out by two men from about 100 cubic yards of gravel taken from the bar in 1908. Some platinum was found with the gold. The concentrates included magnetite, ilmenite, hematite, limonite, quartz, garnet, zircon, and a little platinum. Each cubic yard of gravel is said to have contained 3 pounds of black sand. About 0.1 cubic yard of gravel from the water's edge was panned for the writer and found to contain some fine gold and a few grains of platinum. Four claims are held at Round Bend Bar and vicinity, and seven drill holes have been sunk, but none of them have reached bedrock.

At Boulder Bench, on the same side of the river and downstream from Round Bend Bar, a small open cut about 600 square feet in extent has been made in the gravel bank about 15 feet above the river's edge. This has been prospected at different times since 1907. The gold-bearing bedrock is exposed at a height of about 6 feet above the river, but a layer of hardened gravel and clay about 9 feet above the river has been used as a false bedrock. The average amount of gold to the cubic yard from this cut indicates a commercial gold placer, but the extent of the pay gravel is not known. A little platinum also was found here in pieces as much as one-eighth inch in diameter. No drill holes have been sunk at Boulder Bench.

Other bars along the Kahiltna also carry some gold. At Leslies Bar, about 2 miles above the camp, on the west side of the river, four men working in 1907 made $13 a day for each man, and another bar near by produced $500 in 1906. At both these localities, however, the pay gravel was within 1 foot of the surface. One drill hole was put down 9 feet on Leslies Bar in 1916 and is said to have shown favorable conditions. Five drill holes were sunk in 1917 on the Red Hill Bar, across the river from the Round Bend claims.

COAL DEPOSITS.

The coal-bearing formation, as shown on the accompanying map (Pl. VI), includes many beds of lignitic coal, which crop out at numerous localities in Kahiltna Valley. These coal beds range in size from mere stringers a few inches thick up to beds 14 feet thick. The coal is classed as lignite, though it varies somewhat in grade. There is little promise that such fuel will ever have a market, even in the near-by Cook Inlet district, because of the presence of better coal in the Matanuska Valley which can be more easily procured. Yet a good opportunity exists to use this coal locally for fuel and power, and this is now being done by the Cache Creek Mining Co.

A number of coal beds are exposed on Short Creek, a tributary to Cache Creek. Probably the best one is a bed of high-grade lignite about 8 feet thick, without partings, near the head of the creek. An entry 100 feet long was driven into this coal seam, and it was mined for a period by the Cache Creek Dredging Co., but the upkeep of the wagon road up the canyon of Short Creek was found to be too costly and the work was abandoned.

At present the company is mining another coal bed at the mouth of Short Creek, about half a mile below the mouth of Falls Creek. About 1,000 tons a month was mined during the summer of 1917, most of which was used for generating power on the dredge. Some of it, however, was used for heating in the camp. Ten men, including a foreman, were employed. This coal bed strikes about west, or perhaps N. 80° W., and dips about 10° S. An entry 475 feet long, with a height of 6 feet in the clear, has been driven on the strike of the seam, and rooms have been turned off at regular intervals to the northwest, at an acute angle with the tunnel, in order to avoid working directly up the dip. So far eight rooms have been turned off, the largest of which, No. 8, is 200 feet long. Gravity haulage is employed in the rooms. A tipple with a capacity of 50 tons has been built at the mine entry, and from this tipple coal is dumped into wagons and then hauled downstream to the dredge on Cache Creek.

The coal seam is rather uniform in thickness, averaging 5 feet 2 inches. About 14 inches of coal is left in the roof to support the overlying clay, and the rooms are therefore 4 feet high. No clay partings are present, but a streak about 4 inches thick in the upper half of the seam is of noticeably lower grade.

Another promising bed of coal is exposed along the east bank of Peters Creek about 2½ miles below the mouth of the canyon. This bed contains a fairly high grade coal, which is reported to do fairly well for blacksmithing. The strike of the bed is about N. 45° E. and the dip about 70° NW. The shale footwall is exposed, but the hanging wall is covered by slide. About 10 feet of coal is exposed, but the total thickness of the bed is probably 12 or 14 feet.

CHROMITE DEPOSITS IN ALASKA.

By J. B. MERTIE, Jr.

Deposits of chromite have been known in Alaska for a number of years, but they became of economic interest only in 1917, when the relatively high price of the ore recalled them to the attention of mining men, with the result that ore is commercially mined at one property.

The chromite deposits of present economic interest are at the southwest end of Kenai Peninsula, in two areas, one along the north shore of Port Chatham and the other at Red Mountain, about 16 miles to the northeast. (See fig. 3.) Both deposits occur in bodies of altered peridotite, and, so far as known, these are the only bodies of peridotite in this vicinity, but exploration farther from the coast, in the mountains, may reveal others.

Peridotite of the same kind also occurs in large and small masses at several other places in the area between Yukon and Tanana rivers, and at Livengood, in that area, there is a deposit of chromite, but the ore in the interior of Alaska could not be mined profitably except when prices are very high.

The chromite of southwestern Kenai Peninsula occurs in lens-shaped bodies that range in thickness from a few inches to 20 feet and that lie in attitudes ranging from horizontal to vertical. None of the lenses appear to be more than 150 feet long, and most of them measure considerably less. The ore is not of uniform grade. Some of it averages 50 per cent of chromic oxide, and some is a mixture of chromite and peridotite, the leanest part of which may yield only 5 to 10 per cent of chromic oxide. All gradations between these extremes are found.

The deposit now being mined is on a spit at the southeast end of a peninsula known as Claim Point, which projects southeastward into Port Chatham. This peninsula measures about 4,000 feet from east to west and about 2,200 feet from north to south, and is joined to the mainland by a neck of land about 200 feet wide. The rock of Claim Point is entirely peridotite, which crops out also on the mainland to the north and continues southward into Port Chatham for an unknown distance. The known area of peridotite here covers about three-fifths of a square mile.

The ore body is almost completely covered by water at high tide, so that mining must be done between low and half tide. The deposit is in a vertically placed lens, which has a length of about 100 feet and a maximum width of 20 feet.

About 800 tons of ore containing from 46 to 49 per cent of chromic oxide was mined in 1917, and about as much more remains in sight

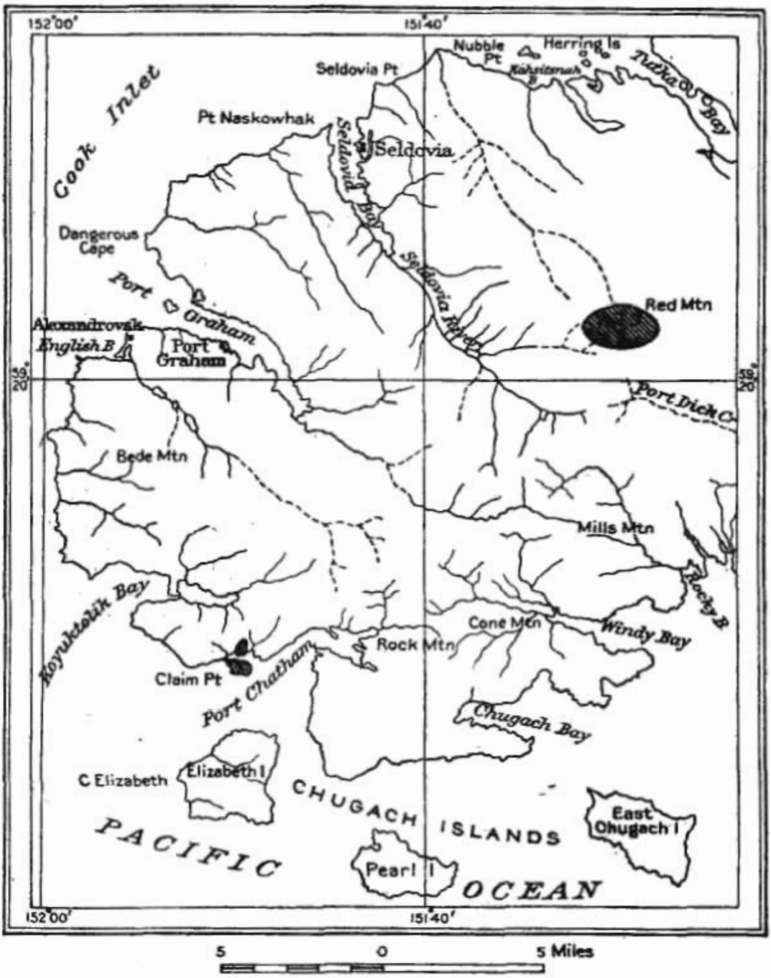


FIGURE 3.—Map of the Seldovia district. Shaded areas show location of chromite deposits.

above half tide. Ultimately it will be necessary to work from a shaft or cofferdam and hoist ore to the surface, a method that will increase materially the cost of mining.

Probably the upper half of the deposit has been removed by erosion. If so, and if the deposit becomes thinner downward for 50 feet and the ore has a specific gravity of 3.9, only 4,000 or at most 5,000 tons remains below the level of half tide.

Several other lenses of high-grade ore, none more than 3 feet thick, occur in this vicinity, as well as a number of bodies of low-grade ore that range in thickness from 5 to 20 feet and in content of chromic oxide from 5 to 15 per cent. At one place on the north side of Claim Point, near the crest of the peninsula, there are four lodes that stand nearly vertical, and the owners are considering the feasibility of driving a tunnel from a lower point on the hillside to crosscut them. These four bodies should produce, when concentrated, about 3,000 tons of 50 per cent ore, but it is likely that the tunnel contemplated might also reveal other deposits. There should be available at Claim Point at least 15,000 tons of chromite ore of a grade containing 50 per cent of chromic oxide.

The freight rate on ore from Port Chatham to Seattle is $3.50 a ton, and from Seattle to an eastern smelter is about $12 a ton, to which must be added the cost of lighterage to the steamship anchorage in Port Chatham or lighterage to the wharf at Port Graham.

The body of peridotite at Red Mountain is much larger than that at Claim Point but is more difficult of access, and the grade of the ore there is not so well known. The peridotite covers about 3 square miles and contains many stringers and lenses of chromite ore, of both high and low grade. The largest deposit observed was a lenticular body of high-grade ore not more than 75 feet long, that had a maximum thickness of 8 feet at the center and contained probably not over 1,000 tons. At this place there are many other smaller deposits and perhaps some as large or larger, all of which should yield at least as much chrome ore and possibly several times as much as the body at Claim Point. On the other hand, these ores occur at an elevation of about 3,000 feet and at a minimum distance of 6 miles from tidewater, from which much of the route lies through a precipitous and densely vegetated country. In winter the ore might be sledded out to tidewater, but in summer it would have to be carried by a tram.

GEOLOGIC PROBLEMS AT THE MATANUSKA COAL MINES.

By G. C. Martin.

INTRODUCTION.

A brief visit was made to the Matanuska coal fields from August 26 to 31, 1917, for the purpose of reviewing the mining developments that have been undertaken since the detailed geologic survey[1] of that field was made and of conferring with Mr. Sumner S. Smith, the engineer in charge of the coal-mining operations of the Alaskan Engineering Commission, in regard to structural and other geologic problems that had come up in connection with mining.

MINES ON ESKA CREEK.

GENERAL GEOLOGY.

The mines on Eska Creek are in the NE. ¼ NE. ¼ sec. 16, T. 19 N., R. 3 W., which is part of leasing block No. 7. At the time that the field work was done the workings included nine openings, all of which are drifts from natural exposures of coal beds near the level of the creek. Three of these openings were productive mines, and the others included prospect openings, abandoned mines, and mines that had not yet become productive. (See fig. 4.)

The coal beds that are being mined and prospected on Eska Creek are exposed in a discontinuous series of low cliffs that extend intermittently along one or the other bank of the creek but generally not on both of them. Between these cliffs are covered slopes, and back from them are gravel terraces and gently sloping areas covered with glacial drift and containing few if any exposures of rock. The outcrops on Eska Creek show that the creek cuts across two eastward-trending belts of gently dipping coal-bearing rocks—a southern or northward-dipping belt, in which the Emery, David, and Kelly drifts are situated, and a northern or southward-dipping belt, in which the Maitland, East Eska, Shaw, Martin, and West Eska drifts are situated. The southern belt lies north of and is separated by a concealed interval from Cretaceous rocks that are older than the coal. The northern belt lies south of and merges into or is separated by a fault from a belt of intensely deformed coal measures

[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley: U. S. Geol. Survey Bull, 500, 98 pp., 19 pls., 1912.

that probably is practically barren of workable coal and that extends northward into the great zone of faulting on the southern border of the high mountains. For immediate practical purposes only the

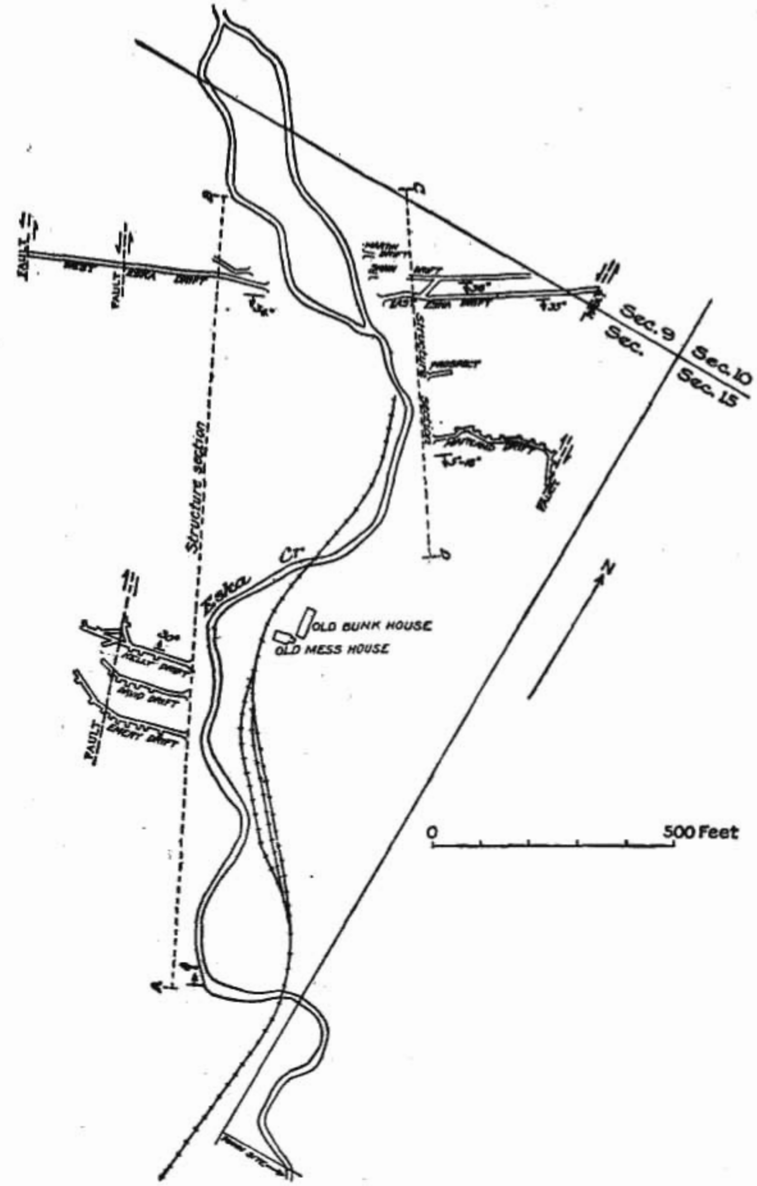


FIGURE 4.—Map of the Eska Creek coal mines.

two gently dipping belts of coal measures need to be considered in further detail. As shown below (p. 273), these belts may be fault blocks or may be the opposite flanks of a syncline. The rocks of each belt are cut by faults, some of which show at the surface, whereas others have been encountered in mining. Nowhere has the magnitude of any of the faults been determined.

The southern or northward-dipping belt of coal-bearing rocks extends from a point near the northwest corner of Eska town site to a point between the Kelly drift and the upper railroad bridge just above the old mine camp. The strike is in general N. 60°–75° E., and the dip 30°–40° NW. Near the northern edge of this belt the following section is exposed:

Section on west bank of Eska Creek opposite old mine camp.

		Ft.	in.
Sandstone.			
Coal (Kelly seam)	Coal	2–2½	
	"Clod"	4–6	
	Coal (average)	3	
Concealed		10±	
Shale (partly concealed)		6	
Sandstone		5	
Gray shale with some ironstone		4	
Shale		5	
Coal (David seam)	Coal	2	6
	Yellow shale		1½
	Coal		10
Carbonaceous shale		6	
Ironstone			4
Gray shale		5	
Ironstone			6
Gray shale		2	
Ironstone			6
Gray shale		3	
Ironstone		½–2	
Gray shale		4	
Ironstone		½–1	
Gray shale		2	
Ironstone concretions			6
Gray shale		5	
Sandstone lens (grades into shale)		5	
Shale with a few ironstone nodules		12	
Shale with a little coal		3	
Shale and coal		2	
Coal (Emery seam)	Bone		6
	Coal	2	3
	Soft shale		1
	Coal		4
	Soft shale		2
	Coal		10

These beds strike about N. 80° E. and dip 30° N. Their relations are shown graphically in figure 5.

Beneath this section the rocks are mostly concealed. Near the bridge at the lower end of the railroad yards is an outcrop which shows about 4 feet of impure coal that strikes N. 60° E. and dips

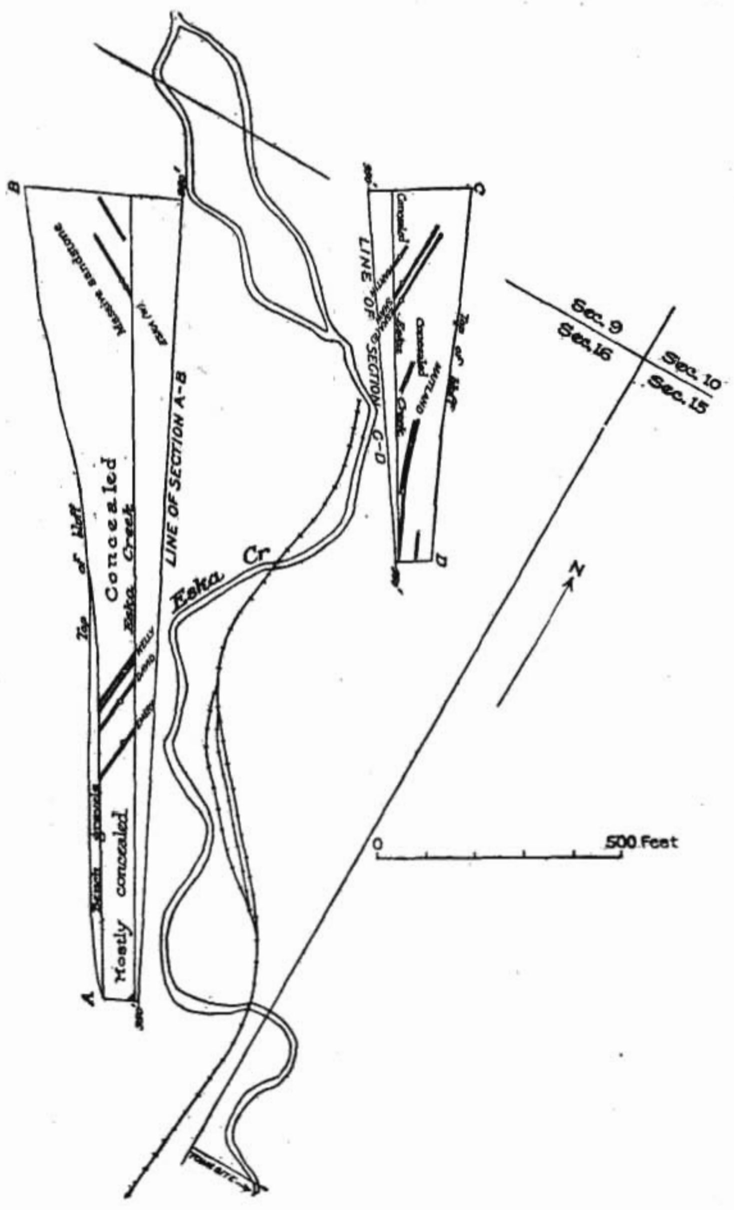


FIGURE 5.—Structure sections at the Eska Creek coal mines.

45° N. This bed should be about 300 or 400 feet below the Emery seam, if there is no fault in the concealed interval. On the east bank of the creek near the northwest corner of Eska town site is an outcrop of shale, in part coaly, that should be several hundred feet lower than the coal last described.

The next known outcrops, down the creek, are of Cretaceous sandstone in the bluff near the northeast corner of sec. 21. The intervening gap, about half a mile wide, would contain the contact of the coal measures with the underlying formation. There are reasons for suspecting that this contact is locally along a fault. The base of the coal-bearing formation is certainly not exposed along the creek, and apparently it is not exposed in the near-by hills. Consequently it is not possible to estimate the position of the coal beds just described relative to the base of the coal-bearing formation, or to state whether there are other coal beds beneath them.

The northern or southward-dipping belt of coal-bearing rocks extends from the upper railroad bridge to the vicinity of the main forks of Eska Creek near the northeast corner of the SE. ¼ SW. ¼ sec. 9. The general strike is N. 60°–90° E., and the dip 5°–35° S. The discontinuity of the exposures, the presence of faults, and the presence of disturbances that may be caused either by faulting or by slumping and tilting of blocks of strata on the steep hillsides make it impossible to describe a complete section or to determine the thickness of strata and the number and position of the coal beds. The exposed strata are at least 300 feet thick and include four or more coal beds, among which are those opened at the Maitland, Eska, Shaw, and Martin drifts. Detailed measurements and discussions of the several incomplete local sections are given on pages 274-275. The base of the coal measures is not exposed in this belt, and there is no information available in regard to the total thickness of the coal measures or the number of the coal beds beneath the surface.

The contact of the two belts of gently dipping coal-bearing rocks lies in a concealed interval near the upper bridge in the railroad yards. Because of this concealment it is impossible to state whether these belts lie on opposite flanks of a syncline or are fault blocks. As their contact lies approximately in line with the synclinal axis of Wishbone Hill, it might be assumed that the synclinal relation is the more probable. However, the synclinal structure of Wishbone Hill is shown only in exposures of the Eska conglomerate, which is less disturbed than the coal measures and overlies them possibly in unconformable relation, and consequently an unfaulted syncline in the conglomerate need not necessarily extend east to Eska Creek or down into the coal measures. Furthermore, the locality here discussed is nearer in line with the possible fault that marks the southern boundary of the conglomerate mass of Wishbone Hill than it is with the synclinal axis of the hill itself. The strata exposed on the opposite sides of the concealed interval are not sufficiently characteristic (see p. 274) to furnish reliable evidence as to whether they are identical. It must be concluded, therefore, that either a fault or a synclinal axis is possible at this locality. The writer believes that the fault is more probable, but the actual relations can be determined with absolute certainty only by following the coal underground through the concealed interval.

The northern or southward-dipping belt of coal-bearing rocks appears in a discontinuous series of exposures that extends along the east bank of the creek for about 600 feet, beginning near the railroad bridge, or about 400 feet above the Kelly drift. (See fig. 5.) The southernmost and presumably the highest (stratigraphically) of these exposures is the following:

Section on east bank of Eska Creek near upper railroad bridge.

		Feet.
Shale.		
Coal, with shale partings		4
Sandstone and shale		20
Sandstone		7
Shale		3
Coal (Maitland seam)	Coal	3
	Shale	3–6
	Coal	3

It is possible that the Maitland seam is the same as the Kelly seam. This correlation is suggested by the general similarity in section of the coal seams themselves and by the presence of a massive sandstone above the Maitland seam like that above the Kelly seam. The writer believes that this correlation should be considered as probable, though not proved.

The strata are mostly concealed for a distance of about 300 feet up the creek from the Maitland drift. About 150 feet above the Maitland drift is an old prospect opening that shows about 3 feet of coal. This coal bed and the strata in the concealed intervals on each side of it should lie below the Maitland seam and have a thickness of 50 to 150 feet unless they have been faulted. The probable presence of at least one fault in this interval is indicated by the fact that the Eska coal, which has been opened (see section below) near the northern end or at the stratigraphic base of this concealed interval, is not overlain by the massive cliff-making sandstone and other strata which overlie the Eska coal on the west bank of the creek, nor is there room for these strata in the concealed interval. (See section, p. 275.)

At the upper end of this concealed interval is an exposure in which the East Eska, Shaw, and Martin drifts have been driven. The section at this locality is as follows:

Section on east bank of Eska Creek at upper end of railroad spur.

	Ft.	in.
Sandstone	20	
Shale	5	
Coal (Eska seam)	2	6

		Ft.	in.
Shale		9	
Coal (Shaw seam):	Ft. in.		
Coal	1 1		
Shale	1		
Coal	10½		
Shale	1½		
Coal	2 0		
		4	2
Concealed (partly shale and sandstone)		25±	
Coal (Martin seam)		3±	

Above this point the best exposures are on the west bank of Eska Creek, where there is a discontinuous series of exposures that extends north from a point opposite the upper end of the preceding section. There are no exposures on the west bank of the creek between this point and the Kelly drift, a distance of about 800 feet. At the southern end of these exposures a drift (West Eska) has been driven on the Eska seam. The following section is exposed at this locality:

Section in cliff on west side of Eska Creek opposite upper end of railroad spur.

		Ft.	in.
Sandstone (cliff)		75±	
Soft sandstone		9	
Shale with a little coal		2	
Concealed (shale and sandstone)		64	
Shale		16	
Coal (Eska seam)		3	
Shale with coal streaks		5	
Shale		14	
Carbonaceous shale		2	
Shale and coal		5	
Coal (Shaw? seam):	Ft. in.		
Coal	11		
Shale	3		
Coal	10		
Shale	3		
Coal	10		
Shale	1		
Coal	1 9		
		4	11
Shale		5	
Ironstone		1	
Shale		5	
Coal (shaly)		2	6
Coal		2	
Shale		5	
Coal		2	2
Shale with ironstone concretions		23	
Coal		1	
Shale		6	
Coal		1	
Shale		10	

The thick sandstone at the top of this section forms a cliff that extends continuously westward along the top of the bluff west of Eska Creek from the West Eska drift to a point near the northwest corner of the NE. ¼ sec. 16. Beneath this sandstone cliff are gentler slopes, generally covered with talus and soil, in which reliable exposures are by no means numerous or extensive. Some of the exposures

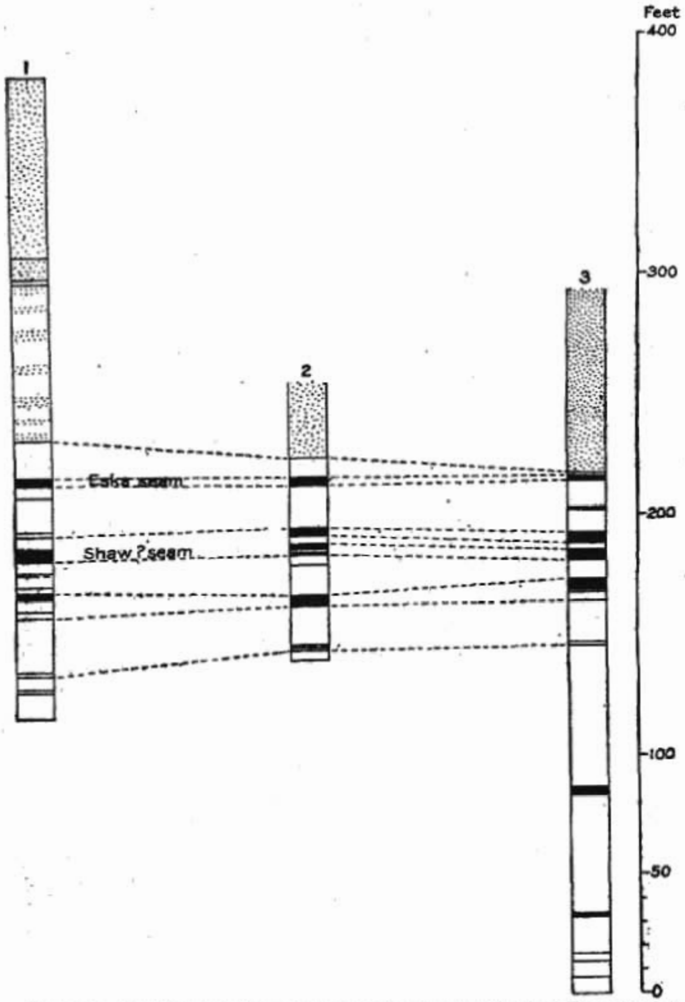


FIGURE 6.—Hypothetical correlation of coal beds on west bank of Eska Creek, in the N. ½ NW. ¼ sec. 16, T. 19 N., R. 3 E. 1, Cliff near West Eska drift; 2, about 1,250 feet below forks; 3, about 1,100 feet below forks.

at the base of the bluff apparently indicate faults and local folds that were not seen in the sandstone of the cliff. Some of the exposures are certainly blocks that have been tilted or have fallen on the steep hillside. A larger number of the exposures may either be rocks in place or tilted or fallen blocks. If they are rocks in place the soft shales and coal beds may have yielded more than the massive sandstone under the forces that caused the folding and faulting, or the sandstone may overlie the coal-bearing shales with an undetected unconformity and for that reason does not partake of all their structural complexity, or it may be that there is an undetected fault along the base of the sandstone cliff.

The writer has published elsewhere [1] a section which shows the strata beneath the massive sandstone at a locality about 1,200 feet above the West Eska drift. In another section [2] he shows the strata including and underlying the same sandstone at a locality about 1,350 feet above the West Eska drift.

It will be assumed, in the absence of evidence to the contrary, that there is neither an unconformity or a fault at the base of the sandstone. Therefore, if the coal beds are persistent the coal beds in section 36 and those in the upper half of section 37 may possibly be correlated with the coal beds exposed in the cliff near the West Eska drift, as is indicated in figure 6.

A short distance above the place where section 37 was measured several faults are exposed in the west bank of the creek. One of these faults shows considerable displacement. This fault possibly marks the northern edge of the block of rock that forms Wishbone Hill. Just north of this fault several northward-dipping coal beds are exposed, of which the following section was measured:

Section on west bank of Eska Creek 1,450 feet above West Eska drift.

	Ft.	in.
Sandstone.		
Coal (lenticular)	4	
Shale	14	
Coal	2	6
Shale	2	
Coal	2	6
Shale	8	
Coal		4
Shale		8
Coal	2	
Shale	1	
Coal	1	
Shale	20	
Coal (with some shale)	2	
Shale	5	

The northward dip at this locality is believed to be a local feature caused by drag on the fault plane. The next exposures up the creek are of southward-dipping strata and do not show coal beds.

The exposures on the west fork of Eska Creek, above the main forks in the SE. ¼ SW. ¼ sec. 9, are of closely folded and much-

[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 84–85, section 36, 1912.

[2] Idem, pp. 85–87, section 37.

disturbed rocks, in which several thin coal beds and stringers of coal were noted. The thickest coal seen is near the northern boundary of sec. 9 and is recorded in section 38.[1] This exposure is possibly the same as that of which Mr. Sumner S. Smith has furnished the following measurement:

Coal bed on west bank of Eska Creek near the north boundary of sec. 9, T. 19 N., R. 3 E.

	Ft.	in.
Dark-brown shale that contains ironstone nodules.		
Mixed sandstone and shale	1	10
Intrusive (?)	2	6
Dark-brown shale that contains petrified wood and nodules	6	
Dirty coal that carries bands of sulphur	1	4
Dark shale	1	4
Very hard black coal	2	2
Shale		1
Very hard black coal		3
Shale		1½
Very hard black coal	2	10
Shale that contains concretions		10
Strike, N. 70° E.; dip, 73° S.		

The writer believes that any coal beds that may occur in this belt of intensely deformed rocks on the border of the high mountains are so inaccessible and probably are so lenticular that they have no immediate value.

PROGRESS OF MINING.

The workings on Eska Creek consisted, in the summer of 1917, of nine openings, three of which (the Kelly, David, and Shaw drifts) are in the northward-dipping belt of coal measures, and the others (the Maitland, East Eska, Shaw, Martin, and West Eska drifts, and the unnamed prospect opening between the Maitland and East Eska drifts) are in the southward-dipping belt of coal measures. Some of these mines (the Kelly, David, Emery, and Maitland drifts and perhaps some of the others) were formerly worked by lessees. The Kelly, David, and Emery drifts had been abandoned, because the coal had been cut off by a fault, up to which it had been worked out above drainage. In the West Eska and Martin drifts main entries were being driven preparatory to mining. The Maitland, East Eska, and Shaw drifts were producing coal in an aggregate average amount of about 100 tons a day. In addition to the fault that cut off the coal in the Kelly, David, and Emery drifts, a fault cuts off the coal in the Maitland drift, and since the writer left the field faults have been encountered in the East Eska, Shaw, and West Eska drifts. None of these faults show at the surface. The position of each of these faults in the mines is indicated in figure 4. The extent of the faults beyond the present workings is not known.

[1] Martin, G. C., and Katz, F. J., op. cit., p. 87.

CHICKALOON RIVER.

The coal outcrops on Chickaloon River are situated in the S. ½ NE. ¼ sec. 25, T. 20 N., R. 5 E., and in the SW. ¼ NW. ¼ sec. 30, T. 20 N., R. 6 E., which constitute part of leasing block No. 12.

Chickaloon River enters the general area of the Matanuska coal field (the Matanuska Valley proper) in the northern part of T. 20 N., R. 6 E. After flowing through a gorge cut in the Eska conglomerate in sec. 5, it comes out into a more open valley, where there are discontinuous exposures, first on one bank and then on the other. These exposures, from the lower end of the conglomerate gorge in sec. 5 to the point where the river turns west in the SW. ¼ NW. ¼ sec. 30, consist of steeply folded rocks that belong to the Chickaloon formation and of several intrusive masses. The Chickaloon formation underlies the Eska conglomerate and includes the coal beds of the Matanuska field. However, it is not everywhere coal bearing, and none of the exposures just mentioned contain any coal. The outcrops on the north or west bank of Chickaloon River in its east-west course from the eastern boundary of the SW. ¼ NW. ¼ sec. 30, T. 20 N., R. 6 E., to the bend just above the west boundary of the NE. ¼ sec. 25, T. 20 N., R. 5 E., contain numerous exposures of coal. These outcrops will be discussed more fully below. The south or east bank of the river in this interval contains no known outcrops of coal. From this locality to its mouth Chickaloon River flows past almost continuous exposures of steeply but somewhat irregularly folded rocks that belong to the Chickaloon formation and of numerous intrusive masses. These exposures contain no coal. Throughout the series of exposures along Chickaloon River, from the point where it comes out of the high mountains into the general area of the Matanuska coal field to its mouth, the general dip is northward. The structure, however, is not a simple monocline, for the rocks are probably repeated by faults as well as by partly overturned folds. The discontinuity of the exposures, the presence of faults of undeterminable throw, the possibility of unseen faults and folds in the concealed intervals, and the lack of characteristic horizon markers make it impossible to describe the structure except in general terms.

The area back from the river is mostly covered with terrace or glacial gravels. Exposures are in fact practically confined to the banks of the larger streams and to knobs of intrusive rocks. The only exposures of coal known to the writer in the area between Chickaloon and Kings rivers are an 18 or 20 inch bed of impure coal about 200 feet above the mouth of the creek that enters Chickaloon River in the SW. ¼ NW. ¼ sec. 25, a 15-inch bed of impure coal in the NW. ¼ NW. ¼ sec. 22, and a 3 or 4 foot bed of coke where a creek crosses the west line of the SW. ¼ sec. 15.

The coal exposures on Chickaloon River are in the face of the bluff that extends for a little more than half a mile along the north or west side of the river in its east-west course through the S. ½ NE. ¼ sec. 25, T. 20 N., R. 5 E., and the SW. ¼ NW. ¼ sec. 30, T. 20 N., R. 6 E. This bluff, which is about 100 feet high, rises from the alluvial flat on the river's edge to a gravel terrace that is about a quarter of a mile wide. The upper part of the bluff is composed of terrace gravels, and the lower part is composed of steeply dipping coal-bearing rocks that are partly concealed by gravels that have slid down over them. Several coal beds are exposed in outcrops on this bluff, but more complete exposures are afforded by 11 tunnels that have been driven into the face of the bluff. Detailed measurements of the coal beds and other strata in these tunnels, as they were exposed in 1910, are given elsewhere.[1] Additional measurements were doubtless made by the engineers of the Bureau of Mines in the course of their mining operations of 1913, but these have not been published.

The attitude of the coal beds differs somewhat in different parts of the exposures. The tunnels on Chickaloon River are situated in four groups between which the rocks are more or less concealed. This grouping is indicated in the following list, in which the tunnels are arranged in sequence from east to west:

Coal tunnels on Chickaloon River.

1. Bend of river in east part of SW. ¼ NW. ¼ sec. 30, T. 20 N., R. 6 E.
A, B, 2. E. ½ SE. ¼ NE. ¼ sec. 25, T. 20 N., R. 5 E.
3, C. W. ½ SE. ¼ NE. ¼ sec. 25, T. 20 N., R. 5 E.
D, 4, 5, E, F. SW. ¼ NE. ¼ sec. 25, T. 20 N., R. 5 E.

The five western tunnels (Nos. D, 4, 5, E, and F) and the easternmost tunnel (No. 1) are situated farther north than the others. At all of these tunnels the strike is approximately east and the dip is 50°–70° N. In the southernmost tunnels (Nos. A, B, and 2) and probably also in the near-by intermediate group (Nos. 3 and C) the strike is northwest and the dip is 65°–85° S. In tunnel No. 2, the presence of what seems to be a typical underclay on top of one of the coal beds indicates that the rocks are locally overturned.

The attitude of the coal beds as described above, and the restriction of the known coal outcrops to this eastward course of the river, can not be definitely explained at present. There are several possible theories concerning the local structure that may explain the known facts, but none of them can be proved or disproved without further knowledge of underground conditions. These theories are thus outlined:

(1) That the coal outcrops lie on a monoclinal northward-dipping block of coal-bearing rocks, in the southern part of which (as in tunnels A, B, and 2) the rocks are folded beyond the vertical.

[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 78–81, 1912. Regulations governing coal-land leases in the Territory of Alaska, 86 pp., maps, U. S. Dept. Interior, 1916.

If this theory holds, the coal lies only north of the river. The rocks south of the outcrops are barren of coal unless another block of coal or another horizon at which coal is present passes under them from the south. Eastern and western extensions of the coal belt may lie concealed beneath the terrace gravels, or these extensions may be cut off by transverse faults.

(2) That the coal outcrops lie in an anticline, of which the coal beds of tunnels A, B, and 2 are on the southern limb.

According to this theory, the coal may be present in depth both north and south of the river. Such an anticline may extend east and west beneath the terrace gravels, it may plunge in either or both directions, or it may be cut off at one or both ends by a transverse fault. The exposure at tunnel No. 1 seems to indicate anticlinal folding. The northward-dipping rocks along the river below the tunnels indicate that the anticline, and possibly the coal beds also, are cut off by a fault and do not extend west of the bend of the river in the SW. ¼ NE. ¼ sec. 25, T. 20 N., R. 5 E.

(3) That the coal outcrops lie in two monoclinal blocks separated by a fault.

Under this theory the coal may underlie at considerable depth an area both north and south of the river. The coal-bearing strata may extend east and west beneath the terrace gravels or they may be cut off by transverse faults.

The actual structure at the Chickaloon coal outcrops and consequently the extent of the coal in depth can obviously be determined with certainty only by underground exploration. Because of this condition, and because there is very little coal above drainage at this locality, it is intended to sink a slope for 600 or 800 feet on one of the coal beds and then explore in depth with the purpose of blocking out, if possible, an area of workable coal.

MINES AND PROSPECTS ON MOOSE CREEK.

The Doherty mine, operated by the Doherty Coal Co. under a 10-acre mining permit, is situated on the west bank of Moose Creek in the NW. ¼ sec. 2, T. 18 N., R. 2 E. This mine was opened in 1916. The section of the coal bed is as follows:

Section of coal in Doherty mine.

	Ft.	in.
Sandstone (roof).		
Bone ("cap rock")	1	1
Coal	1	11
Bone		1
Coal	1	3
Carbonaceous shale ("black dirt")		3
Shale (floor).		

Strike N. 67° E., dip 45° SE.

The coal is mined by the room and pillar system and is hoisted on a slope from the entry on the 400-foot level. On reaching the surface it is screened and handpicked to remove the pieces of "cap rock" that come down in mining. The coal that goes through the screens is mixed with that which goes past the pickers and is hauled by a steam locomotive over a narrow-gage railroad, 3,000 feet long, to bunkers on a railroad spur one-fourth of a mile west of the mouth of Moose Creek. The output, about 50 tons a day, was sold in part to the Alaskan Engineering Commission and in part to the public in Anchorage. It is reported that the mine has been abandoned.

The coal shipped from this mine is high in ash. A cleaning plant was being installed, which should result in a better product. If the operators of this mine are able to compete with other producers they will probably be able to find a moderately large area of workable coal in the vicinity of their mine. No structural disturbances have thus far been discovered. The mine is situated on the north flank of a small local basin or else on a southward-dipping fault block. If mining operations are extended at this point the slope should be continued either to the axis of the basin or to the lower edge of the fault block.

A prospecting tunnel was being driven into the hill from the east bank of Moose Creek in the NW. ¼ sec. 27, T. 19 N., R. 2 E., by prospective lessees of leasing blocks 2 and 3. The coal beds at this locality [1] lie near the supposed zone of faulting that apparently forms the northern boundary of the structural mass of Wishbone Hill. They are badly disturbed and have also been burned. The tunnel was being driven in an attempt to get into an area of workable coal beyond the disturbed and burned zone. At the time the locality was visited the driving of the tunnel was still in progress.

LITTLE SUSITNA RIVER.

A brief visit was made also to a locality on Little Susitna River, where a bed of lignite has been found in a "trap" from which ballast was being taken for the railroad. The locality is in sec. 21, T. 18 N., R. 3 W., near mile 175 from Seward. The bed is reported to have the following section:

Section of lignite near Houston.

	Ft.	in.
Sand.		
Lignite	2	8
Shale and bone	2	
Clay.		

At the time the locality was visited by the writer the coal was not exposed, the pit which had been dug into it being filled with water. The beds exposed in the trap are semi-indurated sand and clay like those of the Kenai formation of Cook Inlet. The lignite was found at the level of the swamp and is said to dip about 6° N. The bed consequently does not extend above drainage level.

[1] Martin, G. C., and Katz, F. J., op. cit., p. 87 (sections 40–42).

SULPHUR ON UNALASKA AND AKUN ISLANDS AND NEAR STEPOVAK BAY, ALASKA.

By A. G. Maddren.

INTRODUCTION.

Sulphur claims have been recorded at three localities in southwestern Alaska—in the crater of Makushin Volcano on Unalaska Island, on Akun Island, and near Stepovak Bay on the Alaska Peninsula. (See Pl. VII.) The deposits covered by these claims have not yet been mined, but during the last year they have received considerable attention with a view to production.

These sulphur-bearing deposits are of the volcanic type termed solfataras—that is, they are surface deposits formed by sublimation from hot sulphurous volcanic vapors. They are situated in the belt of active and quiescent volcanoes that extends throughout the Alaska Peninsula, the Aleutian Islands, and Japan. Similar deposits undoubtedly occur at other localities in this belt.

Unalaska and Akun islands are near the east end of the Aleutian Islands, in latitude 54° N. and longitude 166° W. They lie west of Unimak Pass, the chief thoroughfare for vessels to Bering Sea. Stepovak Bay is on the south coast of the Alaska Peninsula, about 200 miles northeast of Unimak Pass, in latitude 55° 50′ N. and longitude 159° 40′ W., about 1,600 miles from Puget Sound.

The only regular access to southwestern Alaska is by a small mail steamer that sails from Seward once a month. Unalaska is about 1,150 miles from Seward and about 1,750 miles from Seattle in an air line or 3,000 miles by way of Seward. During the summer steamers from Seattle to Nome and St. Michael enter Bering Sea through Unimak Pass but seldom call at Unalaska or near-by ports because of lack of trade. However, they would be available for shipment of freight to Puget Sound. Fishing vessels and Government patrol and supply steamers make irregular cruises along the coast during the summer and occasionally replenish their coal bunkers at Unalaska. A Navy wireless station at Unalaska is available for transmitting commercial messages.

The following descriptions of the sulphur-bearing deposits are based upon examinations made by the writer during August and September, 1917.

MAKUSHIN VOLCANO.

TOPOGRAPHY.

Makushin Volcano, about 6,000 feet in altitude, is in the northern part of Unalaska Island, about 12 miles west of Dutch Harbor. (See figs. 7, 8.) It is 5 to 6 miles from the northwest coast and about the same distance north of Makushin Bay.

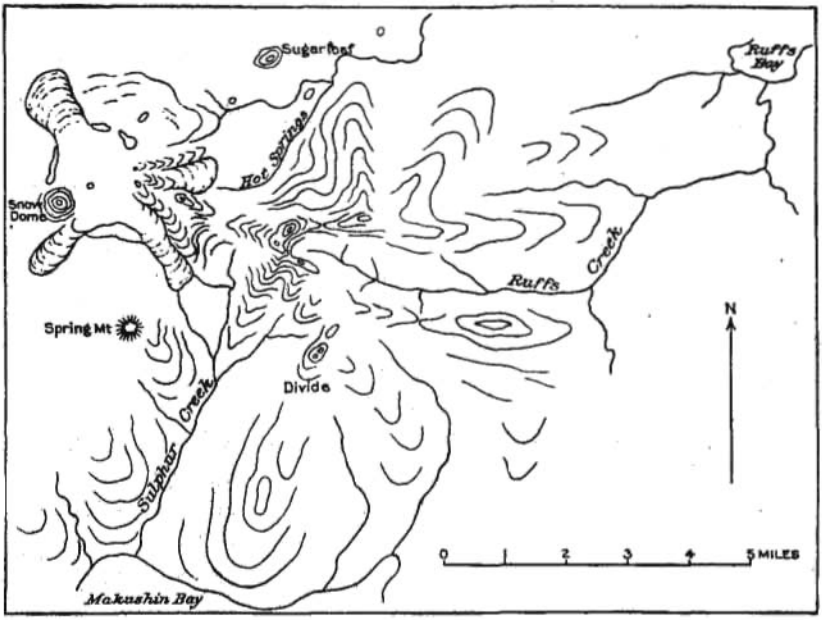
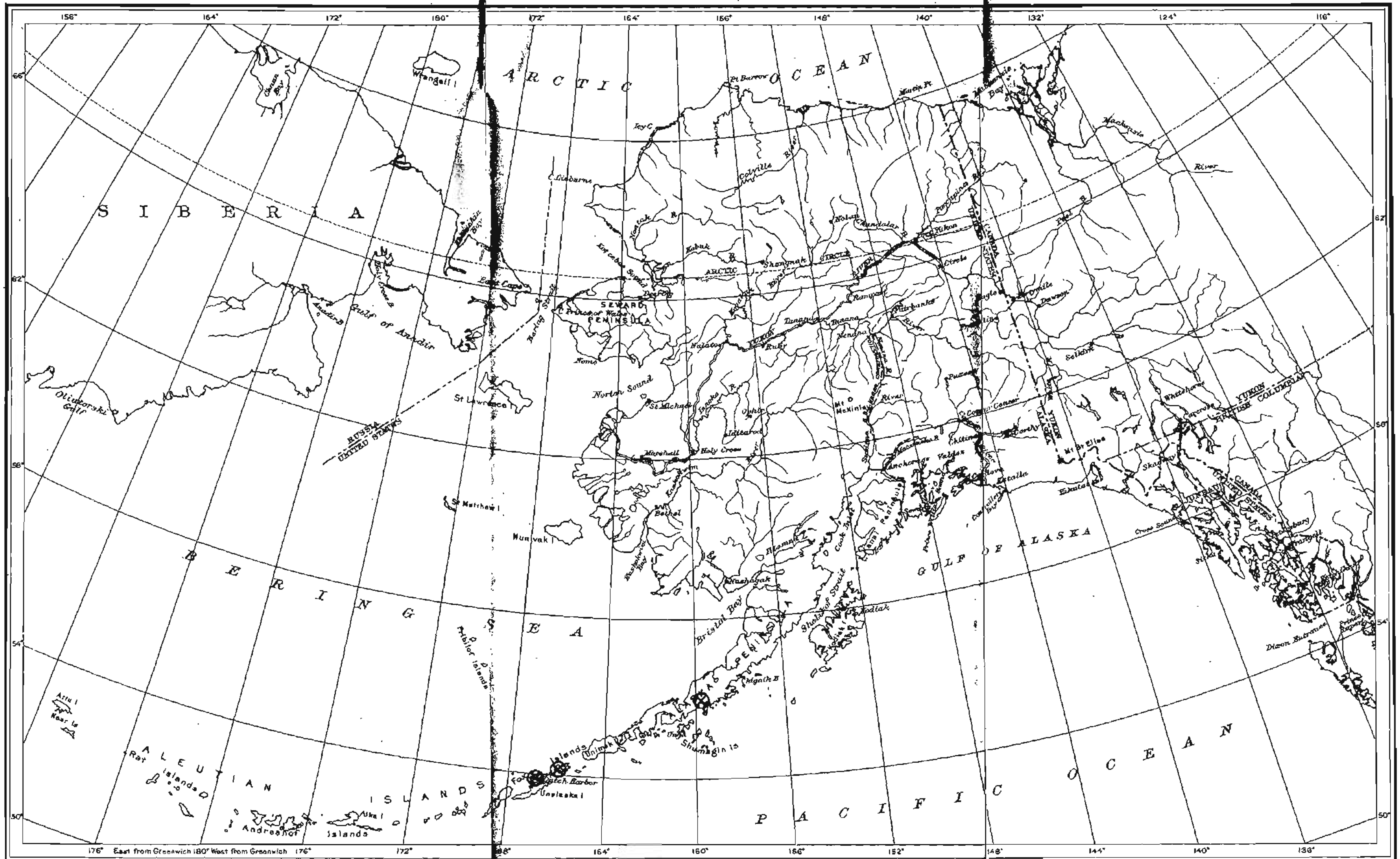


FIGURE 7.—Sketch map of Makushin Volcano and vicinity.

Makushin Volcano is a composite volcanic pile built up of alternating accumulations of basaltic lava, scoria, lapilli, and dust. In shape it is a broad dome, which forms a prominent feature of the landscape on account of its snow and ice capped summit and flanks. Glaciers descend its slopes to points about 2,500 feet above sea level, and rugged radiating ridges lie between the glaciers. A ring of ragged peaks surrounds a broad depression which marks the crater of a large extinct volcano. The mountain topographically dominates the part of the island it occupies over a radius of 5 or 6 miles.

The crater of Makushin Volcano, as defined by its rim ridges, is broadly oval or horseshoe-shaped in plan and is nearly 2 by 1½ miles in dimensions. Nearly continuous ridges form the crater rim except

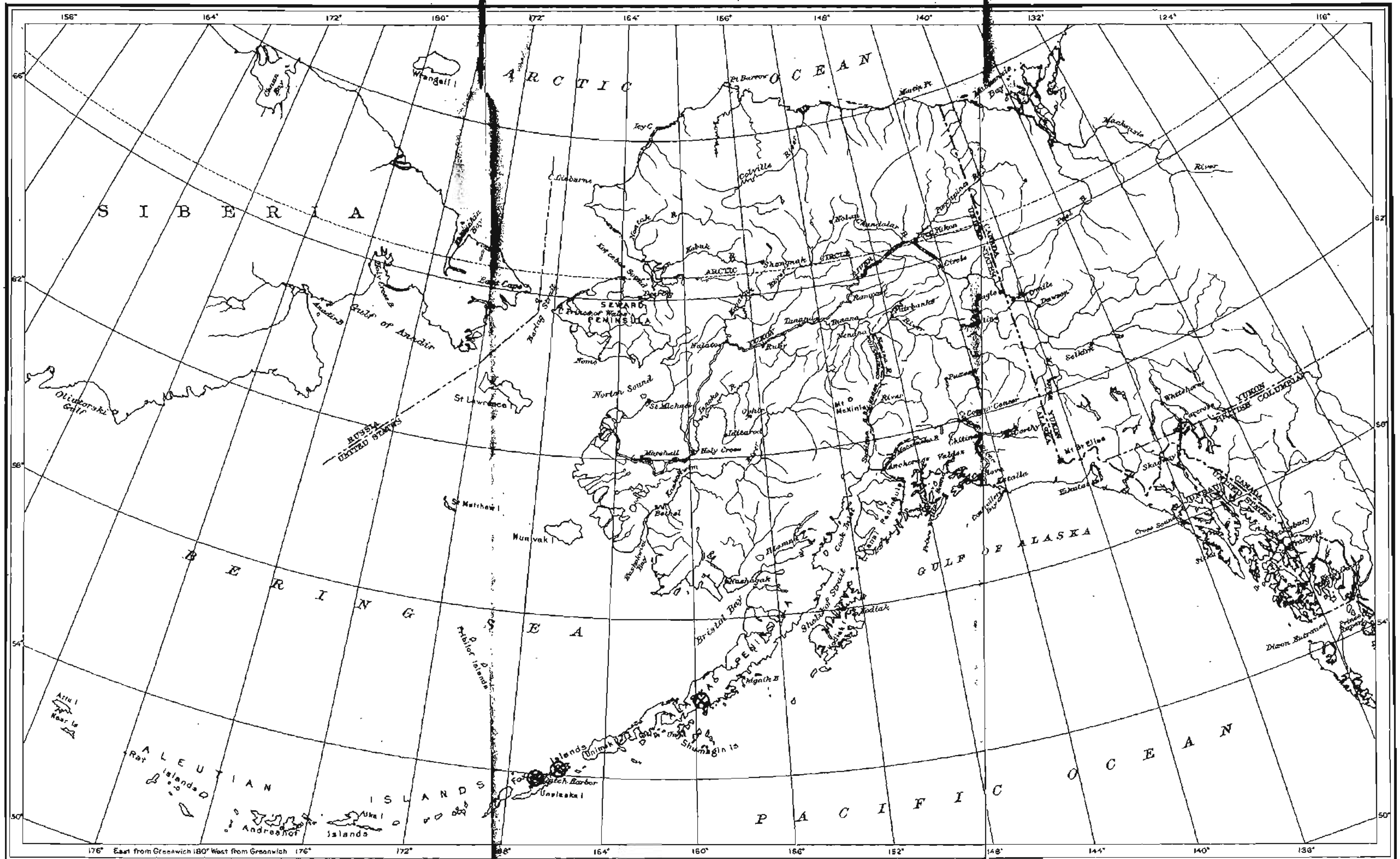


MAP OF ALASKA SHOWING LOCATION OF SULPHUR DEPOSITS

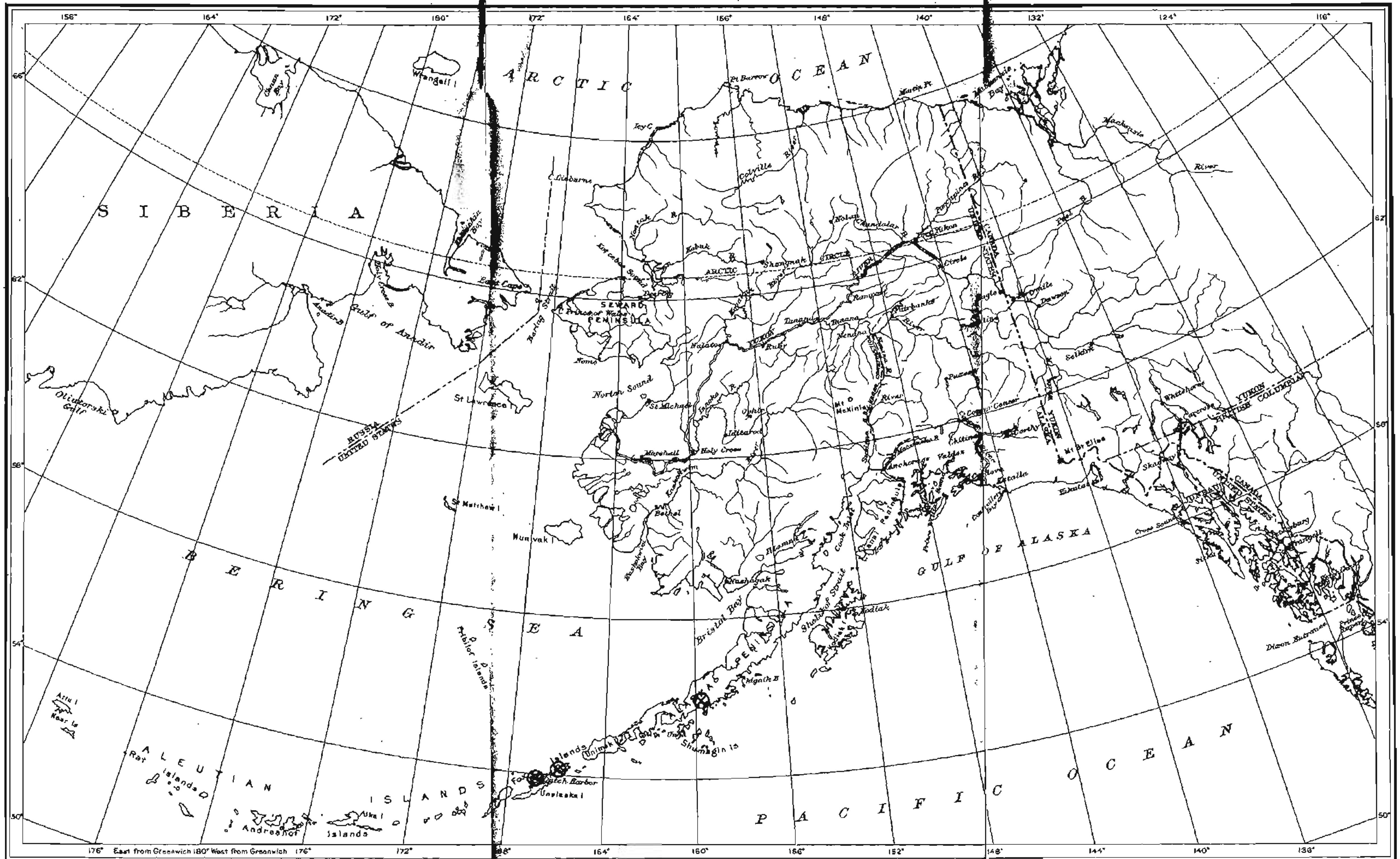
100 0 100 200 300 400 500 Miles

100 0 100 200 300 400 500 Kilometers

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY



MAP OF ALASKA SHOWING LOCATION OF SULPHUR DEPOSITS



MAP OF ALASKA SHOWING LOCATION OF SULPHUR DEPOSITS

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

on the northwest side, at Big Gap, and at lesser gaps in the south and southeast sides.

The floor of the crater is 300 to 500 feet below the higher crags of the rim, but the floor of the basin is exposed only in an area of 20 to 30 acres, where the sulphur deposits occur. Except in this bare area, the basin is occupied by glacial ice and snow that probably is several hundred feet thick in the central part of the basin. This ice and snow sags away from the walls of the crater and presents a concave surface that slopes northwestward to the Big Gap. This gap is the chief outlet of the crater, and the flow of ice toward it is indicated by the crevasses.

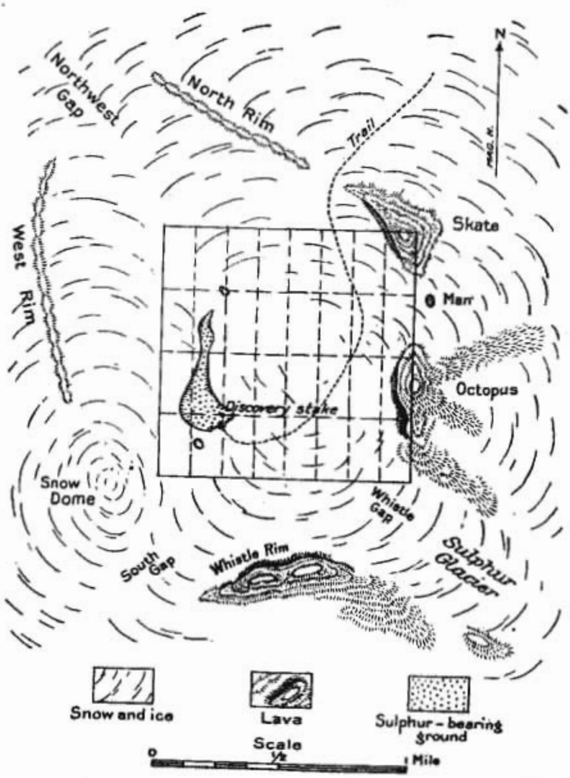


FIGURE 8.—Sketch map of part of Makushin Volcano showing location of sulphur claims.

THE SOLFATARA.

POSITION AND CHARACTER.

The sulphur deposit of Makushin Volcano is situated a short distance southwest of the center of the crater and is the only part of the crater that appears to be permanently free from snow and ice. The bare area comprises a main southern portion about 1,200 feet long and 700 feet wide and a narrow tongue-like strip that extends north from the main area for about 1,500 feet and has an average width of 200 feet. (See fig. 9.) The area of these tracts is estimated to be 20 and 10 acres respectively. Some minor marginal patches extend beneath the overhanging edges of the ice. These marginal areas are, however, a variable quantity and are inaccessible, because they comprise the floors of grottoes or caverns and tunnels melted from the under surface of the snow and their roofs collapse from time to time.

Although the earth is highly siliceous no sinter deposits were observed. Slight cementation occurs, but the somewhat crusty character of the surface zone seems to be due in part to the drying out induced by the warmth of the ground and also to the deposition of sulphur in the upper 1 or 2 feet of porous ground, especially on the immediate surface of the tracts that are more or less constantly bathed by sulphurous vapors.

SOLFATARIC ACTION.

The most striking feature is the rather vigorous solfataric activity of the greater part of the bare ground. This activity may be divided into two phases that are somewhat distinct but nevertheless closely related. The most manifest activity is the discharge of hot sulphurous vapor that deposits sulphur in the cooler part of the deposit. The other phase of solfataric activity is the corrosive chemical action upon the rock in the zone of oxidation, which has caused the formation of a highly decomposed earthy residue that includes the bulk of the sulphur-bearing deposit and that rests upon the volcanic rocks from which the hot vapor emanates. Sulphurous and sulphuric acids probably are formed in small quantities in this surface zone.

The most active escape of hot vapor seems to be in the southern part of the area of bare ground near the highest part of the ridge. At this place vapor at relatively high temperature issues with a roaring sound from several openings. The largest vent is at the southeast end of the ridge in the lower wall of a pit, about 75 feet in diameter and 40 feet deep, the bottom of which is filled with steaming gray mud. The sound from this fumarole can be distinctly heard for a distance of half a mile. The temperature of this fumarole was not measured, but that of a smaller one on top of the ridge was 310° F. at a point 2 feet down its throat. Temperatures of 170° and 180° were observed in crevices from which the escape of vapor was much less active, and fragments of ice were boiled in about 10 minutes in a kettle placed over one of the openings after the crust of sulphur that partly sealed it was broken away.

The temperature of 310° F. indicates that the vapor is far hotter than the melting point of sulphur, which liquefies at about 240°. It was noted that no sulphur was being deposited where the temperature was 310°, although near the cooler border of the opening was a thin incrustation of sulphur.

Several test holes that were drilled into cooler parts of the deposit tapped hot sulphurous vapor at depths of 4 to 8 feet, indicating that the porous earthy mantle is more or less charged with hot vapor. Thus it appears that except for a comparatively thin superficial zone the solfataric deposit as a whole is probably too hot at a short distance below the surface to permit the deposition of sulphur, or conversely that the heat of the deposit below the surface is sufficient to keep most of the sulphur that may be present in a molten or vaporized state until it reaches the surface. In this connection it may be noted that sulphur may be extracted from ores of this character by melting it with steam under a pressure of about 60 pounds to the square inch. Steam under this pressure has a temperature of about 292° F. No field evidence was noted, however, of any of the sulphur having been melted after its deposition by sublimation.

The commercial bodies of sulphur in this deposit are clearly surficial. The percentage of sulphur at the surface does not indicate that rich deposits exists at depth, as is usually believed by the optimistic prospector.

THE SULPHUR DEPOSITS.

OCCURRENCE.

The richer deposits of sulphur occur within 2 feet of the surface, but there is also more or less finely divided sulphur disseminated to a depth of at least 16 feet, the greatest depth from which samples were obtained. Some of the finely divided sulphur may be redeposited, especially in the earthy accumulations along the lower flanks of the ridge, but most of it was undoubtedly sublimed from the vapor where it is now found.

The most conspicuous deposits of sulphur occur along crevices or large clefts that intersect the surface of the ground in many directions and around the holes from which large volumes of hot vapor issue continuously. Some of the larger holes are true fumaroles. The cracks in the surface might be attributed to shrinkage of the earthy mantle, but as they have no geometrical arrangement it is more probable that they lie just above open fissures in the underlying rock.

The largest masses of sulphur occur as irregular pieces, some of which are 8 to 10 inches in diameter. These pieces have more or less completely sealed the vents. Incrustations of sulphur an inch or more thick are being deposited on the lips of crevices and about the open vents. Hot sulphurous vapors issue from these openings in considerable volume, but only small amounts of vapor escape from sealed crevices. There may be a circulation of the sulphurous vapors from one set of crevices to another or from one part of a crevice to another part as the sealing progresses, the vapors seeking an outlet along passages of least resistance. In this way the sulphur may become distributed over the solfataric area.

At present the most abundant deposition of sulphur appears to be in the crevices and vents which have temperatures of about 170° to

180°. Comparatively little sulphur is being deposited about the hot fumaroles, such as one whose temperature is approximately 310°.

In addition to the sulphur that may be brought from primary sources in the hot vapors and deposited directly at the surface, it is probable that sulphur is revolatilized from the hot lower zones of the deposit and recondensed in the cooler surface zone. Thus there may be a migration of the sulphur from deeper parts of the deposit to its surface. It also seems possible that some of the sulphur reaches the surface dissolved in superheated water vapor and is directly sublimed upon condensation of the water vapor in the cool atmosphere.

Some of the sulphur may be precipitated from mixtures of hydrogen sulphide (H_2S) and sulphur dioxide (SO_2), two compounds which presumably can not exist together and which when commingled set sulphur free. To judge by the odor, small quantities of both these compounds seem to emanate from the solfatara, but they undoubtedly constitute a very small percentage of the total vapor. The odor of hydrogen sulphide was evident but not very marked. As one ten-thousandth part of sulphur dioxide in air is intolerable to human beings there probably is not much sulphur dioxide in the vapor, for no particularly suffocating effects were experienced upon breathing the vapor, even near the hot fumaroles. Water vapor is by far the most abundant emanation. It contains some dissolved sulphur which it deposits when it is condensed on the ice.

AMOUNT.

The sulphur deposit has not been sampled comprehensively, and it is very doubtful whether ordinary methods of sampling will give sufficiently accurate results to serve as a reliable basis for estimating the content of sulphur.

The deposit may be divided roughly into two zones on the basis of percentage of sulphur—a richer zone that forms a surface layer from 1 to 2 feet thick that seems to owe its crusty character chiefly to the sulphur deposited in it, and a poorer subsoil zone that consists in greater part of moist, hot, porous, decomposed material in which a small percentage of sulphur is disseminated as grains and blebs to a depth of at least 15 to 20 feet at some points.

The surface crust of the solfatara is rather irregular in general contour and quite uneven and hummocky in relief. Its minor ridges, hollows, and hummocks seem to owe their form partly to uneven deposition of sulphur along the intricate mesh of crevices and vents and partly to subsequent erosion by wind and rain. The higher tracts along the main ridge of the solfatara appear to owe their general prominence to the proximity to the surface of the lava, which probably underlies the whole solfataric area at no great depth, for all the blocks that are scattered about on or protrude from the surface of these tracts are of a uniform crystalline basalt and the walls of the fumaroles and larger openings appear to be similar solid rock to a level within a foot or so of the surface.

No definite data regarding the thickness of the lower layer or zone are at hand, and it can not be assumed that the earthy mantle has a uniform thickness throughout the solfataric area. It is assumed to be thickest along the lower flanks of the area, where it has been tested to a depth of at least 16 feet. Over some of the higher tracts it is generally thin and in places is entirely absent.

The sulphur is very irregularly distributed even in the crusty surface zone of the deposit. Although practically pure masses of sulphur occur as fillings in some of the dormant and semidormant crevices and vents and seal their outlets it does not extend down these openings very far. Some of these masses are estimated to contain several cubic feet of reasonably pure sulphur that could be mined by careful hand methods. The aggregate crevice and vent space thus occupied with sulphur is relatively small. Although a few of the crevices are 10 to 12 inches wide, most of them are not more than 2 or 3 inches wide, and the cracks and crevices in which sulphur has been deposited are about the same size. The sulphur-bearing crust between the crevices averages about 12 inches in thickness, although in some places it is as much as 2 feet. In many places the upper half of this crust is composed chiefly of sulphur, and the lower half contains a large percentage of earthy material. The amount of sulphur in the solfatara is not so striking as the area of gray earth, streaked and dotted here and there by the sulphur deposited along discontinuous cracks and about small vents that are irregularly distributed over the surface of the ground in more or less definite tracts.

Of the approximately 20 acres of bare ground that comprise the main area of the solfatara probably not more than 5 acres, in the southern part of the area, may be classed as containing a good grade of sulphur-bearing material, the remainder being of inferior grade, and only certain rather small tracts in the 5 acres of better ground contain high-grade material, even in the surface crust zone. Probably the average sulphur content of this surface crust is about 60 per cent of the material that would be handled in mining. If this estimate is correct it indicates about 260,000 cubic feet of sulphur, on a basis of 2 feet of depth, which is 12,500 tons at 125 pounds to the cubic foot.

The high-grade sulphur deposited at the open vents is about 98 or 99 per cent pure and is estimated to constitute about 5 per cent of the surface material as a whole. It is estimated that about 70 per cent of this surface material, to a depth of 1 or 2 feet, is composed of material of which four analyses show a sulphur content of 86.3

to 89.6 per cent and average about 88 per cent. According to these figures, the average sulphur content of the surface material to a depth of 1 or 2 feet is about 60 per cent. If the weight of the dried material is about 70 pounds to the cubic foot, as is indicated by the determination of the specific gravity of a sample that was assumed to be representative, the 5 acres of better ground should contain about 1,800 tons of sulphur to the acre within 2 feet of the surface.

It is difficult to make even a rough estimate, like that just given, for the sulphur content of the remainder of the deposit, especially of the earthy portion beneath the surface crust. In the first place this earth can not be assumed to be of uniform thickness, and secondly, in the absence of comprehensive sampling over the whole area, the quantity of sulphur that may be disseminated in it is a matter of conjecture. Five samples taken in the southwestern flanks of the deposit from depths of about 4, 8, 10, 12, and 16 feet contain, respectively, 47, 29.8, 14.7, 13.8, and 9.5 per cent of sulphur, averaging about 23 per cent. If this average holds the zone from 2 to 16 feet below the surface should contain from 716 tons of sulphur for each acre-foot at a depth of 4 feet to 145 tons for each acre-foot at a depth of 16 feet, or a total for the entire 14-foot zone of 4,900 tons to the acre.

PURITY.

The chief impurity of the sulphur is the earthy material in which it is deposited. In the small samples collected by the writer this impurity ranges from 1.5 or 2 per cent in selected pieces of solid sulphur to 75, 80, and even 90 per cent in the poorer earthy material. This finely divided earthy impurity is composed chiefly of silica and lime and is comparatively light in weight. The separation of the sulphur could be accomplished by heating the ore, for the sulphur would melt at a relatively low temperature and be drained off, making a commercial product of nearly pure sulphur.

AKUN ISLAND.

GEOGRAPHY.

Akun Island lies on the western side of Unimak Pass about 23 miles southwest of Unimak Island. (See fig. 10.) The settlement of Unalaska, on Unalaska Island, is about 45 miles southwest of the northern end of Akun Island.

Akun Island is about 12 miles long from north to south, has a very irregular coast line, and the northern part is nearly divided from the southern part by two large embayments that lie opposite each other—Akun Cove on the east coast and Lost Harbor on the west coast. The heads of these bays are separated by a strip of low land about 1 mile wide. Except this narrow strip of land, the island is comparatively high and has a general rolling relief that is marked by rugged ridges. Rugged topography is particularly characteristic of the northern

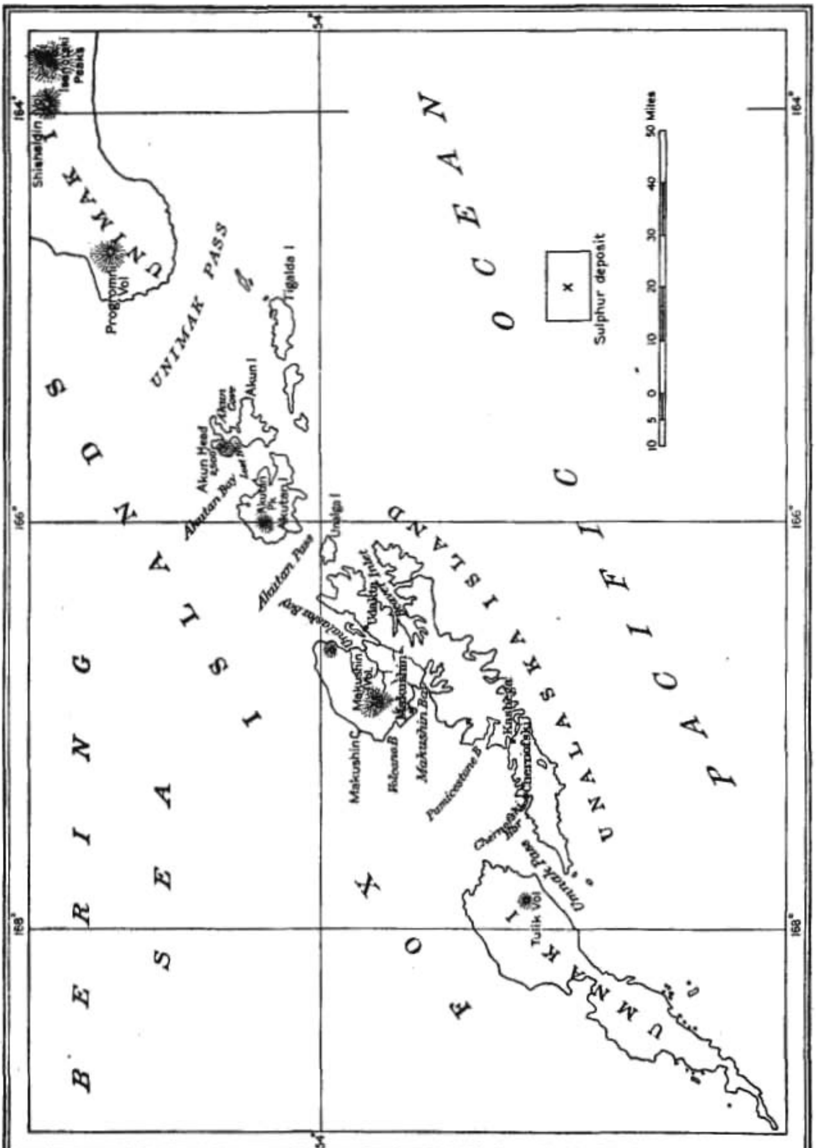


FIGURE 10.—Map of Unalaska and Akun islands showing location of sulphur deposits.

third of the island, the highest point of which is the summit of a roughly conical volcanic mountain 2,500 feet high. This volcanic mountain, locally called Akun Peak, stands near the northwest shore, and its westward and northward slopes terminate as abrupt sea cliffs 500 to 1,000 feet high.

GEOLOGY.

The hard rocks of Akun Island consist at the base of rudely stratified volcanic fragmental materials (agglomerates and tuffs) that are overlain by andesitic lava flows. Each of these formations is 1,000 feet thick where it attains its maximum development. Akun Peak is a typical volcanic cone and appears to have been one of the chief centers of outflow for the lava in the northern part of the island. Its conical form suggests that it is a comparatively recent volcano, and the lavas that flowed from it are little altered except by surface weathering. On the other hand, the basal deposits of agglomerates and tuffs, upon which the lavas rest, are considerably cemented and oxidized, and it is probable that they are considerably older than the lavas. At one exposure on the north side of Lost Harbor, where the contact between the lavas and the agglomerates and tuffs is well displayed, it is evident that the lavas flowed out and buried an old land surface that had been eroded in the agglomerates and tuffs.

THE SULPHUR DEPOSIT.

LOCATION AND AREA.

The sulphur-bearing area on Akun Island, upon which mining claims have been located (see fig. 11), is situated on the upper flanks of a rugged mountain ridge, 1,800 feet high, that lies about a mile northeast of Akun Peak. This ridge is a somewhat detached outlying spur

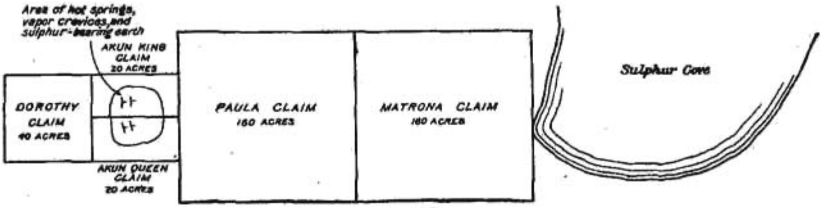


FIGURE 11.—Sketch of sulphur claims on Akun Peak.

of Akun Peak, and divides the northward and southward drainage of this part of the island. The solfatara lies in the broad headwater basin of a steep gulch that descends to a small cove immediately west of Akun Head on the north shore of the island and is about 1 mile from the cove. The southward drainage from this ridge flows to the north shore of Lost Harbor in a gulch about 2 miles long, and the easiest approach to the solfataric locality is by way of this valley. The best route is along its eastern slopes and thence through a small gap, at the head of a tributary gulch, that lies immediately south from the deposit at an altitude of 1,600 feet. The sulphur-bearing area is between 15 and 20 acres in extent and stands from 1,300 to 1,500 feet above sea level, but the part of the deposit that is characterized by mild solfataric activity comprises only about 5 acres.

VOLCANIC ACTIVITY.

The solfatara is in rather mild or semidormant activity. Within the smaller area of about 5 acres small volumes of steam and scalding water, accompanied by a small quantity of hydrogen sulphide gas (H_2S), issue from fissures at widely spaced intervals, and the remainder of the area shows no particular evidences of the escape of subterranean heat. The most striking evidence of solfatarism is of chemical decomposition of the rock.

GENERAL FEATURES.

The surface of the deposit consists of highly decomposed material, apparently of residual origin, that resembles the deposits of the solfatara in the crater of Makushin Volcano but is thinner. This earth is light gray to dull yellowish and forms a mantle from 1 to 4 feet thick. Much of it is essentially in place, but the steepness of the slope on which it rests has caused movement of some of the material and the hot waters that flow from crevices are transporting a small quantity to lower levels.

The earthy deposit is of uniform character throughout the area as is proved by the sections exposed in numerous open cuts that were dug in 1917. Many of these excavations are only 4 to 5 feet deep, but about six of them are from 12 to 15 feet deep and show the nature of the ground. All these cuts show a highly decomposed, leached, porous surface layer of light-gray earth from 1 to 4 feet thick that conforms to the slope of the ridge.

Beneath the surface layer is a zone of dark-gray semileached decomposed rock which in some places where it is saturated with water resembles massive clay. This zone ranges from 6 to 10 feet in thickness, and in its lower parts, where less decomposed, the joint planes and brecciated fragments may be seen. Along some of the seams in this subsurface zone a small quantity of alum salts is being deposited. This salt indicates that one of the changes which is taking place in the country rock is the decomposition of the feldspars.

In the bottoms of the deepest cuts, 12 to 15 feet below the surface, the highly decomposed rock of the subsurface zone grades downward into a less decomposed compact crystalline rock and although considerably altered shows the mineral constituents distinctly.

The highly decomposed rock and earth within the solfatara appears to be directly derived from the andesitic lava that composes the body of the mountain ridge, good outcrops of which may be observed on the crest of the ridge immediately above the solfatara. The area of the sulphur-bearing earth is clearly a locality where solfataric vapors have found an outlet and have intensely decayed the rock by highly corrosive chemical reactions.

The present solfataric activity at this locality is of a much milder stage than that of the solfatara on Makushin Volcano. In fact on Akun Island the activity seems to be entering into the hot spring stage. The evidence furnished in the open cuts as to the relatively shallow depths to which the solfataric decomposition extends indicates that this solfatara has never been extremely active. This conclusion is further indicated by the comparatively small amount of sulphur present.

THE SULPHUR.

MODE OF OCCURRENCE.

The sulphur in this deposit occurs chiefly in the form of crystalline incrustations one-sixteenth to one-eighth of an inch thick on the walls of narrow crevices and small cavities in the porous earthly surface zone. Most of the crevices are not more than one-eighth inch wide, and few of the larger ones are as much as one-fourth to one-half inch wide, and usually they are only partly filled with sulphur. Some sulphur is also disseminated through the decomposed material, but there are practically no solid bodies of sulphur, even of small size, in any part of the deposit. Apparently a small quantity of sulphur has also been deposited in the cooler parts of the subsurface zone, as is shown by incrustations observed along the walls of the deeper open cuts at points 10 to 12 feet below the surface, but this sulphur may have been deposited since the excavations were made by small jets of water vapor that now find an easier passage into the excavations. The sulphur-bearing vapor evidently rises through the material of the subsurface zone from a subterranean source by way of rather tight seams that mark joint fractures in the original lava. Where these crevices have been exposed in the excavations the vapor issues from them.

The temperature of the vapor is little above the boiling point (212° F.), and scalding water issues from some of the crevices, indicating that a considerable volume of the vapor condenses before reaching the surface.

AMOUNT.

Most of the sulphur in this deposit occurs in the porous earthy mantle within 1 to 4 feet of the surface. The average thickness of this mantle is believed to be about 2 feet. Two samples, one taken at the surface and the other at a depth of 4 feet, contained 55.5 and 22.8 per cent of sulphur, respectively. If the average thickness of the sulphur-bearing surface mantle is 2 feet, and if its average sulphur content is 40 per cent, it should contain 1,200 tons of sulphur per acre.

MINING AND SHIPMENT.

Although this deposit is of low grade and is not very extensive, it is fairly accessible. If the material should prove to be of sufficient value to justify mining it, there are no engineering difficulties to hinder development.

The sulphur-bearing material can easily be excavated and could then be transported to Lost Harbor by an aerial cable tramway that would be a little more than 2 miles long. The rise from Lost Harbor to the gap in the ridge about 1,000 feet south of the solfatara is 1,600 feet and the descent from this gap to the deposit is only 200 to 300 feet.

The sulphur doubtless could be extracted from its earthy gangue by melting in retorts with steam, but there is no fuel on the island. Oil, however, is now shipped from California to a whaling establishment on Akutan Harbor, 10 miles from Lost Harbor, for use in generating steam, and coal which might be developed for local use is reported to occur on Avatanak Island, about 5 miles southwest of Akun Island. It would probably be unprofitable to ship the sulphur-bearing earth in bulk to a distant point for treatment.

Lost Harbor does not afford good shelter for vessels, as it is open to the heavy southwest swell of Bering Sea and has a rocky bottom. Several vessels have been wrecked on its shores because their anchors failed to hold.

STEPOVAK BAY.

Stepovak Bay is on the south shore of Alaska Peninsula in latitude 56° N. and longitude 160° W. The only important sulphur deposit reported in the vicinity (see fig. 12) is about 7 miles northwest of the head of the bay, at an altitude of 3,000 feet, near the crest of the Aleutian Range, which is glaciated and contains numerous dormant or active volcanoes. This deposit was not visited because of the danger in crossing the crevassed glaciers covered with newly fallen snow that obstruct the only available route to it. As seen from a distance of about 2 miles, the supposed sulphur-bearing bed is a light-colored zone 100 feet thick and half a mile long in the wall of a cirque that may be the site of an extinct crater. A glacial moraine that extends from this cirque consists largely of sulphur-bearing rock that was probably derived from the light-colored band already noted.

The sulphur-bearing rock in the morainic deposits consists of porous volcanic breccia that contains compact crystalline sulphur in the interstices of the breccia and also in the vesicles of the constituent fragments. Some specimens probably contain 20 per cent sulphur (by bulk) in veins one-eighth to one-fourth inch thick and show masses up to 1 inch long at the intersections of the veins. In much of the rock the sulphur is finely disseminated and probably does not constitute more than 5 or 10 per cent of the rock. In regard to the sulphur content of the morainic material as a whole, it may be stated that parts of the moraine may contain 10 per cent

FIGURE 12.—Map of Stepovak Bay and vicinity showing location of sulphur deposits.

of sulphur, but larger parts are practically barren. The material in the moraine is probably poorer in sulphur than the bed from which it was derived and furthermore is a mixture of many different rocks rather than of those from the best parts of the sulphur deposit. Some of the sulphur-bearing boulders are 30 to 40 feet thick, thus indicating a minimum thickness for the bed from which they are derived. The abundance of the sulphur-bearing material in the moraine also indicates that the original source was of considerable extent.

THE BEACH PLACERS OF THE WEST COAST OF KODIAK ISLAND, ALASKA.

By A. G. Maddren.

INTRODUCTION.

This paper is based on about three weeks' field work in July, 1917. Previous to the writer's visit the west coast of Kodiak Island had not been examined by the Geological Survey since 1895, when Becker and Dall [1] landed there in the course of an extended cruise along the Pacific coast of Alaska. Becker [2] published a brief account of the beach placer mining in progress at the time of his visit.

It is not known in what year placer gold was discovered in the beach sands on the west coast of Kodiak Island, but mining has been carried on there for about 30 years, and the value of the annual production of gold is estimated to have been from $3,000 to $10,000 during that period. The total production of the west coast district is variously estimated to be from $50,000 to $150,000.

It is stated that as many as 100 men have mined along this coast in some years, especially during seasons when heavy storms have reworked and concentrated the sands, but generally the number of miners has averaged not more than 25. In 1917, when the writer visited the district, only about 12 men worked for part of the year. The most profitable operations have been conducted early in the spring and late in the autumn. During the winter the beach deposits are often frozen, and during the summer the patches of sand that contain the best concentrations are as a rule covered by an overburden of light sands that is unprofitable to remove.

GEOGRAPHY.

GENERAL RELATIONS.

Kodiak Island (see Pl. VIII) is situated between 57° and 58° north latitude and 152° and 155° west longitude. It is about 90 miles long from northeast to southwest and 50 miles wide from

[1] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 800, 843, 1896.

[2] Becker, G. F., Reconnaissance of the gold fields of southern Alaska: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 86, 1898.

northwest to southeast and is the largest of a group of islands that is separated from the mainland of the Alaska Peninsula, about 30 miles distant, by Shelikof Strait. Afognak Island, the only other large member of the group, lies northeast of Kodiak Island and is separated from it by a narrow channel. The remainder of the group comprises about 12 islands of comparatively small area, which are distributed along the shores of the two large islands. The group as a whole is about 150 by 50 miles in extent and trends southwesterly. In general it may be considered to be the submerged extension of the Kenai Peninsula, which lies to the northeast, just as Shelikof Strait may be considered the southwestward extension of Cook Inlet.

RELIEF AND SHORE LINE.

The surface of Kodiak Island and also its associated islands is dominantly rugged and mountainous. Altitudes of 1,500 to 2,500 feet are reached in many sections of the coast, and in the central interior several summits stand between 4,000 and 4,500 feet in elevation. The greater part of the shores is rock-bound and rugged, and the coast line, which is generally irregular, is indented by numerous deep narrow fiords and bays, some of which extend far inland. Many sections of the coast are bordered by outlying rocky islets and reefs, and most of the bays are more or less strewn with rocks.

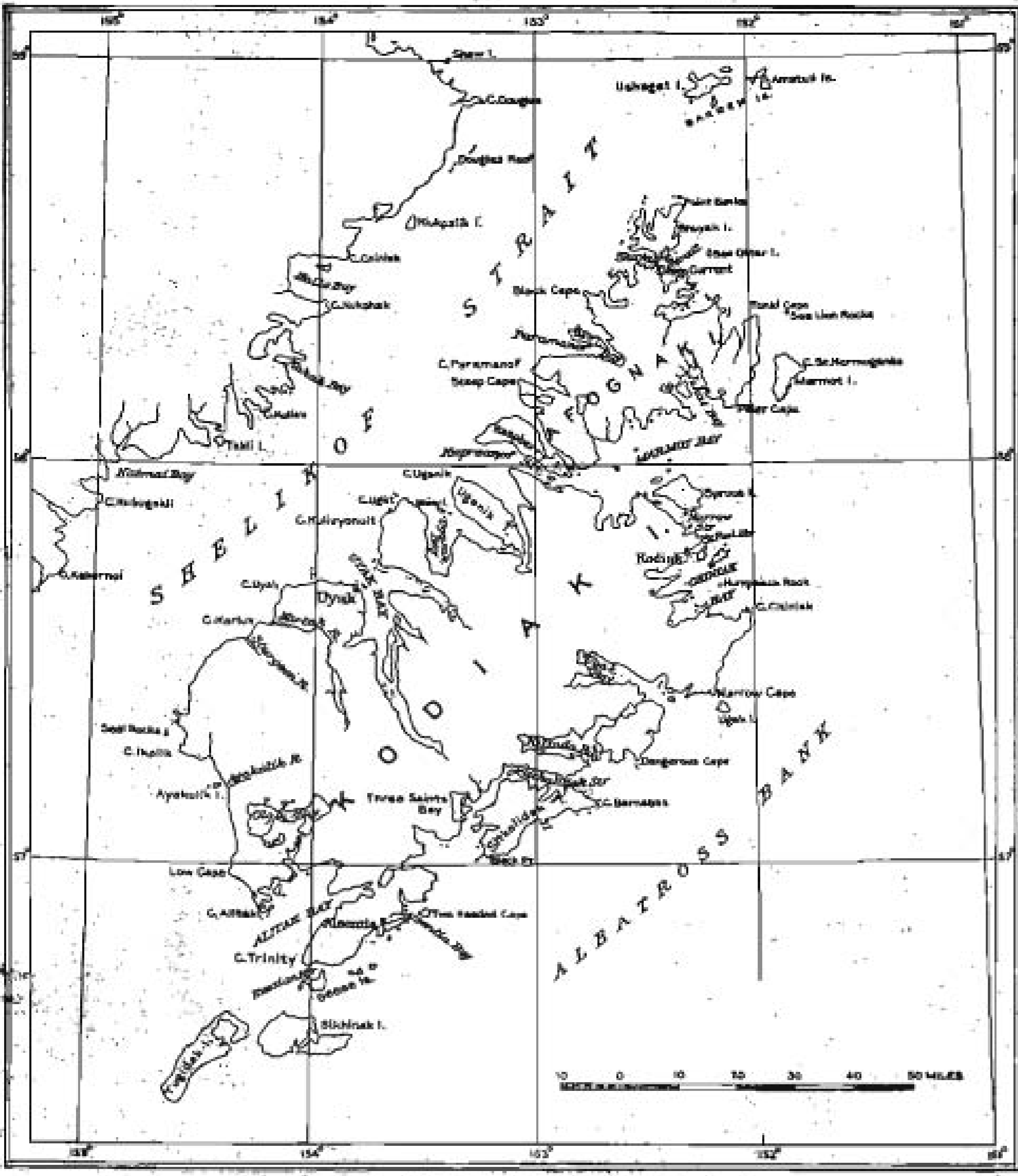
GEOLOGY.

Only the general features of the bedrock geology of Kodiak Island are known. These features have been briefly described by Martin,[1] but the observations of the writer in the western part of the island have increased the knowledge of that district. In this report the geology, as described by Martin, will be reviewed and will be supplemented by the notes of the writer concerning the western part of the island.

GENERAL FEATURES.

The rocks of Kodiak Island and the neighboring islands consist chiefly of slates and graywackes, which are cut by numerous but for the most part small intrusive masses, partly granitic. Schists that probably underlie the slates and graywackes are present along the northwestern part of the island, and small areas of poorly consolidated Tertiary sediments are reported to lie along the southeastern flanks of the island. Quaternary sediments that consist of ground moraine overlain by glacial outwash gravels and recessional moraines occupy the floors of all the larger valleys and form a considerable belt

[1] Martin, G. C., Mineral deposits of Kodiak and the neighboring islands: U. S. Geol. Survey Bull. 542, pp. 128–131, 1913.



MAP OF KODIAK ISLAND.

of coastal plain along the west coast. The sequence of the rocks may be expressed as follows:

Sequence of rocks of Kodiak Island, Alaska.

Quaternary:
- Present stream and beach deposits. Glacial outwash sediments, recessional moraines, and terrace gravels due to glacial ponding, ground moraine, or till.

Tertiary (?):
- Sandstones.
- Lignite-bearing beds.

Mesozoic (?):
- Granitic intrusive rocks.
- Graywacke and slate.
- Cherts and volcanic rocks of Triassic (?) age.

Paleozoic (?):
- Schist, greenstone, quartzite, and marble.

SCHISTOSE ROCKS.

Schistose rocks have been observed in only a small area on the northwest shore of Kodiak Island between Uyak and Sevenmile Beach, but from the reports of prospectors such rocks probably form a belt that extends southwestward from Uyak to the vicinity of Cape Ikolik and northeastward parallel to the northwest shore of the island, where they appear in outcrops on most or all of the promontories that overlook the coast of Shelikof Strait. Near Uyak these rocks comprise fine-grained quartzitic schist, crystalline limestone, and chloritic schist and constitute a group of diverse lithologic character but of uniform degree of metamorphism and structural complexity.

Associated with the schistose rocks are cherts and lavas, presumably of Triassic age, and slates and graywackes, but the relationship of these rocks to the schists has not been determined. However, it is presumed that the schists are older than the cherts and volcanic rocks, which are tentatively considered to be of Triassic age because they closely resemble similar rocks in Seldovia Bay, on Kenai Peninsula, that are definitely known to be of Triassic age. At Seldovia Bay highly metamorphosed rocks similar to the schists here considered are closely associated with the cherts and volcanic rocks.

On the west coast of Kodiak Island schistose rocks which correspond to those near Uyak were not observed in place, although pebbles and cobbles of this character were found in the beach deposits. These materials may be derived from the Cape Ikolik peninsula, where some schistose rocks are reported to occur. This area was not examined, except in its southern part, where observations were made along its south shore for a short distance west from the mouth of a stream that is locally known as Old Red River. At this locality the rocky sea cliffs consist of highly deformed and somewhat severely metamorphosed volcanic agglomerates, tuffs, and breccias whose massive bedding strikes east and dips 40°–50° N. These rocks are composed primarily of volcanic fragmental materials, but some of the tuffaceous parts contain rounded cobbles of dark-blue, finely crystalline, hard brittle limestone. The tuffaceous matrix in which these limestone cobbles are embedded is schistose and well foliated, especially around the limestone cobbles, to which it is firmly welded. Some members of this formation are highly silicified, and one massive member in particular is altered to a bright-red jasperoid rock, but it shows no bedding-like sedimentary cherts.

Possibly these volcanic clastic rocks of the Cape Ikolik area represent a lithologic phase of the cherts and volcanic rocks near Uyak, which are presumed to be of Triassic age. However, the degree of metamorphism of the Cape Ikolik rocks suggests that they may be more closely related in age to the schistose rocks of the island.

SLATE AND GRAYWACKE.

A series of interbedded slates and graywacke sandstones of considerable thickness forms most of the bedrock of Kodiak Island, to judge from the widespread outcrops of these rocks that have been observed along the northeast and northwest coasts, in the mountains of the southwestern part of the island, and along the shores of the long fiord inlets, such as Uyak and Alitak bays, that extend far into the interior. Apparently the only other rocks that may displace any considerable areas of these rocks in the interior of the island are massive bodies of granitic intrusive, one of which occupies a considerable area along the shores of Alitak Bay.

For the most part these semimetamorphosed sediments consist of approximately equal amounts of interbedded graywacke sandstone and slate in moderately thin beds, but in some outcrops the beds are more massive. Some conglomerate is present here and there; in one outcrop it is a hundred feet or more in thickness in the foothills north of upper Olga Bay.

The slates and to a less degree the graywackes have well-developed secondary cleavage, which has generally obliterated the bedding except where marked differences in composition preserve it. In general the dynamic metamorphism that has affected these rocks is expressed chiefly as thin cleavage in the slate members, which commonly show a tendency toward foliation, and as brecciation of the argillaceous graywacke members, which is generally marked by an intricate network of quartz veinlets deposited along the fractures. In some zones, however, the quartz-vein mineralization is chiefly of the tabular type, extending along bedding planes.

The stratigraphic thickness of these slates and graywackes and their structural details are not known, but a thickness of at least several thousand feet and probably a much greater thickness is indicated. Isoclinal structure appears to be dominant. The average strike of these rocks throughout the island is northeastward, parallel with the trend of the belt, which ranges from N. 20° E. to N. 60° E. (true), and the dip ranges from 20° to 80° NW.

INTRUSIVE ROCKS.

The slates and graywackes of Kodiak Island are intruded by small dikes and sills, among which quartz-mica diorite, porphyrite, and soda rhyolite have been recognized. Large massive intrusive bodies of quartz-mica diorite and mica granodiorite also occur at wider intervals, and several such bodies have been noted along the northeastern coast and in the southwestern part of the island. Becker[1] has described such a granite mass which forms Karluk Head, and the writer observed two large granitic areas in the vicinity of Alitak Bay, one of which forms the peninsula of Cape Alitak and the mountain mass named the Twins, immediately north of Lazy Bay, and the other a promontory locally known as Stockholm Point, on the south shore of lower Olga Bay.

In general the age of these intrusive masses is considered to correspond to that of the great bodies of similar rocks that are widely distributed throughout the coastal provinces of Alaska and which, where stratigraphic evidence is available, have been assigned with considerable assurance to late Mesozoic or early Tertiary time.

TERTIARY SEDIMENTS.

The Tertiary sediments so far reported to occur on Kodiak Island appear to be distributed almost wholly along the southeastern or Pacific seaboard of the island, although rocks of this age have been mentioned in Russian reports of doubtful accuracy as occurring in the northwestern part of the island.

The only locality examined by the writer from which Tertiary sediments have been reported is that mentioned by Dall[2] as situated in the bight of the west coast near Red River (locally known as Old Red River) about 2 miles north of Ayakulik Island. Upon careful examination the outcrops that presumably were referred to the Tertiary prove to be marine beach sediments interbedded with deposits of till, which are described under "Quaternary deposits." (See pp. 311–316.)

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[1] Becker, G. F., Reconnaissance of the gold fields of southern Alaska: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pp. 36, 41–42, 1898.

[2] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, p. 800, 1896.

The best-developed Tertiary sediments on Kodiak Island are fresh-water deposits which contain beds of lignite and are generally referred to as of Kenai (Eocene) age. Sediments of this character are reported at several localities along the southeastern coast of the island, particularly in the vicinity of Kiluda Bay; and also on the high island of Sitkinak, situated a few miles south of Cape Trinity, the southwestern extremity of Kodiak. The lignite-bearing deposits of Sitkinak Island are reported to contain a number of coal beds, one of which is said to be 10 to 12 feet thick.

QUATERNARY DEPOSITS.

OCCURRENCE.

Unconsolidated deposits of Quaternary age are well developed in many parts of Kodiak Island, especially about its borders, and more particularly in its southwestern part, where they form a coastal plain of considerable extent. As the sediments of this coastal plain constitute a complete section of the Quaternary deposits, from the oldest to the youngest, a description of them may serve for the whole island.

The thick covering of volcanic detritus that was deposited over all the northeastern part of the island by the eruption of Mount Katmai in June, 1912, did not extend west of Uyak Bay in noteworthy amounts and need not be considered in connection with the strictly sedimentary deposits, although fragments of pumice occur in the beach deposits.

CLASSIFICATION.

The unconsolidated sediments of the island may be divided, according to the manner in which they have been formed and deposited, into four rather distinct but related classes. In sequence from oldest to youngest these classes comprise (1) the ground moraine or till deposited by glacial ice during the period when the ice was advancing over the island from the interior mountainous highlands to and beyond the present shore line; (2) the widespread sheets of outwash gravels, sands, and silts that rest upon or are incorporated with the till and were formed by streams that accompanied the melting of the glacial ice during its movements of retreat from its maximum limits back to the mountains; (3) the terminal and lateral moraines which were deposited by the glaciers at points where they halted temporarily during their retreat into the mountains, and the most prominent of which now form the dams that retain the large lakes occurring in many of the glaciated valleys; and (4) the sands and gravels of the present beaches and streams, which are the result of postglacial erosion and deposition and are derived chiefly from the three classes of glacial material just outlined. Some of the material, however, in both the streams and beaches is due to postglacial erosion of bedrock, especially in the higher mountains and along the rocky sections of the coast.

The first three classes of deposits here outlined are essentially aggradational, or are built up by the deposition of superimposed unassorted detritus. Only the deposits of the fourth or youngest class are of the degradational or assorted type favorable to the segregation of placer metals, and on Kodiak Island only the beach deposits are dominantly of this kind, for the present stream system has not materially eroded the unconsolidated deposits or the bedrock areas of the island.

CHARACTER.

The most extensive exposures of the unconsolidated Quaternary sediments on Kodiak Island are in the sea bluffs that bound the coastal plain along its western shore from Cape Alitak to Old Red River, a distance of about 30 miles.

These bluffs range from 25 to 250 feet in height and their continuity is broken at only a few points by the narrow valley mouths of the larger streams. Their base stands at the average level of high tide, and they are actively eroded by the waves whenever a surf is running, especially during violent storms, for this coast is open to the full sweep of the ocean from the southwest.

The bluffs are chiefly composed of typical till but in some sections contain also a considerable proportion of outwash gravels and sands. At several localities coarse morainal boulder trains are present. For the most part the till is compact and stands well in the bluff faces where freshly exposed. Where it is of uniform clayey composition, with little admixture of sand and gravel, it presents characteristic massive exposures that weather to a hackly surface owing to an irregular incipient fracturing that is developed in it. There are, however, large areas of the bluffs that have not been eroded recently, where the steep slopes are partly mantled by loose material that slumps and slides down from above to the upper edge of the beach. The till, besides making up the chief part of the bluffs, also forms most of the bedrock of the coastal platform upon which the loose beach sands and gravels rest. Without doubt the till extends some distance seaward as the floor of the coastal shelf upon which the surf is cutting, for it was noted that the sea was discolored by clay in suspension to a distance of 1,000 feet or more offshore whenever the surf was active.

The till is unoxidized and of a typical gray color, as are also most of the outwash sediments associated with it, although in places discontinuous strata in the outwash sediments and some portions of them near the tops of the bluffs are discolored brownish red and are slightly cemented with iron oxide. Springlike seepages are not uncommon at the contact of the underlying impervious till and the overlying porous outwash sediments. Along the greater part of the bluffs from 3 to 6 feet of peaty soil or turf overlies either the outwash sediments or rests directly on the till deposits, and disrupted masses of turf are strewn about on the bluff slopes where slumping has been pronounced.

Sand dunes 20 to 30 feet high occur locally on the tops of some of the higher bluffs.

In general the bluffs consist of a basal member of till overlain by gravels and sands which from their poor assortment and the cross-bedding are thought to consist of outwash material. Considerable sections, however, consist wholly of till, and some sections of lesser extent consist chiefly of gravels and sands with little typical till. There is also a section, about a mile long, in which two distinct members of till are developed that are separated by a more or less continuous but variable member of sands and gravels, parts of which at least have been subjected to wave washing as a beach, for they contain many water-worn fragments of marine shells, some specimens of which are complete enough to be identified specifically. A considerable number of water-rounded boulders of lignite are also embedded in the beach deposit. On weathering, these masses of lignite disintegrate into fragments that are strewn along the base of the bluffs. Evidently the presence of these masses led Becker to surmise that Tertiary lignite-bearing sediments were present in the bluffs of this vicinity, as noted by Dall,[1] but so far as the writer could learn lignite beds are absent. The lignite boulders apparently have been transported to this locality from a distance, together with the outwash deposits with which they are associated, and it is probable they once were morainal débris.

This assorted beach outwash material crops out along the northern part of the bluffs north of a higher part of the bluffs that is locally named Canvas Point, or from 1 to 2 miles north of Ayakulik Island. The following species of marine shells have been identified tentatively by W. H. Dall, of the Survey, from the collection made by the writer, with the comment that the specimens are rolled and broken fragments of forms now living in the vicinity and that the assembly indicates a colder temperature than that now normal to the locality.

Pecten (Chlamys) islandicus Müller.
Monia macroschisma Deshayes.
Tellina lutea Gray.
Macoma middendorffii Dall.
Venericardia crebricostata Krause.
Venericardia? paucicostata Krause.
Venericardia crassidens Broderip and Sowerby.
Mya intermedia Dall.
Latisipho halli Dall.
Tachyrhynchus polaris Beck.
Astarte borealis Schumacher.
Saxidomus giganteus Deshayes.
Chrysodomus sp. fragment.
Boreotrophon sp. fragment.
Balanus sp. fragment.

[1] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, p. 800, 1896.

The beach sand member that contains the marine shells just enumerated and with which the water-rounded masses of lignite are closely associated, ranges from 20 to 40 feet in thickness and is clearly interbedded with till deposits. The till deposit above the sands is from 50 to 100 feet thick, and the till below them is exposed along the base of the bluffs to heights of 20 to 30 feet above the present high-tide level. Thus the present position of this old beach deposit, lying above the present sea level, indicates that an uplift of 30 to 50 feet has taken place along this particular section of the coast. It is clear that the old beach deposit was formed after at least 30 to 40 feet of typical till, upon which it rests, was laid down by glacial ice; that the ice then receded sufficiently to allow beach washing and deposition to take place at this locality, and that this interval was followed by a readvance of the glacial ice accompanied by renewed deposition of till to a thickness of 50 to 100 feet on top of the old beach sediments. This wave-washed beach member resulted from sedimentation that took place in the interval between the deposition of the older and the younger beds of till.

The same relationship between beds of till and interstratified gravels is indicated along other sections of the bluffs, except that the absence of marine shells or similar fossil remains in the intertill sediments shows that they were not reworked or assorted by wave action or, in other words, deposited along a strand line. Yet in some exposures such sands and gravels, instead of being cross-bedded, like most of the outwash material, are fairly well assorted, as if deposited in ponded waters, and it is reported that some of the best placer concentrations occur in areas along the beach where these sands form the bedrock.

Although the assorted beach material that contains marine shells and occurs along about a mile of the bluffs is the only conclusive evidence that elevation has taken place on this coast during Quaternary time, the bluffs present certain structural features which indicate that slight deformational movements occurred. It was noted that the outcrop of the upper surface of the basal deposit of till, as it is exposed along the bluffs, has a broadly undulating configuration and that although the till has a considerable horizontal extent, there are sections where the surface of the till sinks below the present high-tide level, and in these sections the bluffs are composed wholly of outwash sands and gravels. This might be interpreted as indicating merely irregularities in deposition of the till and outwash deposits, such as often characterize glacial sedimentation of this kind. In view, however, of the evidence furnished by the older elevated marine beach along the northern part of the bluffs, it seems probable that a general but slight deformation of the unconsolidated sediments has occurred along this coast in late Quaternary time. This deformation is chiefly expressed by elevation of the lower bed of till to the extent of 30 to 50 feet above high tide, and in some places a corresponding depression in others. The coastal plain may then be considered to be made up of gently warped beds that form broad anticlines and synclines whose structure is possibly reflected in the generally rolling surface of the plain. However, it must be borne in mind that such features, with the exception of the elevated marine beach, may be fully accounted for by irregularities in the original deposition of the sediments.

ORIGIN.

As all placer deposits are directly or indirectly related to the topographic development of the region in which they occur, it is useful to note the physiographic processes that have affected the placer beach deposits of Kodiak Island, especially because here they are clearly evident. As all the gold-placer deposits so far discovered on Kodiak Island are confined to the present ocean beaches and as practically no valuable placer concentrations have been found in any of the present stream gravels, the topographic development of the whole island must be considered in a study of the origin of the placers. The physiographic history of the island is therefore treated somewhat more fully than might otherwise be considered necessary.

Glacial erosion.—In general the topography of Kodiak and the neighboring islands is the product of severe glaciation. The length and depth of the fiord inlets and channels are evidence of ice erosion that gave the major surface features their present form; and the numerous lakes in overdeepened or dammed-up sections of glaciated valleys afford further evidence on the former presence of ice streams which failed to erode their valley troughs to the depth of those now occupied by the sea. The arrangement and trends of the fiords, channels, and deep valley troughs, some of which contain large lakes, shows that the glaciation of Kodiak Island was essentially local in origin and had its center of development in the high mountainous interior, where it took the form of an ice cap that buried all but the highest summits and ridges. This ice cap was the source and feeding ground of numerous glaciers that flowed from it in all directions. At the stage of maximum glacial development some of the larger ice flows extended even beyond the present limits of the island. In fact, the whole of Kodiak Island appears to have been generally overridden by ice, with the possible exception of a small area situated in its northwestern part. There a group of low mountains, the western extremity of which forms Cape Ikolik, appears to have remained free from ice, as a nunatak area, in the western margin of the ice fields.

With particular reference to the western part of the island, Uyak and Alitak bays may be noted as examples of great fiords that were fully occupied by large glaciers, whose terminal lobes extended beyond the present headlands during the stage of maximum ice development. Olga Bay was occupied by a great ice lobe that extended to and beyond the present western shore line of the island in the vicinity of Low Cape, as shown by the morainal deposits that outcrop in the present coastal bluffs. The present western shore line of this bay is determined by a great crescentic terminal moraine that was deposited along the border of the ice lobe during a stand in the general retreat of the ice. The valley of Karluk River and lake was eroded by a long glacier, and likewise the valley basins now occupied by Ayakulik Lake and several other lakes of considerable extent, contiguous to Olga Bay, were eroded by glaciers and later dammed off by moraines.

Thus the whole of Kodiak Island is dissected by a ramifying series of glaciated valley troughs, some of which now stand above sea level but many of which are partly occupied by the sea. These valleys radiate from the high central mountainous part of the island, upon which the ice cap formerly rested. The ice cap that now occupies much of southwestern Kenai Peninsula illustrates in many respects a stage of glaciation through which Kodiak Island passed before the ice disappeared from it.

Glacial deposition.—The lowland features of Kodiak Island, as well as its highland features, are distinctly of glacial origin. Thus, all the lowland tracts in the western part of the island are the result of glaciofluvial sedimentation that accompanied glacial erosion in the highland areas. Primarily, the development of the lowlands depended upon the deposition by the glaciers, during their advance, of large quantities of detrital material that was eroded and transported from the bedrock of the highland areas. The greater part of this material was laid down about the borders of the island and along the larger valleys in the form of ground moraine or till—sediments composed chiefly of clays, with some sands and gravels—which contain scattered angular fragments of rock and subangular or fairly well rounded boulders and cobbles. The lowlands also contain widespread outwash deposits of silts, sands, and gravels that were formed during the retreat of the ice front from its maximum limit back into the valleys. Besides the outwash sediments that overlie much of the ground moraine there are also terminal and lateral moraine deposits, chiefly of the recessional type, whose form has been little modified since they were laid down.

Practically all the lowland deposits are of glaciofluvial origin. They are present at the heads of the fiord inlets and bays and along the bottoms of the valleys that extend inland from tidewater; but in the valleys that have not been eroded by glaciers below the present sea level the valley floors are flat marshy tracts that are poorly drained by the present streams and that contain many ponds and small lakes. Many of these valleys contain large lakes in basins which were formed either by unequal erosion of the bedrock or by the deposition of moraines that formed dams across the valleys. In some places both causes probably acted in combination.

The most extensive lowland tract on Kodiak Island extends along its western coast from Cape Alitak northward nearly to Cape Ikolik. This tract constitutes a typical fluvioglacial coastal plain, about 30 miles long and from 2 to 5 miles wide, made up of coalescent sheets of ground moraine and outwash sediments with some modified terminal and lateral moraine deposits. Its rolling surface stands from 25 to 200 feet above sea level and has the typical uneven configuration of glacial sedimentary deposits, little modified by the erosion of postglacial streams. The greater part of the surface of this coastal plain apparently stands to-day as it was deposited by the outwash drainage from the retreating ice. Numerous poorly drained ponds and small lakes lie on its surface, and the few large streams that flow across it from the highlands have eroded only narrow valleys into the plain.

Along its coastal margin this plain is bounded by practically continuous sea bluffs cut in the unconsolidated sediments by the waves. These bluffs range in height from 25 to 200 feet, but in most places along the greater length of the 30 miles of coast they are between 50 and 100 feet in height. This rather uniform line of steep wave-cut bluffs may indicate that the coastal plain was elevated since its formation. Some evidence to support this view was found in the bluffs at one locality, where marine shells occur in wave-deposited beach sands at a height of 20 feet above the present limit of high tide. For the most part, however, the wave-cut bluffs may be considered as a measure of the horizontal wave erosion that has occurred along this section of the coast since the coastal plain was formed, for it is probable that the original limit of the plain was seaward from its present position and that a marginal belt of the unconsolidated sediments, from 1 to 2 miles wide, has been cut away by postglacial wave action.

At any rate, it is clear that the unconsolidated deposits of this coast have been eroded and reworked by the waves, and it is logical to presume that the placer metals now found in the beach sands were concentrated by wave action, especially as no placers have been found in the narrow valleys cut by postglacial streams in the coastal-plain deposits. There are, however, several factors to be considered in this connection that will be discussed with reference to the bedrock sources of the placers.

Postglacial erosion.—The present drainage of Kodiak Island was conditioned by the drainage that preceded glaciation. All the larger streams flow in valley troughs which were deeply eroded by the glaciers that formerly occupied them, and most of the large streams are merely the overflow outlets of the glacial lakes that occupy basins in these valleys. There are only two large streams on the island, Karluk and Ayakulik or Red rivers, and both of these drain large glacial lakes. Consequently most of the stream systems consist of one or more headwater branches and their small tributaries, which empty into the lakes, and a trunk stream that drains the lake to the sea. In general, the present streams have performed an insignificant amount of erosion and have modified only slightly the dominantly glacial topography of the island. The sediments that the headwaters of these streams erode from the bedrock areas of the highlands are deposited chiefly in the lakes, and the sediments that are eroded by the streams below the lakes are transported to the sea to be incorporated in the beaches. The principal erosion going on now is the cutting of relatively narrow valleys across the unconsolidated glacial deposits of the lowlands. Thus little erosion or concentration either of mineralized bedrock or of older unconsolidated sediments which could form placer deposits of commercial value has been done by the present streams.

To sum up the evidence presented by the topographic development of Kodiak Island it may be stated that postglacial wave erosion and concentration along the shores of the island, especially along the shores composed of unconsolidated fluvioglacial sediments, is the most active agency favorable to the formation of placer deposits.

THE BEACH DEPOSITS.

GENERAL FEATURES.

The present beach along the foot of the bluffs that extend from Cape Alitak to Old Red River, a distance of about 30 miles, is the longest section of continuous sandy shore line on Kodiak Island. Sevenmile Beach, so named from its approximate length, which extends westward from Uyak Bay along the foot of similar bluffs of till, is the next longest beach on the island. None of the other beaches, most of which extend across the mouths of glaciated valleys, are more than 1 or 2 miles long, and the greater part of the coast line is characterized by rocky bluffs and headlands.

The width of the west coast beach, as exposed between average high and low tide levels, ranges from 200 to 500 feet. The thickness of the loose beach deposits is from 3 to 6 feet, but, as in all beach sands and gravels that are undergoing active washing by surf, the thickness differs from place to place and time to time according to the manner in which the deposits are shifted back and forth by the surf and the variations effected by the ebb and flow of the tide.

As the upper limit of the beach is determined in greater part by the base of the bluffs, which in turn is determined by the average limit of high tide, there is a comparatively small development of higher storm beach deposits along this coast. The only beach deposits of this kind are the short spits across the narrow valley mouths of a few large streams, which have cut down through the coastal plain to sea level, and several sections of barrier beach across the entrances to shallow tidal lagoons that occur between Cape Alitak and Low Cape, where certain tracts of the coastal plain are somewhat less elevated than elsewhere.

The bedrock or marine platform upon which the loose beach deposits rest is, for the most part, the compact clay till that forms the chief part of the bluffs. There are variations in the composition of the bedrock, however, that correspond to variation in the material in the bluffs and which are directly controlled by them. Thus, in the localities where morainal boulder deposits are incorporated with the till the beaches are characterized by boulder pavements that rest on the beach platform and the greater part of the beach deposits consist of coarse gravels, cobbles, and boulders. A few of these boulders are from 5 to 10 feet in greatest dimensions and a number of them reach dimensions of 2 to 3 feet. Where the more or less assorted outwash sands and gravels, which are associated with the till, extend below sea level the bedrock is commonly composed of sandy silt and somewhat resembles quicksand in behavior when excavated. This condition appears to be due to its being charged with considerable water, possibly derived from seepage and under hydrostatic pressure.

The typical till bedrock is said to be somewhat too slippery to retain the gold as well as the "quicksand" bedrock, but nevertheless good concentrations are made upon it under certain conditions, particularly during violent storms that sweep it quite clean of the loose beach sands. The so-called "quicksand" bedrock is said by the miners to be the most favorable for the retention of the placer gold and to afford the best yields, but the areas of such bedrock are not extensive. The boulder pavement areas of the beach platform are considered to be unfavorable for the concentration of the gold in profitable amounts, and besides they are the most difficult to mine.

DERIVATION OF THE BEACH PLACERS.

It is evident that marine wave erosion has produced the practically continuous line of till and outwash bluffs which extends for about 30 miles along the west coast of Kodiak Island, and that the present beach deposits along the bases of these bluffs are the result of concentration by the waves of the sediments that compose the bluffs, with the exception of the small proportion of similar sediments deposited on the beach by the larger streams that cross the coastal plain.

If the present configuration and extent of the coastal plain are accepted as a basis for estimating the former seaward extension of the original plain it would appear that before postglacial marine erosion set in the former shore line was from 1 to 3 miles west of the position it now occupies. If the composition of that part of the coastal plain that apparently has been thus eroded away was similar to that of the present bluffs some idea may be formed of the character and great quantity of sediments that have been acted upon by marine erosion during postglacial time in producing the present beach placers. If the placer deposits of the present beach represent the concentrations from a belt or strip of coastal-plain sediments about 30 miles long, 2 miles wide, and 40 feet thick, it would appear that more than 2,000,000,000 cubic yards of material has been reduced by wave erosion. Probably the average gold content of these deposits was not more than 1 cent in 50 cubic yards of the original coastal-plain deposits as laid down by glacial sedimentation. The small gold content of the gravels is indicated by the fact that practically no colors of gold have been obtained in prospecting the coastal-plain sediments as they occur in the bluffs, even in those parts where the outwash gravels and sands show evidence in the form of stratification of having been somewhat thoroughly assorted. The writer was informed that only in two or three places have even very fine colors of gold been obtained in such prospecting. The results obtained in prospecting along the beds of the present streams that cross the coastal plain are also reported to be wholly negative.

Apparently the slight stream erosion that the unconsolidated coastal-plain deposits have undergone since they were formed has contributed practically no placer metals to the beach deposits.

CONCENTRATION OF THE BEACH PLACERS.

Prospects show that finely divided gold is present along the whole length of the beach from Cape Alitak to Old Red River, as well as in the shorter beaches along other sections of the coast of Kodiak Island. However, the best concentrations occur chiefly in the form of local patches that are comparatively small and are not permanent as to position or richness, because the loose sands and gravels and the placer metals associated with them are being continually reassorted and shifted according to the direction and violence of the storms. Because of this unstable condition of the beach deposits the concentrated heavy minerals do not form pay streaks in the usual sense, although the heavier sands do have a tendency to accumulate along the upper limits of the beaches near the base of the bluffs that arrest the surf and regulate its backwash action.

The west coast of Kodiak Island is exposed particularly to storms from the southwest and northwest quarters and as a rule the best concentrations of the beach result from such storms. The storms of autumn and spring, together with the higher tides of those seasons, are considered to be the most effective in concentrating the placer metals in the beach sands. The waves induced by these storms cut away the basal parts of the bluffs and add small quantities of new material to the beach to be concentrated. Apparently the beaches have become enriched by this process, which has acted for a long period of time on a great quantity of sediment.

The ordinary range of tide on this coast is from 8 to 10 feet, and during the spring and autumn the extreme range is from 12 to 16 feet. Thus there is a considerable increase in the zone of wave attack during the spring and autumn that enables the surf to reach and erode the foot of the bluffs more strongly. The higher surf also sweeps the rather resistant compact clay bedrock quite clear of the usual overburden of gravel and sand and more thoroughly concentrates the fine gold with the heavier sands in patches that may be easily mined during the intervals of falling tide, provided they are found at once and recovered without delay.

"Banking up" and "washing down" are the terms used by the miners to describe the constant eroding and concentrating action of surf on the beach. The power of the storm surf on this coast is great enough to move boulders that weigh several tons, of which there are a few distributed here and there along the beach. Boulders of this weight have been noted to change their positions appreciably in the course of several years. It is said that a moderate surf, such as accompanies a "lazy summer swell," is often very effective in "washing down" small areas of the beach and concentrating the fine gold on the compact beach platform of till in patches that yield good returns in mining, although the surf that accompanies ordinary moderate weather usually "banks up" the loose sands and thus builds up an overburden of the lighter sands from 4 to 6 feet thick that is practically barren of placer.

Although the shifting about of the loose sands and gravels on the beach platform, together with the placer metals which they contain, is always more or less marked during a single storm and is carefully noted by the miners, the erosion of the compact till bluffs is rarely noticeable in a short period of time. Apparently there are periods of several years during which the appearance of the bluffs changes but little as a result of marine erosion. On the other hand, there are periods in which the accumulative effects of wave action are considerable, especially in conjunction with other factors. Miners who have resided on this coast say that for several years previous to a series of rather violent earthquakes late in October and early in November, 1912, which are supposed to be related to the eruption of Mount Katmai in June of that year, the bluffs along the west coast of Kodiak Island for considerable distances had the aspect of a smooth and even-sloped escarpment, the surface of which was mantled by a well-established growth of turf from high-tide level to the top. The earthquakes in 1912, however, were severe enough to disrupt not only the bluffs but the greater part of the coastal plain as well. The ground was frozen at the time, so that the surface fracturing was emphasized. The compact till was ruptured and slightly faulted, some blocks were displaced to the extent of 3 feet with relation to one another, and the turf-covered surface of the coastal plain was greatly broken far inland from the bluffs, so that some cracks stood open as much as a foot.

Since these earthquakes the bluffs have been eroded back by the waves 15 to 20 feet or more along practically their entire length, as is shown by well-established landmarks, such as cabins and other structures. In consequence of the concentration by the surf of the new material loosened from the face of the bluffs, it is stated that the gold content of the beach sands in recent years was noticeably greater than it had been for several years previous to 1912. This statement corroborates the view that the placer gold is derived chiefly from the bluffs of till and outwash sediments.

In 1917 the bluffs presented sheer cliff walls for long distances, and although some sections were much broken by steps or benches the faces of the bluffs are so steep that ladders have to be provided for their ascent. Slides or slumps, such as characterize steep banks that are largely composed of clay, are common features, and small trickling streams erode steep gullies back short distances. No doubt such agencies tend to reduce the bluffs to a more mature aspect during periods when they are not disturbed by earthquakes or very strong marine erosion. Although no data are at hand as regards their number, earthquakes of considerable violence are known to occur frequently in this part of Alaska, and they may accelerate erosion, especially in tracts of unconsolidated sediments such as the coastal plain here considered, where steep escarpments facilitate the delivery of loosened material upon a beach where it may be directly attacked by heavy surf. However, storms of unusual intensity or duration are the chief factors in concentrating the loose beach deposits and forming the temporary segregations of placer sands. The autumn of 1902 is stated to have been a particularly good season for mining on the Kodiak beaches, the good yields being attributed to a series of northwesterly gales that washed the upper parts of the beaches almost clean of the overburden of gravel and sand and left the gold concentrated in patches with a minimum of waste.

Thus the loose beach deposits are undergoing a never-ending assortment and reassortment with the addition of comparatively small quantities of new material from the bluffs at irregular intervals of heavy storm erosion. In this way the beach placers, whose aggregate content of placer metals is not great, pass through seasonal periods of temporary local enrichment that are more marked in some years than in others. These periods alternate with others during which erosion and concentration by the waves is not so vigorous. Successful mining therefore depends chiefly upon the opportune recovery of the better concentrations at localities that can not be selected beforehand and at times that can not be predicted.

THE PLACER MINERALS.

The chief minerals that make up the heavy concentrates of the beach comprise magnetite, pyrite, chromite, gold, and a little platinum. In most of the concentrates as mined there also is present a considerable percentage of artificially introduced metals, such as lead in the form of bird shot, solder from cans, and shoe nails of iron and brass. Some of the concentrates contain many heavy flakes of oxidized iron that probably are derived from disintegrated cans and nails. Amalgam lost from previous operations is recovered in small amounts.

By far the chief mineral of the concentrates is magnetic black sand (magnetite), which constitutes fully 95 per cent of several samples examined, the remaining 5 per cent of nonmagnetic material being pyrite and chromic sand, which in dried samples may be readily separated with a hand magnet.

For the most part the magnetite sand is fine grained; nine-tenths of it readily passes the 40-mesh screen, of which from one-third to two-thirds passes the 100-mesh screen.

The following analysis (No. 3214) of placer platinum from Canvas Point, west coast of Kodiak Island, was made by R. C. Wells, of the United States Geological Survey:

Analysis of placer platinum from Kodiak Island, Alaska.

SiO_2, etc	1.2
IrOs, Rh	26.9
Ir from part of IrOs	6.1
Rh from part of IrOs	.1
Pt	55.3
Ir	2.4
Fe	6.4
Au	.3
Rh	.7
Pd	.1
Cu	.6
Ni	.08
Zn and Ag	Trace.
	100.18

Specific gravity, 17.2.

MINING METHODS.

The mining practice has been that usually followed by beach miners, that is, rough washing of the sands in rockers or small portable sluice boxes which save only the coarser flake or scale gold and that part of the finer gold which amalgamates readily. It has always been realized that much of the fine or flour gold and also some of the light scaly gold was lost with the black-sand concentrates. Heretofore, the concentrates have been considered an unavoidable hindrance to the recovery of the gold, especially the flour gold, and, until recently, they have been discarded as soon as possible without secondary treatment. The platinum, which has been recently recognized in small amounts, in association with the gold, was overlooked in the earlier years of mining, for the manner of washing the sands was too crude to reveal it. Recently, however, secondary panning of the concentrates, followed by drying and blowing and crude separation with small horseshoe magnets, has been practiced by a few of the more careful miners with a view of saving more of the fine gold; and this has resulted in the recovery of a few pennyweights of platinum.

The use of undercurrents in treating the concentrates, or, better still, the use of some form of concentrating tables, would without doubt give a much greater saving of the gold in the sands and a better separation of the platinum metals. But such treatment of the concentrates on a commercial scale, to be fully effective, would require a community of interest in the mining operations that has not existed up to the present time and probably would be difficult to establish and maintain.

Mining operations can be conducted on the beaches of Kodiak Island only during periods of receding or low tides, because high tides, or at least the wash of the surf during such periods, reach to the base of the bluffs along practically the whole length of the west coast at all times. Consequently all mining equipment must be removed from the beach during high tide, and seldom can more than four or five hours actual mining be done on the beach in one day. Thus no preliminary preparation is possible beyond prospecting with a pan or shovel as the tide begins to ebb to determine a favorable place to mine. In former years rockers were used exclusively for such transient operations, but recently small portable sluice-box equipment has been used to a considerable extent along certain sections of the beach where water is obtainable. Rockers are still used where water is not available and during winter when the water supply for sluicing freezes; they are also used for washing rich sands, which are sometimes collected from the beach in small quantities and accumulated in holes on the bluffs for future treatment and for reworking concentrates.

The sluicing operations are generally carried on by two or three men working in partnership and depend upon a water supply obtained from the small lakes or ponds that lie on some parts of the coastal plain within short distances of the top of the bluffs. The water is brought to the edge of the bluffs in ditches, and thence it is conveyed to the beach, 40 to 70 feet below, by canvas hose; or, in favorable situations, where the bluffs are benched, a combination of ditches and flumes is built to carry the water along the face of the bluffs in either direction from the supply ditch, so that it is available for sluicing operations along a considerable section of the beach. The same result is also accomplished by extending canvas hose along the bluffs. Thus some of the miners are able to use the portable sluice boxes at any point along a section of the beach within half a mile of their main ditch, and, in a general way, such zones of operation are recognized as belonging to the claimants of water rights and main ditches.

The portable sluicing equipment consists of three boxes about 10 feet long, 10 inches wide, and 8 to 10 inches deep. The two lower boxes are fitted with wire grating on top of burlap. The third or upper box, into which the sands and gravels are shoveled, is provided with slat riffles. A little quicksilver is generally used in the upper part of the lower box. The box line is set up on four or five horses that admit of adjusting both the height and grade as desired. The usual grade is about 8 per cent. The water is led into the boxes by canvas hose, about 6 inches in diameter, that is connected with the permanent system by which it is conveyed along the bluffs.

The usual practice is to prospect the beach as the tide begins to fall and thus locate a spot where good concentration is taking place without too much overburden of barren sand and gravel. The boxes are set up on a satisfactory spot as soon as the tide has receded sufficiently. Generally a foot or so of the top sands is shoveled aside from a strip 6 or 7 feet wide along each side of the boxes, and 6 to 12 inches of the heavier sands that rest on the clay bedrock are shoveled into the boxes from both sides. The area of beach mined during one recession of the tide by three or four men working together is seldom more than may be properly shoveled into the boxes as they are set up in one position—an area about 30 feet long and 14 feet wide or from 400 to 450 square feet—although occasionally two set-ups or about twice this area may be mined. When the tide rises the equipment is removed to a safe place on the bluffs.

It is considered unprofitable to attempt to mine in places where the overburden is more than 2 feet thick, and if possible a locality is selected where the back wash of the surf has temporarily "washed down" the loose sands and gravels to a foot or less in thickness. Such "washing down" or transient concentration of the beach usually occurs in a marked manner as a result of the backwash of heavy surf, and occasionally it is so thorough that all but 1 or 2 inches of the heaviest placer-bearing sands are swept from the clay bedrock along the base of the bluffs. But the areas so concentrated are generally small and of little permanence, for often they may be covered by 2 feet of lighter sands during the next advance of the tide and the placer concentration may be dispersed with this change. Such concentrations are often scraped up hurriedly, shoveled into buckets, and placed in safe places on the bluffs, to be washed later with rockers.

The miners patrol the beach at frequent intervals, test it here and there by panning for the development of favorable conditions of concentration, and thus secure the best yields. But under such transitory conditions mining is uncertain, and a month or more may pass without opportune conditions for activity, particularly in the summer, during which many of the miners make little effort to work.

The compact till bedrock usually presents a surface that allows very little of the gold to become lodged within it, especially in those areas where it has been freshly scoured by the heavy surf that forms the best concentrations. Consequently it is seldom necessary to mine more than one-half to 1 inch of the somewhat softened surface of the bedrock in order to deliver practically all the gold-bearing material to the washing apparatus, except in localities where the bedrock is of the so-called "quicksand" variety, which consists essentially of a plastic mixture of sand, silt, and clay, charged excessively with water. In this quicksand bedrock the gold often finds lodgment to a depth of 6 to 12 inches below the ordinary surface of scour, and as the gold is retained by it to better advantage such areas are stated to be more enriched than those where the bedrock is of compact till. Such areas of bedrock are particularly searched for by the miners and are mined to a depth of about a foot. Apparently the patches of so-called quicksand bedrock occur chiefly along those sections of the bluffs where outwash sediments that are incorporated with the till deposits dip below sea level and thus form the beach platform upon which the surf scours. Sediments similar to the quicksand may be observed in the bluffs above high-tide level that do not contain prospects of gold, so it is probable that the richer concentrations of gold noted in this kind of bedrock are formed on the present beach. It appears that the quicksand bedrock favors enrichment, as contrasted with the compact till, simply because it is a looser-textured medium that offers more secure lodgment for and better retention of the heavier beach concentrates from the washing action of the surf as it shifts the loose sands and gravels about on the beach platform.

Mining is seldom attempted on those sections of the beach where boulders and cobbles are particularly abundant, and the comparatively small amount of coarse material that may occur in areas that are mined is shoveled or rolled aside, according to size, as it is encountered during the progress of digging.

MINING IN THE FAIRBANKS DISTRICT.

By Theodore Chapin.

GENERAL CONDITIONS.

The mineral production of the Fairbanks district in 1917 included placer gold, valued at $1,310,000; lode gold, valued at $47,781; placer silver, valued at $6,904; lode silver, valued at $1,827; and lead, tungsten, and antimony, valued at $58,257. The total value of the mineral output in 1917 was $1,424,769, as against $2,039,744 in 1916. The decrease was due in large part to a general retrenchment on the part of operators owing to the high cost of supplies, which prevented the working of low-grade ground. Failures were recorded in 1917 on ground which in previous years netted a good profit, and but for the general retrenchment other failures would doubtless have resulted.

Quartz mining showed a slight increase, which in large part was due to the interest in tungsten lodes. Two tungsten mines were in course of development. At one of these mines one unit of a 75-ton mill was in operation, and in the summer of 1917 was turning out several hundred pounds of scheelite a day. On the other property a similar mill was in course of construction during the summer. Development was in progress at both properties. The surface showings indicate the possible presence of large tungsten-bearing deposits.

Five gold quartz mills were in operation during a part of the year, and several other properties not equipped with mills made small outputs. On the whole the gold quartz mining was insignificant.

The production of antimony in 1917 was small. Stibnite was mined at two localities, and at a third some ore was recovered from old tailings.

One silver-lead lode in process of development made several shipments of high-grade argentiferous galena.

GOLD LODES.

FAIRBANKS CREEK.

The Crites & Feldman mine and mill, on Moose Creek, a tributary of Fairbanks Creek, were operated throughout the year. The character of the mineral deposits has been described in previous publications and need not be repeated here.

The Mizpah mine on Fairbanks Creek was operated by a small crew. The mine is developed on an eastward-trending vein that dips steeply south. An inclined working shaft extends along the vein to a depth of 160 feet, from which drifts extend east and west. On the 80-foot level a slope 170 feet long reaches to the surface. The lode is a quartz vein from a few inches to 3 feet wide. It carries considerable stibnite and in places free gold is abundant and some very rich shoots occur. On the east end of the workings a galena-bearing lode has been encountered, which has been traced on the surface for a long distance. Last year a little scheelite was produced. The mine is equipped with a Huntington mill.

Development work was continued on the Gilmore & Stevens property east of the Mizpah mine. A prospecting adit is being driven northerly into the hill for the purpose of crosscutting the Mizpah and other lodes which have been opened on the surface. In September, 1917, this adit was 800 feet long and presumably is not far from the ore-bearing zone, which on the surface contains a number of lodes. The property is equipped with a 5-stamp mill.

Near the head of Fairbanks Creek development work has been continued on the McCarty property, and some production has been made of both gold and antimony.

SKOOGY GULCH.

The David mine on Skoogy Gulch was in operation during the summer. The property lies west of that of the Rainbow mine and is probably on the same vein that is exposed in the Rainbow workings. The underground workings consist of an adit driven from Skoogy Gulch along the vein for about 100 feet and an overhead stope 65 feet long. The lode is a quartz vein which differs in width from place to place from 6 inches to a gouge seam. The property is equipped with a 2-stamp Hendy mill with two 8-foot plates. A wood-burning boiler furnishes steam for mill, hoist, and compressor. The Rainbow mine is idle on account of litigation.

The Overgard property on Skoogy Gulch made a small production. This property is equipped with a homemade 1-stamp mill.

The Heilig & Creighton property on the divide between Skoogy Gulch and Cleary Creek is now being prospected. A shaft has been sunk 60 feet and crosscuts started which show two parallel veins that strike N. 30° E. and dip 65° NW. The mine is equipped with a Little Giant mill and gasoline engine.

CLEARY CREEK.

Work was continued on the Tony Goessman property on Bedrock Creek tributary to Cleary Creek and a small production was made.

There was no mining in 1917 at the Chatham mine, but the old tailings were picked over and some high-grade ore sorted out for shipment.

ESTER CREEK AND VICINITY.

Considerable development work was done on deposits on the divide between Eva and Ace creeks. Twenty-seven claims covering an ore body known as the Ryan lode and a number of adjacent lodes were bonded by the Alaska Mineral & Development Co., and from October, 1916, to June, 1917, some exploration work was done. The Ryan lode was opened by one adit and five shafts, from which the lode was prospected by nine crosscuts across the lode at depths of 50 to 100 feet. Where examined by the writer the lode is 50 feet or more wide. It is a stringer lode and is composed of veins of quartz that inclose fractured and mineralized schist and seams of gouge. The lode carries considerable stibnite and is highly colored with the stains of antimony oxides. The lode strikes about north and dips east at high angles. Development work was started on the Ryan lode in October, 1916, and was suspended in June, 1917.

On the Combination claim a few shallow pits exposed a quartz vein with arsenopyrite scattered through it and coatings of scorodite and cervantite. The size or extent of the ore body was not evident from the few exposures. The claim is on the slope of Eva Creek near the Ryan lode.

Development work was continued by McGlone & Smith on the Bill Sunday Fraction lode claim. This claim is on the divide between Eva and St. Patrick creeks, northeast of the Fairchance claim, and is probably on the same or a parallel lode. The lode strikes N. 25° E. and dips from 70° SE. to nearly vertical. It has been opened by two shafts 100 feet and 20 feet deep and by surface cuts. At the surface the lode is solid quartz about 3 feet wide, but at depth it widens considerably. At a depth of 50 feet the lode consists of stringers of quartz which cut mineralized schist and carry large seams of gouge. The quartz carries a large amount of stibnite and cervantite and in places free gold. Fine gold is easily obtained by panning either the quartz or schist of the lode.

The St. Paul mine at the head of Eva Creek was operated throughout the year. The property is equipped with a 7-foot roller mill which has a capacity of 20 tons a day.

Roy McQueen is opening an antimony lode on the Jennie C. claim, situated on the divide between Ready Bullion and Nugget creeks. The lode is nearly solid stibnite with a little quartz and occurs in lenses. In places it is 18 to 24 inches wide, and in others it pinches to a seam of gouge matter. The vein strikes N. 45° W. and dips 75° NE. The ore is mined by surface trenching and is hand picked and sacked at the mine.

SILVER-LEAD LODES.

A silver-lead deposit is being developed near the head of Cleary Creek on property leased from the Eldorado Mining & Milling Co. Development work in the fall of 1917 consisted of an inclined shaft 45 feet deep and about 30 feet of drifts and stopes. On the surface the vein was about 3 feet wide, and where the shaft was sunk it was composed principally of stibnite. Below the surface the vein attains a width of 10 to 15 feet. The vein incloses large bunches of pure galena, which is said to be rich in silver. Disseminated pyrite is abundant in parts of the lode. A strong hanging wall strikes N. 45° E. and dips steeply northwest. The footwall is not well defined and is marked by a gradation from lode to country rock. The ore is hand picked and sacked for shipment at the mine.

TUNGSTEN DEPOSITS.

Tungsten lodes have been discovered at two neighboring localities in the Fairbanks district; one at the divide between the tributaries of Fish and Smallwood creeks, and the other at the heads of First

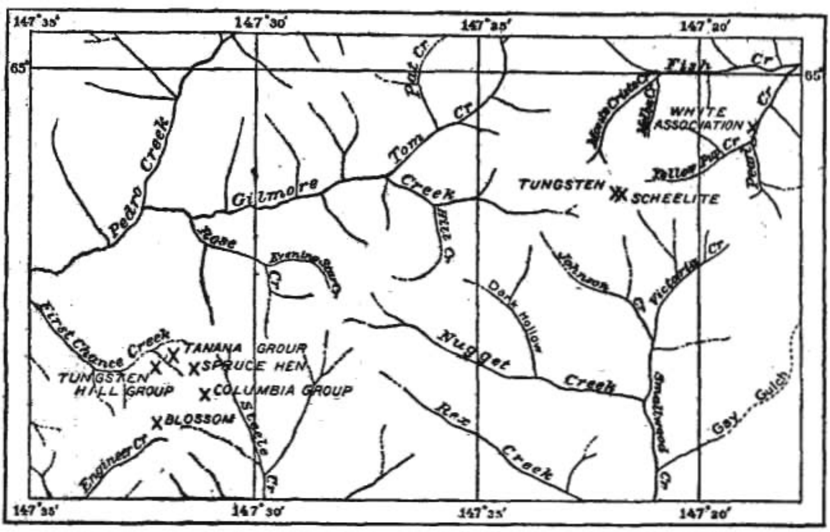

FIGURE 13.—Sketch map showing tungsten lode claims in the Fairbanks district.

Chance, Steele, and Engineer creeks. (See fig. 13.) At the first property one unit of a mill is in operation, and during the summer of 1917 it was producing 500 pounds of scheelite concentrates a day. At the other property a mill was in course of construction and active development work was being carried on. Besides these two mines, a number of claims are located on the scheelite-bearing lodes. The scheelite deposits of the Fairbanks district are believed to be much more extensive than the surface outcrops show and to give promise of a large future production of tungsten.

GEOLOGY.

The tungsten lodes occur in an area of Birch Creek schist, described by Prindle [1] as a series of highly metamorphosed siliceous sediments that consist of massive quartzites, quartzite schists, quartz-mica schists, hornblende schists in part amphibolitic, carbonaceous schists, crystalline limestone, altered calcareous rocks, and associated eclogitic rocks, andalusite hornfels, and a small amount of granitic gneiss derived from intrusive porphyritic granite.

ORE DEPOSITS.

The ore deposits are for the most part replaced portions of the limestone and calcareous beds that occur interbedded with the schists. The deposits as far as noted appear to lie in a more or less continuous zone that strikes about N. 70° E. and parallels the general strike of the schist. The lodes are composed of quartz, calcite pyroxene, hornblende, garnet, epidote, biotite, and scheelite—minerals which are believed to have been formed by the replacement of the limestone and calcareous sediments by the tungsten-bearing solutions. Besides the lodes that represent replaced calcareous sediments there are quartz veins which also carry scheelite. The quartz veins follow the silicification of the limestone beds and in places cut the earlier formed lodes, resulting in an enriched ore body. The known tungsten deposits of this region all occur on the border of a body of porphyritic granite and are believed to be genetically connected with it.

MINES AND PROSPECTS.

ALASKA TUNGSTEN MINES CO.

The Alaska Tungsten Mines Co. has property on Yellow Pup, one of the tributaries of Fish Creek and on the knob between the heads of Gilmore, Smallwood, and Fish creeks. The principal work has been on the Tungsten claim at an elevation of 2,472 feet. The property is reached by a first-class wagon road from Gilmore on Pedro Creek by way of Gilmore Creek. The lode strikes N. 70° E. parallel to the schistosity of the country rock and dips from 20° to 40° NW. The footwall is well defined and follows approximately the bedding planes of the greenstone and quartzite schist. The vein ranges in thickness from 2 to 12 feet and more, but the richest ore is confined to lenses from 2 to 5 feet thick. There is no definite hanging wall to the lode, but back of each is more ore. These are evidently structural planes, either bedding planes or less permeable zones in the original rock along which replacement has taken place. Thin stringers of scheelite-bearing quartz of later origin than the replaced rock follow the bedding planes and cut across them.

[1] Prindle, L. M., Geology of the Fairbanks district, Alaska: U. S. Geol. Survey Bull. 525, pp. 59–131, 1913.

The mine is being developed by an inclined shaft driven along the vein. In September, 1917, this shaft had been extended for 160 feet and dips at an angle of 40° to 18°. In places the shaft widens out to stopes and chambers, and the lower part has been opened to a width of 40 feet.

The Scheelite claim joins the Tungsten on the east, and the ore bodies on the two claims are presumably the same. No mining was in progress in 1917. The development is reported to consist of a 75-foot inclined shaft along an ore shoot 10 feet wide and from 4 to 6 feet high.[1] About 250 tons of ore was shipped from this property in 1915–16.

The mill and camp of the Alaska Tungsten Mines Co. is on Yellow Pup at an elevation of about 1,600 feet. One unit of a Faust concentrating mill was installed during the summer of 1917 and in September was turning out 500 pounds of scheelite concentrates a day.

The Murphy claim, on Yellow Pup just below the mouth of Pearl Creek, is under option to the Tungsten Mines Co., who are developing it. At the time of the writer's visit the workings were inaccessible. Grab samples taken from the dump and crushed and panned appeared to be rich from the amount of concentrate the pannings yielded. The vein is said to be 4 feet wide and to strike N. 75° E.

COLUMBIA MINE.

The Columbia mine is being developed by the Columbia Mining Co. The group of claims now controlled by this company represents the original locations of Jacob Meier and other claims acquired since. The claims are at the head of Steele Creek, about 10 miles from Fairbanks, with which they are connected by a good wagon road.

A number of scheelite-bearing lodes have been located. Location was made on the Columbia claim, where a scheelite lode and quartz vein that is associated with it have been exposed by an open cut and adits. The upper adit has been driven for 80 feet along the vein which follows a granite hanging wall and strikes about N. 20° W. and dips northeast. The lode apparently replaces calcareous beds but is cut by large quartz veins, which also appear to carry scheelite. A lower adit is now being driven to cut this lode.

The Spruce Hen claim, now being developed by the Columbia Mining Co., is on the divide between First Chance and Steele creeks. From appearances several lodes have been opened by crosscuts at intervals for the entire length of the claim. The principal ore body appears to be an iron-stained lode about 4 feet wide. This lode has been opened by one cut to a depth of 8 feet. It strikes N. 50° E. and dips 45° NW. The lode appears to be composed of silicates,

[1] Mertie, J. B., jr., Lode mining in the Fairbanks district, Alaska: U. S. Geol. Survey Bull. 662, p. 421, 1917.

which have replaced limestone beds, and is cut by quartz stringers. Both the silicates and later quartz stringers are rich in scheelite. A little molybdenite also occurs. Seams of gouge occur along both walls of the lode.

The camp and mill were in course of construction in 1917. The camp is at the head of Steele Creek at an elevation of 1,830 feet. The mill is on Steele Creek at an elevation of about 1,200 feet. A Marathon mill was first constructed, but this did not prove satisfactory. The new mill is a Faust concentrating mill.

The Ptarmigan and Franklin claims, on the head of Gilmore Creek, are being developed by J. F. Zimmerman. Surface cuts, made across the claims at a number of places, have disclosed several mineralized zones, one of which appeared to be 15 to 20 feet across. The lodes strike N. 40° E. and dip northwest. The lode material is quartz, and silicate rock has presumably replaced limestone along selective zones. Scheelite occurs in the quartz and silicates.

The Tanana group of five claims occurs at the head of First Chance Creek. On the Tanana No. 1 claim an inclined shaft has been sunk 40 feet along the lode. The ore body is a mineralized zone of schist about 4 feet wide and follows the schistosity of the inclosing quartzite schist. The lode strikes N. 50° E. and dips northwest.

The Tungsten Hill group of claims lies near the head of First Chance Creek. Of these Mertie[1] says:

> Four scheelite lodes had been discovered on these claims by August, 1916, and it is likely that others are present. On the Grand Duke Nikolas claim a scheelite lode in the schist country rock had been exposed in an open cut. This deposit consists of 6 to 8 feet decayed schist, carrying scheelite. Vein quartz containing a little gold is also present, cutting the mineralized zone.
>
> On the Tungsten No. 1 claim another open cut had been made in a country rock of mica schist and quartzite schist. A zone mineralized by scheelite is present, but the width of the lode was not apparent from the work done.
>
> On the General Joffre claim a scheelite lode, 14 feet wide, has been exposed. The lode as a whole was considered low-grade ore; but it contains in the central part an 18-inch stringer of decayed schist, which is of considerably higher grade.
>
> These claims certainly deserve further prospecting, for they are as advantageously situated with regard to the granite as other scheelite claims in the district on which workable lodes have been developed.

The Black Bear and Blossom claims are west of the Tungsten Hill group and are apparently in the same mineralized zone. The lodes consist of quartz stringer lodes in schist. Considerable open trenching has been done on these two claims, and several lodes are exposed that apparently extend across the two claims. The scheelite occurs in the quartz stringers that penetrate the schist. These stringers in places are very rich, carrying large crystals of scheelite, and should be further developed.

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[1] Mertie, J. B., jr., op. cit., p. 424.

A MOLYBDENITE LODE ON HEALY RIVER.

By Theodore Chapin.

A molybdenite-bearing quartz vein has recently been opened on Healy River. Its location is near the extreme head of the river on the south slope of Rainey Mountain, near the divide between Healy and South Fork of Goodpaster rivers. It is about 160 miles southeast of Fairbanks by trail. This deposit was not visited by the writer and the following description is abstracted from a report made to the owners by Albert Johnson, of Fairbanks.

The ore deposit is described as a quartz fissure vein inclosed in granite. It trends east and dips north. The lode has not been developed to any extent but has been traced by shallow surface openings and float for three claim lengths and is believed to be continuous for this distance. The vein is described as hard white quartz that carries bunches of molybdenite scattered sparingly through the vein and rather evenly distributed.

The deposit is 6,000 to 6,500 feet above sea level and considerably above timber, but timber is said to be available on Healy River within 3 miles of the property, and the water of Healy River is regarded as sufficient for all mining purposes. Supplies are brought up Tanana River, a distance of 130 miles, to the mouth of Healy River, where a trading post has been established. From this place to the molybdenite deposit it is 40 miles. In summer pack horses may be taken along the ridge between Volkmar and Healy rivers and in winter the Healy can easily be traveled by double enders.

MINING IN THE HOT SPRINGS DISTRICT.

By Theodore Chapin.

MINERAL PRODUCTION.

The chief mineral product of the Hot Springs district is placer gold. In a portion of the district a considerable amount of cassiterite (tin oxide) occurs with the gold, but the amount recovered is insignificant in value compared with the gold. There are no independent tin placers, but the tin content of many of the gold placers is sufficient if recovered to add considerably to the total value of the output.

The production of gold in the Hot Springs district for 1917 was $450,000. In 1916 it was $800,000. This decrease was due to several causes. One of the principal causes is that which is common to all placer camps—the depletion of the bonanza ground. One of the immediate causes, however, was the cessation of the large scale operations of Howell & Cleveland, who for the last two years employed a large force of men on Woodchopper Creek. Another important factor in this decline is the high cost of food and mining supplies, which prevented the working of any except the richest ground.

It is not believed, however, that a decline in mining will continue from year to year, for there are large bodies of low-grade placer ground, which, under normal conditions, will be worked profitably for a great many years.

In all about 16 plants operated for all or a part of the season and employed about 150 men. Besides there were a number of men prospecting and working in a small way. Several small outfits were reworking old tailings for the recovery of tin concentrates and whatever placer gold might be recovered by methods more refined than those used when the ground was first worked. At that time the miners seldom used Hungarian riffles in the sluice boxes, and much of the gold was lost in the clay lumps which would go over the pole and bar riffles without breaking up.

Prospecting in 1917 showed that both gold and tin occur in the basin of Sullivan Creek, considerably below the area which has yet been mined. Large bodies of low-grade gravels are being worked on Boulder Creek.

The production of tin in the Hot Springs district in 1917 is estimated at about 25 tons of ore that contained about 30,000 pounds of tin, valued at $14,400. In 1916 about 70 tons of ore that contained about 84,000 pounds of tin, valued at $36,500, was recovered. The decrease was due largely to the shutting down of the large plants on Woodchopper Creek.

TIN ORE.

OCCURRENCE.

Although the stream tin, which occurs with the gold, has proved a considerable source of revenue, it is nowhere concentrated to such an extent that it can at present be mined profitably, except as an accessory to the gold. The bedrock sources of tin, which without much doubt occur somewhere within the drainage basin of Sullivan Creek, may contain workable deposits and will possibly support a more permanent mining industry than the placers.

For a number of years the tin concentrates were thrown aside by the miners as their nature and value were not known, and they were considered a nuisance, as they blocked the riffles and interfered with the recovery of the gold. In 1911 the true nature of the tin ore was pointed out to the miners by H. M. Eakin, of the Geological Survey, during a reconnaissance of this district, and since that time about 173 tons of cassiterite containing 208,000 pounds of tin, worth about $79,000, has been recovered. There was at first little incentive to save the ore, as the miners generally did not know where it could be sold, and the price was not high enough to make its recovery worth while. Speculators at first offered 5 cents a pound for the concentrates, and shipped them to Singapore and Wales for smelting. Since that time the price has advanced until in 1917, 14 and 15 cents a pound was offered at Hot Springs for the concentrates, a price which netted the producer 12 to 13 cents a pound at the mines.

Since the value of the tin became known, most of the operators have recovered as much of it as could be readily won. The tin ore is so much lighter than the gold that by a proper elevation of the sluice boxes the main separation of cassiterite and gold is easily made. The small amount of fine gold that goes over with the tin concentrates is recovered by cyanidation or amalgamation. The most difficult operation, and one which at present entails a considerable waste of high-grade tin ore, is the separation of the cassiterite from other heavy concentrates, principally pyrite and hematite, which are not easily separated from the tin by the ordinary sluicing methods. The tin ore ranges in size from particles the size of beach sand to boulders several inches in diameter and a few pieces nearly

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EXTENT AND SOURCE.

The tin ore is practically confined to the basin of Sullivan Creek, and its concentrations in general appear to coincide with the gold placers of that basin. Stream tin has been reported on several streams below the workable gold placers, but naturally the lighter minerals are carried farther downstream. The upper limit of the tin ore on Sullivan Creek and its tributaries appears to be rather well defined. Evidently the bedrock source is somewhere in the present basin of Sullivan Creek and is presumably covered by gravels. Even if the lodes of Moose Mountain contain tin, they are not believed to be the source of the tin of Sullivan Creek, for then the heaviest concentrations of stream-tin ore would normally occur just below the lodes and decrease downhill toward Sullivan Creek. As a matter of fact, little stream tin is found between the lodes of Moose Mountain and a point a short distance above Old Tofty, where the rich concentrations begin very abruptly.

The amount of tin ore that can be won under present conditions and costs is not large. As long as the placers of Sullivan Creek valley continue to operate on their present scale, there should be a production of 25 to 50 tons of tin ore a year, or possibly twice that amount if more refined methods of recovery are used. In the old tailings and in the low-grade gravels, however, several thousand tons of tin concentrates could be recovered at a higher cost of production.

MINING OPERATIONS.

The productive area of the Hot Springs district extends from a point near Fish Lake northeastward for about 35 miles to Pioneer Creek, a tributary of Eureka Creek. It comprises the drainage areas of Boulder, American, Sullivan, and Baker creeks.

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AMERICAN CREEK.

American Creek is a comparatively short creek that flows into Fish Lake. Mining is carried on in the upper part of the valley, which is floored with a deposit of shallow gravel from 10 to 18 feet deep. Below the mines the depth of the gravels increases at a steep grade toward Fish Lake. Three plants that employed about 16 men were in operation in 1917, using both open-cut methods and drifting. Gravity water is available for the lower workings, but at one plant it is necessary to pump water to elevated sluice boxes.

BOULDER CREEK.

Boulder Creek is a stream about 25 miles long that flows into the swampy lake area west of Fish Lake. Its main branch heads on the south slope of Moose Mountain, but several large tributaries enter it from the north and head in the main ridge that forms the main divide between Yukon and Tanana rivers. Prospecting has been carried on in Boulder Creek for a number of years, and low-grade deposits were known to exist, but not until recently were there any active mining operations.

Ground was staked on the main fork of Boulder Creek, known locally as Big Boulder, 1½ miles above the main forks, and active development work was started in the spring of 1916, when work was begun on a ditch which brings water 4 miles from a point near the head of Boulder Creek. The company controls 4½ miles of ground. An option was taken on this ground by Cleveland & Howell and worked by them during a part of the season of 1917, but work was stopped in August, and the owners continued to work on a small scale.

The south wall of the creek is steep and contains no gravel. North of the creek the valley wall forms a gentle slope which is floored with shallow alluvium, from 8 to 12 feet deep, that carries gold. The deposits are low grade and spotted but are extensive and easily worked by hydraulic methods. The gold occurs on this bench for a length of several miles, and the workable areas, where explored, have a width of 1,200 feet. Over 200,000 feet of bedrock was cleaned in 1917.

One man was prospecting on Little Boulder, the main tributary of the creek. The stream was diverted from its course and carried for half a mile through the flat at the mouth of the creek. The alluvium is from 6 to 12 feet deep and consists of silt that carries layers and lenses of angular slate fragments.

Trail Creek is the first tributary of Boulder that enters from the north below the main forks. On one of its branches, known as Dry Creek, one plant was operating in 1917. The gravels are shallow and angular. Where exposed by the cut they are from 3 to 6 feet deep and are composed of black slate, graywacke, quartzite, and schist, rocks similar to those exposed on bedrock. Water is not plentiful, but the ground is easily handled.

TIN DEPOSITS OF THE RUBY DISTRICT.

By Theodore Chapin.

The following statement is based on a hasty reconnaissance of the Ruby district in 1917 to determine the possibility of the production of tin. Although stream tin occurs at a number of places in the gold placers, there has been only a slight output. Cassiterite has been noted in the concentrates from Long, Spruce, Short, Tamarack, Midnight, Trail, Monument, Birch, Ruby, Poorman, Flat, and Greenstone creeks. The cassiterite is plentiful at few places, and at no place has enough been found to pay for mining it, except as an accessory to the gold. The gravels on Midnight Creek have been prospected for tin, and 14 sacks of concentrates were shipped to Singapore. This shipment consisted of 1,037 pounds of ore which assayed 52.2 per cent, or 537 pounds, of metallic tin. The net return of $156.22 from ore recovered from 6,000 square feet of bedrock gives a yield of about 2½ cents a square foot. Evidently the amount of tin recovered from even the richest tin placers now known is so small that even the shallow gravels can not be worked profitably for the tin alone. At best it adds but little to the profit derived from the gold. It is also evident that the tin ore is so disseminated that it will be very difficult to recover any large quantity, although a few tons may be saved each year by the placer gold miners.

THE GOLD AND PLATINUM PLACERS OF THE TOLSTOI DISTRICT.

By George L. Harrington.

INTRODUCTION.

The Tolstoi district as considered in this report includes an area about 12 miles wide by 20 long that lies on the northwest flank of Mount Hurst. The drainage from the district reaches the Innoko mainly through Tolstoi and Dishna rivers.

A time and compass traverse was made of the Dishna River from its mouth to the mouth of the Tolstoi, and thence up the Tolstoi to Madison Creek. Early in July, 1917, two weeks were spent in the vicinity of Tolstoi in collecting the data upon which this report and a portion of the accompanying geologic sketch map (Pl. IX) are based.

TOPOGRAPHY.

Mount Hurst, the highest point in the area, reaches an elevation of nearly 3,000 feet and gives a maximum relief to the district of approximately 2,500 feet. Northeastward from Mount Hurst extends a range of hills which have elevations between 1,200 and 1,800 feet above sea level, becoming lower as they approach the Innoko to the northeast. West of these hills the country presents a much less rugged aspect, and low, broad, flat-topped hills between which stretch wide valleys are the characteristic features, though some of the minor streams are rather sharply incised. Northward toward the Innoko there appears to be a succession of low hills, between which there are wide swampy areas that merge on the west with the lowlands of Innoko and Dishna rivers.

Most of the area under discussion lies within the basin of Tolstoi River, and the high ridge of hills which culminates in Mount Hurst forms the divide between the Tolstoi drainage and that of the upper Innoko.

The trend of the drainage when taken in conjunction with the geologic map, indicates that the northerly course of a number of streams is due to bedrock structure. Modifications, however, have been caused by alluviation or by lateral erosion, the latter in places where the streams flow on bedrock as well as where the banks are of unconsolidated material.

Numerous lakes are a characteristic feature of the poorly drained lowlands. They are usually small in area and occupy slight depressions in unconsolidated sediments rather than depressions in bedrock. They lie at higher elevations than the oxbow lakes that are formed by changes in stream channels, and they are probably the composite result of a number of factors which include soil flow, the damming of sluggish streams by the growth of vegetation, and the thawing of lenses of ground ice.

CLIMATE.

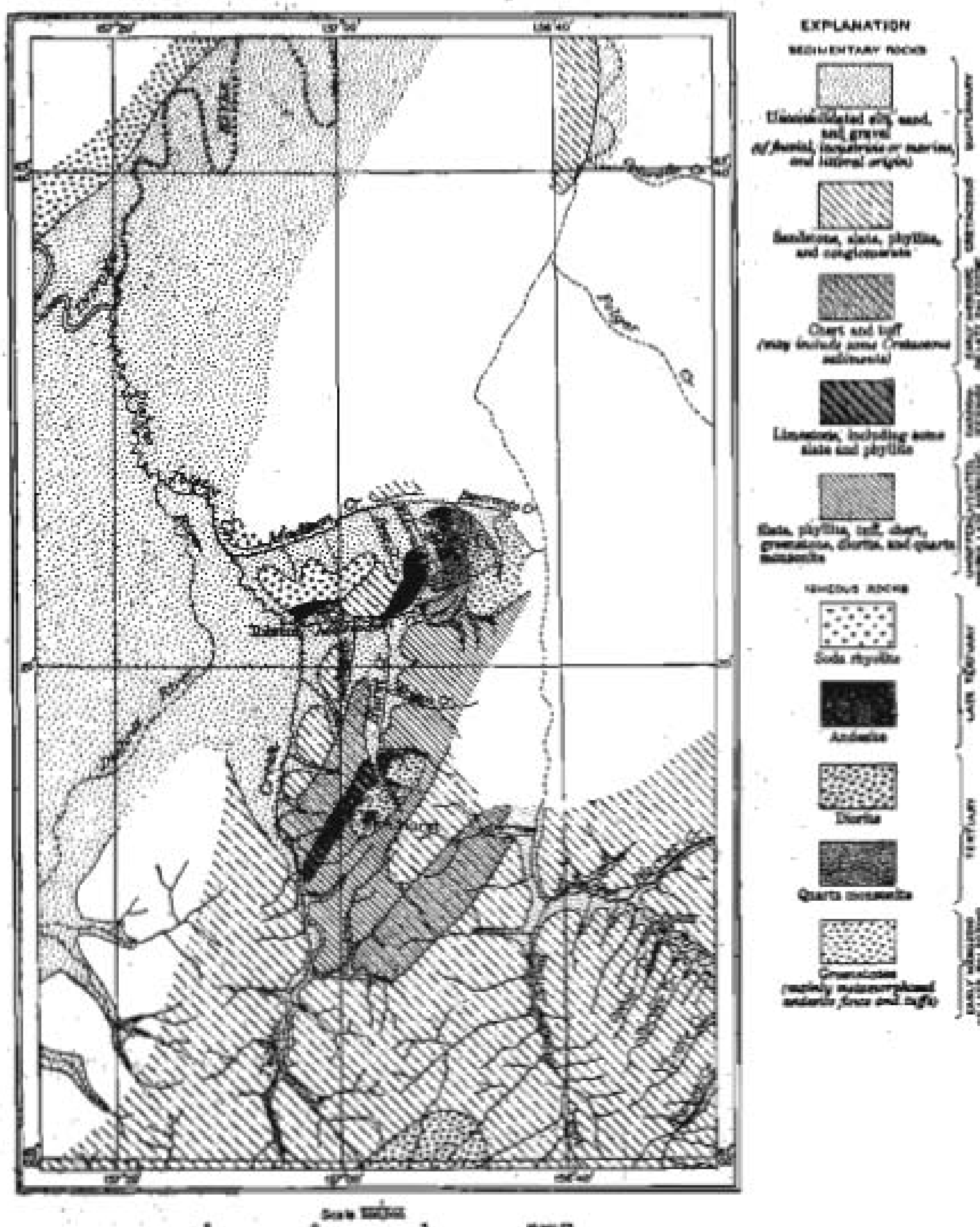
Climatic conditions in this district are essentially the same as those found elsewhere within the lower Yukon drainage basin. Winters are somewhat more moderate than in the Upper Yukon, although they are both long and cold.

Fair days in summer are usually very pleasant, but their number varies from year to year, as do the number of rainy days and the amount of rainfall. Usually, however, the later part of the summer has the greater precipitation. During July, 1917, the rains were unusually heavy and frequent, so that the Tolstoi reached and maintained a stage of water for about 10 days comparable with that of the normal spring high water. In one rain during this period there was a precipitation of more than 2 inches in a few hours. In the high hills near Mount Hurst, the rainfall is apparently greater than in the low areas along the lower courses of Tolstoi and Dishna rivers, as these hills were frequently hidden in clouds when the sky was fairly clear over the valleys.

VEGETATION.

A heavy carpet of sphagnum mosses covers all but the highest peaks and steep slopes or heavily timbered areas. Where conditions are favorable, in areas with good drainage, grasses make up a greater proportion of the vegetal covering. Alders, willows, and dwarf birch form the low growth of minor stream valleys and of the hillsides, and the larger species of willows, together with spruce, tamarack, cottonwood, and some birch, make up the major growth along the Dishna and Tolstoi and their larger tributaries, where thawed and drained ground present conditions most favorable for their best development. The poorly drained interstream areas are occupied by a scattered and stunted growth of spruce. Tamarack may occasionally be found associated with it. Good timber occurs on the flanks of Mount Hurst up to 1,800 or 2,000 feet. Though this timber is mostly spruce, there are some patches of tamarack and a few birches.

At Tolstoi there were gardens where the more rapidly maturing vegetables were raised. The amount so produced, however, was only a small proportion of the total quantities consumed, with the exception of radishes and lettuce, of which practically the entire consumption was of local production.



GEOLOGIC SKETCH MAP OF THE TOLSTOI DISTRICT.

ANIMAL LIFE.

Black bear are said to be fairly common in this region, and one was seen on the Dishna. Caribou are only occasionally seen. Smaller animals are numerous.

Geese and ducks were seen along the streams, and the swampy areas afford ideal breeding places for them. Ptarmigan are found on the higher hills in small flocks, though in lesser numbers than in former years.

Grayling and trout are found in the streams and may be taken with a fly. King salmon ascend the Dishna and sometimes ascend the Tolstoi also. The smaller species of salmon were taken in nets in considerable number at the mouth of Mastodon Creek.

ECONOMIC FACTORS AFFECTING MINING.

In the vicinity of the creeks, where there has been more or less prospecting, a scattered growth of stunted spruce has afforded fuel for the small plants used for thawing. With an increase in magnitude of operations, however, this type of fuel is unsatisfactory and uneconomical. In addition, it is necessary to have larger timber for use in mining. For the operations on Boob Creek cordwood and timber were hauled a distance of 2 to 4 miles from Tolstoi River and from Mastodon Creek. On other creeks, except those directly tributary to Tolstoi River, where mining may be carried on, even greater difficulty in obtaining fuel will be found, and it is probable that for large operations it will be necessary to use liquid fuels.

Such fuels can be carried by gasoline scows up Tolstoi River as far as Tolstoi and possibly still farther under favorable conditions of high water. Winter transportation from Tolstoi River would probably prove most economical. Under present conditions even winter transportation to the upper portion of Madison Creek costs about 5 cents a pound from Tolstoi River. Supplies can be brought by water from Holy Cross to the mouth of the Tolstoi for 2 or 3 cents a pound.

Navigation to this point is comparatively free from difficulties except in unusually low stages of water on Innoko and Dishna rivers. On Tolstoi River navigation is not practicable for power boats at low stages.

Wages during the summer of 1917 were about the same as at other Alaskan camps, \$5 a day of 8 hours with board being paid for underground work and \$6 a day of 10 hours with board for surface work. No natives were employed in mining but some worked at the sawmill at the mouth of Tolstoi River.

The early summer of 1917 was unusually wet, yet on many of the smaller streams where prospecting was being carried on there was but little surplus of water over that required for sluicing. In normal seasons it would appear that there will be a scarcity of water unless ditches are built to bring in water from two or more streams, or dependence must be placed either on the water supply furnished by the melting snow in spring or on that afforded intermittently by rains during the summer. An intermittent supply may be obtained by damming and "splashing."

As the creek gradients are low in the lower courses, some difficulty may be experienced in securing dump room and grade for sluice boxes without building trestles.

GEOLOGY.

The geology of the region in general is simple, though its interpretation is at first somewhat difficult because outcrops of the formations are not everywhere common, especially on the lower hills and gentler slopes. Vegetation covers these areas, and the nature of the underlying rocks is revealed only by the material taken from prospect holes, by isolated projecting rocks, or by exposures here and there along stream courses. The trend of the structural features, however, affords considerable help in geologic mapping and was relied on where other data were lacking.

PALEOZOIC ROCKS.

The most conspicuous of the Paleozoic rocks is a limestone, which forms the high conical hills on the northwest and west flanks of Mount Hurst and extends southwestward nearly to Tolstoi River.[1] It crosses Hurst Creek and appears at the base of the hills on the east side of this stream a short distance below the now abandoned Jap Roadhouse. A small outcrop lies between the forks of Mastodon and Mammoth creeks, and another appears on the south side of Myers Creek. Limestone pebbles are found in the gravels of Iron Creek, and this rock is said to crop out on the north side of the creek. It is not known whether or not it extends north of Madison Creek.

Schistose and siliceous phases of the limestone appear in the vicinity of Mount Hurst, and the siliceous rock is finely crystalline. Elsewhere the rock appears to show but slight effects of crystallization.

Areas of phyllites or schistose argillitic rocks are associated with the schistose limestone, but they are comparatively small, and on account of their similarity in composition can not everywhere be readily separated from some of the Cretaceous argillitic rocks which have been metamorphosed. As fossils have not been found, it is not possible to make a definite statement of the age of the limestone. Because of their lithologic similarities the limestone and associated rocks are considered to be of late Carboniferous age and to be correlated with similar rocks on the lower Kuskokwim and on the lower Yukon near Marshall.

[1] Maddren, A. G., oral communication.

PALEOZOIC OR MESOZOIC ROCKS.

GREENSTONES, GREENSTONE TUFFS, AND CHERTS.

Although the rocks of this group are of widely diverse types they are believed to be of like origin and to be closely related in age. They have been separated, however, in mapping, the tuffs and cherts being grouped together and the greenstones shown separately.

They occur chiefly on the northwest flank of Mount Hurst and along the divide between Tolstoi and upper Innoko rivers, at the heads of Mastodon and Madison creeks, and probably also between Hurst Creek and upper Innoko River, south of the head of Mastodon Creek, in the area mapped as undifferentiated. Small areas are also known from other parts of the district, and cherts appear on the north side of Mastodon Creek about a mile northeast of Tolstoi. As considerable faulting and folding were produced by the intrusions which form Mount Hurst and by the monzonite between Mastodon and Madison creeks, numerous other small patches of these rocks representing fault blocks will probably be found elsewhere in the district.

Andesite rocks constitute a large portion of the greenstones, including most of the dense fine-grained dark-greenish tuffs between Hurst Creek and Tolstoi River and the more schistose phases, which probably represent altered flows, at the head of Mastodon Creek.

In addition to these two types other igneous rocks, including basaltic flows and the even more basic intrusives, which are probably the source of platinum in this district, occur in a number of small areas in the vicinity of Mount Hurst as well as to the north of Mastodon Creek. Their areal extent is not known, for they are not conspicuous in places where they are associated with the greenstones and, as has already been pointed out, an additional difficulty in mapping is caused by the widespread distribution of the Quaternary deposits, which effectually conceals the underlying bedrock. Pyroxenites occur in close association with the greenstones. They are dark, coarsely granular, nonporphyritic rocks that consist mainly of augite and lesser amounts of diallage. In some platiniferous placer areas the source of the platinum has been found in rocks of this type.

The cherts occur north of Mastodon Creek and along the ridge leading to Mount Hurst west of Hurst Creek. They may be either light or dark, ranging from light horn-colored to dark greenish gray, and may resemble some of the phases of the tuffs with which they are closely associated.

No definite age determination has yet been made of these rocks, but they overlie limestones which have been tentatively assigned to the Carboniferous. Chert cobbles and pebbles are found in a conglomerate which overlies the greenstones and which marks the base of the Cretaceous in this district. The age of the group is therefore very late Paleozoic or early Mesozoic. It is not certain whether the basic intrusive rocks are of this age or younger.

CRETACEOUS ROCKS.

In the Tolstoi district Cretaceous rocks have considerable extent, appearing on both sides of Tolstoi River and on the north side of both Mastodon and Madison creeks. Small patches of those rocks also appear along the lower part of the ridge west of Hurst Creek, and they probably form the bedrock of Boob Creek and of the area between Boob Creek and Tolstoi River.

The lithology shows considerable variation. Wherever the base of these rocks was observed, as along the ridge between Hurst and Ledge creeks and also north of Mastodon Creek, it is a conglomerate composed of chert pebbles that rests on the irregular surface of the underlying cherts. The sandstones show a greater diversity of materials, including quartz, feldspar, fragments of carbonaceous rocks, and minerals of probably secondary origin, such as chlorite and calcite. If ferromagnesian minerals, such as hornblende, augite, or olivine, were originally present, they have now been so completely altered to secondary minerals as to be unrecognizable. The feldspars are also undeterminable on account of kaolinization.

A considerable proportion of the Cretaceous sediments are of the fine-grained argillaceous type and have been metamorphosed to form slates. Intrusion by the dioritic mass of Mount Hurst as well as by the diorites on the headwaters of Madison Creek, has produced phyllitic phases of some of these rocks, so that they are not readily distinguishable from the older phyllites that are associated with the Paleozoic limestone. Both the slates and phyllites are cut by numerous small quartz veins, which are probably the source of the gold. Some of the veined slates show pyritization.

No fossils were found in the Tolstoi district, so that correlations must be based on stratigraphic and lithologic features. These rocks are essentially similar to the slates and sandstones in near-by regions which are of known [1] Cretaceous age and are therefore considered as belonging to that period.

TERTIARY IGNEOUS ROCKS.

QUARTZ MONZONITE.

Pinkish quartz monzonite, which is locally known as granite, occurs along the ridge between the Madison and the Mastodon drainage at the head of Eldorado Creek, between Myers and Iron creeks, and also between Iron and Madison creeks. The areas mapped as monzonite may also contain some sedimentary rocks, as between Iron and Madison creeks, where limestones occur.

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[1] Mertie, J. B., jr., and Harrington, G. L., Mineral resources of the Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 642, p. 233, 1916.

It has been pointed out in a previous bulletin[1] that elsewhere in the Ruby-Kuskokwim region there is a close genetic connection between the auriferous mineralization and the monzonitic rocks. In the Tolstoi district this relation also probably holds, and the occurrence of gold placers is to be attributed to these intrusives. There is said to be some residual placer gold on the slopes of gills made up of the monzonite, and the auriferous quartz veins, which occur in the near-by areas of sedimentary rocks, are believed to be derived from the monzonite intrusion.

The quartz monzonite is made up of quartz, orthoclase, and plagioclase in about equal amounts, together with hornblende and biotite. Apatite and magnetite are present as minor accessory minerals.

A correlation with similar rocks elsewhere in the Ruby-Kuskokwim region[2] would establish a Tertiary age for the quartz monzonite.

DIORITE.

Diorites are perhaps more widely spread than the geologic map indicates, for it is extremely likely that in the area of undifferentiated rocks east of Hurst Creek a number of the higher peaks are composed of this type of rock. There are also numerous small outcrops in the greenstone areas, which are too small to represent on the map. These outcrops represent dikes from the larger batholithic intrusives which form Mount Hurst and appear on Joffre Creek. From the relations of the diorite and greenstone at the head of Joffre Creek, it appears likely that even where the diorite is not exposed it lies below the greenstone where that rock appears between Mount Hurst and Madison Creek. There are also dikelike intrusions of considerable extent in the Cretaceous sediments, in the limestones, and in the greenstones and greenstone tuffs. In the greenstones especially, the similarity of appearance on weathered surfaces makes a determination of the extent of these intrusions difficult.

Some differences in the appearance of the diorite are due partly to the amount of weathering that the rock has undergone and partly to differences in composition. Weathering gives the rock a much darker and greener color than it has when unaltered, owing to the formation of secondary silicates and ferromagnesian minerals, such as zoisite, chlorite, and hornblende, as well as hydrous iron minerals.

Where the rock is unaltered its constituents are plagioclase feldspar, biotite, and augite, together with a minor and varying amount of quartz. Apatite and magnetite are everywhere present, the magnetite varying considerably in amount. In some places ilmenite appears to take the place of some of the magnetite and occurs in somewhat larger grains. The feldspars range from albite oligoclase to labradorite, but the mean appears to be oligoclase andesine.

[1] Mertie, J. B., jr., and Harrington, G. L., op. cit., pp. 235, 264, 1916.
[2] Idem, p. 235.

Possibly the basic granular rocks that are associated with the greenstones, and from which the platinum is derived, are differentiates from the dioritic magma, but confirmatory evidence on this point is lacking, although the diorites in the greenstones are somewhat more basic than either the main mass of Mount Hurst or the intrusive mass on Joffre Creek.

Although gold has been found on Joffre and Madison creeks, in the diorite, the gold may not have been derived from deposits which owe their origin to the intrusion of the monzonite.

Age determinations are only possible where relations to both younger and older rocks are known. The diorite cuts Cretaceous rocks and therefore is post-Cretaceous and probably early Tertiary. Its age with relation to the monzonite is not known but both are assumed to have been introduced during the same period of igneous activity.

SODA RHYOLITE AND ANDESITE.

North and northwest of Mount Hurst low flat-topped hills appear to merge into the lowlands of the Dishna and the Innoko. So far as is known, these hills are made up of rhyolite flows and tuffs, though andesite is present in dikes and flows and possibly also in tuffs. They are mapped separately, but the rhyolite areas may include some andesite, and the area mapped as andesite may contain some rhyolite.

The rhyolites are light-colored rocks and at a distance present an appearance like that of limestones with a slight buff tinge. In thin section they are seen to be fine-grained porphyritic rocks, the phenocrysts being quartz and the plagioclase feldspar. The quartz is usually of the smoky variety. Albite is the principal plagioclase, but the feldspars range between albite and oligoclase. Biotite is usually present in a few foils, which are also sometimes apparent in the hand specimen. Less commonly hornblende may be seen in the section. Magnetite may also be present. For the most part the groundmass is very fine grained and almost glassy in appearance. The flow or tuffaceous character of the rock is apparent from the typical texture seen in thin section.

In the hand specimen the andesites are light to dark greenish gray and can be readily distinguished from the rhyolites on account of their color. Where the andesites are in the field they are also much darker, and they are usually more completely covered by vegetation than the rhyolites. Associated with the flows or dikes are minor areas of dense fine-grained rocks which resemble argillites in appearance but which are probably fine-grained tuffs or volcanic muds. The rhyolites appear to make up the entire hilltop and in many places the steep slope to the flat of Tolstoi River, but the andesites north of Tolstoi appear at an elevation below the crest of the main ridge in small subsidiary ridges which trend northeastward in conformity with the general structural trend. Between Eldorado and Mastodon creeks the andesites occupy higher positions on the ridges, which correspond to those occupied by the rhyolites farther west.

In thin section andesine feldspar appears to be the chief constituent of the rock, making up the phenocrysts as well as a considerable amount of the very fine grained groundmass. Phenocrysts of augite are also present in places. Magnetite occurs in small grains in widely varying amount. Much of the groundmass is altered and indeterminable and has been converted in part to secondary hydrous iron oxides, which give a general brown appearance to the section.

It is not possible to make exact age determinations of these rocks, although some generalization may be made. There is a suggestion as to the relative ages of the andesite and rhyolite afforded by the form of the outcrops of the andesite and by the relative position of the two series. The ridges north of Tolstoi may represent the upturned eroded edges of flows the source of which lay eastward, although this is by no means proved. If this supposition is correct the rhyolites which lie to the west of the andesites flowed out over and are younger than the andesites.

In other areas in western Alaska rocks of one or the other type are rather widely distributed. The exact lithologic equivalent of the rhyolite was seen on the north bank of the Innoko about halfway between Shageluk Slough and the mouth of Iditarod River. Collier[1] reports that both andesites and rhyolites cut the Cretaceous rocks between Ruby and Holy Cross. Andesitic and dacitic dikes, tuffs, and flows were found by the writer[2] to have a considerable extent along Anvik, Stuyahok, and Bonsila rivers, as well as in places along the Yukon between Anvik and Andreafski. At these occurrences they are younger than the Cretaceous rocks with which they are sometimes associated and are older than the late Tertiary or Quaternary basalts of the lower Yukon. In other portions of the Ruby-Kuskokwim region both rhyolites and andesites have been found[3] which are of late Cretaceous or Tertiary age, and these are to be correlated with the corresponding rock types in the Tolstoi area.

QUATERNARY DEPOSITS.

Unconsolidated material which is mainly of Quaternary age covers much of the lowland area of the Tolstoi district and extends nearly to the heads of many of the smaller streams and occupies the interstream ridges. This material is in part alluvial but probably is also in part of marine or lacustrine origin, and the flat-topped hills at

[1] Collier, A. J., unpublished notes.

[2] Harrington, G. L., The Anvik-Andreafski region, Alaska (including the Marshall district): U. S. Geol. Survey Bull. 683, pl. 2, 1919.

[3] Mertie, J. B., jr., and Harrington, G. L., Mineral resources of the Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 642, p. 236, 1916.

elevations of 800 to 1,000 feet may be wave-cut terraces upon which these sediments were deposited. For the most part, the sediments are thin and in large measure have been removed or have been left in only small areas. In the lowlands the former stream courses were filled with gravels, sands, and silts, but upon the reestablishment of drainage systems after the period of inundation a large amount of the unconsolidated material was removed. Between Tolstoi and Boob Creek prospect holes which have been sunk to a depth of 125 feet pass through about 60 feet of muck and ice which overlies an equal thickness of silts, sands, and gravels.

In the silts there are large amounts of ice, in sheets rather than in wedges. These ice sheets appear to contain different amounts of silt and bands of clear ice from an inch or less to several feet in thickness, alternating with bands of frozen siltlike material, which show variations in thickness equally great. Possibly some of the numerous small lakes in the flatter, low-lying areas are due to depressions caused by the melting of ice layers underneath.

The gold and platinum content of the gravels has been concentrated by either the action of waves on beaches or by the current of streams, or there may have been a reconcentration by streams from older deposits formed along beaches or streams.

A somewhat unusual feature in connection with the placer gravels is that a short distance above the gravels there are fragments of vegetation and tufts of grass which resemble the niggerheads on the present surface. Their presence is easily explained. There is a covering of silts and sheet ice over practically all the gentler lower slopes, and when a small or intermittent stream has cut through the surface mat of vegetation it rapidly erodes the silt and ice to the gravels or to bedrock. By sloughing of the steep sides vegetation may reach the bottom of the cut, 20 feet or more in depth. By continuous sloughing, or by repeated freezing and thawing in fall and winter, the crevice is completely filled with ice and muck, and the following year the stream may follow a different course.

The occurrence of tusks, teeth, and other bones of Pleistocene mammals in the placer gravels indicates the age of the deposits, although it is possible that later reworking has taken place and that some of the placers are later than the Pleistocene.

The Quaternary history of this region has not been completely worked out, so that it is not possible to differentiate between the Pleistocene and Recent deposits on account of their similarity and the grading upward of one into the other.

The deposits which are definitely of Recent age embrace stream alluvium, talus, and other detritus produced through the action of frost and other processes of weathering and the vegetal accumulations which cover large areas throughout the interior of Alaska.

MINERAL RESOURCES.

HISTORY OF MINING DEVELOPMENT.

The earlier history of the region has been given in the report of Maddren[1] on the mining developments in the Innoko basin to the time of his investigations in 1908. Some additional notes have been contributed by Eakin[2] as the result of a reconnaissance trip from Ruby to Iditarod in 1912.

Incident to the stampede to the Innoko, in the vicinity of Ophir, many claims were staked on streams in the Dishna drainage. A few men prospected their claims faithfully, although the high cost of supplies and the difficulty of getting them at any price necessarily made prospecting difficult. Many claims were held by other men, however, and upon them only sufficient work was done to maintain titles or not even the amount of work required by law. Title to most of these claims had been permitted to lapse by 1915, and when a rush during the spring and summer of 1916 followed the discovery of gold during the previous winter most of the ground along the creeks lay open for restaking. Prospecting was carried on quite extensively during the summer of 1916, but Boob Creek alone made any production and that small. Preparations for mining on a larger scale were made, however, and during the winter and spring of 1916–17, a considerable production was made by the plant which operated on claim No. 2 below Discovery and the adjoining fraction above this claim. During the winter of 1916–17 there was a stampede from Ruby, Ophir, and Iditarod, which brought the population of the district up to about 450, most of whom staked claims. This stampede was followed during the winter by active prospecting on a large number of the creeks tributary to Tolstoi River, but for the most part this work failed to develop workable placer ground. As a result the population dwindled, until in July, 1917, there were only about 50 left in the district. About $50,000 in gold was taken out in 1917, the result of the operations of about 25 men on five plants, most of the production being on Boob Creek. Boob Creek is the only creek in the district that produced platinum. The platinum was not separated from the gold but was sold with it to the bank in Iditarod. The platinum in the gold was said to amount to about 1 per cent, so that about 30 ounces of platinum was produced in 1917.

GOLD PLACERS.

The only plant which made any considerable production up to July, 1917, is located on Boob Creek. Extensive mining operations have been confined to that creek, where one plant was in operation,

[1] Maddren, A. G., The Innoko gold placer district, Alaska: U. S. Geol. Survey Bull. 410, pp. 19–24, 1910.
[2] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 39, 1914.

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and several outfits were engaged in prospecting during the spring and summer.

The deposits are worked by underground methods for the auriferous gravels, 2 to 4 feet thick, lie beneath 25 to 35 feet of muck and ice. The surface gradient of the stream is low, not over 50 feet to the mile.

Besides gold and platinum other minerals which may have economic importance are cinnabar and cassiterite, which are found in small amounts. Cinnabar occurs in small pebbles up to half an inch in diameter of a characteristic red color. Cassiterite in the form known as wood tin occurs in the typical botryoidal form, showing radiate structures when cracked open. The pebbles are somewhat darker than those seen in the Ruby district, being nearly black. The crushed mineral gives a very light brown powder.

A small sample of the platinum from Boob Creek was presented to the Survey by Mr. J. S. Pitcher, of Tolstoi. It was analyzed by R. C. Wells in the chemical laboratory of the Survey and found to have the following composition:

Analysis of specimen of platinum from Boob Creek, Tolstoi district.

Platinum	83.4
Iridium	.4
Palladium	.3
Copper	None.
Rhodium	.3
Iron	9.8
Osmiridium, silica, and undetermined	.6
Nickel	None.
	94.8

Pyrite, magnetite, garnet, feldspar, and quartz also occur in the concentrates. The quartz is found in small brilliant transparent crystals as well as in the milky white form from veins. A considerable number of grains of nearly opaque, brownish-black grains of obsidian or volcanic glass were also noted.

Some of the tributaries of Tolstoi River, which head against Mount Hurst or its spurs, were prospected during the spring and summer. Up to July none had made any production. Considerable prospecting had also been done on tributaries of Mastodon Creek other than Boob, but without result.

On Madison Creek and several of the streams flowing into it, including Esperanto, Joffre, and Eldorado creeks and their tributaries, considerable prospecting has been done. On Iron Creek, which empties into Eldorado, there were at one time seven or eight outfits, but in July only one of these was working about 2 miles from the head of the creek. Mining was being done in an open cut by three men who were shoveling into the boxes. The gravels were largely composed of phyllitic rocks and granite but included some pebbles of limestone. Sections show from 2 to 4 feet of gravel overlain by about 4 feet of muck. A considerable amount of stripping had been done, and it was planned to work during the summer. No platinum was found on this creek. A considerable amount of prospecting had been done on a number of claims near the head of Madison Creek, but work during July was confined to two claims. On claim No. 5 above Discovery three men were working. At this locality 4 feet of muck overlies about 8 feet of gravel, and the gold is found in the lower 4 feet. The gold from this claim is flaky, fine, and worn. No platinum was seen in pannings, which in addition to the gold contained magnetite, ilmenite, augite, hornblende, garnet, and zircon, none of which have economic value under these conditions of occurrence. The creek valley is about 150 to 200 feet wide on this claim. The ground in the center is said to be thawed, although it is frozen on either side. Operations were largely carried on with the purpose of ascertaining the extent and richness of the stream gravels. A small production was made from this and adjoining claims under the same ownership.

One man was working on claim No. 7 above Discovery. A number of prospect holes had been sunk and the dirt from these holes and some short crosscuts had been rocked out. The gold, although somewhat worn, is considerably coarser than that found on claims lying farther down the creek and is described as "shotty" rather than flaky. An association of minerals similar to that on the lower claims is found in the concentrates.

TIN MINING IN SEWARD PENINSULA.

By George L. Harrington.

SUMMARY OF MINING OPERATIONS.

A résumé of the history of tin mining in Alaska up to 1914 has been compiled by Eakin,[1] and the following summary of operations up to that date is largely abstracted from his report.

Stream tin was first found on Buhner Creek, a tributary of Anikovik River, in 1900, and there has been some production of cassiterite from placer operations in the York region since 1902. In 1911 a dredge was installed on Buck Creek which has been in operation each season since. Two dredges were installed on Anikovik River in 1914 for the recovery of both gold and cassiterite but were operated only during that and the following season. A second dredge was installed on Buck Creek in 1915 and has worked each summer since that date. The machinery of one of the dredges on Anikovik River was removed from the hull in 1916 and installed on a dredge on Swanson Creek, a tributary of Agiapuk River. The hull was carried out to sea by high water and lost. The other dredge on Anikovik River was idle in both 1916 and 1917.

Collier states[2] that "small specimens of stream tin have been found in the northern part of Seward Peninsula, from Cape Prince of Wales to the south shore of Kotzebue Sound, and in the southern part of the peninsula the ore has been found in several streams of the Nome district."

Hess mentions[3] that Goldbottom Creek in the Nome district, Fred Gulch, north of Mount Distin, Dick Creek, Old Glory, and a "few other creeks of the Arctic slope east of Ears Mountain carry some stream tin."

Cassiterite lodes were discovered at Cape Mountain in 1902 and on Lost River the following year. Mining operations have been carried on at both localities ever since, although in a somewhat desultory fashion. Two stamp mills have been erected at Tin City to handle ore from two properties, and a small tonnage has been produced, but both properties have been idle for several years. At Lost

[1] Eakin, H. M., U. S. Geol. Survey Bull. 622, pp. 81–94, 1915.
[2] Collier, A. J., U. S. Geol. Survey Bull. 259, p. 126, 1905.
[3] Hess, F. L., U. S. Geol. Survey Bull. 284, p. 157, 1906.

River assessment work has been done annually for a number of years on a group of claims, and a fair stage of development has been reached. This property has been leased to different corporations which did some mining, milling the ore in a small test mill at the mine on Cassiterite Creek. In 1917 lumber and machinery for a mill at this property was at Teller, but the only assessment work was done at the mine.

Assessment work has been done for a number of years on several lode prospects at several places in western Seward Peninsula. By far the largest proportion of the Alaskan tin production has come from the placer operations on Buck Creek or from Grouse Creek, into which it flows. A small production of placer tin has been made from Cassiterite Creek.[1] Placer tin has also been recovered in the Yukon-Tanana region in the Hot Springs district, and a small production has been made in the Ruby district. Investigations of the possibilities of the tin production of these two districts were made in 1917 by Theodore Chapin, and his reports appear in another chapter of this volume.

Investigations of the tin deposits of the York region have been made by a number of Geological Survey parties, the scope ranging from hasty reconnaissance trips to obtain the new facts revealed by mining developments to detailed studies of the one occurrence. The most complete of these studies were made by Collier and later by Knopf, in whose reports will be found a description of most of the essential features covering the geologic occurrence of the cassiterite. The following publications deal primarily with the tin deposits of Seward Peninsula:

Brooks, A. H., A new occurrence of cassiterite in Alaska: Science, new ser., vol. 13, No. 328, p. 593, 1901.

Brooks, A. H., An occurrence of stream tin in the York region, Alaska: U. S. Geol. Survey Mineral Resources, 1900, p. 270, 1901.

Collier, A. J., The tin deposits of the York region, Alaska: U. S. Geol. Survey Bull. 229, 1904.

Collier, A. J., Recent developments of Alaska tin deposits: U. S. Geol. Survey Bull. 259, pp. 120–127, 1905.

Hess, F. L., The York tin region: U. S. Geol. Survey Bull. 284, pp. 145–157, 1906.

Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: U. S. Geol. Survey Bull. 358, 1908.

Hess, F. L., Mineral resources of Alaska, 1911: U. S. Geol. Survey Bull. 520, pp. 89–92, 1912.

Eakin, H. M., Tin mining in Alaska: U. S. Geol. Survey Bull. 622, pp. 81–94, 1915.

The following publications contain only incidental references to the occurrence of tin in the same region:

[1] Eakin, H. M., op. cit., p. 89.

Brooks, A. H., A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska: U. S. Geol. Survey Special Pub., pp. 132–139, 1901.
Collier, A. J., A reconnaissance of the northwestern part of Seward Peninsula, Alaska: U. S. Geol. Survey Prof. Paper 2, pp. 49–51, 1902.

A demand for a knowledge of the present possibilities of production of both the lode and placer tin deposits of the York region, resulting from the urgent need of tin, and the desire to find a source of this metal nearer than the Asiatic deposits led to the somewhat brief reconnaissance of portions of the York region in 1917. This report aims to present briefly the data obtained regarding developments and possibilities of production rather than to present geologic facts which have been given in the reports already cited, especially those of Collier, Knopf, and Eakin.

Acknowledgments are due and gladly given for courtesies received from Mr. T. A. Peterson, of the York Dredging Co., and Mr. A. Graham, of the American Tin Dredging Co., on Buck Creek, and Mr. William O'Brien on Lost River. Information regarding the tin deposits of Ear Mountain was received from Mr. T. Winfield, of Teller. Mr. Fred Hinton, of Teller, gave the writer his information regarding developments at Tin City.

CASSITERITE LODES.

Other work seriously curtailed the scope of the tin investigations in 1917, so that it was not possible to visit either Ear Mountain or Tin City. A superficial examination of the lode prospects near Potato Mountain was made, and portions of two days were spent on Lost River.

LOST RIVER.

In September, 1917, about 150 feet of additional drifts had been driven since Eakin visited the property in 1914. He says concerning the development on Cassiterite Creek at the Cassiterite and Ida Bell lodes:[1]

> The maximum width developed is 23 feet, and the average width is estimated at 12 feet, from the evidence afforded by numerous crosscuts along about 1,100 feet of drifts. The extreme limits of development work embrace a horizontal distance of 1,420 feet and a vertical distance of 410 feet above the creek bottom. The indications point to the persistence of the lode in form and character below the creek level, and no special mining difficulties at depth are indicated.
>
> Some strong veins carrying tin crop out 300 feet north of the Cassiterite lode and dip 45° S. The lode itself dips 85° in the same direction, and if these dips persist the veins should meet the lode at a depth of about 300 feet below the creek level.
>
> Developments on the Cassiterite lode in July, 1914, consisted of 1,094 feet of drifts on five levels, besides a number of crosscuts, and an upraise of 108 feet between the first and second levels east.

[1] Eakin, H. M., op. cit., pp. 86, 87.

About 2,000 tons of ore taken from the first and second levels east lies on the dump at the portal of the lower adit.

The test mill of the Lost River mine plant has operated for two successive seasons. The dump, containing about 2,000 tons of run-of-mine ore, was sampled by trenching entirely across its center and milling all the ore as it came. The results of the test probably indicate very closely the general tenor of the dump as a whole and of a large body of minable ore blocked out by the developments indicated.

The managers report that about 4 per cent of concentrates were obtained from the ore milled during the two seasons and that no notable variation was observable at any period of operation. The concentrates are very clean and are said to contain an average of 62.31 per cent of metallic tin and 11.08 per cent of metallic tungsten.

The Ida Bell lode strikes northeast and intersects the Cassiterite lode at the surface 700 feet west of the creek and 225 feet above creek level. Its dip is approximately 90°. It is wider than the Cassiterite lode, ranging from 25 to 35 feet. Developments on this lode include a 70-foot adit and a 60-foot winze sunk at its extremity.

Like the Cassiterite lode, the Ida Bell is a quartz porphyry dike, but the pronounced alteration of the former is not here duplicated. For the most part the lode consists of firm, slightly altered quartz porphyry intricately traversed by thin, rich veinlets with cassiterite as the only conspicuous valuable mineral. The ore is reported to be of good quality, but owing to its hardness it will require different treatment from that adapted to the Cassiterite lode ores, which are soft. Further development of this part of the mine will await a higher development of the reduction plant.

Development work since 1914 had been mainly on the east side of the creek; that for 1917 contemplated the enlarging of the main haulageway of the lowest level of the mine.

This property has sufficient ore either mined and on the dump or developed so that production could be commenced as soon as a mill is installed. Milling machinery and the necessary lumber for the erection of a mill building were at Teller in 1917. It is probable that this equipment could be most easily hauled to the mine during the winter, for the road from the mouth of Lost River to the mine crosses the river by fords severals times and would be impassable at high stages of the water. Where it is above high-water stages, this road is in good condition. If a great amount of hauling was to be done it would probably be economical to build a road on the east side of the creek, which would involve comparatively little work.

For summer work hydroelectric installation would probably prove most satisfactory. For year-round operation, however, auxiliary power would be needed, which would be most economically furnished by internal-combustion engines, using crude oil or distillate as fuel. No timber other than driftwood on the beach is available for fuel. Timber for the mines must be shipped in.

In addition to cassiterite the ore contains considerable wolframite, which may equal the cassiterite in amount. It adds materially to the value recovered from the ore. The two minerals should be separated before smelting.

This property appears to offer the greatest hope of an increased production of tin, but although it is sufficiently developed to warrant the installation of a small mill, after thorough sampling and after data have been obtained as to costs of production, the output in the next few years is not likely to amount to more than a very small percentage of the country's needs.

EAR MOUNTAIN.

The lode deposits of Ear Mountain, together with their earliest geologic features, have been described by Knopf.[1] A considerable amount of prospecting has been done in this vicinity, and there has been some development work since Knopf's visit. This work has for the most part amounted only to the annual assessment work necessary to maintain title to the claims.

This area is much more difficult of access than Lost River, for it is 12 miles from Shishmaref Inlet—a large lagoon of shallow water navigable only to very shallow-draft boats. Light-draft steamers must unload at least 1½ miles from the entrance to the lagoon. On account of these conditions, a considerably higher grade of ore must be found in this locality than on the south side of Seward Peninsula in order to make mining profitable.

POTATO MOUNTAIN.

A number of open cuts have been made on the tops of the hills near Potato Mountain, some of which are said to have shown good ore in the bottom. Bedrock has, however, been covered by the caving in of the sides of the prospect pits. The geologic features of the deposits of this area are described by Knopf.[2] Since Knopf's visit a number of other cuts and prospect holes have been dug. A short tunnel, which shows some stringers of quartz with cassiterite, has also been driven. Prospecting has failed to afford any indications of the extent of the ore bodies shown in the openings.

This prospect lies about 16 miles from York. A road which has been in use for teaming supplies for the Buck Creek dredges since 1911, runs within about 2 miles of the prospect. The road lies mostly along the watercourses of Anikovik River and Grouse and Buck creeks, crossing and recrossing them, and consequently is not especially good for heavy hauling.

Until further development has taken place the possibilities of the production of this property can not be stated. Under present con-

[1] Knopf, Adolph, op. cit., pp. 25–32.
[2] Idem, pp. 32–35.

ditions it would take at least two or three years before any production could be made.

CAPE MOUNTAIN.

A considerable amount of work was done for a number of years near Cape Mountain. A study of these deposits also was made by Knopf and a description of them is contained in his report.[1]

Two properties have been extensively prospected by tunnels, shafts, and winzes, and a number of other claims have had a small amount of work done on them.

On the property formerly belonging to the Bartels Tin Mining Co., which was later sold to the Empire Tin Mining Co. and still later is said to have been sold at marshal's sale to Fred Hinton, of Teller, there are about 1,255 feet of tunnels and winzes. Knopf states[2] that at the time of his visit an 18-inch belt of tin ore about 400 feet from the mouth of the tunnel had not been exploited. A few tons of ore were milled in 1914 from the North Star claim, but the place in the workings from which it was obtained is not known. Some of the ore is said to run very high in cassiterite, but the reported average of such ore as is developed is about 3 or 4 per cent. The property includes a small mill, containing three stamps and a table. This group of claims has been patented and no work has been done since 1914.

Although a considerable length of tunnels, cross drifts, and winzes has been driven, on this property, there appears not to have been development commensurate with the labor expended. Probably the claims of the group contain some bodies of good tin ore, but the development has failed to outline them, and further work is necessary before a statement of the potentialities of the property can be made.

On the property of the United States Tin Mining Co. a shaft has been sunk on a quartz ledge and a rather long tunnel driven in hard granite to intersect this ledge. A mill has been erected near the beach at Tin City to handle ore from this property. The claims are patented, but no work has been done on them for a number of years.

Sufficient data are not at hand to warrant any statement as to possibilities of production from the group of claims held by this company. However, as no work has been done for some time, notwithstanding the prices prevailing for tin in recent years, it may reasonably be inferred that the stage in development has not yet been reached where any appreciable production can be counted on in the near future.

[1] Knopf, Adloph, op. cit., pp. 35–41.
[2] Idem, p. 40.

OTHER LODES.

In addition to the properties above mentioned, there are a number of other prospects in the York region, including Brooks Mountain and others than those already mentioned in the vicinity of Cape Mountain. The work on these properties has been of a desultory character and of relatively small amount. They appear to be negligible in any consideration of the possibilities of the production of tin.

Besides the lodes which are being worked for tin mainly or chiefly, tin could possibly be recovered as an accessory mineral from other lodes in the York region. There are a number of silver-lead prospects on Lost River, on two of which some work was done during the summer of 1917. A third on Rapid Creek, a tributary of Lost River, is said to be extensively developed. At the Southern Cross lode tunnel on Lost River, opposite the mouth of Tin Creek, assays are said to show a small percentage of tin and tungsten, which probably occur as cassiterite and wolframite. In any treatment of the ores involving concentration on tables these minerals would be recovered. It is not known whether or not cassiterite occurs at the other prospects. The output of tin as a by-product of these lodes will probably be small.

CASSITERITE PLACERS.

LOST RIVER.

A small production of placer tin was made one year on Cassiterite Creek, and it is said that a considerable amount of residual placer tin occurs on the slope of the hill near the mine. If hydroelectric power was used on this property and the water flumed to the mill, this ground could be sluiced and the tin recovered.

EAR MOUNTAIN.

A number of the creeks that head in Ear Mountain carry placer tin. Knopf[1] states that nuggets of cassiterite several inches in diameter can be picked off the bedrock riffles of Eldorado Creek, but on account of the small body of gravel the creek offers no placer possibilities.

The gravels on Tuttle Creek are said to carry 5 ounces of cassiterite to the pan, but their extent is not known, so that the opportunity for commercial placer development can not be stated. If the gravels are as rich as reported a small sluicing plant could possibly operate successfully. Transportation of supplies to this locality, however, involves a haul to the edge of Shishmaref Inlet and ship-

[1] Knopf, Adolph, op. cit., p. 26.

ment across this lagoon to Sarichef Island, where during favorable weather, small coasting schooners lay offshore and pick up or deliver freight.

BUCK CREEK.

By far the largest production of tin in the York region has been from the placers of Buck Creek, although during 1916 and 1917 the York Dredging Co. was operating on Grouse Creek, into which Buck Creek flows. The dredge of the American Tin Dredging Co. operated on Buck Creek. The area of placer ground on both streams suitable for working with a dredge is small, and a very few more seasons of work will exhaust the deposits. Sutter Creek was being prospected during the summer with a view to dredging, but this also is a short stream and would afford not over two or possibly three seasons' work with a dredge. There is a possibility that a considerable amount of ground above the limits of dredging operations can be worked profitably by shoveling or scraping into sluice boxes. The amount that could be recovered in any one season is small, for the supply of water for sluicing is not great and the scope of operations would depend largely upon the quantity of water available.

During the summer of 1917 two men took out a few tons of cassiterite from Iron Creek, a short tributary of Sutter Creek, heading against Buck Creek in the saddle just east of Potato Mountain. It is estimated that the gravels, which are 4 or 5 feet deep, carry about 15 pounds of tin to the cubic yard for a width of 15 to 20 feet. Placer ground on this creek extends not over a mile, and the upper limits of operations had been nearly reached in 1917, at a point where the stream valley becomes very narrow and the amount of gravel negligible in amount. Water for sluicing was scarce, and an intermittent supply for sluicing was obtained by building a small dam, which gave a full sluice head for a sufficient length of time to permit the successful washing of the gravel. Three boxes, 8 inches wide, were used, and the grade was 10 inches to the box length. Iron riffles were employed.

In all about 26 men were engaged during the year on Iron, Buck, and Grouse creeks in the production of placer tin. Two dredges and one plant shoveling in were operated.

ANIKOVIK RIVER.

No production of placer tin has been made on Anikovik River since 1916. The one dredge on this stream was idle in 1917 also. Assessment work was done on a number of claims. Data are not available to warrant any statement as to their placer possibilities.

SUMMARY.

Lode mining in 1917 was confined to development work on Lost River and Ear Mountain without any production. Lost River is believed to have possibilities as a producer of lode tin. Further development is necessary at other properties.

Placer mining in 1917 was limited to the vicinity of Buck Creek. About 300 tons a year appears to be the limit of production for this area, and this production will be limited to a period of not over five years; after that time there will be production of only a few tons annually from sluicing operations. Placers may be developed in the vicinity of Ear Mountain, but the production in this vicinity will be small. On Lost River a few tons of residual placer tin may be recovered when water is available for sluicing. Anikovik River has a greater area of stream gravels which may be dredged than any of the other placers. A bedrock of finger slates, in a nearly vertical attitude and with numerous reefs, may interpose difficulties in dredging, involving a loss of some cassiterite and probably a considerable amount of the gold. The possibilities of the stream can not be stated.

GRAPHITE MINING IN SEWARD PENINSULA.

By George L. Harrington.

The graphite deposits of Seward Peninsula have long been known, but a number of factors have hitherto prevented their exploitation and development.

Gold has so long occupied the dominant position in the mineral production of the district that other minerals have been but little considered by the miner. Moreover, gold mining possesses an exceptional advantage in that the product has usually an immediate local market through banks and merchants, at a reasonably high percentage of its value, the base price remaining constant. With other minerals, and especially with graphite, it has been necessary to obtain a higher grade of product than that which results directly from mining operations. With graphite hand sorting at the mine and further treatment after shipment to Seattle or San Francisco has been necessary before the material could be marketed. A system of treatment had to be developed and a market found for the refined product after tests had demonstrated its adaptability to certain uses and its unsuitability for others. The rather small market on the Pacific coast and the distance to the eastern market have also affected the output. Low prices until recently have been an additional drawback to mining in Alaska, where comparatively high prices for supplies and labor prevail. The high prices in 1917, combined with the fact that wages and southbound freight charges had increased but little, appeared to warrant extensive development of the deposits, provided a market could be developed.

These deposits were described by Moffit[1] as follows:

Graphite is abundant in some of the black schist beds belonging to the Nome and Kigluaik groups and gives them their characteristic color but is not known in a form to make it of economic importance within the Nome and Grand Central quadrangles. Just north of the Grand Central area, however, in the headwater areas of Grand Central River and Windy Creek, especially in the vicinity of the divide between these two streams, are graphite deposits of considerable size. Their occurrence, as well as that of graphite on the north side of the Kigluaik Range west of Cobblestone River, has been known for a long time, but only recently have they received especial attention from prospectors.

[1] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, pp. 135–136, 1913.

A sharp ridge made up of biotite schist striking east and west and intruded by dikes and sills of coarse granitic rock or pegmatite rises on the south from the saddle between the Grand Central and Windy Creek. Some of the schist is highly graphitic, the graphite appearing as abundant small scales on the cleavage surface and much of it not being distinguishable on casual examination from flakes of biotite. Locally graphite is segregated in beds or much flattened lenticular masses that conform in direction with the schist cleavage and reach thicknesses of 6, 8, or even 18 inches. These beds include thin layers of schist containing numerous large garnets and much quartz. The raw graphite found at this place is heavier than the higher grades of graphite, owing to its included quartz.

The sills and dikes of pegmatite cutting the schist also contain graphite, which is associated with them in such a way as to suggest a close relationship between the intrusives and the graphite. Graphite appears to be an original mineral in the pegmatite as well as to be associated with it in the schist. At one place about 8 inches of solid graphite is included between a pegmatite sill and the overlying schist. The steep slopes of the mountain are strewn with graphite fragments, which, owing to the fact that they are much lighter in weight than either the schist or the pegmatite, appear more abundantly on the surface, especially in gullies where water has brought about a rough sorting. One block, with dimensions of approximately 7 feet, 6 feet, and 30 inches, consists of about equal thicknesses of schist and apparently almost pure graphite.

The graphite-bearing schist extends eastward beyond the east fork of Grand Central River and westward across Windy Creek and the head of Cobblestone River to the region south of Imuruk Basin, in which the graphite is even more extensively developed than in the locality described and from which a number of commercial shipments have been made.

Development work has been chiefly confined to those deposits on the north side of the Kigluaik or Sawtooth Range, west of Cobblestone River. Most of the work has been limited to two groups of claims, those of the Alaska Graphite Mining Co. and those of the Uncle Sam Alaska Mining Syndicate. The claims of the first group lie about 4 miles east of Graphite Bay, an arm of Imuruk Basin, and 2 miles west of Cobblestone River. The camp of the other group is 2 miles south of Graphite Bay and about 2 miles west of the camp of the Alaska Graphite Mining Co.

From Graphite Bay there is a moderately gently sloping gravel plain that extends up to the camps, the upper part of the slope being somewhat steeper than the lower part. The plain is formed of the gravels and alluvial débris, which were brought down from the higher parts of the range, and talus in interstream areas. Streams flow for short distances in V-shaped valleys, up to 50 feet deep through the talus accumulations, then their valleys widen and coalesce with the frontal plain of the range.

At an elevation of 500 feet a distinct change in topography marks the contact of the talus and alluvial material with the underlying schists and gneisses, which form the steep north slope of the Kigluaik Range. Graphite lenses are found along this steep slope for several miles west of Cobblestone River. Development work has been confined to those outcrops which lie between elevations of 500 and 1,000 feet, although there are said to be other lenses higher up the slope. In September, when this area was visited, recent snows extended down to about 750 feet, preventing any geologic work above that elevation.

The lenses of graphite occur in association with quartz schists that carry biotite, but garnetiferous schists that carry some calcite are also locally present. Some of the quartz schists have the appearance of beds of metamorphosed sandstone. Tourmaline was noted in small grains in the graphite at one locality. Granitic rocks appear to make up a portion of the core of the range. The general trend of the schists in which the graphite occurs is a little north of west, and the dip is 60°–75° N. Locally there are two or three series of graphite lenses which are parallel in strike and dip, but it can not be positively stated, without further very detailed studies, that they represent more than one horizon which may have been repeated by faulting or close folding.

The topographic situation and nearness to water transportation have favored development work at these deposits, in comparison with those which are said to occur for several miles eastward, extending along the front of the range beyond Cobblestone River, and appearing on the hill slopes or in the stream valleys which are incised into the range.

The first claims were staked in 1900, but in the succeeding years little has been done until recently except assessment work. Small shipments have been made from time to time for making mill tests or for samples of the material, but no steady production has been maintained. About 120 tons were shipped by the Uncle Sam Alaska Graphite Mining Syndicate in 1912,[1] but no shipment has been made by this company since. Assessment work has, however, been done on the nine claims of the group. As the lenses dip with the slope of the hillside, but more steeply, little work has been necessary to prove the existence of the bodies, and the assessment work has therefore taken the form of open cuts, from each of which a few sacks of graphite have been taken, so that there is now sacked and ready for shipping a considerable amount of hand-sorted graphite. Some of this graphite will require resacking before shipping. Two short tunnels have been driven on claims of this group. The development work to date has shown the presence of a number of lenses of graphite which may be continuous, but their size and continuity have not been proved.

A small frame bunk house is the only building on the property.

[1] Mertie, J. B., jr., U. S. Geol. Survey Bull. 662, p. 449, 1917.

The property now being worked by the Alaska Graphite Co. consists of five claims which were staked in 1905 and three claims which were staked by N. Tweet in 1915 or 1916. In 1906 the bunk house on the property was built, and the following year about 35 tons of graphite was picked from the talus on the steep hillside and shipped. Other smaller shipments followed in succeeding years.

Several tons of graphite were mined in 1916 but not shipped. In 1917 a large portion of the time of the seven men employed was consumed in making and repairing the road to Graphite Bay, as the unusually rainy weather during August made it necessary to corduroy the roads with alders, the only material at hand. In spite of this delay, however, a considerable tonnage of hand-picked graphite was mined from an open cut and shipped to San Francisco, together with that which was mined the previous year.

Most of the production of 1916 and 1917 was made from an open pit about a hundred yards west of Glacier Creek, the first stream west of Cobblestone River. As exposed in the pit, the lens on which the mining was done had a width of 4 to 6 feet of graphite, the impurities in which consisted of thin seams of quartz and schist. It appears in the bottom of the cut for a length of 30 feet, and the footwall has a height of about 20 feet. The graphite, which is exposed at one end of the cut, has a greater horizontal dimension than that given, and its vertical dimension has not been determined. On the east side of Glacier Creek a lens or series of closely spaced lenses of graphite that has a total vertical height of 400 feet or more is exposed. A few small open cuts afford some indications of a thickness which is comparable to that in the pit that is being worked.

An 8-inch hydraulic pipe 400 feet long serves to convey the graphite from the pit to the loading station, 150 feet lower. Hand-sorting is done at the pit, and there are a number of tons of low-grade graphite on the dump.

Transportation from the mine to Graphite Bay is by trucks drawn by a gasoline caterpillar tractor. At Graphite Bay the graphite is loaded on scows, which are towed to Teller, and there it is loaded on ocean steamers.

In addition to the open pit near Glacier Creek there are a number of short tunnels and open cuts about a quarter or half a mile west of Glacier Creek, near the bunk house and cook tent of the company, from which there has been some production in previous years.

On the steep hillside between the pit and bunk house are a number of exposures of graphite, but little development work has been done to afford an indication of the size of the bodies. Some of these bodies, so far as can be told on a surface partly obscured by talus, are at least 100 feet long, 50 feet wide, and a foot or more thick.

There appears to be an opportunity for the development of a large amount of graphite from these deposits. Transportation problems are relatively simple. If a sufficient tonnage is mined aerial trams, possibly of a gravity type, might be used from one or both properties. For smaller tonnage good roads could be easily constructed for team or power haulage, and the power required for hauling loads would be small, on account of the generally uniform downhill slope to the shipping point. Graphite Bay affords a good shallow harbor, for numerous small coves and islands give protection from storms.

If a mill should be erected at either property hydroelectric installations would probably prove the more economical for summer operations, power being derived from some of the small streams which cross the claims. For winter operations other power would be necessary.

THE GOLD AND PLATINUM PLACERS OF THE KIWALIK-KOYUK REGION.

By George L. Harrington.

INTRODUCTION.

The principal work of the Geological Survey in the general region of the Kiwalik and Koyuk basins was done by three parties, those of Peters and Mendenhall,[1] who in 1900 ascended the Koyuk; of Witherspoon and Moffit,[2] who mapped both topographically and geologically the region south of Kotzebue Sound; and of Smith and Eakin,[3] who mapped the area between Nulato, on the Yukon, and Council. In addition data in regard to water resources have been obtained through the work of F. F. Henshaw[4] in 1907 and 1909 and some geologic notes were also obtained by Mendenhall[5] at the close of the field season of 1901, when he visited the shores of Kotzebue Sound.

The following report is based upon the reports of the earlier workers in this field, supplemented by data obtained by the writer during August, 1917, when he spent a few days in the vicinity of Candle, two days on Bear Creek, and about two weeks in the study of the gold and platinum placers of Sweepstakes and Dime creeks.

No additional information was obtained regarding the region outside of the Kiwalik, Bear Creek, and Koyuk drainage, but for the sake of completeness the drainage and geologic features of the adjacent region are shown on the accompanying map (Pl. X).

The kindly hospitality of the miners and prospectors of the region is gladly and gratefully acknowledged by the writer, for without their assistance it would not have been possible to carry out the investigations so easily or so speedily.

[1] Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900: U. S. Geol. Survey Special Pub., 1901.

[2] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 247, 1905.

[3] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, 1911.

[4] Henshaw, F. F., and Parker, G. L., Surface-water supply of Seward Peninsula, Alaska: U. S. Geol. Survey Water-Supply Paper 314, 1913.

[5] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: U. S. Geol. Survey Prof. Paper 10, 1902.

GEOLOGY.

GENERAL FEATURES.

The region covered by this report contains a number of geologic units. As far as possible these units have been mapped separately, but lack of outcrop and the brevity of the time spent not only by the writer but by other Survey parties engaged in geologic investigations in this region have prevented the obtaining of the information necessary for accurate mapping. Errors of detail may therefore occur, but the main geologic features will be found essentially as mapped. (See Pl. X.) For the sake of completeness, the map is made larger than necessary to cover the work in 1917 in order to show the broader areal relations, which have been elucidated by the work of previous investigators.

The oldest rocks of the region are the series of Paleozoic or older schists, slates, and limestones, which, in the northern portion of the area, appear mainly west of the Kiwalik, although to the east of this river some outcrops are known. The series extends south to Golofnin Sound, where it includes also some metamorphosed igneous rocks.

A series of andesitic volcanic rocks, which embraces some waterland tuffs and includes flows and breccias, occupies much of the area north of the Koyuk between the Kiwalik and the Buckland. These rocks have suffered some alteration, owing in part to weathering and in part to the stresses to which they have been subjected. Upon these and the other rocks Cretaceous sediments were deposited in large areas east of the East Fork of the Koyuk and of the West Fork of the Buckland, and in much smaller areas west of these streams. These rocks for the most part show considerable deformation of the beds, and although slaty cleavage has been developed in argillitic rock types, none show schistosity.

At several geologic periods igneous activity has been manifested in this region by different types of intrusions, each intrusion resulting in the deformation of some of the older rocks. Of this character are the greenstones of the Fish and Tubutolik river valleys, and the granites, monzonites, syenites, and diorites, which are found more or less widely distributed throughout the region, in many places, as at Kiwalik and Granite mountains, making up the highest points, or as in Bendeleben and Darby mountains constituting an integral part of those ranges.

After the deformation of the Cretaceous beds, which probably occurred during early Tertiary time and was caused by intrusions such as those of Granite Mountain, there appears to have been periods of alternate elevation and depression of the land surface with respect to sea level, but these movements have been of regional rather than local character, and though there may have been some slight tilting of the land surface there has been no folding. During later Tertiary time vegetal material accumulated to form lignite beds such as those at the head of the Kiwalik. Somewhat later in the Tertiary period or early in the Quaternary period lavas covered much of the terrane of what is now the base of Seward Peninsula and may have covered some of the region now occupied by Norton Bay.

The events of the Quaternary period are so involved that it will require much more detailed studies than it has been possible to make to work out the complex history of the unconsolidated deposits of that period. Oscillations of the land surface have caused inundations, and each change of base-level has affected the topography. The stream valleys were overflowed by the sea, which later withdrew either partly or wholly. In those areas not inundated, and in the inundated areas after their emergence, the processes of erosion normal to subarctic climates, including frost disintegration and soil flow, have been active. There has resulted an almost universal cover of Quaternary deposits, which ranges in thickness from a few inches to 200 feet or more. In a general way the covering due to rock disintegration in place and to solifluction has been mapped with the underlying bedrock, and only those deposits of alluvial or marine origin have been represented on the map.

PALEOZOIC ROCKS.

The Paleozoic rocks in the northern part of the region have been described by Moffit[1] as follows:

> Under the head of "Metamorphic series" are grouped together a number of rock types of widely different character, the relationships of which are difficult to establish clearly, and the ages of which are in doubt. They possess the common characteristics of having been in all cases greatly altered from their original condition at the time of consolidation. The changes include the folding of the beds and the production of secondary structures, such as schistosity, cleavage, jointing, or faulting, resulting from pressure and the various movements of the rock mass; the recrystallization of the mineral constituents and the development of new minerals; the infiltration of quartz, giving the numerous veins, stringers, and lenses of that mineral which are so frequent in the outcrops and are so important in some places because of their gold content; the peculiarities of structure due to the intrusion of large masses of igneous rock; and other less noticeable features. The series includes massive and thin-bedded crystalline limestones and marbles, banded black and gray slates, and a variety of schistose rocks, both sedimentary and igneous, among which are micaceous, graphitic, quartzose, chloritic, felspathic, and amphibolitic phases.

In the mapping, as far as practicable, the limestones have been shown separately from the other Paleozoic rocks. In the area visited during the summer of 1917 the Paleozoic rocks were seen only in

[1] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 247, p. 19, 1905.

the vicinity of Candle and in the Haycock Ridge between Dime Creek and the Landing. At both places the strike is about N. 20° E., and the dip is nearly vertical or steeply to the west. Schist pebbles were also seen in the gravels of Wilson Creek, at the head of the Kiwalik drainage, although no outcrops were noted. A few pebbles of slate and schist were taken from the bottoms of prospect holes on Little Eldorado Creek, and schist was seen at a few places on the east slope of the ridge farther south. The rounded knobs from which Haycock Ridge derived its name are of a light-gray schistose limestone. It is flanked on the east by a metamorphosed argillitic rock. The gravels on the claims below Discovery on Dime Creek contain slate pebbles which may be derived from them or which may represent a somewhat metamorphosed phase of some of the more argillaceous Cretaceous rocks.

No reliable estimate of the thickness of this group of rocks can be made, for although they are in places nearly vertical in attitude, and horizontal distance would therefore ordinarily afford an approximation of their thickness, they are badly faulted and show some folding, so that probably there has been much duplication of bedding.

Definite age determinations have not been possible for the individual members of the Paleozoic. From the earlier work of Smith and Eakin [1] there appears to be ground for the belief that these rocks range in age from pre-Silurian and possibly pre-Cambrian to Carboniferous, and that the greenstones which intrude them are probably Devonian or Carboniferous.

ANDESITIC TUFFS, FLOWS, AND BRECCIAS.

In the region extending from the Koyuk, near the East Fork, northward along the Buckland-Kiwalik divide, is a complex series of volcanic rocks, chiefly andesitic in character but also including diabases and peridotites. These rocks occupy one of the areas mapped by Smith and Eakin [2] as "undifferentiated, nonmetamorphic intrusives and effusives." In the northern part of the Buckland-Kiwalik area they were grouped in mapping by Moffit [3] with the much later basalts. In the present report the basalts have been partly separated in mapping, but north of Quartz Creek the data at hand are not sufficient to warrant an attempt at separation, and the andesites as mapped, therefore, include areas of the later basalts.

A number of different phases occur in this series in a section that was examined for several hundred feet along Sweepstakes Creek.

[1] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 93–95, 1911.

[2] Idem, pl. 6.

[3] Moffit, F. H., op. cit., pl. 3.

Typical graywacke beds appear, together with conglomerates and tuffaceous rock, yet they are composed of fragments of the near-by distinctively effusive andesites or of essentially the same minerals. These rocks, which are sedimentary in origin, are not greatly different in appearance from the effusive types, and it is not always possible to separate the two without recourse to a microscopic examination of thin sections. Practically all are dark gray, usually with a strong greenish tinge. Porphyritic facies are fairly common and the coarser grained of these are locally known as "diorite." Different degrees of metamorphism have been suffered by the series in different parts of the area; west of Granite Creek, between it and the bend of Sweepstakes Creek, and half a mile below the Hot Springs on Spring Creek, the rocks have been deformed and appear to be much jointed, faulted, and sheared and to have a considerable development of quartz and calcite veins. Elsewhere they have suffered little deformation, as at the head of Greenstone Creek, where they can not be readily distinguished from the much later basalts, which here are less vesicular than usual.

One of the features of a phase of these rocks on Dime and Sweepstakes creeks is the weathering along closely spaced joints, so that it is difficult to get a fresh fracture surface, as the rock tends to break along the joints. The brownish-black weathered surface is termed "burnt rock" or "burnt lava" by the miners.

Typically these rocks consist of phenocrysts of plagioclase, chiefly andesine, and augite in a finer groundmass of similar composition, and accessory magnetite is usually present. Ilmenite and olivine may be present also in some specimens. Secondary minerals give the rock its green color and consist largely of chlorite and some hornblende.

With the rocks of this composition, which are essentially extrusive in character, intrusive rocks are closely associated in some small areas. The intrusives are generally of a more basic character and include gabbros, diabases, and peridotites, the last characterized by their dark color, as they consist essentially of olivine and a dark pyroxene. From these rocks the platinum is probably derived, as well as the chrome spinel, which together with the olivine appears in the concentrates wherever platinum has been found in this area.

Several factors prevent the determination of the attitude of these rocks. Exposures in undisturbed outcrops are not especially common and where present are generally massive, showing little or no structural features. On Sweepstakes Creek, on some of the sedimentary beds, strikes ranging from northeast to east and steep northerly dips were observed. These rocks are much disturbed, as shown by the exposures on Spring Creek, yet from their wide distribution and the general lack of infolded older or younger geologic units, it is apparent that the series must have a maximum thickness of several thousand feet.

Data as to the age of these rocks do not permit a statement of the exact time of their formation. They are younger than the Paleozoic rocks and older than the Cretaceous sediments, so that they may be very late Paleozoic or early or middle Mesozoic. As the basic coarsely granular intrusives in this series are not known to occur elsewhere, they are probably closely related in age to the rocks in which they occur.

GRANITES, SYENITES, AND DIORITES.

The granitic rocks in the southern portion of the area have been described by Mendenhall[1] and by Smith and Eakin,[2] and those in the northern portion by Moffit.[3] Only one area of these rocks was seen by the writer, the intrusive mass which forms Granite Mountain. Moffit[4] describes these rocks as follows:

> Hornblende is the prevailing dark mineral of the granites, but at times biotite takes its place. By a decrease in the amount of quartz the granites approach syenites in composition, such phases being characterized by the abundance and large size of orthoclase crystals, which usually show Carlsbad twinning and have a roughly parallel arrangement, with the small intervening spaces filled with hornblende, biotite, and a small amount of quartz. Titanite is abundant.

Moffit[4] also describes a garnet pyroxene malignite which is related to the syenitic rocks just mentioned. Similar types appear in the gravels of Cub Creek, and black garnets (melanite) from the same source are very common in the concentrates from Rube Creek and less so in those from Sweepstakes. Coarsely porphyritic rocks of approximately the same nature are found on Sweepstakes Creek near the mouth of Granite. Near the hot springs on Spring Creek the rock is a typical diorite, composed essentially of plagioclase feldspars and hornblende, together with small amounts of accessory constituents.

Dikes of syenitic type cut the andesite series, so that the dikes are the younger. From the fact that the pebbles of the Cretaceous conglomerate[5] along the East Fork-Buckland divide are similar in character to these igneous rocks, their pre-Cretaceous age appears to be well established. Possibly, however, some of the types are pre-Cretaceous, whereas others were not intruded until later and are approximately synchronous with the deformation of the Cretaceous sediments.

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[1] Mendenhall, W. C., Reconnaissance in the Norton Bay region, Alaska, in 1900: U. S. Geol. Survey Special Pub., p. 204, 1901.

[2] Smith, P. S., and Eakin, H. M., op. cit., pp. 64–70.

[3] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Bull. 247, pp. 27–30, 1905.

[4] Idem, p. 29.

[5] Smith, P. S., and Eakin, H. M., op. cit., p. 56.

CRETACEOUS SEDIMENTARY ROCKS.

From a study of the distribution of the Cretaceous rocks of western Alaska it appears that at the beginning of the Cretaceous period a broad valley or embayment occupied much of the area east of the Darby Mountains, which included much of the Koyuk, lower Yukon, Innoko, and lower Kuskokwim valleys. Scattered through this wide area were small land areas, such as the Kaiyuh Mountains and their northeastern extension, as well as minor elevated points, which for a time furnished material for the vast amount of sediments of this age but which were later covered by transported silts and sands derived from other sources. In this region the presence of the early Cretaceous has not been proved. During that epoch it probably constituted a portion of the land surface. During later Cretaceous time, however, by a subsidence of the region now occupied by rocks of that age, the sea gradually encroached upon the land areas. Where the coasts were bold and rocky, like much of the present southern coast of Seward Peninsula between the mouth of the Kwiniuk River and Topkok Head, conglomerates were deposited. The offshore deposits were sands, and the zone of conglomerates was relatively narrow. Where the sea encroached upon delta areas, as at the mouth of the Tubutulik or Kwik or the much larger deltas of streams corresponding to the Yukon, much finer sediments were laid down, such as fine sands and silts, which later by consolidation formed sandstones, shales, and slates. The offshore deposits were practically all shales, some of which were somewhat calcareous. The coal beds of this age were probably accumulated in swampy areas but little above sea level, where the climatic conditions of that time particularly favored vegetal growth and accumulation.

The distribution of the Cretaceous sediments is indicated on the map (Pl. X), but several areas, such as the small areas on Peace River and the coal-bearing bed of the Kugruk, have not been delineated.

Several types of deposits are illustrated by the rocks in the valley of Dime Creek, or near it. At the mouth of Silver Gulch the conglomerates represent the near-shore or beach deposits along a coast, the rocks of which were Paleozoic limestones and slates. The pebbles of the conglomerate are largely of these two lithologic types. Farther out in the valley of Dime Creek much finer grained rocks appear. They are highly calcareous, showing that the probable source of a large portion of the grains composing them was the limestone. Quartz grains and clayey material make up most of the remainder of the sandstones.

The grits and fine conglomerates found near the landing are characterized by the presence of great numbers of small white rounded quartz pebbles. It appears likely that these sediments represent either stream or offshore deposits. Quartz veins in the Paleozoic rocks were the source of the pebbles.

In the valley of Peace River a little evidence of the former presence of Cretaceous rocks is found, and it is probable that detailed examinations of all the exposures, and of fragments of bedrock from the numerous prospect holes would reveal a much wider occurrence of these sediments than the present mapping indicates. On Flat Creek fragments of sandstone were seen on the dump of a prospect hole, and on Moon Creek, less than half a mile from the river, another dump showed fragments of slate and many white pebbles similar to those in the grits. These pebbles were probably of local origin, rather than stream-borne gravels.

The other areas of Cretaceous rocks have been described by Smith and Eakin [1] and are essentially the same in character as in the vicinity of Dime Creek. Fossil plants [2] from the Kwik-Tubutulik divide serve to establish the Cretaceous age of the series. Moffit [3] correlates the beds associated with the coal on the Kugruk with those of the Koyuk.

TERTIARY ROCKS.

It is not known how long sedimentation continued after the close of the Cretaceous. In near-by regions there is reason to believe that it was uninterrupted until well into the Eocene. By that time a considerable thickness of Cretaceous beds had accumulated, a large portion of which has since been eroded. At or near the close of the Eocene, however, earth movements of considerable magnitude took place [4] in different parts of Alaska, and this region was affected by them. Igneous intrusions along the axes of the folds accompanied this diastrophism. Some of the rocks of the Granite Mountain area, already described, and the accompanying dikes, which are found on Bear and Candle creeks, may be of this character.

Smith and Eakin [5] describe a series of rocks which range in character from augite andesite to augite diorite in the vicinity of Christmas Mountain, and on the Shaktolik quartz porphyry was found by them. These rocks are post-Cretaceous.

The topography formed by these intrusions and the earth movements was much more rugged than that of the present, and consequently there was little or no deposition of terrestrial sediments until quite late in the Tertiary, when land forms comparable in character with those now found had been developed. In some of the basins of

[1] Smith, P. S., and Eakin, H. M., op. cit., pp. 54–60.
[2] Idem, p. 56.
[3] Moffit, F. H., op. cit. p. 26.
[4] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 266, 1906.
[5] Smith, P. S., and Eakin, H. M., op. cit., pp. 70–71.

that time terrestrial deposits were formed. It is not possible to state the extent of these deposits, both on account of the small amount of field work and on account of their great resemblance to alluvial material of considerably later age. One area has been described by Smith and Eakin[1] as occurring on the Rathlatulik. Another small area was observed by the writer on Wilson Creek, one of the headwater streams of the Kiwalik. At both areas are deposits of lignite in association with clays.

On Wilson Creek the lignite is several feet thick and contains squeezed and carbonized tree trunks of small size. Overlying it is a bluish clay, which is oxidized to yellow on the surface. This clay has crept or flowed over the lignite until it has almost completely covered it. A small amount of lignite had been mined and the opening showed that the bed was at about the level of the creek. Apparently overlying the clay were basalt flows, which crop out on the west bank of the stream about 75 yards or less from it. About 200 yards farther downstream, at a second small cropping, a thickness of 6 or 8 inches of lignite was exposed. Neither the rocks above or below it were exposed, and the lignite was partly covered by moss and other vegetation.

There is no direct evidence of the age of these deposits, whether Tertiary or Quaternary. From the fact that they are apparently older than the basalts, which are believed to have been extruded during the late Tertiary or early Quaternary, an assumption of late Tertiary age is made.

BASALTS.

Vesicular basalts, generally containing olivine and in places, as at St. Michael, associated with tuffs, are widely distributed in western Alaska, especially at the base of Seward Peninsula and the near-by regions to the south. In the Kiwalik-Koyuk region they occupy areas comparable in size with those of any other lithologic unit and form the divides between the Koyuk and the Buckland, the Koyuk and the Kiwalik, and the divide at the heads of the Koyuk, Kuzitrin, and Goodhope. They probably occupy considerably larger areas along the Kiwalik-Buckland divide than the map shows, and formerly their extent was certainly much greater than now. Thus, the entire valley of Peace River may have been filled, so that the areas on either side of the river near Moon Creek were continuous, and, indeed, the three large areas already mentioned may have been continuous. The basalts would thus have filled the entire valley of the Koyuk and extended south to include the area north of the Mukluktulik and that on the Tubutulik. Possibly the area at the head of the Koyuk had a different source and did not reach the other flows.

[1] Smith, P. S., and Eakin, H. M., op. cit., p. 140.

Whether there was a connection between these flows and those on the south side of Norton Sound has not been proved.

Concerning the lavas along the Koyuk, Mendenhall[1] states:

The lava is a green, gray, or black rock, the color depending in part upon its freshness. It is compact or vesicular and usually porphyritic, olivine being the most conspicuous of the phenocrysts, although plagioclase is recognizable megascopically in some instances. Sometimes the vesicles are filled with opal; more frequently they are without filling. The rock varies in texture, having sometimes a very glassy groundmass and in other cases showing a coarse, well-defined, interstitial arrangement with almost no glass. * * * The basalt beds have not been disturbed since they were poured out. They are horizontal wherever their attitude is determinable and overlie all the other rocks.

Moffit,[2] after describing the lavas west of the Kugruk, says:

The basalts and diabases of the area west of Kiwalik River are somewhat different in occurrence from those previously described, in that they are found at considerably higher elevations and apparently are not directly connected with those of the more western area. The hills facing Kiwalik River on the east are largely made up of lavas in which the diabases predominate over the basalts. Sheeted flows do not occur frequently, and under the microscope the rock is seen at times to be somewhat altered.

Whether the Kiwalik-Buckland-Koyuk flows were connected with those at the head of the Koyuk is not readily apparent. Probably the lavas were discharged from different vents, even though the Koyuk from its source to its mouth was once filled. From the features which have been described by Moffit it appears likely that some of the lavas from the vents at the head of the Koyuk are relatively recent. On the lower Koyuk, however, there is the evidence of the erosion of a thickness of 200 feet or more of these rocks from the valley of Peace River, by a relatively small stream, which, however, probably had a gradient much greater than it now possesses. Valleys cut since the extrusion of the lava have been filled to a depth of nearly 200 feet with gravel, and new channels, such as the present course of the Koyuk, were again cut. From this evidence it is apparent that the lavas must have been extruded in either Tertiary or very early Quaternary time.

QUATERNARY DEPOSITS.

Since the extravasation of the lavas, which in this area at least probably occurred in late Tertiary time, there have been oscillations of this portion of the earth's crust which have caused the submersion and emergence of the land surface and which were possibly repeated several times. These movements took place with little or no attendant warping or folding. From the forms of the valleys and the

[1] Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900: U. S. Geol. Survey Special Pub., p. 206, 1901.

[2] Moffit, F. H., op. cit., p. 34.

depths of gravels, which in places lie well below sea level, it is apparent that the land surface once stood at least 50 feet or more higher than it does at present with regard to sea level. An elevation of 100 feet, which is by no means improbable, would now make a land surface of Norton Bay and much of Norton Sound.

Throughout the Quaternary period erosion was in progress wherever the land lay above sea level. From the erosional débris a complex series of imbricated unconsolidated marine and alluvial deposits was formed through surface oscillations and filled the lowlands and stream valleys. Sections of these deposits are obtainable only from prospect holes and show alternations of sand and gravel. In places their thickness is more than 200 feet. On Dime Creek holes over 100 feet deep have been sunk. In some of these holes fragments of shells have been found, but the fragments are not of a nature to permit a determination of their character and age.

The older gravels are indistinguishable from those that occur along the present stream courses and beaches, so that possibly some of them may antedate the extrusion of the basalts, but until more definite information is at hand as to the age of both the basalts and the older gravels, it appears logical to assume that the basalts are of Tertiary age and that the gravels, some of which contain basalt pebbles, are of Quaternary age.

In addition to those deposits of alluvial or marine origin, unconsolidated débris and organic deposits cover much of the surface. Mechanical disintegration through different phases of weathering produces an angular rock talus on all uncovered slopes; this material is gradually transported to the bottoms of the valleys by solifluction, of which gravity and the action of frost appear to be the principal forces. A large number of the gentler slopes show the lobate forms which characterize soil flows, and the scarps at their front may be exceptionally as much as 6 to 10 feet high, but normally are 1 to 2 feet.

Except on the very steepest slopes and on some of the strongly wind-swept higher ridges there is an almost universal covering of vegetation, largely mosses and lichens. This vegetation serves to hold moisture and also to prevent the melting of the underlying frozen, moisture-saturated peaty material, thus perpetuating the conditions most favorable for growths of this kind. As a result extensive bogs cover much of the area, on the broad, flat-topped ridges at moderate elevations as well as in the lowlands. In the flatter areas there is a tendency toward an accumulation of peat, but on the slopes, the vegetation is disturbed by the soil movements and shows less tendency to accumulate.

MINERAL RESOURCES.

HISTORY OF MINING DEVELOPMENT.

Soon after the discovery of gold at Nome there was active prospecting over much of the more readily accessible streams of Seward Peninsula, and Candle Creek was staked[1] during July, 1901. Bear Creek was staked and recorded in August of the same year but is said to have been staked though not recorded[1] in 1900.

Mining has resulted in a considerable production yearly from Candle Creek. The annual output from Bear Creek has shown considerable variation; in some years little or no production was made.

In the basin of the Koyuk some prospecting has been done on a number of streams during the period from 1899 or 1900[2] up to the present. A summary of this work up to 1909 is included in the report of Smith and Eakin.[3] Until that time no workable placers had been discovered in the Koyuk region. In 1909 some prospecting had been done on Peace River near the mouth of Sweepstakes Creek, and in the fall of that year Sweepstakes Creek was staked for about 9 miles, practically its entire length, by S. B. Smith and several associates. After prospecting for a number of years, the title to the lower 4 miles of the creek was allowed to lapse. Gold valued at a few thousand dollars is said to have been taken out from this creek in 1910, and an average annual production between $4,000 and $5,000 is reported for the period from 1910 to 1917, inclusive.

In 1910 Dime Creek was staked and some prospecting was done on some of the lower claims, but no commercial placer ground was discovered. Rube Creek, then called Diamond Creek, is also said to have been staked the same year, and a small amount of prospecting was done but with negative results. No further work was done by the original holders of this ground, and their title was lost. In 1915 Dime Creek was again prospected, and gold was discovered at the mouth of Eldorado Creek on April 4. On the hypothesis that the gold had been derived from the metamorphic rocks which form the divide between Peace River and Dime Creek, the discoverers staked the first claims on Eldorado Creek, leaving what proved to be the richest ground open to staking by later comers, who staked not only the creek but the first and second tier bench claims, on both the right and left limits of Dime Creek. Many of its smaller tributaries

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[1] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 247, p. 50, 1905.

[2] Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900: U. S. Geol. Survey Special Pub., p. 212, 1901.

[3] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 110–115, 1911.

have also been staked, as have a number of the near-by tributary streams and gulches of both Koyuk and Peace rivers, as well as some of the tributaries of Sweepstakes Creek. A number of claims were staked on Rube Creek and some small gulches tributary to it on March 31, 1917.

When the first claims were staked on Sweepstakes and later on Dime Creek, recording had to be done at Council, as the Koyuk Basin lay within the limits of the Council City precinct. To facilitate recording, however, a new precinct was formed by dividing the Council City precinct into the Council City and the Koyuk precincts. The Koyuk precinct, as defined by a decree of the court dated December 28, 1916, includes the drainage basins of the Inglutalik, Koyuk, and Kwik rivers, as well as a few small streams that lie between the Inglutalik and Kwik and that flow into Norton Bay.

ECONOMIC CONDITIONS.

MEANS OF COMMUNICATION.

Candle, on the northern side of the peninsula, is located on Kiwalik River, about 7 miles from the town of Kiwalik, at the mouth of the river, where supplies are brought in summer by small coastwise vessels from Nome or by the larger freighters direct from San Francisco or Seattle. They are carried up the river in shallow-draft power scows. The effects of the higher tides are sometimes noted at Candle. On the other hand, at normal or low stages of water, if a south wind is blowing, considerable difficulty may be experienced in reaching Candle by boat, for the wind may be sufficient to overcome the effects of the incoming tide. In summer the mail is brought from Nome by a small coasting vessel, on a two or three weeks' schedule, which may be lengthened to nearly a month by unfavorable conditions. In winter communication and transportation of the mail is by dog team, and the mail is on a fortnightly schedule. There is a telephone line from Candle to Nome, and a local line from Candle out to Candle Creek.

Bear Creek is about 40 miles from Candle, with which it is connected by a wagon trail that is poorly defined on some of the wide, flat-topped tundra-covered ridges over which it runs. Most of the mining supplies are brought to Bear Creek in the spring by horse team and sled, although some supplies are brought in by wagon during the summer. Mail for this creek goes to Candle.

It is about 15 miles from Bear Creek over Granite Mountain to Sweepstakes Creek, at the mouth of Granite Creek, about 10 miles from Sweepstakes to the road house on Dime Creek, and about 7 miles from there to the place known as Dime Landing, or simply "the Landing," on Koyuk River. A number of small gasoline schooners, some of which made an effort to maintain a 6-day round-trip schedule, afford frequent communication between Nome, Golofnin (Cheenik), and the Landing. During the summer of 1917 mails were brought on a monthly schedule to Golofnin from Nome and St. Michael and carried from there to the Koyuk. Haycock post office is located at the mining center on Dime Creek. Freighting was done from the Landing to the creek over two very soft trails. The miners on Sweepstakes got in most of their supplies during the winter, but some freighting was also done by wagon during the summer.

SUPPLIES.

A large part of the supplies for both Candle and Dime creeks are brought from Nome. The local rate from Nome to Kiwalik was $20; that from Seattle to Kiwalik on general merchandise in 1917 was $19 for less than car-lot shipments and $14 for car lots, not including lighterage. Freight from Kiwalik to Candle was $5 a ton. From Candle to the mouth of Patterson Creek (claim 19 above Discovery), the summer rate was 2½ cents a pound. A considerable amount of the tonnage of supplies to all the creeks in the area consists of gasolene and distillate for use of the engines used in pumping or on the dredge on Candle Creek. A fairly good wagon road to the mining plants makes summer freighting at Candle but little more difficult than that to many mining camps in the States. Supplies are hauled as far as possible in winter.

Supplies are obtained on the Koyuk from both Nome and Golofnin, and the freight rate from Nome to the Landing on the Koyuk is $20 a ton. An example of the effect of poor roads on the cost of haulage is shown by the fact that the summer rate from the Landing to Dime Creek is 4 cents a pound, when the hauling is done over the extremely poor and rough roads across the tundra, whereas the winter rate is 1 cent a pound, when the hauling is done by sleds and the roads are fairly good. The cost of freight from Seattle to Nome, when added to the charges just mentioned, makes prices at Dime Creek about 6 cents a pound higher than those in Seattle through transportation charges alone. At one of the stores on the creek the following prices were charged in August, 1917: Potatoes, 12 cents; flour, 12 cents; bacon, 60 cents; ham, 50 cents; sugar, 16½ cents a pound. A road is to be constructed by the Territorial Road Commission from the Landing to the center of mining operations on Dime Creek, and this should reduce the cost of transportation considerably.

During the winter and spring of 1916–17 supplies were difficult to obtain, largely on account of the shortage of teams for hauling. In the fall of 1917 conditions had improved, for in addition to two or three teams used for private hauling there were two teams engaged in freighting, and it was reported that others were coming. If a shortage occurs during the winter, supplies could be freighted from Golofnin.

Little wild game, except ducks and geese, is to be found in this region. Rabbits are sometimes plentiful. Ptarmigan are scarce. Occasionally bear are seen, but not often. The few caribou that are reported here have probably strayed from one of the reindeer herds which are pastured near by.

In the smaller streams, where mining operation have not muddied the water, both grayling and trout are found. In the larger streams salmon are caught and dried for dog feed.

TIMBER AND COAL.

A scanty growth of spruce covers parts of eastern Seward Peninsula, and good-sized trees are found along the high, well-drained banks of the larger streams up to about 400 feet elevation or possibly a little higher. There is no timber in the vicinity of Candle, although it grows on the upper part of the Kiwalik and Buckland rivers. In the Koyuk basin good-sized timber, suitable for ginpoles or masts for mining, is found along some of the larger tributaries, such as Peace River and the East Fork. Timber is present for only a short distance up Sweepstakes Creek. A fair growth is said to have once fringed Dime Creek, but this has been removed and there now remains only scattered stunted trees common to poorly drained and boggy hillsides, although some of the steeper-sided valleys, where the drainage is better, support timber which furnishes excellent fuel, and even house logs are obtained. A large number of logs of good size will be required in the construction of the road from the Landing to Dime Creek, and this will materially decrease the available timber.

Gasoline and distillate are used generally wherever pumping is to be done and on the dredge on Candle Creek. Coal is the principal fuel used in the vicinity of Candle, but on Dime Creek its use appears to be confined mainly to domestic purposes at present. Within a very short time it will be necessary, on account of the scarcity of timber, to use coal or oil for power and thawing in mining operations also. It appears likely that the production of gold in 1917 would have been somewhat larger had there been a sufficient number of teams to haul wood for fuel during the spring and early in the summer, and mining operations could then have been carried on much later than they were. It is said that some wood was hauled by dog teams. The cost of wood at the boilers ranged from $16 to $20 a cord.

Lignite is obtainable in the Candle district from the vicinity of Chicago Creek, on the Kugruk. This coal formerly sold at about $30 in Candle, but none had been brought from the mine in 1915, 1916, or

1917, and bituminous coal, which had been shipped in, was used. It cost about twice as much as the Kugruk coal but was rated about twice as high for steaming. Coal of a generally similar character is found near the mouth of the Koyuk, just about at sea level, where one 4-foot seam is said to be exposed. Near by is a 2-foot seam, and several seams of a few inches in width also occur. In this connection it is interesting to note that a fragment of coal was picked up from the dump of a prospect hole at about claim 9 below Discovery on Dime Creek, together with some angular sandstone pebbles, indicating that the coal series is probably present in this general vicinity. An analysis of the coal at the mouth of the Koyuk, made for Mr. John La Montaigne, is given for comparison with that from the Kugruk.

Analyses of coal from Seward Peninsula.

	Koyuk coal.	Kugruk coal.[a]
Fixed carbon	39.87	33.58
Volatile combustible	33.94	38.15
Moisture	19.89	24.92
Ash	5.86	3.85
Sulphur	.44	.68
	100.00	101.18

[a] Analysis made in laboratory of the Geological Survey. See Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 247, p. 67, 1905.

The locality on the Koyuk was not visited, but it is said to be near or at tidewater, and some difficulty might be had at times in mining on account of flooding the workings. This coal is about 20 miles from the scene of mining operations on Dime Creek, and winter haulage should present little difficulty. Summer haulage might be attempted by boating the coal up to the Landing in scows and hauling it by wagon from there. If the deposit is workable, it should furnish a fuel at least as good as wood at about the same price a ton as the wood costs a cord.

Another possible source of fuel is the lignite on Wilson Creek, one of the headwater tributaries of Kiwalik River. This deposit lies about 2 or 3 miles from Sweepstakes Creek, and is therefore between 12 and 14 miles from Dime Creek. A small opening has been made on the lignite, but it was badly caved at the time of the writer's visit and but little could be told of the nature of the bed or its extent. It lies on the west bank of the creek, and apparently has a slight dip into the bank and upstream. The lignite is extremely fibrous and contains tree stems, in some of which the annular rings are still plainly discernible, the wood apparently being altered but little, although it appears carbonized. A thickness of 3 feet was exposed in the face by digging, but from the occurrence of the coal in the caved-in adit, it appears that the total thickness is much greater, 7 or 8 feet or even more not being improbable. Overlying the coal is a very stiff gummy clay, and apparently overlying the clay are basaltic lavas. The lignite was exposed along the stream for a distance of about 15 feet, but most of it was covered by the clay, which had crept down over it. Fragments of the lignite appear below the outcrop in the stream gravels for several yards. About 200 yards downstream a second outcrop shows a thickness of a few inches, but the thickness of the deposit may be much more than this.

It has been used to a small extent for domestic purposes and seems to be quite satisfactory. No tests had been made, so far as known, of its suitability for making steam.

WATER.

As in many other parts of Seward Peninsula, the question of a water supply in this region is serious, and numerous expedients have been adopted to utilize the water that is available. Ditches have been constructed and pumps are used to some extent, probably much more than in most Alaskan mining districts. Where winter work is done, a large part of the sluicing of the winter dumps is done with the flood waters which result from the melting of the winter snows.

In the vicinity of Candle the problem is especially serious. A ditch from west-side tributaries of the Kiwalik furnishes water for hydraulicking operations on John Bull Hill, near Candle, but at times during the season the ditch carries so little water that mining is impossible. The same conditions prevail on Candle Creek and its tributaries, but the dredge can operate in its pond, even though but little additional water is coming in. Those plants which pump water are somewhat better off than those which depend on ditch water for sluicing, although some losses of gold are probably entailed in the use of dirty water. On the benches there is difficulty in getting water, and often short ditches are cut in the face of the hillsides to catch the run-off for use in sluicing, in connection with the water obtained from some of the small depressions. At times Patterson Creek carries considerable water, and this has been utilized in mining.

It is said that if water was available, it would pay to groundsluice off the overburden from a number of claims on the benches and to rework the old piles of tailings as well. It may be possible to work some of this ground with water from the Kiwalik ditch after the exhaustion of the placer gravels upon which the ditch company is now operating, but rather extensive surveys would be necessary in order to determine how much of the Candle Creek benches could be worked in this manner.

On Bear Creek the problem of water supply is much less serious than elsewhere, largely because the water for the ditch and other mining plants is taken from streams that head in a high ridge on which there is a much greater and more frequent precipitation than elsewhere in the region. In dry seasons, however, even on this creek a shortage of water is sometimes felt. Aside from the operations of the ditch company, mining is being done on the beds of small streams which usually furnish sufficient water for sluicing the auriferous gravels as they are shoveled into the boxes.

In a general way the conditions on Sweepstakes Creek are analogous to those on Bear Creek, for the streams that head in the high peak of Granite Mountain usually have a flow of water sufficient for all the operations now being carried on. The same conditions prevail in part on Rube Creek and other tributaries of Peace River, but the flow of these streams is normally only moderate in amount, and difficulty may arise in protracted periods of dry weather in getting sufficient water to carry on mining operations, if more than one or two plants are at work, unless additional supplies are obtained from near-by creeks.

On Dime Creek the conditions as regards water supply somewhat resemble those on Candle Creek, and conservation and complete utilization are aimed at. The latest claims staked on the benches are confronted with the greatest problems, for the rights of the earlier staker to creek water which may be brought onto the benches must be observed, and recourse is had, therefore, to numerous expedients, such as pumping the dirty water from the creek or digging wing ditches on the hillside above to collect spring and summer run-off. The supply of water of these systems is frequently augmented by the construction of ditches to one or more small draws or pups. A fairly satisfactory supply of water is obtained in this way for sluicing winter dumps, but for continuous summer work it will prove far from satisfactory. Stripping operations by groundsluicing are practically limited to those claims which have ditch water obtained from the creek, or which pump the water from and return it to the creek.

WAGES AND LABOR CONDITIONS.

The wages common to most Alaskan camps, $5 a day and board and higher wages to hoistmen and blacksmiths, are also paid in this region. Both at Candle and at Dime Creek most of the mining is done during the winter, and only a subordinate amount during the summer, although there is some prospecting in the summer. On Candle Creek most of the summer work is done on the shallow ground of the creek. On Bear and Sweepstakes creeks only summer open-cut work is done. On Dime Creek summer operations were confined to three plants which were open cutting and to a small amount of underground work, largely of a nature preparatory to winter mining. A considerable amount of prospecting and ditch construction was also done.

At Candle but few men were idle who wanted employment, for the road-repair work engaged most of those who had worked in the mines during the winter. On Dime Creek a number of men were idle during August.

GOLD PLACERS.

PHYSIOGRAPHY.

The origin of the placers is so intimately connected with the physiographic history of the region that it is appropriate to discuss this feature in connection with the placers, and an interpretation of the topographic forms may throw some light on the mode of concentration of these deposits.

A striking topographic feature in many parts of the region between Eschscholtz Bay and Norton Bay is the terraced character of many of the hills and mountains. These terraces attain the greatest prominence in areas of massive, well-indurated rocks like the granites or the series of agglomerates, tuffs, and flows of an andesitic character which lie chiefly north of the Koyuk. Moffit[1] states "that a given bench could often be traced from one locality to another, but the contour interval [used in the topographic mapping] was too great to permit any extended correlation of levels." The areas of older metamorphic rocks do not present this terraced appearance, although broad flat-topped or very smooth-crowned ridges are predominant. It is possible, although by no means certain, that these flat-topped ridges correspond to the terraces in the more resistant rocks and with the terraces represent marine benches. If so, there is lacking the confirmatory evidence of widely distributed beach pebbles, such as might be expected if the benches were water cut. Although Moffit[2] states that on some of the upper tributaries of the Kiwalik and on Old Glory Creek elevated benches of gravel were seen at an altitude of about 500 or 600 feet above sea level, the presence of gravels on the terraces is unusual, for he says:[1]

> The floors of the benches are usually covered with débris, which is angular or rounded, and is probably due to weathering rather than to grinding by water currents. The edges of the benches are made up of angular blocks produced by the action of the frost on the bedrock, now only occasionally visible. The blocks appear not to have been moved any considerable distance but simply to have tumbled down and formed a talus along the front of the rock wall, which they now conceal in nearly all cases.

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[1] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 247, p. 44, 1905.

[2] Idem, p. 40.

If these terraces were formed by wave erosion the gravel and sand which were produced in the incision of the benches have been largely if not wholly removed from most of them, although, as already cited, some of the high-lying gravels still remain. It is somewhat difficult to believe that wave-cut terraces would still present such definite scarps as are found at even the highest elevations, and that erosion took place of sufficient magnitude to remove all the unconsolidated beach débris which had been formed in cutting the benches as the sea encroached by stages upon the land surface. If it is assumed that some of the terraces were cut as the land surface emerged from the sea, an even longer period of endurance of the highest terraces is thereby postulated. It may therefore be possible that some at least of the terraces owe their origin to some other cause, although it is believed that the land surface has been depressed to a depth of several hundred feet below sea level. In the Yukon-Koyukuk region similar high terraces have been ascribed by Eakin[1] to a process termed "altiplanation," a phase of solifluction that under certain conditions finds expression in terrace-like forms and flattened summits. Until definite proof of a marine origin is obtained, it appears logical in this region also to accept Eakin's hypothesis of origin for the highest of the terraces, although the sea probably covered the land to a height of 500 or 600 feet and carved the land forms to that elevation. Stream erosion has greatly modified the topography since emergence, and the tendency has been to restore the former topography by sweeping out the unconsolidated sediments from the filled valleys. On the hillsides solifluction has been an important agent in the transportation of the débris to the bottoms of the valleys, where it was removed by the streams.

The numerous exposures of basaltic lavas afford some indication of the topography which existed previous to their extravasation. It appears likely that at that time a very mature topography had been developed and the country was nearly base-leveled. It may be that the extrusion of the lavas occurred shortly after the emergence of the land surface nearly to its present level, when many of the valleys were nearly if not quite filled with gravels and sands resulting from inundation. Drainageways had been established, however, and it was down these that the lavas took their course. At the head of Bear Creek, they are found at an elevation of about 1,200 feet, and this appears to be about the maximum height reached, except in the area at the head of the Koyuk, from which it is likely that a very considerable part of the lavas came. There may also have been vents for these lavas somewhere on the Buckland-Kiwalik divide. Moffit[2]

[1] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, p. 78, 1916.

[2] Moffit, F. H., op. cit., pp. 32–33.

describes the topographic changes due to the lava flows in the following terms:

> Important modifications of the drainage were brought about by the extrusion of the lava, which occupied the depressions and flowed down the valleys in broad rivers of molten rock. At times the cooling of the advancing front wall dammed back the flow and forced it over the low, rounded divides between the watercourses into the next valley beyond, or formed a lake [of molten lava] which finally overflowed the obstruction and resumed its original course, only to repeat the process a little farther on.
>
> In this way islands of bare ground were left between the great finger-like protrusions along the edge of the sheet. At the same time a shifting of the watercourses was brought about, for when not of sufficient volume to fill it the lava occupied the lowest part of the valley and the waters sought a new channel parallel to the old one, along the edge of the hardened flow. A number of lakes and ponds also owe their existence to the damming of streams by lava, among which may be mentioned Lake Imuruk, the largest body of fresh water on the peninsula.
>
> Observations made by Collier on Noxapaga River showed these more recent lavas overlying gravels which are cemented near the contact by indurated clays and contain pebbles of an older flow—conclusive evidence that considerable time must have elapsed between the first outbreaks and the solidification of the flows just described. The source from which the recent basalts of Noxapaga and Kuzitrin rivers were discharged lies to the southwest of Lake Imuruk, this being shown by the scattered lava cones as well as by the direction of movement of the flows themselves.
>
> On the upper part of Koyuk River a similar relation of basalts and gravels was observed by Mendenhall. He found on the truncated edges of the schists 5 feet of gravel, made up of schist, vein quartz, and granite; this in turn was covered by an undisturbed horizontal sheet of olivine basalt, which had been but little affected by the erosive action of the stream since it came to rest, and was therefore believed by him to be of Pleistocene age.

No evidence of flows as recent as those between Noxapaga and Kuzitrin rivers was seen by the writer in the country toward the northeast, where the lavas have been subjected to weathering for a much longer time and have suffered correspondingly. In the region south of Kotzebue Sound it is probable that a drainage system differing very little from the present one and containing a considerable body of gravels was invaded and partly filled by the basic lavas, which formed a sheet of no great thickness across the valleys. The present streams then resumed their work and cut down through the thin lava sheet, uncovered again the older channels, and left the conspicuous rim of lava now seen surrounding many of the valleys. In evidence of this may be mentioned the fact that the lavas in almost all cases appear well up on the sides of the narrow valleys, and that there is no indication that they ever covered the higher hills above the valleys. In one instance, at the west end of the big bend of Kugruk River, the lavas appear at the water's edge; in all other cases, as far as observed by the writer, they are above the streams, which at present occupy channels in the older metamorphic schists and limestones. It should be stated, however, that no contact of lavas overlying gravels, such as that described by Mendenhall and Collier, was observed in the region, since the great quantity of broken blocks, thrown down largely by the action of the frost, prevented a view of the base of the flows. This condition also prevented any accurate determination of the thickness of the lava, though two flat-topped hills of it south of the upper part of Cottonwood Creek have an elevation of 60 feet above the plain on which they rest. In the one nearer the Cottonwood the base is formed by some 8 feet of agglomerate containing boulders of basalt. This relation of the lavas to the gravels is a question of some interest, since, if the ideas here advanced are correct, it is possible that valuable placer gravels may be present somewhere beneath the lavas.

Where the lava rim was seen on the Kiwalik, about a mile above Candle, it was a far less pronounced feature than in the areas to the west that are described by Moffit. At the headwaters of the Kiwalik, on Wilson Creek across the divide from Sweepstakes, and at the head of Moon Creek on the west side of Peace River, the basalt caps the hills, and on the east side of the river opposite Moon Creek it appears nearly to the crest of the ridge. In places at each of these three occurrences there appears a distinct scarp or rim, but elsewhere the presence of the basalt is only indicated by the numerous large angular pieces of the rock which cover the very gentle slopes. Wherever bedrock was seen in the banks of Peace River it consisted of the much older series of andesitic tuffs and flows, generally overlain by unconsolidated gravels. At the head of the Kiwalik, the basalt appears to overlie clay beds above a bed of very fibrous lignite.

It appears likely from the distribution of the basalts that they once covered the gravels which occupied the valleys of Peace River and Sweepstakes Creek, but west of Peace River and north of Sweepstakes Creek they have since been removed by erosion. Moffit[1] states that the presence of the lava on Candle Creek is shown by fragments in the gravel and on the hill slopes and by a few outcrops. It probably also filled the valley of Kiwalik River from Candle up to a point between the mouths of Lava and Hunter creeks. It is likely that detailed work would reveal the presence of remnants of this flow on the west side of the Kiwalik also.

None of the recent basalts are found on Bear Creek except at its head, where their position indicates that if Bear Creek flowed in its present valley at the time of their extrusion a lava stream must certainly have flowed down this depression. They are not now present in this valley, so far as known.

In like manner, basalts occur on the divide between Dime Creek and Peace River, west of Eldorado Creek, and at the head of Flat Creek in positions which indicate that they would have flowed down a depression corresponding to the present valley of Dime Creek had it existed at the time of their extrusion. These basalts have been removed without leaving a trace of their former presence except the olivine found in the heavy sands of the clean-ups.

The presence of the lava on the divide between Mukluktulik River and Kenwood Creek indicates from its position that it must once have been connected with the basalt areas to the north in the Koyuk basin.

[1] Moffit, F. H., op. cit., p. 61.

A measure of the amount of erosion since the extrusion of the lavas is afforded by these numerous flows. An interpretation of the age relations is presented on page 381.

CANDLE CREEK.

Candle Creek has been one of the large gold-producing creeks of Seward Peninsula for many years. The earliest workings were on creek claims, and mining operations in summer are still largely confined to the creek, although some of the more shallow benches are now being worked by open-cut methods. After the discovery of the creek placers, prospecting revealed the presence of valuable ground on the benches, and deposits of such gravels have been worked there for a number of years.

The bedrock in the lower claims is mainly schist, but on the bench claims it is in many places a coarsely porphyritic andesite. It is said that on the upper bench the pay streak follows rather closely the contact between the andesite and the schist. On the creek claims, according to Moffit:[1]

> Schist (often coarse and angular, at times finely divided) forms much the larger part of the gravels in the channel. Quartz-vein stuff with some limestone makes up the remainder. An ice bed of variable thickness, which measures about 12 feet near Patterson Creek and extends to the west of the stream channel several hundred feet, overlies the gravels in the bottom of the valley. The tendency of the débris on the slopes of either side of the valley to slide down toward the creek is shown by the bulging up of the clay from the bottom of the cuts and by the closing in of the sides. In consequence of this tendency the gravels are usually much disturbed and there is no uniformity in the sections. At the mouth of Patterson Creek there are from 6 to 8 feet of gravel and slide resting on a blue-clay bedrock; at Willow Creek the gravels measure from 5 to 8 feet; on a bench claim below Patterson Creek the gravels are not so thick—4 or 5 feet of fine schist, "chicken feed," is covered by 10 or 12 feet of ice and 2 feet of muck; on a bench claim nearly 1,000 feet west of Candle Creek a 33-foot hole put down with a thawer gave the following section:

Section near Candle Creek.

	Feet.
Muck	3
Slide consisting of yellowish and reddish quartz sand with "chicken feed" (finely ground schist)	28
Sand	1
Gravel with rounded quartz pebbles	1
Bedrock, yellowish clay with pieces of lava.	

The gold on the creek claims, where the bedrock is schist, is flattened and black; that taken from bench claims, where andesite is the bedrock, is said usually to be bright. "Iron stones," rounded pebbles of hematite or limonite, are generally found in close asso-

[1] Moffit, F. H., op. cit., p. 61.

ciation with the richer deposits. Other minerals found in the sluice boxes in the clean-up includes arsenopyrite, pyrite, galena, chalcopyrite, magnetite, ilmenite, rutile, zircon, garnet, and cerusite. Of these minerals, arsenopyrite appeared to make up far the largest proportion on a claim near the mouth of Patterson Creek. The chalcopyrite occurs in association with the galena in the same grains. Some of the galena is coated with cerusite. These minerals are found also in the cuts of the Keewalik Mining Co. on John Bull Hill south of Candle, but the iron oxides appear to predominate and occur in well-rounded grains or small pebbles. In addition to the minerals above mentioned, shot coated with lead oxide are found with the heavy sands.

About 12 small plants, employing in all about 30 men, were at work during the winter of 1916–17, either engaged in mining or in prospecting on Candle Creek and its tributaries, including 11 men who worked on Jump Creek. In summer about 55 men were engaged in mining, about half of them with two of the eleven plants that were operating. Power scrapers were used on a number of claims. On some it was necessary to pump water in order to get sufficient elevation and suitable grade for the boxes, as well as dumping room for tailings. One dredge was in operation, and two plants hydraulicked the overburden and the auriferous gravels. China pumps were used on some of the creek claims to remove water from the pits.

The dredge was operating on claim No. 5 above Discovery. Another dredge was to be moved to the creek during the winter of 1917–18. These dredges will operate on the creek claims, and some of the ground will be reworked.

It is said that many of the bench claims contain sufficient gold in the tailings from former operations to warrant reworking if water could be obtained. Considerable losses were entailed in washing the clayey gravels by the methods previously used, largely because of insufficient water. Projects have been proposed for getting water on these claims by the construction of a ditch, but the high initial expense has served to delay the carrying out of any of these plans while the ownership of the ground to be worked is as widely distributed as at present.

BEAR CREEK.

Bear Creek is tributary to Buckland River on the northern drainage slope of Seward Peninsula. Gold has been mined on the main creek and two of its tributaries, Sheridan and Cub creeks. The first claims recorded were staked in 1901 and some work was done later on the richest gravels, Moffit[1] stating that in 1903 about $10,000

[1] Moffit, F. H., op. cit., p. 64

was taken out. Concerning the later developments, Smith and Eakin[1] give the following information:

From 1903 to 1907 a little desultory prospecting and mining was done, but during the latter year the building of a ditch along the west slope of the valley revived interest in the region. The small precipitation of 1908, however, prevented any extensive use of the new ditch, and in 1909 there was no evidence that productive mining was in progress.

Since 1909 changes in ownership have taken place, and in addition to the hydraulicking plant of the former ditch company there has been installed a hydraulic elevator of the open-flume type, which operated in 1916 and 1917. This plant was working on Bear Creek near the mouth of Split. In 1917 two men were engaged in open-cut work on a beach claim near this plant, one man was open cutting on a claim about a mile below, and one man was working on an open cut on Sheridan Creek. In addition some assessment work was done on a number of other claims on Bear Creek, and Cub Creek had been restaked recently, although no work had been done on it early in August.

For the most part, the bedrock is a series of altered andesite tuffs and flows, but intrusive rocks of a more basic character are associated with them, for pebbles of diabase were seen in the creek gravels. Probably the platinum that is obtained in small amount on Bear Creek is derived from rocks of this character. In addition to the basic intrusives there are numerous dikes of acidic intrusives; fresh andesite dikes, which cut the metamorphosed andesitic rocks, were seen on the hills north of Split Creek, and pebbles of syenite and diorite were noted below the mouths of small streams between Split and Cub creeks. In the bed of the main stream dikes were seen, but they were so badly weathered that their original nature was not determinable. The bedrock on the lower part of Cub Creek is of the metamorphosed andesite series, but a large proportion of the boulders of the creek are composed of porphyritic syenite, monzonite, or diorite, and some of them carry the brown garnet melanite. These rock types correspond to those described by Moffit[2] as occurring in the vicinity of Granite Mountain. Pyritic mineralization, of which the deposition of the gold is a phase, accompanied the intrusion of these rocks.

The bedrock surface in the creek is extremely irregular, and its unevenness appears to prevent large-scale operations by methods other than those now being used. A considerable portion of the gold lies close to bedrock, and it must therefore be thoroughly cleaned for successful mining. In the concentrates found in the clean-ups by far

[1] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region: U. S. Geol. Survey Bull. 449, pp. 125–126, 1911.

[2] Moffit, F. H., op. cit., pp. 29–30.

the largest proportion of the heavy sands consist of the iron oxides, magnetite and hematite. The magnetite is easily removed by the magnet, but the hematite gives some trouble, as it is not readily separable from the gold. In addition to these minerals smaller amounts of limonite, ilmenite, pyrite, garnet, olivine, and some of the lighter silicates are also found. Of special interest in connection with the platinum is the occurrence of rounded grains and perfect octahedra of a chrome spinel, which resembles magnetite but is only very faintly magnetite, and in addition appears to have a more vitreous rather than metallic luster. A similar association of minerals is found on Sheridan Creek, where the geologic conditions are essentially the same as those on the main stream.

RUBE CREEK.

Rube Creek is a small stream that enters Peace River from the west about 7 or 8 miles above Sweepstakes Creek. It flows close to the base of the mountain mass that lies to the south, so that there is less workable placer ground, either stream or bench, on that side than on the north, where between Rube and Farmer creeks there is a sloping tundra plain in which these two streams have only slightly intrenched themselves. A number of claims have been staked on both creeks as well as on some of the tributaries of Rube Creek from the south. Most of the work in August, 1917, had been done on a group of claims on Rube Creek, where a ditch had been dug and two open cuts had been made. Most of the work of development had been done on the lower cut, which was about 100 feet long and from 3 to 8 feet deep. Gold is found on a false bedrock, an impervious clayey stratum, and in the superjacent 2 to 3 feet of gravel. Overlying the pay gravel is an uneven thickness of barren gravel and sand, which is overlain by 2 feet or more of muck and vegetation. North of Rube Creek the depth to bedrock is greater, and in one section 6 feet or more of ice containing a small amount of gray-blue muck is exposed below the surface covering of vegetation. At one place several alternating thin layers of gravel and muck were noted. These layers were probably formed by the deposition of the gravels on the moss-covered surface by successive spring overflows, and the accumulation of moss and finer material on the surface between flows.

Pannings from the pay gravels showed several colors to the pan of bright gold, somewhat less flaky than that on Dime Creek. No platinum was seen in the pannings, but it is said to be found. The heavy sands include an unusual amount of black garnet. Besides the lighter silicates, hematite, olivine, zircon, and chrome spinel are also present. Only a few grains of the chrome spinel were seen.

In one of the bare patches between Rube and Farmer creeks a pan of dirt was washed and showed a few fine colors. The minerals in the concentrates were essentially the same as those on Rube Creek, the black garnet being conspicuous.

SWEEPSTAKES CREEK.

Sweepstakes Creek is the main tributary of Peace River from the west, and at their junction the two streams are about the same size. It is untimbered except near Peace River. Like Rube Creek it flows close to its south bank, and there is a very gentle slope on the north side.

During the summer four plants, which employed about 12 men, were in operation. Work was done on rather widely separated claims, extending from the mouth of Bear Gulch, about 2 miles below Discovery claim, which is near the forks of Sweepstakes, to claim No. 10 above Discovery. The ground is shallow, and open-cutting is practiced. A large part of the overburden of muck and vegetation, as well as the upper part of the gravels, is sluiced off, and the auriferous gravels are then shoveled into a line of sluice boxes.

On the upper claims worked the depth to bedrock is about 6 feet, the upper 2 feet of which consists largely of muck and vegetation. The material on this claim contains many angular fragments of rock, 8 inches or larger in dimensions and comparatively little rounded gravel.

On the lower claims the depth to bedrock is somewhat greater, ranging from 7 to 15 feet, of which the gravels make up from 4 to 9 feet. The gravel is well rounded and relatively small, although some boulders are present. The bedrock is similar in character to that of most of the material of the gravels and is somewhat decomposed, so that often the bedrock is excavated to a depth of a few inches and put through the sluice boxes also, in order to prevent the loss of gold.

On most of the creek the bedrock consists of the metamorphosed andesite series, but there are places where the much older metamorphic rocks seem to underlie the auriferous gravels. Elsewhere, as near the mouth of Granite Creek and on the uppermost claims being worked, syenitic rocks appear.

Platinum, comparable in the ratio of its occurrence with the gold to that on Dime Creek, is found on the Circle claim at the mouth of Bear Gulch, and pannings from Bear Gulch are also said to carry considerable amounts of this metal. It was not reported in the gold from the upper claims.

The heavy sands include magnetite, olivine, brown and red garnets, zircon, hematite, and a small amount of ilmenite. Chrome spinel is present also in considerable amounts, and it is probably derived from the same source as the platinum.

DIME CREEK.

Dime Creek is tributary to Koyule River from the northeast between Peace River and East Fork. The first claims were staked in 1910 by Sam Smith and his associates. Prospect holes were sunk on the lower claims, but the results obtained did not warrant further operations, and the claims were abandoned. On April 4, 1915, gold was discovered near the mouth of Little Eldorado Creek by Tom Moon and Henry Ryan. There resulted a stampede to the creek; and, after what were supposed to be the good claims on Little Eldorado Creek were staked, the late comers took first the creek claims and then the bench claims on Dime Creek as well as its tributaries, and claims were also staked in the basins of near-by streams. A production of about $3,000 is said to have been made from three claims [1] during that year. Neither machinery nor supplies were near at hand, and they had to be brought from Golofnin or Nome, so that no considerable production was made until the following year. It has been estimated [2] that the production of 1916 was about $100,000 from eight claims.

In 1917 about 17 plants in operation on 16 claims employed a total of 85 men. It is believed that the production from winter and summer operations was about $150,000. In addition to the gold about 35 ounces of platinum was produced. It is said that on the creek and bench claims at the lower end of Dime Creek there is about 1 ounce of platinum to each $5,000 of gold; on the upper claims this ratio is considerably higher, so that it may amount to as much as 1 ounce to each $2,000 in gold.

The following analysis of platinum from Dime Creek was made by R. C. Wells in the laboratory of the Geological Survey:

Analysis of platinum from Dime Creek, Seward Peninsula.

Gold	0.6
Silver	9.5
Lead	1.4
Platinum	71.5
Iridium (?)	3.8
Palladium	.9
Copper	.1
Rhodium	.9
Iron	6.1
Osmiridium, silica, and undetermined	3.4
Nickel	trace
	98.2

[1] Brooks, A. H., The Alaskan mining industry in 1915: U. S. Geol. Survey Bull. 642, p. 70, 1916.

[2] Mertie, J. B., Lode and placer mining on Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 662, p. 454, 1917.

The highest values that have been reported for the gold from this creek are $19.84 and $19.88 a fine ounce. The fineness of the gold worth $19.88 an ounce was 961 parts gold and 32 parts silver.

The depth to bedrock differs considerably. In a general way the claims at the upper end of the creek are somewhat more shallow than those farther downstream, and the depth to bedrock increases still more on claims as far down as claims 8 or 9 below Discovery. Where mining is being carried on, from claim 7 above to claim 1 below, the depths range from 10 or 12 feet to about 30 feet on the creek claims. On the right limit benches the depths range from 6 to 10 feet; on the left limit, the first tier opposite claim 2 above, the depths are about the same but increase downstream, so that on the second tier bench opposite Discovery the depths to bedrock range from 25 to 50 feet. Bedrock lies a little higher than the present surface of the stream. The section made known by mining operations differs according to the depths of the holes. Normally, however, there is a gravel layer from 2 to 8 feet in thickness overlain by a few feet of muck and ice, which in turn is covered by about 1 or 2 feet of vegetation and peaty material. In some of the deeper holes, especially on the benches, there is a layer of angular rocks and clayey material which appears to be largely hillside talus. This is locally known as "slide" and contains little, if any, rounded gravel. All the ground worked is frozen.

Summer operations were largely confined to open-cut work, prospecting, repairing of ditches, and getting equipment and supplies for winter work. A few small plants that were worked during the summer hoisted with a windlass. There appears to be little reason why, if it is possible to obtain fuel and other supplies, deep mining should not be carried on during the summer, as well as in winter. Open cutting was in progress in August, 1917, on three claims; one plant used ditch water for stripping and sluicing, one pumped from Dime Creek, and the third supplemented water that was pumped from the creek by ditch water when it was available. A large proportion of the overburden of the auriferous gravels on these claims consisted of muck and ice below a protective mantle of vegetation. When this covering had been removed even a small amount of water was effective in stripping.

The gold is found mostly on or near bedrock, but some is distributed through 2 or 3 feet of gravel, so that it is necessary to mine and sluice this amount of material. The amount ranges from 50 cents to over $2 a square foot of bedrock mined. Though the pay streak on the creek claims is fairly well defined, it may in places be divided and on the bench claims there appear to be several lines along which concentration has taken place, as though effected by wave action along beaches at successive stages of elevation or depression of the land surface. Further data are required to prove this hypothesis, which can best be obtained from actual mining operations and observations as to the lineal continuity of pay streaks. In association with the gold and platinum in the sands from clean-ups a number of heavy minerals have been found. These minerals include a little magnetite, hematite, and limonite, and large amounts of chrome spinel and olivine, together with some pyroxene. Garnets are found, although rarely. Rutile was noted from one of the left-limit second-tier bench claims.

Bedrock on the creek consists largely of the metamorphosed andesite series. The older slates and limestones appear, however, on the west side of the creek, and Little Eldorado Creek follows along the contact.

At the mouth of Silver Gulch a Cretaceous conglomerate, which contains pebbles of limestone and slate, appears in the stream banks, and with Cretaceous shale and sandstone forms the bedrock of most of the creek claims below this tributary.

Pebbles of glassy lava in the stream gravels indicate that somewhere on the creek this rock forms the bedrock. The olivine and pyroxene, which are green and greenish-black minerals in the heavy sands, may have been derived from the recent basaltic lavas which occur along the divide between Dime Creek and Flat Creek, as well as on the ridge between Dime Creek and Peace River, and probably once occupied or covered Dime Creek valley, or they may have been derived, together with the chrome spinel, from a peridotite at the head of Dime Creek. This rock probably is the source of the platinum also, and the fact that the platinum grains are so rounded affords an indication of the distance traveled and the amount of abrasion to which they have been subjected. Grains of platinum from the upper claims appeared more commonly to be angular, although even there a large proportion is shotlike.

A composite sample of chrome spinel from several claims on Dime Creek and a sample of concentrates from the left-limit second-tier bench claim opposite Discovery, Dime Creek, were analyzed by Chase Palmer in the laboratory of the United States Geological Survey and were found to contain 51.14 and 15.42 per cent of chromic oxide (Cr_2O_3), respectively.

LODE PROSPECTS.

There has been but little attempt at lode mining within this region, probably largely on account of the poor exposures, except along streams throughout much of the area. In the mountainous areas at the heads of the larger streams exposures are somewhat better, but the difficulties of transportation are such that even moderately rich ores could scarcely be worked at a profit except on a large scale and after the completion of roads or railroads to them.

Only two prospects are known to the writer. What is known as the Beltz prospect consists of ten or more small open cuts on the north side of Split Creek, a tributary of Bear Creek. These lie at an average elevation of about 700 feet above the mouth of Split Creek. The pits are badly caved and filled with talus from the slope, so that it was not possible to obtain any data on width, dip, or strike of the vein. Near some of these pits vein quartz was seen, which carried some copper as chalcopyrite. The weathering of the chalcopyrite had caused the rock to appear rusty from the iron oxide with small patches of green copper carbonate. There does not appear ever to have been any production of ore from this property, and it is not possible to make any statement of its potentialities.

On the Kugruk about a quarter of a mile east of the mouth of Independence Creek there is an argentiferous lead prospect owned by Perkeypile & Ford, which was not visited. Considerable development work is said to have been done on this property by open cuts, tunnels, and winzes. In addition to lead and silver assays show a considerable percentage of zinc, traces of copper, and a small amount of gold.

Transportation of supplies to this prospect and of the ore or concentrates from it appear to be the controlling factors in this development. Candle, 25 miles distant, is the nearest town to which supplies could be brought, although it is possible that they could be brought up the Kugruk to a point somewhat nearer. The future of this property appears to be dependent upon the proving of a sufficiently large ore body to warrant the construction of a road or railroad from the mine to Candle or Deering for the economic handling of supplies and ore. If a road was built to Candle, advantage could probably be taken of that already constructed up Candle Creek. For a small plant winter transportation of both supplies and ore would doubtless prove most economical. Coal for fuel and power could be obtained on the Kugruk within 15 or 20 miles.

COAL.

The workable deposits of coal in this area have already been quite fully discussed under the consideration of the economic factors that affect the mining of placer gold. (See pp. 383–385.) In addition to these occurrences small deposits are also known at the head of Hunter Creek and near the mouth of the Buckland. Nothing further is known regarding these deposits.

HOT SPRINGS.

A slight depression on a bench 50 feet above the west bank of Spring Creek, about half a mile above the forks, contains hot springs which rise up through angular fragments of diorite and metamorphosed andesite. Several basins have been artificially excavated, and the water, most of which comes from a spring at the upper end of the series, flows successively through these basins. The temperature is such that the hand can be held in the uppermost pool without discomfort and is probably about 105° F. The lower pools are slightly cooler. South of the main spring is a small seep. In the basins is a considerable growth of red, yellow, pink, and green algae. There is a slight odor of sulphur dioxide in the vicinity. The rocks over which the spring waters flow have a thin white tasteless coating, but there are no deposits of siliceous or calcareous material. Bubbles of an odorless, noninflammable gas, probably carbon dioxide, rise almost constantly in the pool of the principal spring.

In the bank of the stream just below the spring is a small outcrop of a gray hornblende diorite, which is intrusive in the andesitic series. It appears likely that the spring is fed by atmospheric water, which falls on the upper slopes of Granite Mountain and follows joints and fissures in the rocks down to the zone where it acquires its heat and then rises along another fissure to form the spring. The water is tasteless and odorless and fairly potable after cooling, although a trifle "flat." No utilization has been made of the springs.

SOURCE OF VALUABLE PLACER MINERALS.

The essential facts concerning the source of the placers have been included in the preceding discussion. It may, however, be well to summarize briefly the main features of their origin.

The origin of the gold is attributed to syenitic and dioritic intrusions and possibly on Candle Creek to the more porphyritic andesite. At Candle Creek a portion of the gold of the placers is also probably to be attributed to the breaking down of auriferous quartz veins in the older metamorphic rocks. In a general way, there seems to have been comparatively little quartz deposited in veins accompanying the deposition of the gold, but the quartz was deposited in thin fissures in the older andesites and metamorphic series. The gold was concentrated in the placers along marine beaches or along stream valleys; some deposits were undoubtedly subjected to both beach and stream concentration.

The platinum, which is found in the placers on Bear, Sweepstakes, and Dime creeks, and of which a few grains are reported from Candle Creek differs in origin from the gold in that it is a constituent of the basic igneous rock and is not due to an intrusion later than the platinum-bearing rock. The history of its concentration in placers is essentially the same as that of the gold with which it occurs. The chrome spinel and probably some of the olivine found in the platiniferous placers were derived from the same rock as the platinum.

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GENERAL.

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